Cesium Beam
Frequency Standard
Model 3200

Operating and Instruction Manual

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NEUCHÂTEL   SWITZERLAND

WARRANTY

Our products are under warranty for one year (three years for the cesium beam tube), commencing on the day of delivery to the customer, but fourteen months after dispatch at the utmost. The warranty applies to demonstrably faulty material or poor workmanship.

We shall bear only the cost of repair or replacement in our own works. Should this not be possible for reasons beyond our control, all additional costs will be charged to our customer.

Damages resulting from natural wear, improper maintenance, failure to observe the operating instructions, excessive strain, unsuited consumption material, improper environmental and mounting conditions are excluded from warranty.

The warranty expires if the customer or a third party modifies or repairs our product without our written prior consent or if our customer does not take immediate steps to prevent the damage from becoming more serious; likewise, if insufficient time is provided for repair or replacement.

Our customer will not be entitled to other warranty claims. Thence we are not liable for consequential damage.

OSCILLOQUARTZ SA
NEUCHÂTEL SWITZERLAND

Cesium Beam Frequency Standard – Model 3200

Operating and Instruction Manual

1. General Description

1.1. Introduction

For over 10 years, cesium beam frequency and time standards have demonstrated performance improvements necessary to meet increasingly stringent specifications for frequency and time reference equipment. The availability of easy-to-operate instruments of reduced size and weight, exceptional accuracy and stability, offers the user greater flexibility in the application of cesium standards to todays stringent requirements in navigation, communication and timing systems.

A decade ago, Oscilloquartz SA delivered its first cesium time and frequency standard. Actual field experience has provided Oscilloquartz with great depth of knowledge for its continuing development and construction of cesium standards.

Many Oscilloquartz frequency standards are used at calibration and national standard laboratories around the world. This background has led to the creation of an entirely new line of small, high performance standards to meet current and future technical requirements for frequency reference equipment.

The Model 3200 Cesium Beam Frequency Standard is a primary frequency standard, the basis of which is the ground state hyperfine transition of the cesium atom 133. The frequency of this transition defines the internationally accepted unit of time: the second.

The cesium beam tube used in the model 3200 is an entirely new small size and rugged, high performance unit. It has been developed and is manufactured by Frequency + Time Systems Inc. Danvers, U.S.A., a sister company of Oscilloquartz. It exhibits outstanding reliability and has a guaranteed life of 3 years at normal operating conditions.

The Oscilloquartz Model 3200 Cesium Beam Frequency Primary Standard is a compact instrument package, including AC and DC power supply, standby battery power, self checking control circuits, monitoring instrument and indicators, all dimensioned for a standard 19" rack cabinet. It features an accuracy of $\pm 1 \times 10^{-11}$ and a frequency stability of 5×10^{-12} for the life of the tube. Output frequencies are 10, 5 and 1 MHz with outstanding phase noise spectral purity.

For users with the need to generate and maintain an accurate time scale, the Model 3200 Cesium Frequency Standard may be completed by an accessory frame, model 2201. This accessory frame can accommodate a unique digital clock module with front panel read-out. The clock generates a one-pulse-per-second output which can be advanced or retarded with a resolution of 0.1 µs. Additionally, the clock module provides the necessary facility to introduce positive or negative leap seconds. It also includes a time comparator capable of sub-microsecond resolution with analog output for recording purpose. This option gives to the users the possibility to make time comparisons between clocks with limited peripheral electronic test equipment.

In addition, the accessory frame can accommodate several other optional equipments, such as frequency divider, frequency amplifier and frequency multiplier modules. The accessory frame model 2201 is fitted with its own primary (110/220 VAC) and secondary (24 VDC) power supply and standby battery with automatic charging device.

1.2. Principle of operation

The cesium beam frequency standard is based upon a fundamental atomic property in nature that makes use of quantum transition within the cesium atoms (4,0) ↔ (3,0). The frequency of transition between two magnetic hyperfine levels of the fundamental state of cesium 133 amounts to 9 192 631 770 Hz. This transition is obtained inside the cesium tube which delivers an ultra-stable resonance not affected by any systematic variation with time (aging).

This resonance is then used to frequency lock a low noise 5 MHz crystal oscillator to the cesium transition. The resultant locked loop allows for a 5 MHz primary frequency source to be obtained, featuring the advantage of the long term stability of cesium combined with the short term stability of the 5 MHz crystal oscillator (model B-5400).

The graph of figure 1 shows the typical frequency stability of the high performance crystal oscillator used in the standard compared to the frequency stability of the cesium standard obtained by slaving the oscillator to the cesium transition with a loop time constant of 1 second.

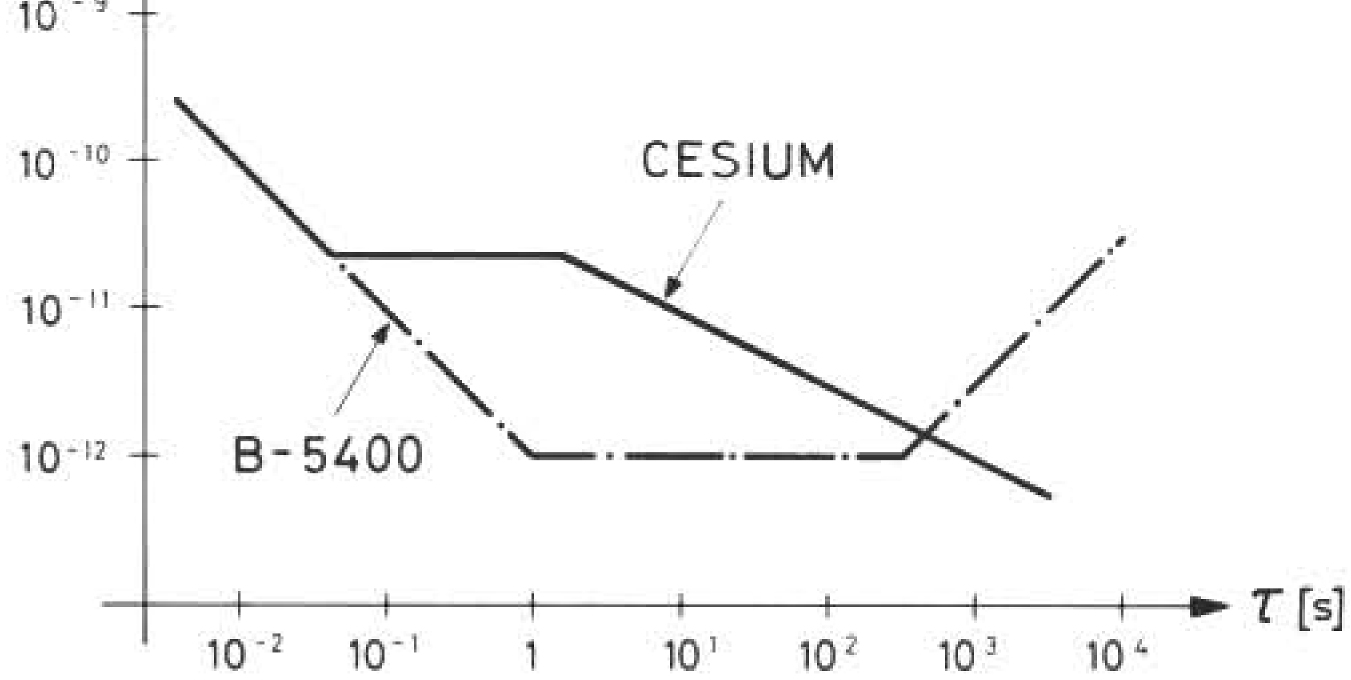


Fig. 1 Comparison of frequency stability between quartz crystal oscillator and cesium beam frequency standard.

2. Technical Specifications

2.1. Definition of terms

Accuracy	Fractional frequency deviation from accepted definition by the 13th General Conference of Weights and Measure.
Reproducibility	Maximum fractional frequency deviation after interruption of operation or after replacement of an electrical module and proper alignment.
Settability	Degree to which the fractional frequency can be set to match a reference.
Short-term stability	Standard deviation of fractional frequency fluctuation (Allan variance).
Long-term stability	Change with time of absolute fractional frequency (does not include environmental effects).

2.2. Standard frequency source

	Accuracy (0° C to +50° C)	$\pm 1 \times 10^{-11}$
	Reproducibility	$\pm 5 \times 10^{-12}$
	Settability	$< 2 \times 10^{-13}$ (total range $\pm 4 \times 10^{-11}$)
	Long term stability (for life of tube)	$\pm 5 \times 10^{-12}$
	Short term stability (5 MHz output) averaging time (sec) $\sigma\frac{\Delta f}{f}(2, \tau, \tau)$	
	1	3×10^{-11}
	10	1×10^{-11}
	100	3×10^{-12}
	100 000	3×10^{-13}
	Warm-up time at 25° C	30 min. typical
2.2.1.	**Cesium beam tube:**	
	Model	FTS-1
	Operating life	5 years typical
	Beam tube warranty	3 years
2.2.2.	**Crystal oscillator:**	
	Model	B-5400 (Oscilloquartz SA)
	Coarse frequency adjustment	4×10^{-7}
	Fine frequency adjustment	2×10^{-7}
	Aging rate	1×10^{-10}/day
2.2.3.	**Frequency outputs**	1, 5 and 10 MHz, BNC connectors on front and rear panels
	Signal wave form	sine
	Amplitude	1 V_{RMS}/50 Ω
	Harmonics	more than 40 dB below rated output
	Spurious	more than 80 dB below rated output
	Phase noise to signal ratio ($\mathcal{L}$)	
	1 Hz	− 85 dB
	10 Hz	−125 dB
	100 Hz	−140 dB
	1 000 Hz	−140 dB

2.3. Power supply and standby battery

2.3.1.	**Power connections:**	
	Primary power	110/220 VAC ±10% (45 to 440 Hz)
	Secondary power	20 to 30 VDC (floating input) absolute max. 35 V Input through Amphenol connector MS 3102A-14S-5p (mating unit MS3106A-14S-5s)
2.3.2.	**Standby battery unit:**	
	Standby power	3 hours at 25° C
	Charging conditions	automatic fast charging and float charge
2.3.3.	**Power consumption:**	
	a) primary power during	
	warm-up	160 VA
	operation at 25° C	100 VA
	b) secondary power during	
	warm-up	80 W
	operation at 25° C	50 W

2.4. General specifications

2.4.1.	**Environmental:**	
	Operating temperature range	0 to +50° C
	Storage temperature	–20 to +50° C
	Humidity	95% up to +50° C
	Note: prolonged operation above +40° C may damage and appreciably reduce the operating life of the built-in standby battery.	
	Fractional frequency deviation with:	
	Temperature 0 to +50° C	$< 5 \times 10^{-12}$
	Altitude 4000 m (12 000 ft)	$< 2 \times 10^{-12}$
	Magnetic field DC; 50/60 Hz; 160 $\frac{A}{m}$ (2 Gauss)	$< 2 \times 10^{-12}$
2.4.2.	**Mechanical:**	
	Size	standard 19" rack/3 U width: 428 mm height: 131 mm depth: 456 mm
	Weight	26 kg
2.4.3.	**Standard accessories supplied**	3 fuses 1.6 A slow-blow (5×20 mm) 3 fuses 3.15 A slow-blow (5×20 mm) 3 fuses 5 A slow-blow (5×20 mm) 2 fuses 1.5 A (microfuse) 1 connecting AC power cable 1 mating connector Amphenol MS3106A-14S-5s 1 mating connector Cannon DP-25P 1 set mounting hardware for installation in a 19" rack 2 instruction manuals

2.5. Accessory frame model 2201 and options

This accessory frame can accommodate several optional equipments. It is fitted with its own primary (110/220 VAC) and secondary (24 VDC) power supply; it also includes a standby battery with automatic fast charging device. The following four accessory modules are available:

a) **Clock module – option 2205**
The clock module – option 2205 includes all the functions necessary to efficiently generate and to maintain a very accurate time scale, according to today's stringent requirements of official time services and communication industry.

b) **Frequency divider module – option 2206**
The frequency divider module provides a series of high stability frequencies derived from the cesium frequency standard 3200. The following frequency outputs are available on the front panel (BNC connectors): 100 kHz, 10 kHz, 1 kHz, 400 Hz, 60 Hz and 50 Hz.

c) **Frequency distribution amplifier – option 2207**
The frequency distribution amplifier module provides two additional outputs (BNC connectors at front panel) for each frequency produced by the cesium frequency standard 3200 (2×1 MHz, 2×5 MHz, 2×10 MHz).

d) **Frequency multiplier module – option 2208**
The frequency multiplier module provides an output frequency above 10 MHz derived from the 3200 frequency standard. This frequency may be chosen as follows:

$f = m \times n \times 10$ MHz where $m = 1$ or 2
$n = 1, 3, 5$ or 7

This frequency is available on front panel (2×BNC connectors) at a nominal power level of 10 mW each on 50 Ω.

3. Operation

3.1. General principles

Operation of the Model 3200 Cesium Frequency Standard is based on a fundamental property of nature; it makes use of the quantized transitions of the atom. Indeed, quantum mechanics shows that atoms undergo a change of energy through a transition between certain well-defined energy states. Such a transition is accompanied by the absorption or emission of an electromagnetic wave whose oscillation frequency depends on the structure of the atom and the difference of energy between the two states concerned. This frequency is very precise and constant.

One of the chemical elements whose transition can be used is cesium. The frequency of transition between two magnetic hyperfine levels of the fundamental state of cesium 133 amounts to 9 192 631 770 Hz.

The cesium beam standard has two important properties. First, it is not subject to natural aging, in other words to a systematic variation of frequency with time. Second, it has a high degree of intrinsic reproducibility and, therefore, constitutes a primary standard. This means that, unlike secondary standards, it does not need a more accurate standard for adjusting its frequency. Independently regulated, without any reference standard, with normally available equipment, a commercial standard has a guaranteed precision of 1×10^{-11} parts.

The basic element of a standard of this type is the cesium beam tube (fig. 2) which has the effect of isolating the desired transition of the cesium and minimizing the influence exerted on the atom by the environment. It thus exhibits the transition frequency F 4,3 $m_F=0$ of cesium 133 while avoiding the errors due to external magnetic fields, variations of temperature or other disturbing factors.

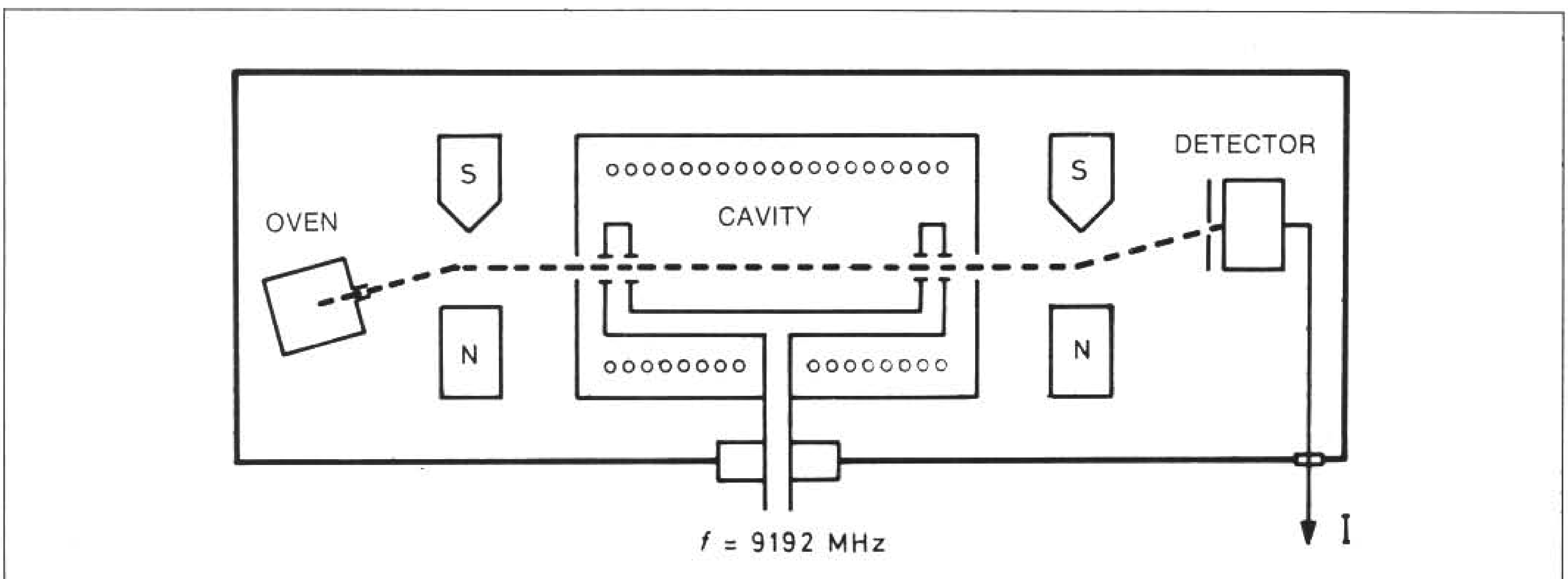


Fig. 2 Principle diagram of the cesium beam tube

A small reservoir of cesium, heated to about 100° C, forms a beam of atoms which passes into the gap of a selecting magnet, so that only the atoms in the desired energy state are directed towards the cavity. This is possible because the atoms behave as tiny magnets whose orientation depends on their energy state. When they pass through the strong field of the selecting magnet, they follow trajectories which differ according to their magnetic state.

The atoms thus selected pass through a slit into the cavity in which they are excited by an alternating electromagnetic field. This high frequency field induces the desired state transition of the atoms. The number of atoms which undergo a change of state, or which are reorientated magnetically, during their passage through the cavity depends on the difference between the frequency of the applied electromagnetic field and the frequency of the energy transition. At the outlet of the cavity, there is a second magnet, which deviates towards the detector only those atoms which have undergone the change of state. The detector supplies an output current which is proportional to the number of atoms detected and is of a sufficiently high level to be used electronically. This output current is at its maximum value when the excitation frequency of the tube corresponds exactly to the desired transition of the atom of cesium 133 (fig. 3). In order to separate the various possible transitions between the magnetic hyperfine levels, the cavity is placed in a uniform magnetic field, which is magnetically shielded from the influence of external fields, either terrestrial or parasitic.

To detect and use this transition frequency, which is both accurate and very stable in time, an electronic system is necessary. The excitation frequency of the tube is supplied, after multiplication, by a high-performance quartz-crystal oscillator whose frequency is regulated by the output signal produced by the tube. A diagram of the principle of the frequency standard thus formed is given in figure 4.

The output signal of the standard, which has a frequency of 5 MHz, is supplied by the servo-controlled quartz-crystal oscillator. A second output signal supplied by this oscillator follows two parallel paths. In the first, it is converted by synthesis to the frequency of 12.631... MHz. In the second, it is modulated by a low-frequency signal at 137 Hz; after a series of stages of multiplication and addition with the first synthesized signal, it produces the frequency of excitation of cesium, namely 9192.631... MHz. The low frequency output signal, which is produced by this modulation, is amplified before being detected. An analysis of this signal makes it possible to determine whether the excitation frequency is exactly that of the desired transition or, if this is not the case, to measure the amplitude and the sign of the frequency deviation of the excitation signal. This error signal is applied to the oscillator so as to vary its frequency and thus correct the excitation frequency of the tube. The control loop is thus closed. Regulated in this way, the quartz-crystal oscillator supplies a signal of very high precision. Indeed, its variation of frequency in course of time, which is called aging, is corrected by the signal supplied by the cesium tube.

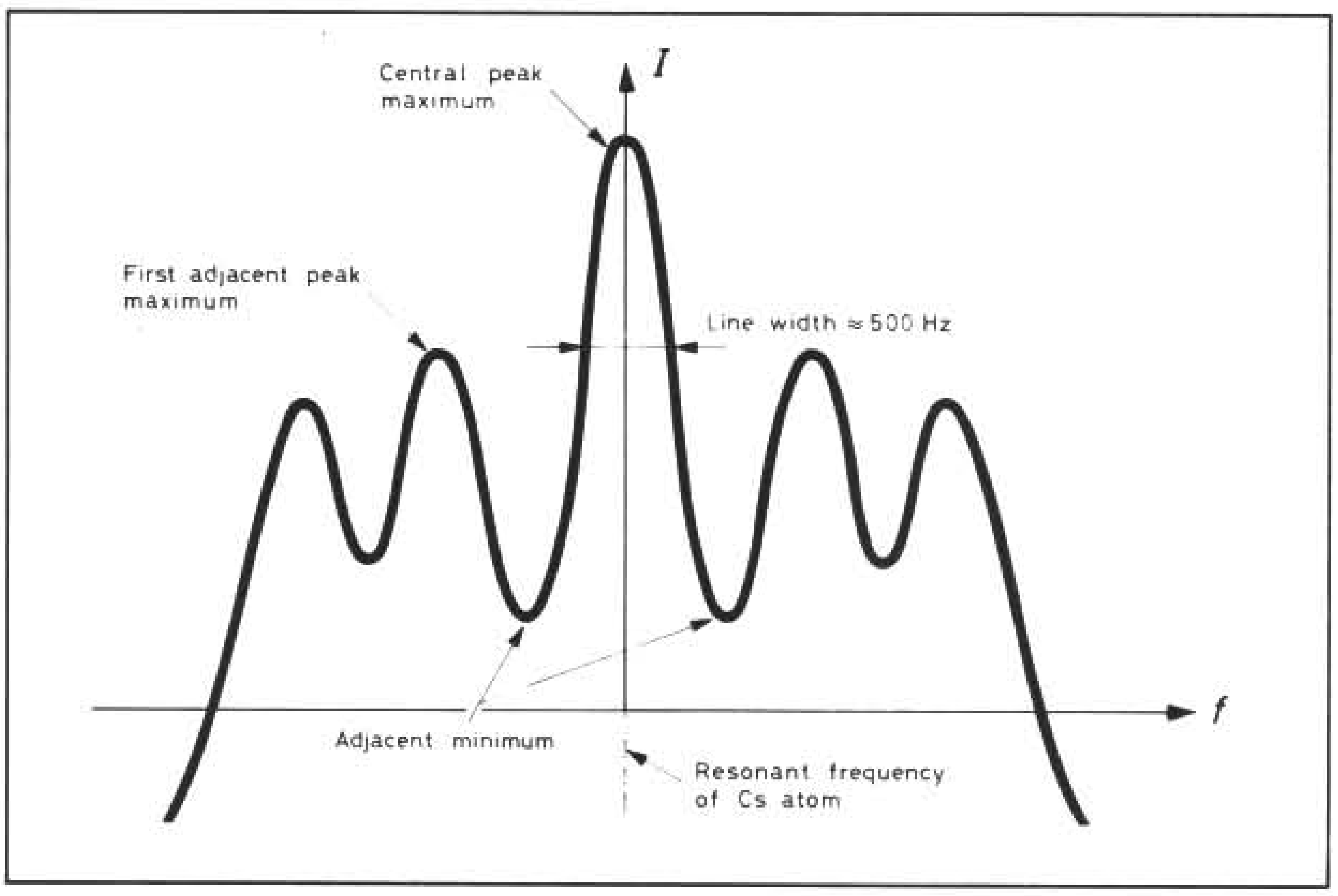


Fig. 3 Beam tube Ramsey response

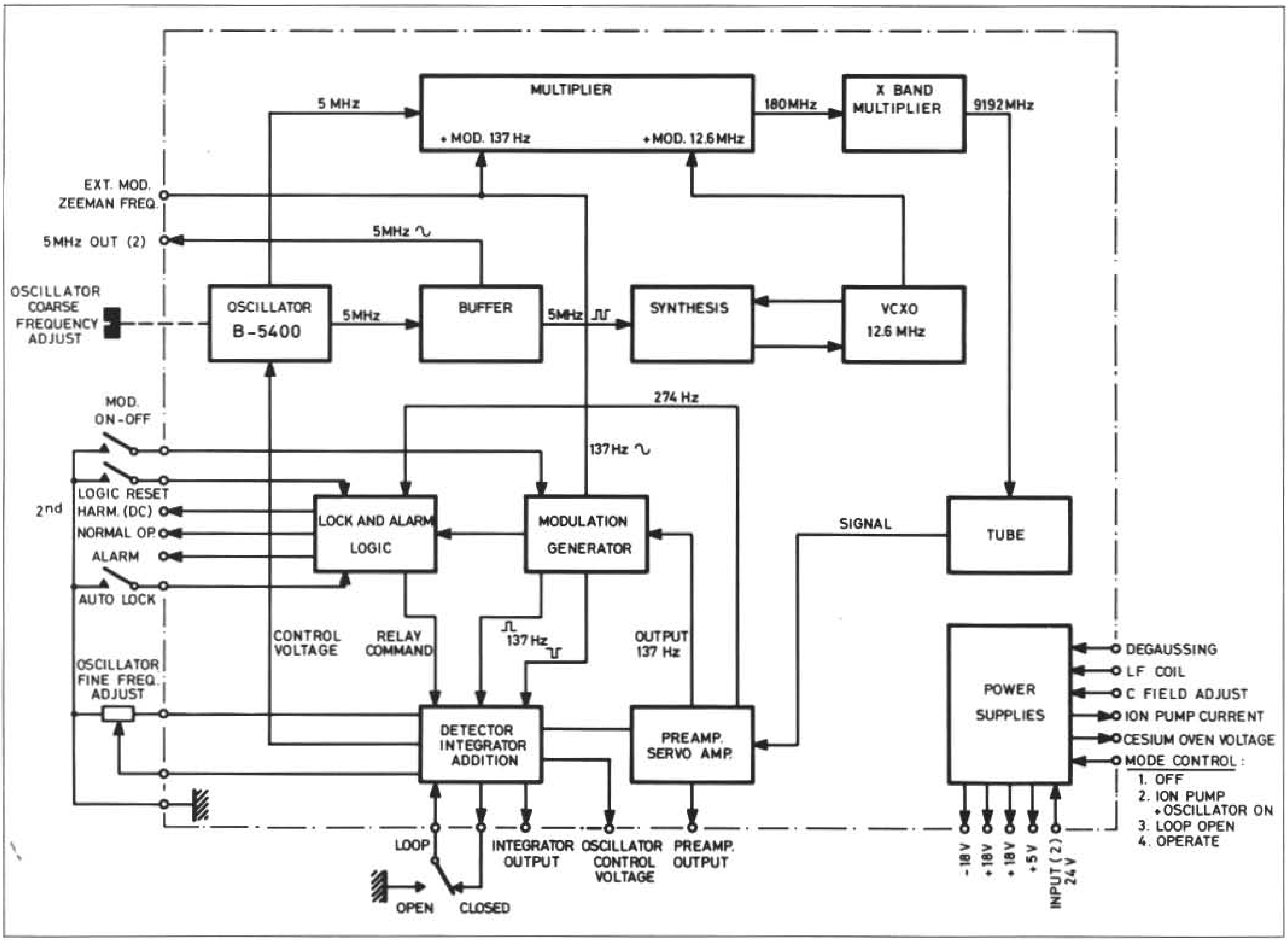


Fig. 4 Block diagram: 5 MHz Cesium Oscillator – Model 3000

3.2. 5 MHz Cesium Oscillator – Model 3000 (figure 4)

3.2.1. Oscillator B-5400

The 5 MHz quartz oscillator is from Oscilloquartz' standard product line. Spectral characteristics of this oscillator were reported at the 1971 Frequency Symposium by Brandenberger and Halford.

3.2.2. Frequency multiplier (942 030 005)

Frequency multiplication from 5 MHz to 180 MHz is accomplished in one module containing two sections. The first section multiplies from 5 MHz to 60 MHz and uses transistors selected for their low phase noise. 137 Hz sinusoidal phase modulation is accomplished at 5 MHz. This phase modulator also has provision for injecting the Zeeman frequency used in setting the beam tube C-field.

The second section multiplies from 60 MHz to 180 MHz using a transistor operating in switching mode followed by filtering and amplification to 300 mW nominal output. 12.631...MHz phase modulation is introduced at the input to the final amplifier. The 12.631...MHz spectrum is thus reproduced as a sideband of the 9 180 MHz signal multiplied from the 5 MHz oscillator. The sum of the two frequencies is the cesium transition frequency. Phase noise added to the signal by the frequency multiplier is about 15 dB below that of the B-5400 oscillator.

3.2.3. X-Band multiplier (942 030 004)

Multiplication from 180 MHz to 9 180 MHz is accomplished in one stage using a step-recovery diode mounted in X-band waveguide. Electrical and mechanical simplicity were emphasized in the design. Two adjustable tuning elements are used at the diode input; two at the diode output; and one matching adjustment to the beam tube cavity.

3.2.4. Pre-amplifier, servo-amplifier (942 030 007)

Gain of the pre-amplifier is adjustable for standardizing the overall servo loop gain to the particular beam tube being used. It also provides DC amplification in order to monitor beam tube current.

The servo amplifier is a fixed-tuned 137 Hz bandpass amplifier with 75 dB rejection of the second harmonic. Amplifying stages are integrated operational amplifiers, operating in appropriate feed-back networks.

3.2.5. Detector, integrator and summing network (942 030 013)

The detector is a conventional transformer-coupled synchronous detector driven by the 137 Hz square wave from the modulation generator. The integrator uses a low drift integrated operational amplifier with high quality capacitors in the feed-back network. A summing network allows addition of a manually controlled voltage for tuning the 5 MHz oscillator when the servo-loop is in the LOOP OPEN mode. A relay command is provided to block the alarm control circuit during adjustments of the servo loop.

3.2.6. Modulation generator (942 030 008)

A free-running 548 Hz multivibrator divided by 4 provides the 137 Hz square wave modulation reference driving the servo loop synchronous detector. The square wave signal is filtered and used for the 137 Hz sinusoidal modulation at 5 MHz. After a 90° phase shift, the square wave reference drives a second synchronous detector which senses the 137 Hz quadrature signal component coming from the beam tube when the microwave frequency does not correspond to the center of the main Ramsey peak. The quadrature signal is used in the alarm logic.

3.2.7. Lock and alarm logic (942 030 009)

The lock and alarm circuit responds to a signal at 137 Hz in quadrature, and to the second harmonic at 274 Hz, coming from the beam tube. When the prescribed relationship between these signal outputs is fulfilled, the logic actuates the servo loop lock, if the OPERATE mode switch is in AUTO LOCK position.

3.2.8. Synthesizer (942 030 011)

A 12 631...MHz voltage-controlled crystal oscillator provides the frequency which is added to the 9 180 MHz derived from the 5 MHz oscillator. In turn, the 12 631...MHz VCXO is phase-locked to a frequency precisely synthesized from the 5 MHz oscillator.

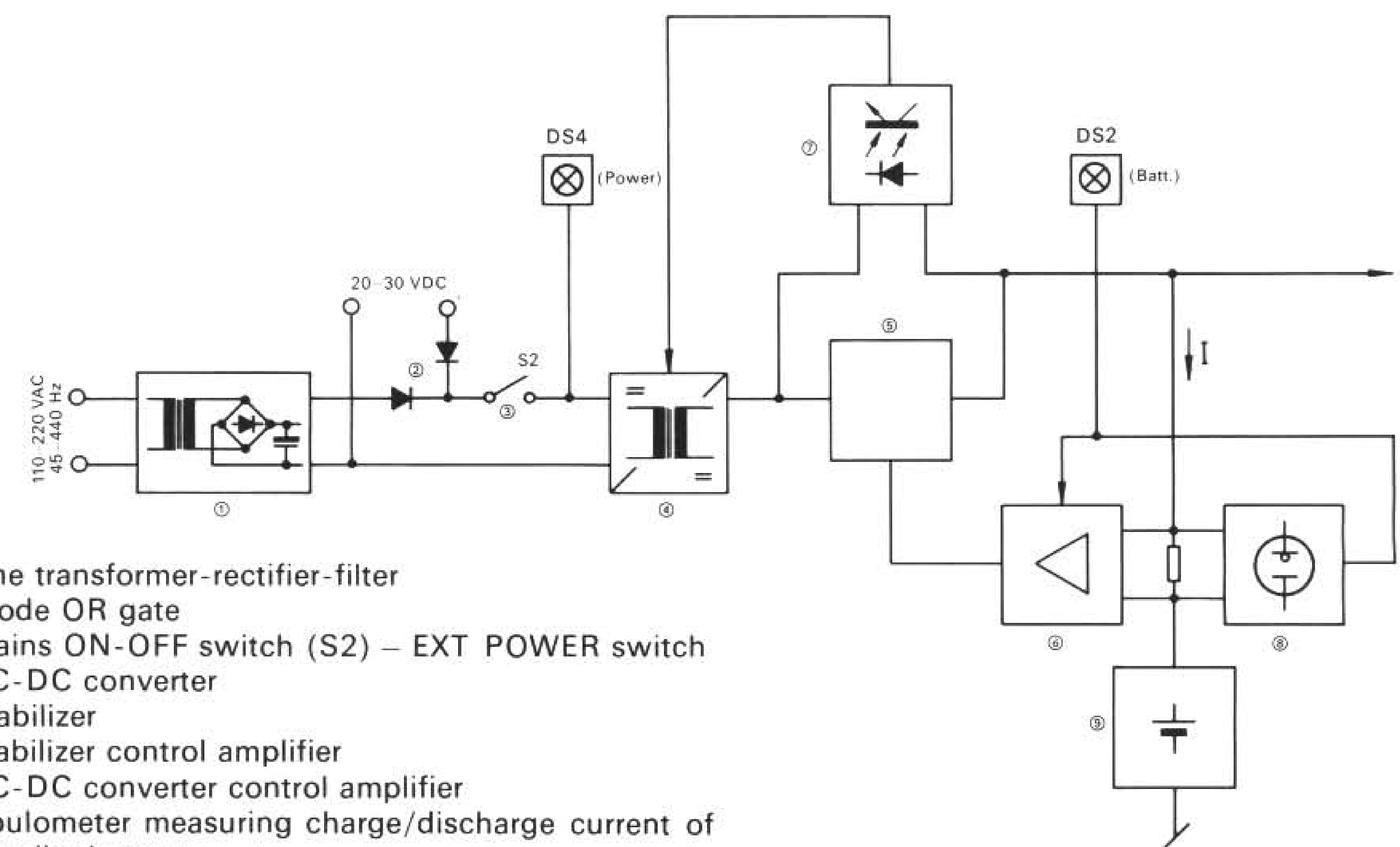
3.3. Power supply and standby battery (942 030 022..023..026) (figure 5)

The power supply and internal battery of the model 3200 are of a design which permits the instrument to be powered in the following three ways:

1) Primary power 110/220 VAC (45 to 440 Hz);
2) Secondary DC power source (20 to 30 VDC), either side ground;
3) Internal rechargeable battery if the above power sources are interrupted.

The main advantages of this power supply unit are:

- It is possible to connect the instrument to an external 24 VDC power source with either + or − grounded.
- The necessary power is supplied to the standard, without alteration of performance, in any condition of power supply (AC or DC).
- Interference from the external DC source to the frequency standard is avoided.



① Line transformer-rectifier-filter
② Diode OR gate
③ Mains ON-OFF switch (S2) – EXT POWER switch
④ DC-DC converter
⑤ Stabilizer
⑥ Stabilizer control amplifier
⑦ DC-DC converter control amplifier
⑧ Coulometer measuring charge/discharge current of standby battery
⑨ Standby battery pack

Fig. 5 Block diagram: power supply and standby unit

- The fast charging mode is automatically controlled as a function of the current drawn during operation on standby battery.
- The frequency standard will always operate from AC power as long as the AC voltage is present.

A full DC isolation is obtained by using a power converter whose chopper pulse length is controlled by an opto-electronic feed-back device. This permits the stabilizer to be operated with the minimum power requirement and ensures the built-in standby battery the best operating condition within a large range of AC or DC input voltages. It also allows for an extended duration of the internal standby power and a longer operating life of the internal battery pack.

Using a fixed chopper frequency for the power converter permits control of unwanted side-bands in the output standard frequency.

The internal standby battery consists of rechargeable Ni-Cd cells which ensure a power reserve for 3 to 5 hours (at 25° C) to the instrument. Should this not be sufficient, the frequency standard can be connected to an external 24 VDC power source (20 to 30 VDC).

A device, consisting of a coulometer coupled with an operational amplifier, controls the amount of energy necessary to charge the internal battery. This device allows for a most efficient operation of the battery which is normally maintained permanently on trickle charge. After being discharged for a certain time, the internal battery will automatically be recharged in a fast charging mode until the amount of energy used has been fully compensated, then it will revert to the normal trickle charge mode. As this control is fully automatic, it precludes the possibility of having the battery damaged by leaving it inadvertendly on fast charging mode, and furthermore ensures that the battery will be again fully charged and operational within the minimum time.

4. Installation and Turn-on Procedure

Unpacking and inspection

Check first that the packing does not present any sign of rough handling such as dents, scratches which might have occured during transportation. Also inspect the instrument carefully for possible damage (knobs broken, dents, etc.).

Should the instrument have suffered any damage, immediately notify the carrier and retain the packing material for inspection, notify Oscilloquartz SA.

Note: For extended storage periods, the ion pump must be energized at least once every three months. It must be continuously operated when the storage temperature exceeds +35° C. In these cases, connect the instrument to an external power as described in § 4.1. below and set the mode selector switch S1 to position OSC+PUMP (fig. 10).

4.0. Installation into standard 19" rack

The Model 3200 Cesium Beam Frequency Standard is delivered with a rack mounting kit as standard accessory which will permit the instrument to be installed into a standard 19" rack.

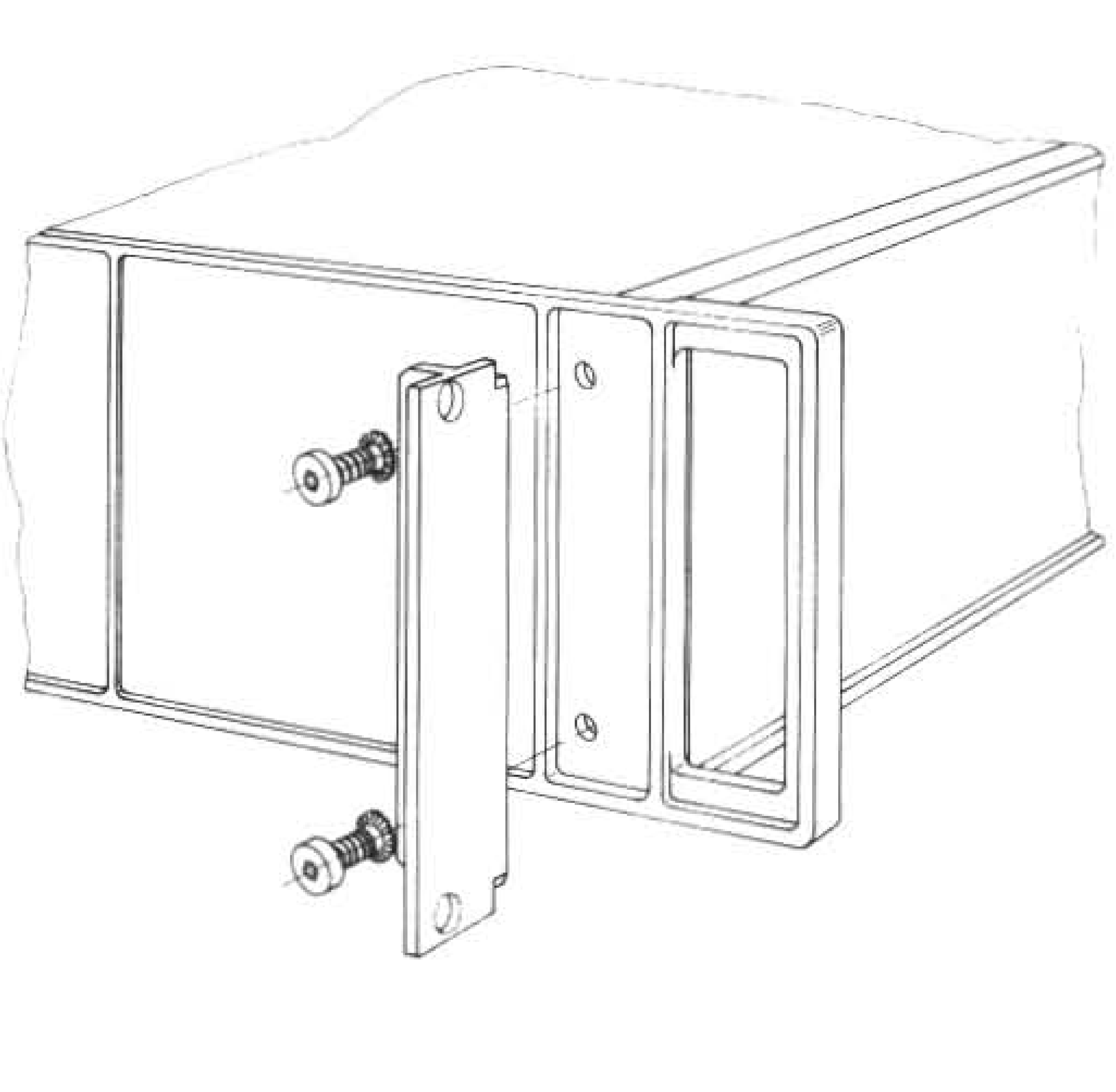
The kit includes two fixing brackets with their respective screws and washers.

To install the brackets proceed as follows:

a) remove small lateral cover plates, located immediately behind the instrument's handles

b) mount brackets to this place using the fixing screws delivered with the kit

c) remove folding feets of instrument, simply by taking off the fixing screw.



4.1. Power connections

4.1.1. Connection to an AC power line

a) **Caution:** Before connecting the instrument, check position of mains voltage selector switch S3 (fig. 6). A black point on the line voltage selector switch blocking plate is located just below the line voltage value (fig. 6) to which the instrument has been set (110 or 220 VAC). To change the setting remove the blocking plate after having taken out the Phillips set screw located just below the switch S3, move S3 to position corresponding with local line voltage, replace blocking plate after having turned it to its other face.

b) Make sure that fuse F1 fig. 6) has correct rating, i.e.: 3.15 A slow-blow for 110 VAC line (fuse 5×20 mm) or 1.6 A slow-blow for 220 VAC line (fuse 5×20 mm).

c) Check that the external power switch S2 is in position OFF (fig. 6).

d) Check that the mode selector switch S1 is in position OFF (fig. 10), only if standard is not operating.

e) Connect external AC source (local power line) to the AC line connector using the connecting AC power cable supplied with the instrument (fig. 6).

f) Turn on the instrument by setting switch S2 EXT POWER to position ON (fig. 6).
Indicator light DS4 (fig. 7) will glow. If the internal standby battery requires charging, indicator lamp DS2 (fig. 7) will glow.

4.1.2. Connection to a DC power line

a) Make sure that fuse F2 (fig. 6) has correct rating (5 A slow-blow); 5×20 mm.

b) Check that the external power switch S2 is in position OFF (fig. 6).

c) Check that the mode selector switch S1 is in position OFF (fig. 10), only if standard is not operating.

d) Connect external DC power source to the plug J1 (through the mating connector supplied with the instrument), on the instrument rear panel (fig. 6) respecting the indicated polarity (fig. 6a).

e) Turn on the instrument as indicated in § 4.1.1. f).

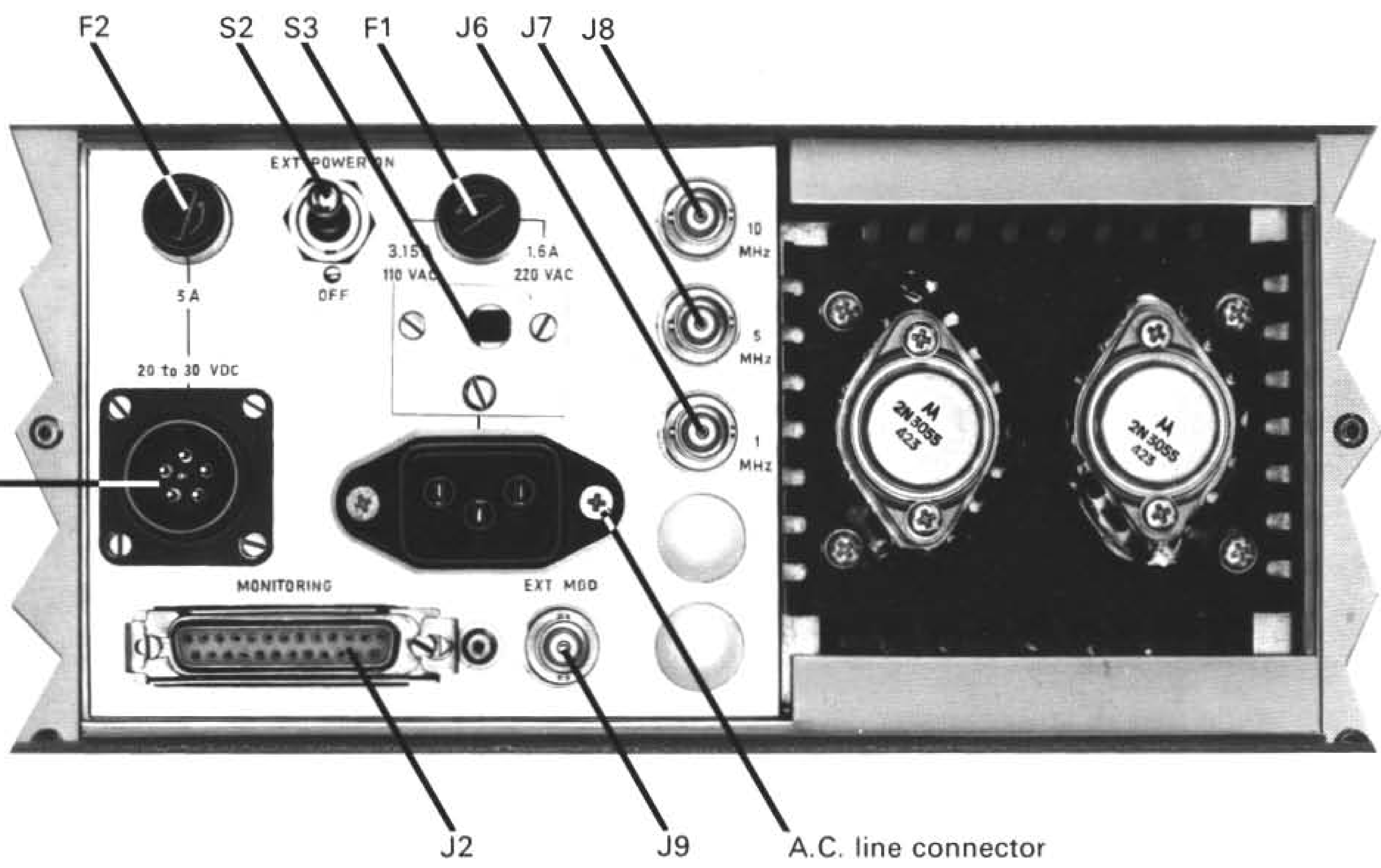


Fig. 6 Cesium Frequency Standard, Model 3200 (rear panel)

F1 AC power fuse
F2 DC power fuse
S2 External power switch
S3 Line voltage selector switch
J1 External DC connector
J2 External monitor connector
J6 1 MHz standard frequency output
J7 5 MHz standard frequency output (ref)
J8 10 MHz standard frequency output
J9 External modulation connector

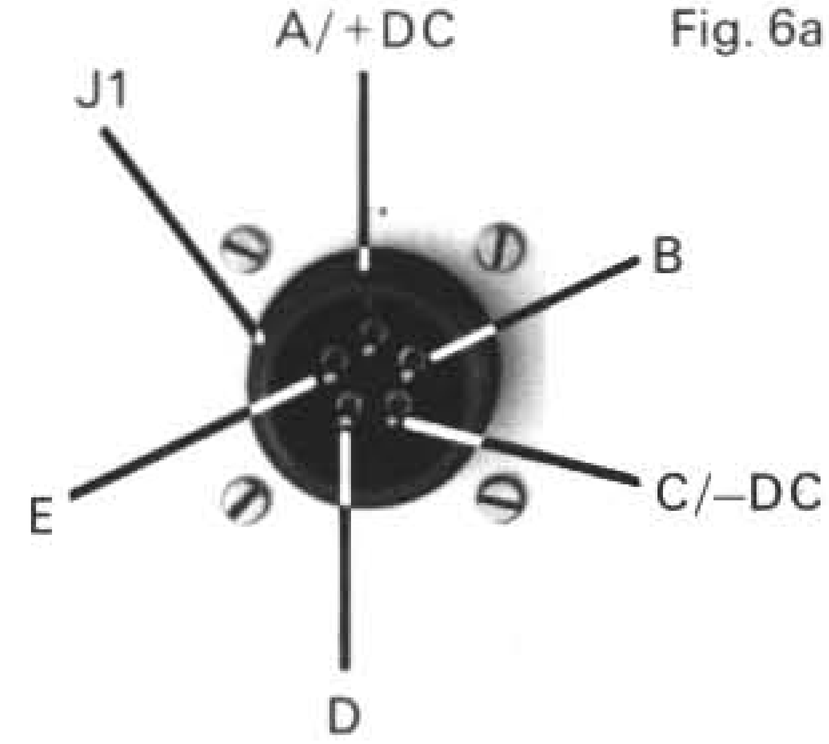


Fig. 6a

4.2. Operation on internal standby battery

Should the external power sources fail, the built-in standby battery will provide the necessary power for the instrument in a fully operating condition for a period of 3 to 5 hours at 25° C.

Note: It is recommended not to initially turn-on the instrument on its standby battery. As the oscillator oven would be cold, the current drain on the battery during the warm-up time would be excessive and appreciably reduce the power reserve. Operation on the built-in standby battery should be permitted only after the unit has warmed-up.

4.2.1. Switching over to standby battery operating mode

Should the external power source fail, the instrument will automatically continue to operate from the internal standby battery without interruption. At this time, indicator DS2 on front panel will glow and DS4 (fig. 7) will go out.

Normal operation will resume when the external power source reaches its rated level. Indicator light DS4 will light up and DS2 will remain on until the built-in standby battery has been fully recharged (fig. 7).

To disconnect and to connect the frequency standard from the external AC or DC power sources and have it operating only from the standby battery, it is recommended to first set EXT POWER switch S2 (fig. 6) to OFF.

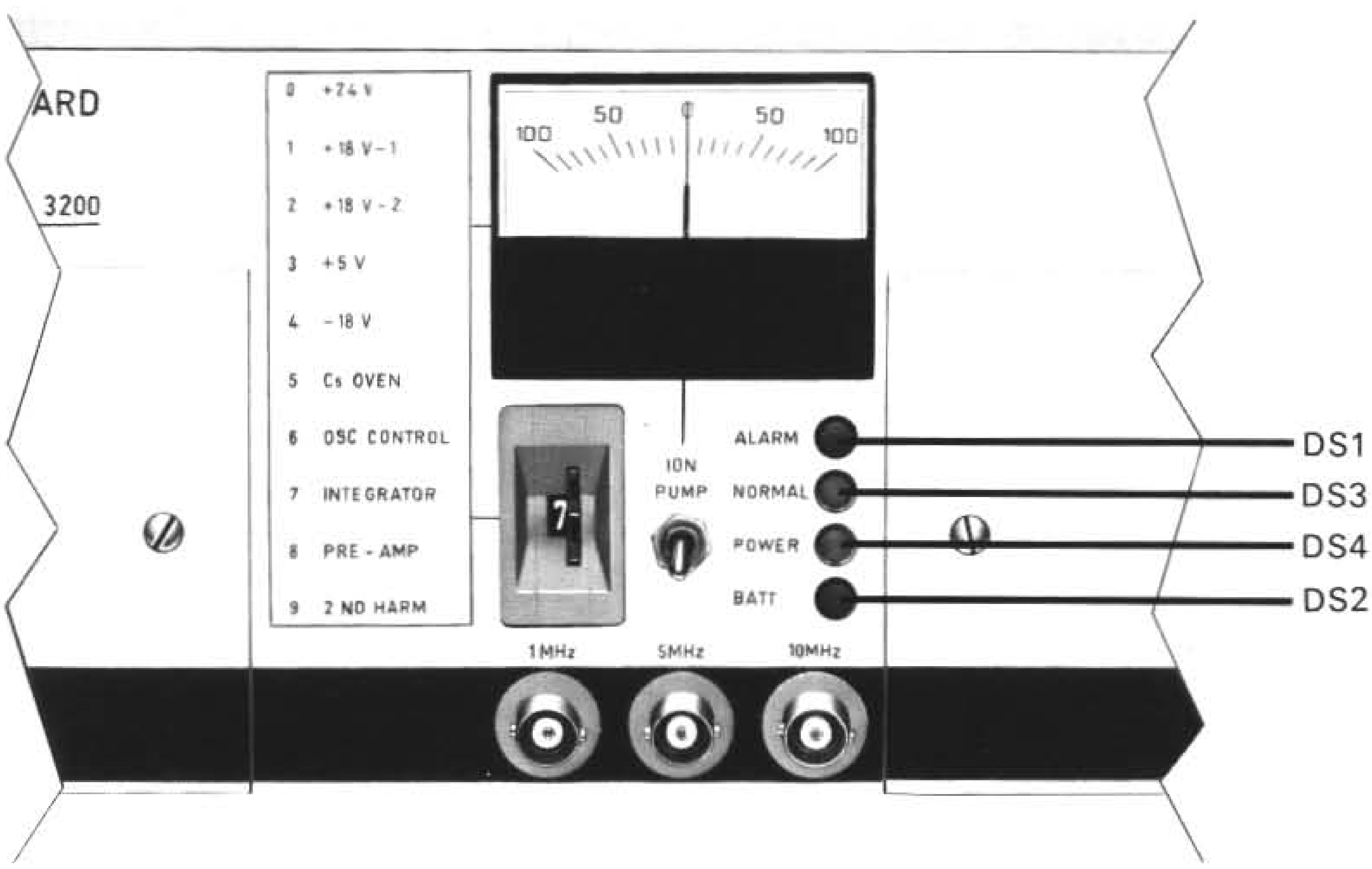


Fig. 7 Cesium Frequency Standard, Model 3200 (middle of front panel)

DS1 (ALARM)	Memorized OUT OF LOCK indicator light
DS2 (BATT)	Standby battery indicator light
DS3 (NORMAL)	Normal operation indicator light
DS4 (POWER)	External power indicator light

5. Operating Instructions

Important note

The model 3200 has been extensively tested at all levels of function: discrete component, circuit module, system element; and finally the entire standard has been subjected to several hundred hours of frequency comparison.

As received at the users installation, all controls and individual circuit adjustments are in their factory-set position (unless damage has occured in shipment) and should not be changed without definite evidence that there has been a change in the operating point of that particular element, and that adequate test equipment is at hand to assure correct operation after readjustment.

The C-field digital potentiometer R2 (fig. 10) has a setting of 500 for the basic calibration of the instrument.

A change of the setting by 1 unit in the third digit changes the frequency by about 1×10^{-13} parts.

The setting of this potentiometer should never be changed from 500 unless for particular reasons relating to the intercomparison with other primary standards for several months or unless for C-field correction after a precise measurement of its value.

5.1. Start-up procedure

After the Primary Frequency Standard, Model 3200 has been switched-on as indicated in § 4.1.1. f), it is ready for the turn-on procedure.

The following sequence of operations is followed to turn-on the standard and the reverse sequence is followed to turn it off. Refer to Table I for a summary of monitor M1 indications (fig. 9) for each step of the turn-on procedure.

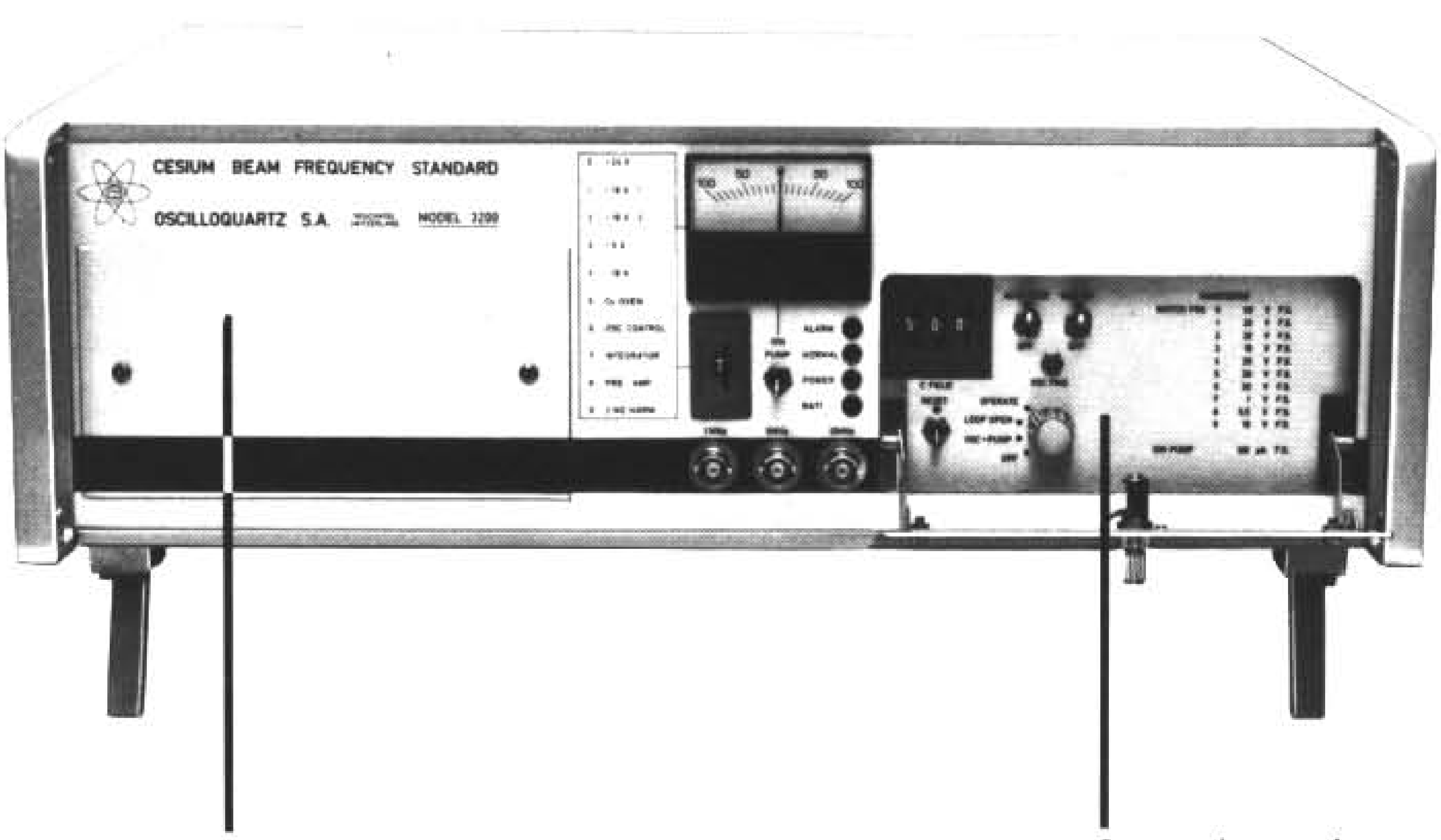


Fig. 8 Cesium Frequency Standard, Model 3200 (front panel)

Sequence of Operation for Turn-on

Function	Result	Indication	Monitoring reading		
			Position	Reading	Full scale
EXT POWER ON	Trickle charge applied to battery reserve	Front panel green lamp POWER illuminates	all positions	0	
MODE OSC+PUMP	Power applied to oscillator and ion pump	ION PUMP switch in UP position shows pump current on monitor BATT lamp may show red if battery is under rapid charge after oscillator is warm	0 other positions	+24 V 0	50 V
MODE LOOP OPEN	All circuits are energized, control loop is open	ALARM lamp illuminates red	0 1 2 3 4 5 6 7 8 9	+24 V +18 V +18 V + 5 V − 18 V 10 V initial; 5 to 10 V after oven is warm + 5 V integrator may be any value when loop is open initial value ~ +20 to +50 mV Final value after oven is at operating temperature Mod is ON=−165 mV typically +4 to +10V when Mod is ON	50 V 20 V 20 V 10 V 20 V 20 V 20 V 1 V 0,5 V 10 V
MODE OPERATE	Control loop closed	RESET toggle extinguishes ALARM lamp NORMAL lamp illuminates green	0 1 2 3 4 5 6 7 8 9	+24 V +18 V +18 V + 5 V − 18 V + 5 V to +8 V at 25° C after warm-up +5 V ~ 0 V depending on OSC FINE tuning control position − 165 mV typically +4 to +10 V, >+3 V in all cases	50 V 20 V 20 V 10 V 20 V 20 V 20 V 1 V 0.5 V 10 V
AUTO LOCK OFF	Allows control loop to operate independent of alarm logic	Loop operation normal			
AUTO LOCK ON	Control loop activated when alarm logic is positive	Operation normal		see § 5.1.2.	
	Integrator deactivated when alarm logic is negative	Integrator output at 0, 5 MHz oscillator frequency at free-running value. Alarm lamp shows red	7	0	1 V

Table I

When EXT POWER switch S2 (fig. 6) is actuated, a trickle charge of approximately 100 mA is applied to the internal battery reserve. After having opened the plate giving access to the control panel (fig. 8) proceed as follows:

5.1.1. OSC + PUMP mode

a) Set monitor meter selector switch S4 (fig. 9) to position 0. (+24 V).

b) Set mode selector switch S1 (fig. 10) to position OSC + PUMP. The monitor meter M1 (fig. 9) will show the value of 24 V supply. If value is less than 20 V and BATT lamp DS2 (fig. 7) is on, this indicates that internal battery is on charge. If this occurs, wait until the battery voltage reaches 24 V.

It is possible to initiate the turn-on procedure when the internal battery is on charge, but only after battery voltage recovery to 24 V has been attained.

c) Monitor the value of pump current by actuating the momentary switch S5 (fig. 9) in direction of ION PUMP and observing current reading on monitor meter M1 (fig. 9). Pump current should be below 50 μA before proceeding to energize the entire electronic system as indicated in § 5.1.2. and 5.1.3. below.

d) **Action of pump alarm circuit**

The pump alarm circuits are actuated for two conditions of pump operation:

1) Pump current in excess of 50 μA
2) Loss of +3500 V pump supply.

Either of these two conditions will shut down the +18 V-2 supply and this in turn de-energizes all power supplies to the beam tube except for the ion pump supply. If the 3500 V is present, the pump will continue to function until the required vacuum (<50 μA) is obtained at which time the +18 V-2 supply will be energized.

This sequence of operation may be observed during the start-up procedure even though pump current is less than 50 μA when the mode switch is placed to LOOP OPEN or OPERATE position. It occurs because pressure can rise when heating power is applied to the oven and ionizer elements within the tube. A check of +18 V-2 (monitor meter selector switch S4 in position 2 – fig. 9) will indicate whether shut down has occured or not.

It is necessary to wait until normal pressure is obtained and +18 V-2 re-energized before continuing with the start-up.

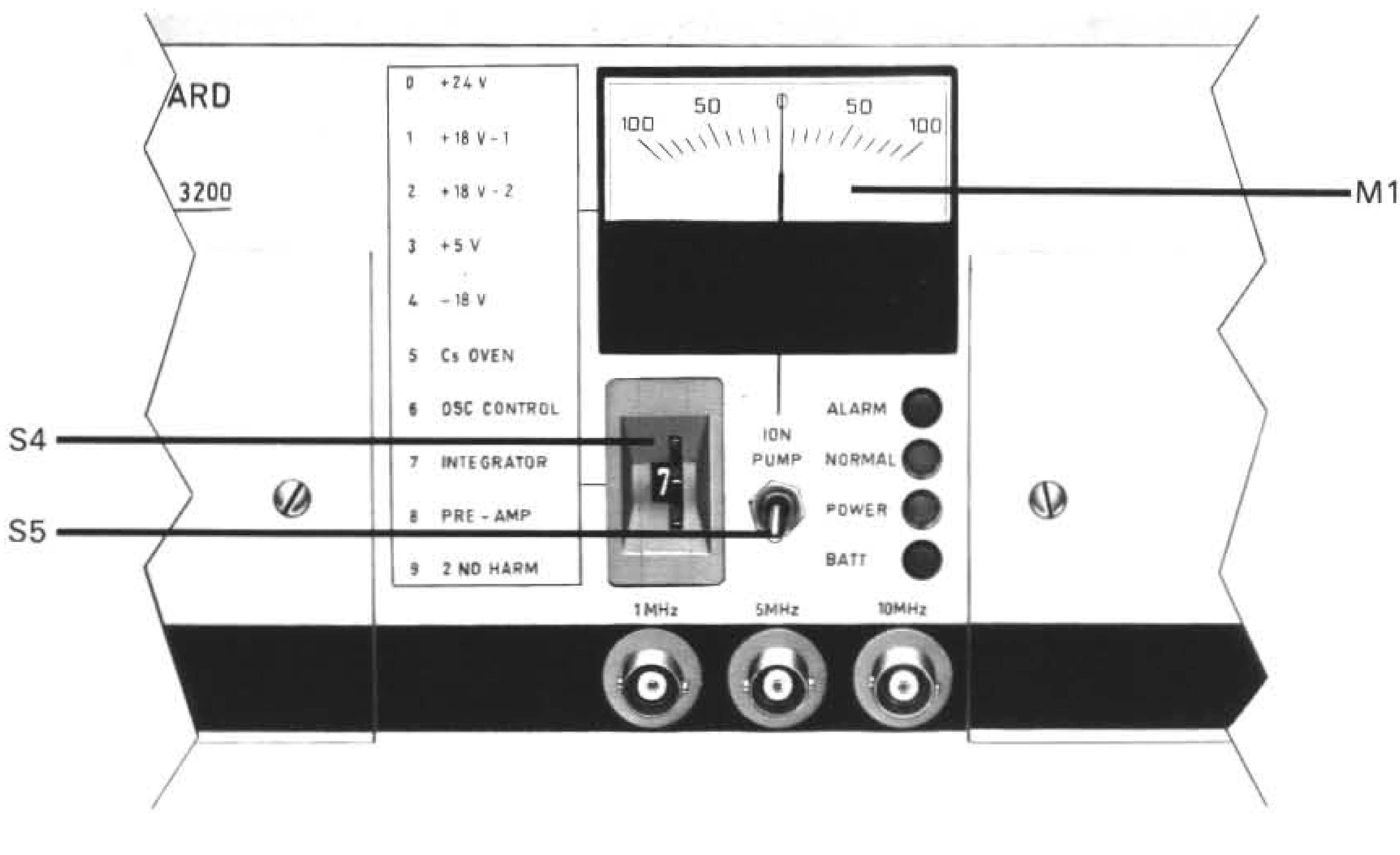


Fig. 9 Cesium Frequency Standard, Model 3200 (middle of front panel)

M1 Monitor meter
S4 Monitor meter selector switch
S5 Ion pump monitor switch

5.1.2. **OPERATE mode**

In the OPERATE mode the control loop to the 5 MHz oscillator is closed and frequency is controlled by the atomic resonance. There are two conditions of operation in the OPERATE mode:

AUTO LOCK ON and AUTO LOCK OFF

It is necessary to understand the operation of the AUTO LOCK and its limitations. The OPERATE mode may be actuated with the mode selector switch S1 (fig. 10) from the OSC + PUMP position without the intervening LOOP OPEN mode.

a) **OPERATE mode – AUTO LOCK ON.**

The essential feature of AUTO LOCK operation is blocking the servo loop integrator output at 0 volt when the correct alarm logic conditions are not fulfilled. The correct logic conditions are fulfilled only when the frequency of the 5 MHz oscillator is within about 1×10^{-9} parts of the frequency determinated by the atomic resonance; and this requirement applies whether the integrator is blocked at 0 volt, or whether it is free to respond to the control signal coming from the beam tube. The transition between these two conditions is delayed by about 10 seconds. The delay thus imposed prevents a too sudden response to noise or frequency transients which may occur in normal use of the instrument.

There are two advantages to this mode of operation:

- the servo system cannot lock the oscillator to a secondary peak of the Ramsey response during the warm-up cycle or because of incorrect manual adjustment of the oscillator frequency.

- in the event of loss of signal in the control loop, the integrator is blocked at 0 and the output frequency of the 5 MHz oscillator will correspond to the value established by oscillator COARSE and FINE settings.

There are also two important limitations to this mode of operation:

- At the end of its warm-up cycle if the final frequency of the 5 MHz oscillator is not within 1×10^{-9} parts from the central Ramsey response, the integrator will be blocked thus preventing servoing the oscillator even though a 1×10^{-9} frequency error is well within the normal control range of the servo loop after it is locked.

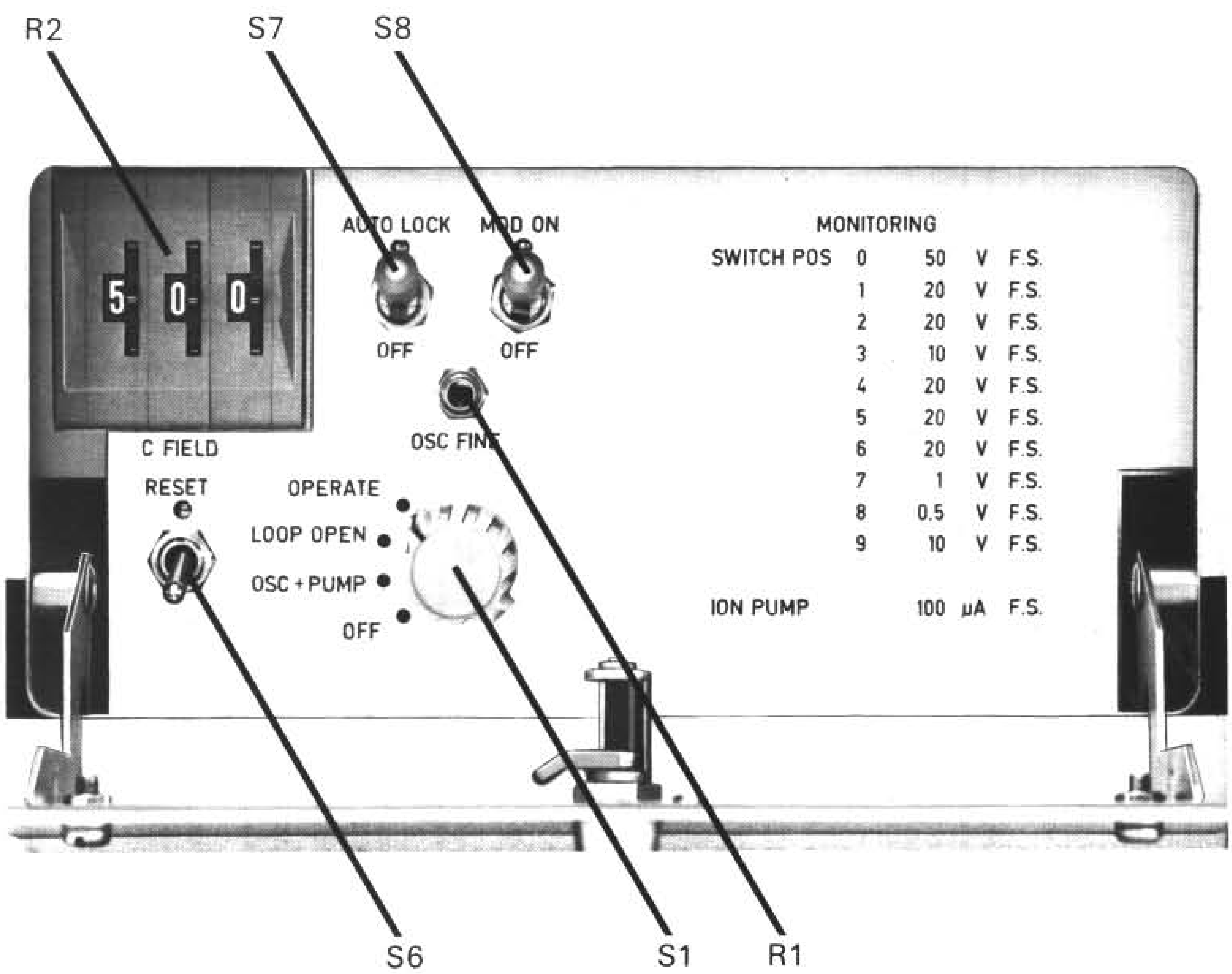


Fig. 10 Cesium Frequency Standard, Model 3200 – Control panel

R1 Oscillator fine frequency control
R2 C-field digital potentiometer
S1 Mode selector switch
S6 Alarm reset momentary switch
S7 Auto lock switch
S8 137 Hz modulation switch

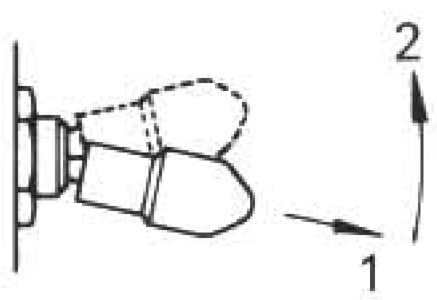
- If the oscillator makes a large frequency excursion due, for example, to environmental conditions such as mechanical shock or large and abrupt temperature changes, the time constant of the servo loop may be too long to allow correcting the frequency of the oscillator before the alarm logic delay functions and blocks the integrator output to 0. If at this time the oscillator is not within the 1×10^{-9} range accepted by the logic, it will be blocked out of lock.

Operation of the auto lock and alarm is discussed in § 5.1.4. For setting OPERATE mode, proceed as follows:

1) Turn mode selector switch S1 (fig. 10) to position OPERATE.

2) Set auto lock switch S7 and 137 Hz modulation switch S8 both to position ON (fig. 10).

Caution
S7 and S8 are locking lever switches which must be first pulled to unlock and operate



1. Pull
2. Operate

Power is supplied to all circuits in this mode. The automatic lock mode of this Frequency Standard takes advantage of frequency repeatibility of the B-5400 crystal oscillator upon warm-up.

During the warm-up transient the frequency of the B-5400 passes through the acquisition and lock range of the frequency control circuit, overshoots and then returns to the nominal lock control range. The green NORMAL indicator light DS3 (fig. 7) will glow several times during warm-up.

The red ALARM indicator light DS1 (fig. 7) will remain on until the RESET switch S6 (fig. 10) is momentarily actuated and alarm logic conditions are fulfilled.

The time normally required for the warm-up and lock cycle is about 20 minutes; however, it may take as long as 24 hours before the instrument reaches its long-term condition of stability in the ambient condition of the installation. Table I gives values of monitor meter M1 (fig. 9) readings normally observed.

If the frequency of the 5 MHz oscillator does not return to within 1×10^{-9} of the correct frequency for the cesium resonance, the range of auto lock may be exceeded. In this case place monitor meter M1 (fig. 9) to INTEGRATOR (position 7) and while observing integrator voltage, set auto lock switch S7 (fig. 10) to OFF. Integrator voltage will depart from 0 in either + or – direction. If the frequency of the oscillator is within the capture range of the central peak, the integrator voltage will stop at some constant value (this value may be off-scale for the front panel meter M1 – fig. 9) and the green NORMAL indicator light DS3 (fig. 7) will glow. Actuate the alarm reset switch S6 (fig. 10) to check that correct alarm logic conditions exist. Set auto lock switch S7 to ON (fig. 10). Proceed as necessary with oscillator FINE adjustment as described in § 5.1.3. c) and d) below, but only after the oscillator has been in operation for 24 hours.

If lock condition cannot be achieved in the above manner, the oscillator frequency is outside capture range of central peak, in which case wait several hours for temperature stabilization, and proceed as explained in § 5.1.3. LOOP OPEN mode and adjust frequency of oscillator as described therein.

b) **OPERATE mode – AUTO LOCK OFF.**

In this mode of operation the servo loop is closed and the alarm logic is prevented from blocking the integrator. The oscillator may be locked to any Ramsey peak equal to the frequency corresponding to the integrator voltage attained, when the OPERATE mode is applied. If the frequency is locked to other than the correct Ramsey peak, the alarm reset switch S6 (fig. 10) cannot extinguish the alarm lamp.

Note: The AUTO LOCK ON operation is recommended when the instrument is used in laboratory or stable environmental conditions. The AUTO LOCK OFF operation is recommended if the instrument must function in rapidly changing environments such as portable service.

5.1.3. LOOP OPEN mode

The start-up procedure may be accomplished with the intermediate step of LOOP OPEN. This mode is also used during test and adjustment of several circuits in the servo system which must be made while the loop is in an unlocked condition.

a) The unit is placed in operation as indicated in section 5.1.1.

b) Place mode selector switch S1 (fig. 10) in LOOP OPEN position. The sequence of warm-up and energizing of circuits is the same as described in section 5.1.2. above, the difference being that auto lock circuits do not function and control of the 5 MHz oscillator is manual.

Control of the 5 MHz oscillator frequency may be accomplished with both the oscillator fine frequency control R1 (fig. 10) and 5 MHz oscillator coarse adjust (fig. 12). The oscillator fine frequency control R1 (fig. 10) is normally used and has sufficient range of frequency adjustment to pass from one adjacent peak of the beam tube Ramsey response to the other (fig. 11). The oscillator should be given several hours to warm-up in order not to have excessive drift while in the manual control mode (LOOP OPEN).

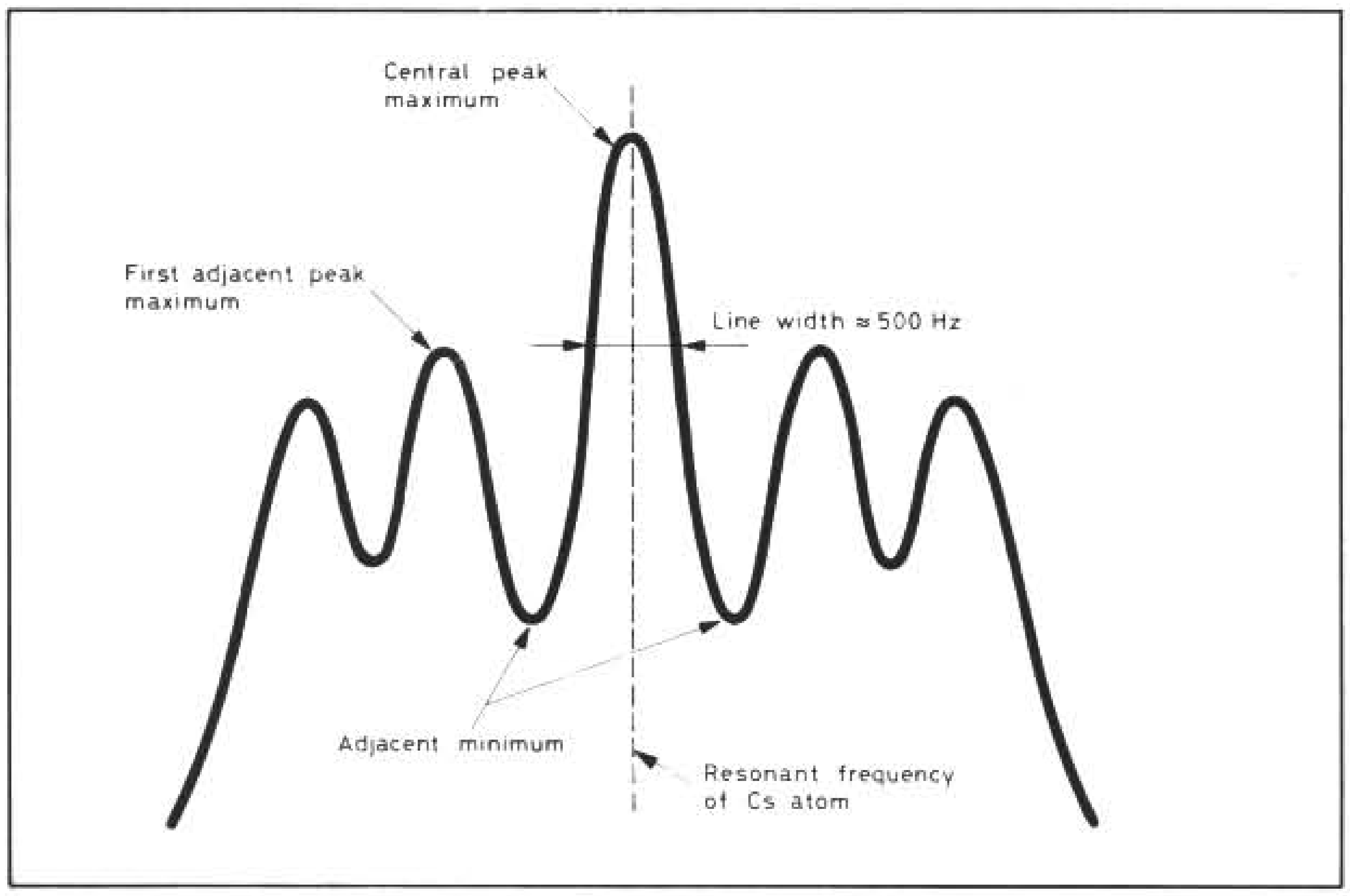


Fig. 11 Beam tube Ramsey response.

c) Place 137 Hz modulation switch S8 in OFF position, auto lock switch S7 in OFF position (fig. 10) and monitor meter selector switch S4 (fig. 9) in PRE AMP (position 8). Monitor meter M1 (fig. 9) will show a pre-amplifier output signal varying between 0 to –250 mV as the frequency is varied through the Ramsey response (fig. 11). The central peak is highest, and it is to this peak that the oscillator is locked. Adjust frequency with oscillator fine frequency control R1 (fig. 10) to central peak maximum. The standard may be placed in OPERATE mode from LOOP OPEN mode by proceeding to step d) below.

d) Place auto lock switch S7 in ON position, 137 Hz modulation switch S8 in ON position and mode selector switch S1 to OPERATE position (fig. 10). After a delay of several seconds, NORMAL indicator light DS3 (fig. 7) will illuminate. Momentarily actuating alarm reset switch S6 (fig. 10) extinguishes the ALARM indicator light DS1 (fig. 7), indicating that beam tube signals are present and system is locked to the correct peak.

e) Place monitor meter selector switch S4 in INTEGRATOR (position 7) and adjust oscillator fine frequency control for center scale, 0 reading.

5.1.4. Operation of auto-lock system and alarm circuitry

The fundamental and second harmonic signals of the modulation coming from the beam tube are applied to an elementary logic circuit which decides whether the servo loop can be actuated or not.

If the auto lock switch S7 (fig. 10) is in position ON, this logic circuit actuates the integrator when the conditions are fulfilled; when they are not fulfilled, the integrator is maintained at zero, and the frequency of the 5 MHz oscillator is determined by the combined OSC COARSE and OSC FINE (fig. 12 and fig. 10) adjustment setting.

If the auto lock switch S7 (fig. 10) is in position OFF, the output of the logic circuit is inhibited; the integrator is then free to respond to its input signal, independently of logic conditions. However, the alarm logic will still actuate the indicator lamps whether auto lock switch S7 is ON or OFF.

The action of the two indicator lights NORMAL DS3 and ALARM DS1 (fig. 7) is determined by the logic condition of the modulation signals aforementioned. The green NORMAL indicator light DS3 will glow and the red ALARM indicator light DS1 be extinguished – with alarm reset momentary switch S6 (fig. 10) – only if the oscillator is locked to the central Ramsey peak.

The transfer from a condition of normal operation to an open loop condition (alarm), is delayed by about 10 seconds. The transfer from the open loop condition to a condition of normal operation is also delayed but by about 4 seconds.

Such action avoids that the alarm condition opens the loop from possible transients or noise in the oscillator servo system. It is important to recognize and understand the presence of these delays in the indication and the circuit response when operating the cesium frequency standard in the various modes.

5.1.5. Monitor meter reading

After the standard has been placed in operation, record all monitor meter M1 (fig. 9) readings in the operating record sheet Table II. Record the readings again after several days of continuous operation and thereafter once a month, or at such intervals deemed appropriate by the user.

6. Adjustment Procedure

6.1. Introduction

The cesium beam tube in the Model 3200 Frequency Standard is a primary frequency reference whose characteristics derive from known physical laws. Utilization of the atomic resonance to control the frequency of a 5 MHz quartz crystal oscillator requires the generation, synthesis, modulation, demodulation, amplification, and filtering of signals ranging from 100 Hz to 9 GHz in frequency and from several nano-amperes to several hundred milliamperes in level. Each of these signal-generating and processing elements must be properly adjusted to avoid distortions and biases producing errors and instabilities at the output frequency which are unrelated to the inherent accuracy and stability of the atomic resonance.

The adjustments described in this manual are divided into two categories according to the usage of the frequency standard:

a) Those adjustments which can be made while the Frequency Standard is used for timing purpose. In this type of usage frequency offsets for extended periods of time, or phase jumps can cause time errors of unpredictable magnitudes. Unless another time reference is available, only the adjustments described in section 6 should be attempted.

b) Those adjustments are possible when the standard is not used for timing purpose. These adjustments and procedures are described in section 7, Maintenance.

6.2. Equipment needed

The adjustments described in section 6 can be accomplished with a screwdriver of 2.5 mm width and the front panel meter M1 (fig. 16).

6.3. Integrator zero adjustment

Design, pre-conditioning and adjustment of circuits are such that long term stability is assured. The normal aging of the 5 MHz crystal oscillator will be evidenced by a slow change in the integrator voltage with time (Monitor meter M1; selector switch S4 position 7 – fig. 16).

The integrator voltage should not be allowed to depart more than 0.5 V from the nominal zero value, otherwise the limits of automatic lock operation can be exceeded if the equipment is shut down.

6.3.1. OSC FINE adjustment

The voltage is returned to zero by adjusting the oscillator fine frequency control R1 (fig. 15) while observing integrator voltage on monitor meter M1, monitor selector switch S4 on position 7 (fig. 16).

Set auto lock switch S7 (fig. 15) OFF. Turn the oscillator fine frequency control R1 (fig. 15) in the direction of the integrator displacement, i.e. for +voltage on the meter, rotate the control clockwise; for –voltage rotate counter-clockwise. The time constant of the integrator is about 7 seconds, therefore, **this adjustment must be made very slowly and in small increments,** otherwise the control loop may become unlocked. Reset auto lock switch S7 to ON (fig. 15) when integrator voltage is at zero.

6.3.2. OSC COARSE adjustment

The OSC FINE adjustment changes the voltage applied to the frequency control of the 5 MHz oscillator. When this voltage has changed about 1 volt from the nominal 5 volts measured on monitor meter M1, selector switch S4 position 6 (fig. 16) it will be necessary to adjust the oscillator coarse frequency setting. To accomplish this, proceed as follows:

a) Remove the cover plate on the left side of front panel by removing the two retaining screws (fig. 8). Set auto lock switch S7 to OFF (fig. 15).

b) Observe value of OSC CONTROL voltage on monitor meter M1 – position 6 of monitor selector switch S4 (fig. 16). For a voltage less than 5 volts, the oscillator fine frequency control R1 (fig. 15) will be adjusted in a clockwise direction, as indicated in § 6.3.2. c); the opposite for a voltage greater than 5 V.

c) Place monitor selector switch S4 (fig. 16) to INTEGRATOR position 7 and adjust OSC FINE in the sense indicated in § 6.3.2. b) above. The integrator voltage will be displaced from 0 and to assure that the loop does not unlock, it is advisable to limit the change from 0 to about 0.5 V.

d) Return the integrator voltage to zero by adjusting the OSC COARSE potentiometer, front panel (fig. 12). The potentiometer is changed in the sence of the displacement of the integrator, i.e. integrator voltage positive, OSC COARSE control clockwise etc.

e) Repeat § 6.3.2. c) and 6.3.2. d) above until the OSC CONTROL voltage, position 6 of monitor selector switch S4 (fig. 16), is 5 V and INTEGRATOR voltage, position 7 of monitor selector switch S4, is again at 0 (fig. 16).

6.4. Pre-amplifier gain adjustment

This adjustment is made if the second harmonic beam tube signal shows a decline in level with time. The monitor meter readings recorded periodically in Table II are the basis of deciding whether a decline has occured or not. The decline can be attributed to an aging of the electron multiplier in the beam tube. The effect of this change is to reduce the loop gain, but it does not otherwise effect beam tube performance.

If second harmonic signal (monitor meter selector switch position 9, – fig. 16) shows a decline to ½ the original value recorded, proceed as follows:

a) Assure that standard is in OPERATE mode (§ 5.1.2.).

b) Remove instrument top cover and the cover plate of the electronic section (left side rear).

c) Set monitor meter selector switch S4 (fig. 16) to position 9 (2ND HARM).

d) Adjust pre-amplifier gain Ⓕ (fig. 18, circuit diagram 942 030 007) until the original value of second harmonic is obtained.

e) Note new reading on operation record data sheet Table II.

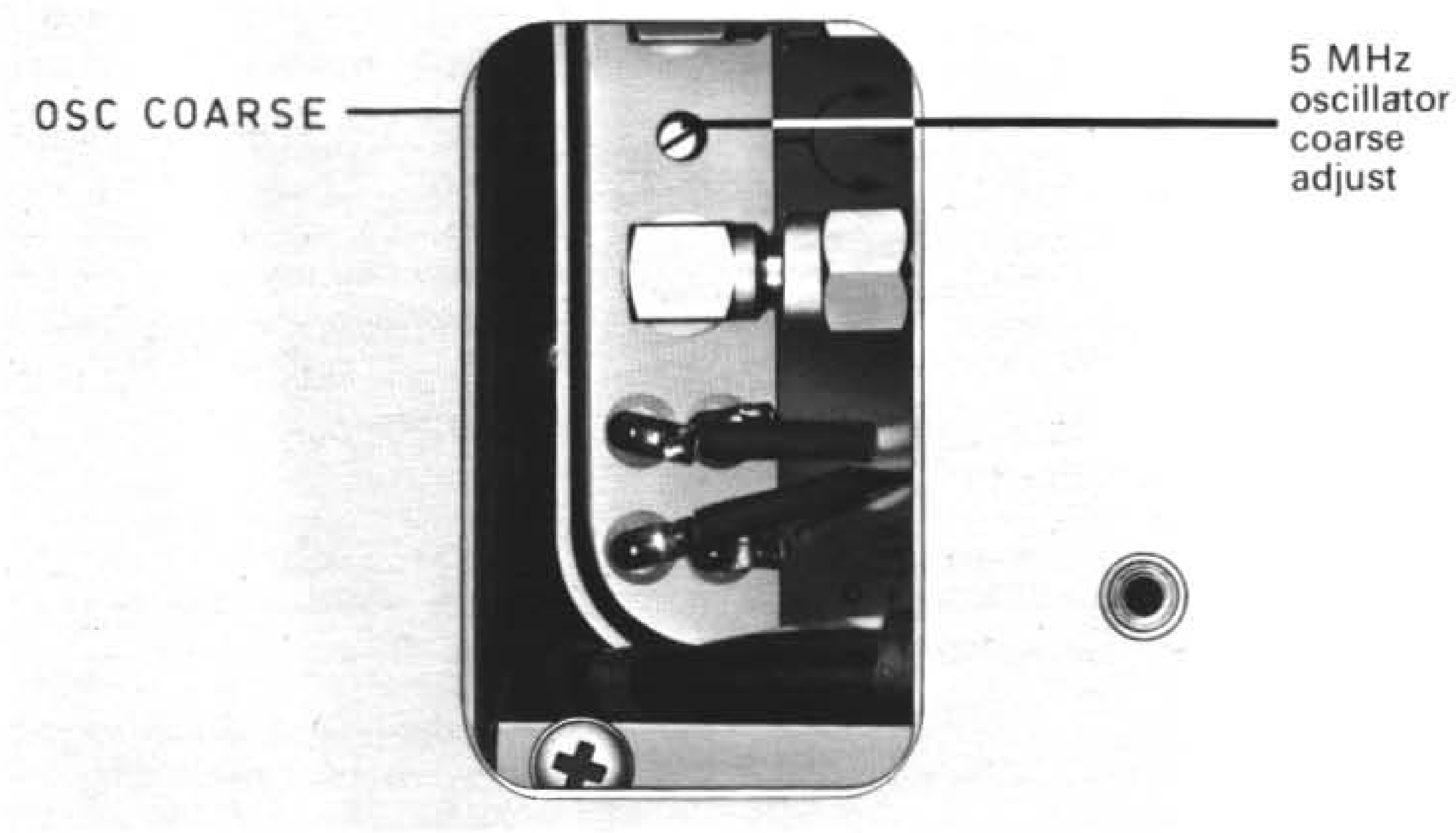


Fig. 12 Cesium Frequency Standard, Model 3200
Front panel oscillator access

7. Maintenance

The maintenance described in this section consists of those operations and adjustments which can be made when the standard is not being used as a primary reference. They can generally be made with ordinary laboratory instruments and careful attention to details of underlying principles of operation. They should seldom be needed, and usually only when a component has been replaced, or when the standard has been subjected to some extreme environmental condition or out of service for a prolonged period of time.

7.1. Equipment needed

- Oscilloscope – TEKTRONIX, Mod. 422 or equal
- Frequency counter, HP, Mod. 5326A or equal
- Multimeter – Siemens Multizet or equal
- Signal generator – WAVETEK, Mod. 142 or equal
- Strip Chart Recorder – HP, Mod. 680M or equal
- Degausser – OSCILLOQUARTZ, Mod. 3098 or equal
- A.C. ammeter 1A (full scale)
- Wave Analyzer QUAN-TECH 304 TDL or equal

7.2. Access to adjustment controls

For the adjustments requiring access to the circuit cards, remove top cover of the frequency standard and the cover plate (left side rear) of the electronic section.

For measurement and adjustment of the C-field, the cover plates both bottom and top of the electronic section must be in place.

7.3. Rear panel connector J2

The connector J2 on the rear panel (fig. 13) allows connection of external instrumentation to measure the test points provided by the front panel monitor and in addition the following internal connections:

a) Degaussing.

b) Beam tube low frequency coil.

c) C-field supply.

Figure 14 shows pin connections. **OSC CONTROL, INTEGRATOR, PRE-AMP, connections are shielded.** The external mating connector is type DP-25 P (Cannon or other manufacturer).

External monitoring enables the use of instruments of greater precision and resolution than the front panel monitor meter M1 (fig. 16) as well as the simultaneous measure of several quantities and is recommended when the following adjustments are to be made.

If an external instrument is used, set the monitor meter selector switch S4 (fig. 16) to position 0.

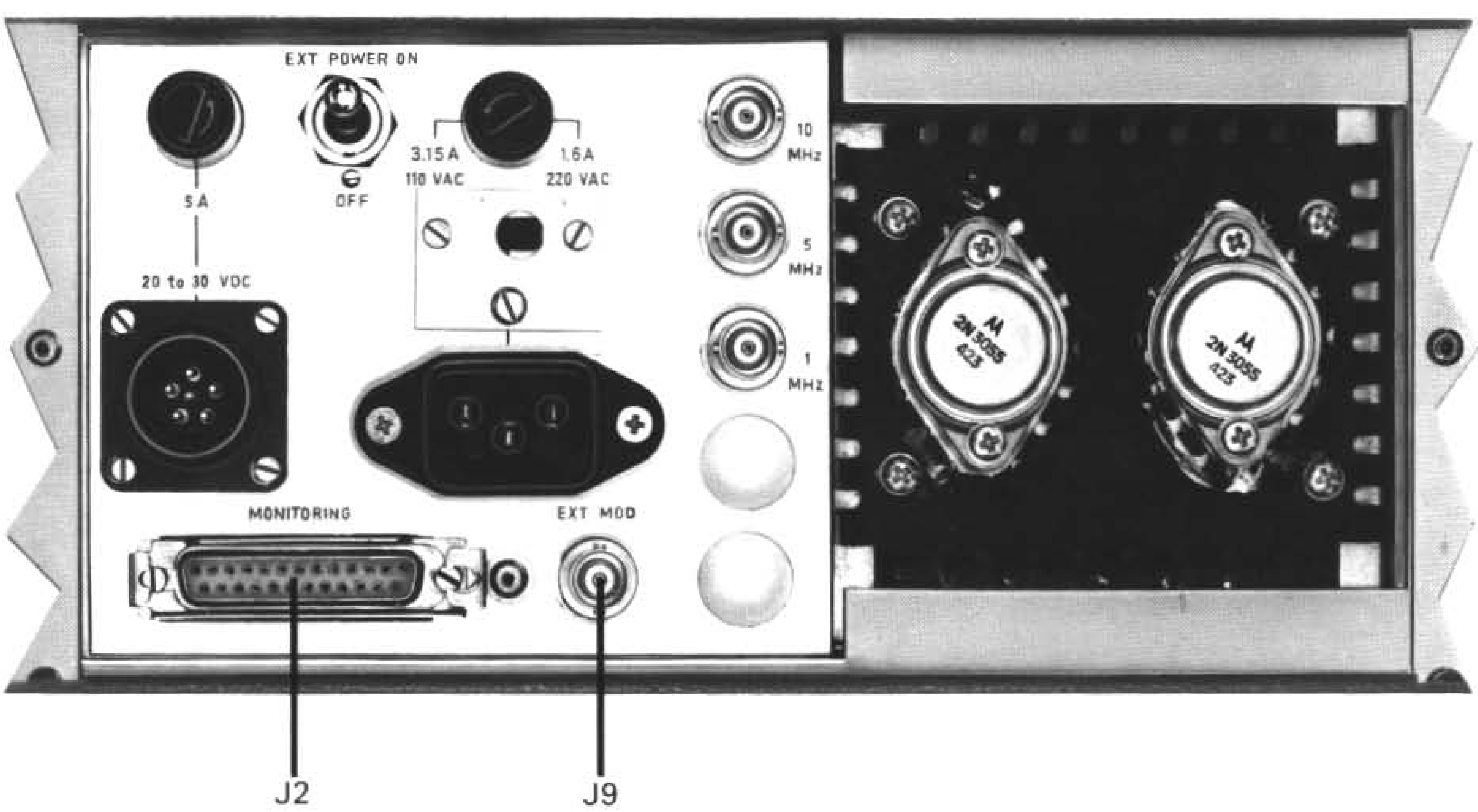
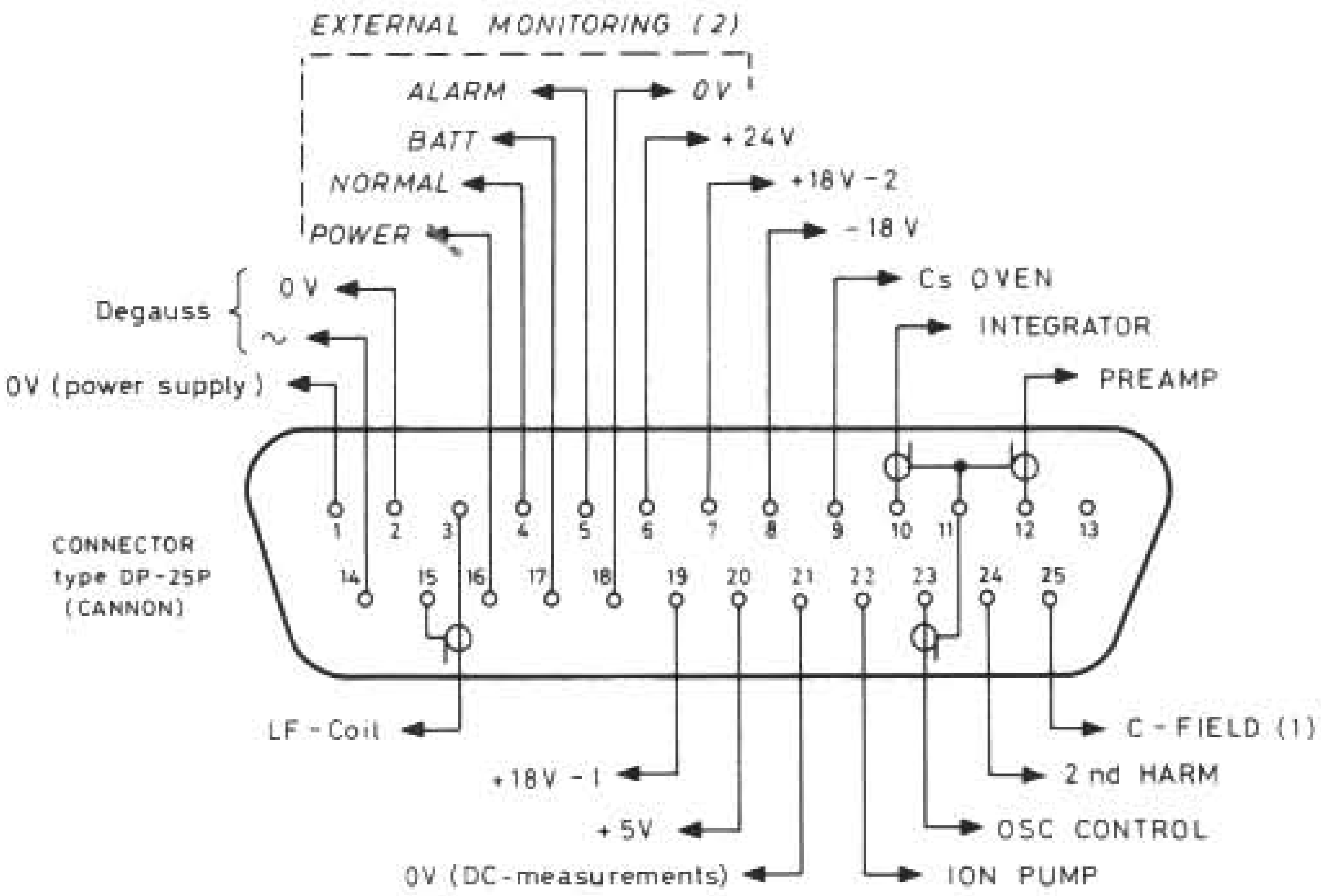


Fig. 13 Cesium Frequency Standard, Model 3200 (rear panel)

J2 External monitor connector
J9 External modulation connector



(1) Output for high impedance voltmeter
(1V corresponds to a C-field current of 10 mA)

(2) Open collector outputs

Fig. 14 Rear panel connector J2

7.4. Normalization of pre-amplifier gain and microwave power

This adjustment standardizes the level of microwave to about 2 dB less than that for maximum (saturation) beam tube signal, and standardizes the overall loop gain to compensate for the particular beam tube signal strength and fixed servo amplifier gain. It also provides a standardized DC output which enables the adjustment of the 137 Hz modulation level.

a) Set mode selector switch S1 to position LOOP OPEN and 137 Hz modulation switch S8 to position OFF (fig. 15).

b) Adjust frequency of oscillator with the oscillator fine frequency control R1 (fig. 15) for maximum value of preamplifier output. For this measurement, front panel monitor meter M1 (fig. 16) may be used, or a monitor meter having 300 mV full scale deflection may be connected to rear panel connector J2 as indicated in § 7.3. (fig. 14).

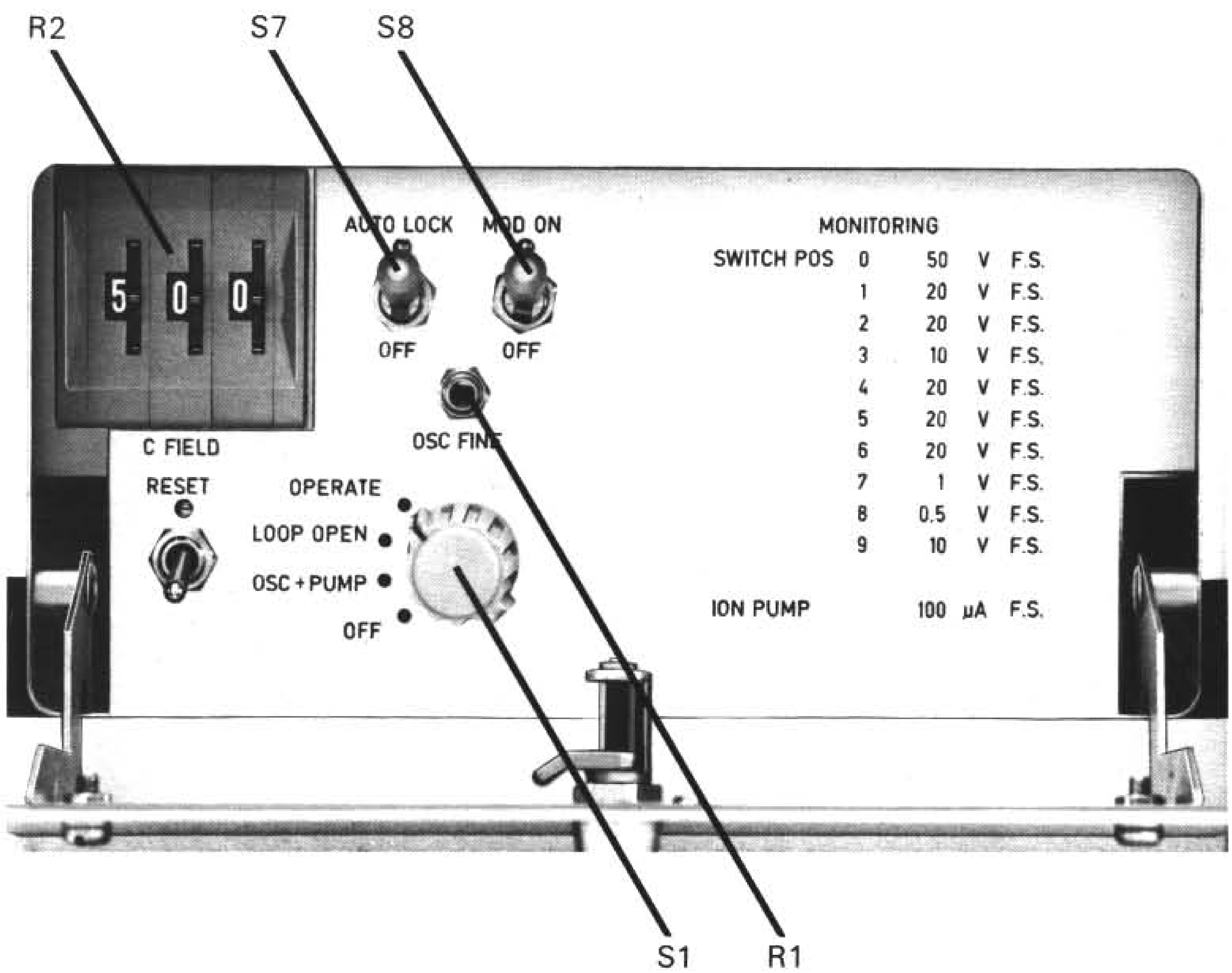


Fig. 15 Cesium Frequency Standard, Model 3200 – Control panel

R1 Oscillator fine frequency control
R2 C-field digital potentiometer
S1 Mode selector switch
S7 Auto lock switch
S8 137 Hz modulation switch

c) Assure that the oscillator is tuned to the central peak of the beam tube Ramsey (fig. 11) by adjusting frequency above and below the centre value with the oscillator fine frequency control R1 (fig. 15) and observing at least one secondary adjacent peak.

d) Increase the microwave attenuation by adjusting the microwave attenuator (fig. 17) in a clockwise direction until the pre-amplifier output is about –150 mV.

e) Adjust modulation level of 12.6 MHz (Ⓐ fig. 18, circuit diagram 942 030 017) until maximum DC signal at pre-amplifier output is obtained. Commence adjustment from position full counter-clockwise of potentiometer. Assure that beam tube is not at saturation microwave level by decreasing microwave attenuator counter-clockwise rotation (fig. 17) – and observing an increase in signal level. If an increase is not obtained, the microwave attenuation must be further **increased** and the 12.6 MHz modulation level reajusted.

f) After assuring that 12.6 MHz modulation level is at maximum value, decrease microwave attenuation-counter-clockwise rotation (fig. 17) – until maximum signal output is obtained. Check that oscillator is adjusted to central peak maximum with oscillator fine frequency control R1 (fig. 15). This value of r-f power is the saturation value. If monitor meter (M1 or external) gives off-scale value at this point, reduce pre-amplifier gain (Ⓕ fig. 18, circuit diagram 942 030 007) as necessary to retain on-scale value.

g) Tune the oscillator with oscillator fine frequency control R1 (fig. 15) between the maximum and minimum signal levels (minimum of response adjacent to central peak maximum – fig. 11) and successively adjust pre-amplifier offset at minimum signal (Ⓔ fig. 18, circuit diagram 942 030 007), and pre-amplifier gain at maximum signal (Ⓕ fig. 18, circuit diagram 942 030 007) for a response of zero at minimum and –300 mV maximum at the two appropriate frequencies. This normalizes the gain of the pre-amplifier.

h) When adjustment is accomplished as prescribed in § 7.4. g) above, set oscillator frequency to central peak with oscillator fine frequency control R1 (fig. 15) and **increase** microwave attenuation in clockwise direction (fig. 17), until pre-amplifier output is –250 mV.
Normalization of pre-amplifier gain and microwave power is now accomplished.

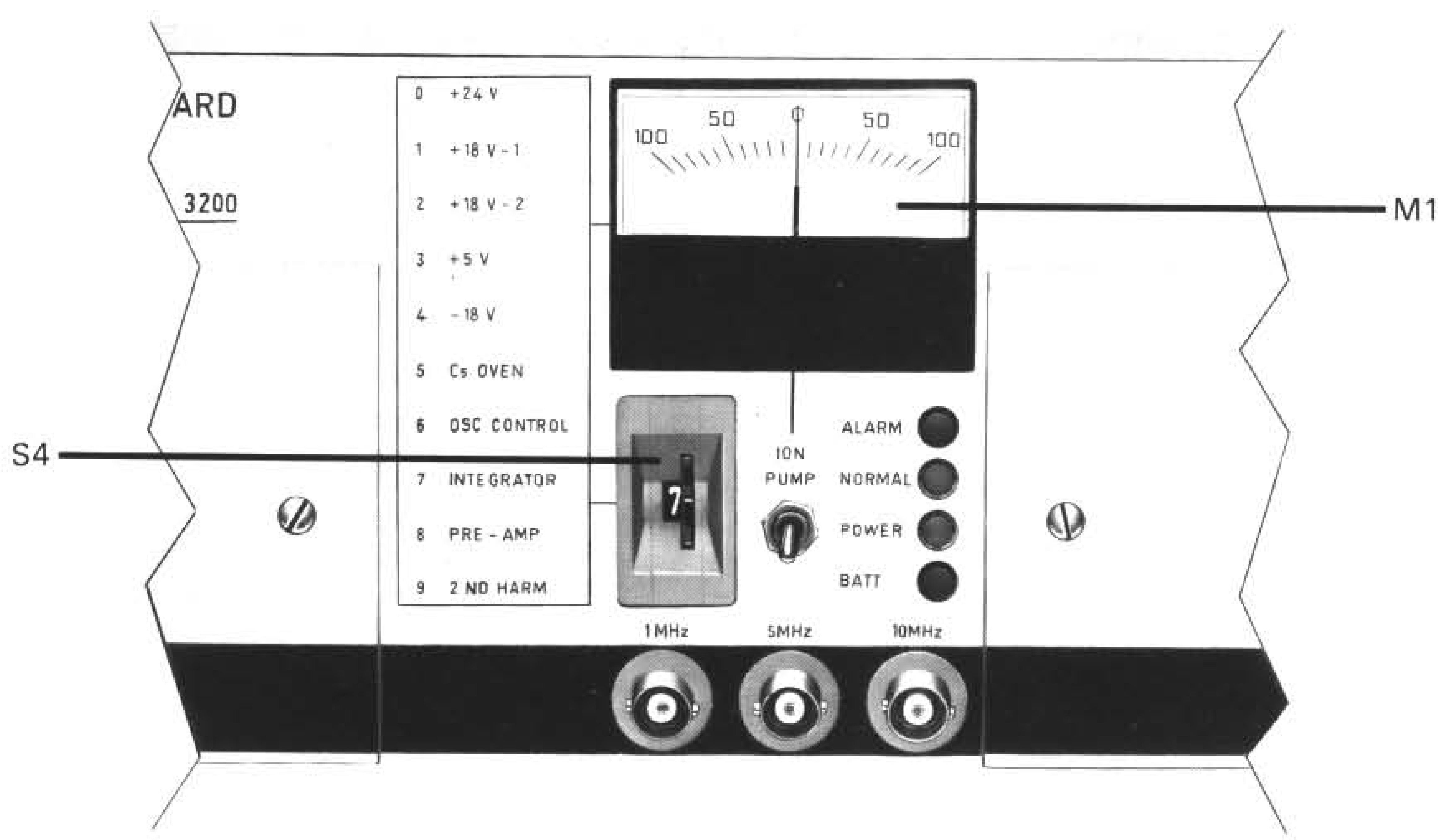


Fig. 16 Cesium Frequency Standard, Model 3200 (middle of front panel)

M1 Monitor meter
S4 Monitor meter selector switch

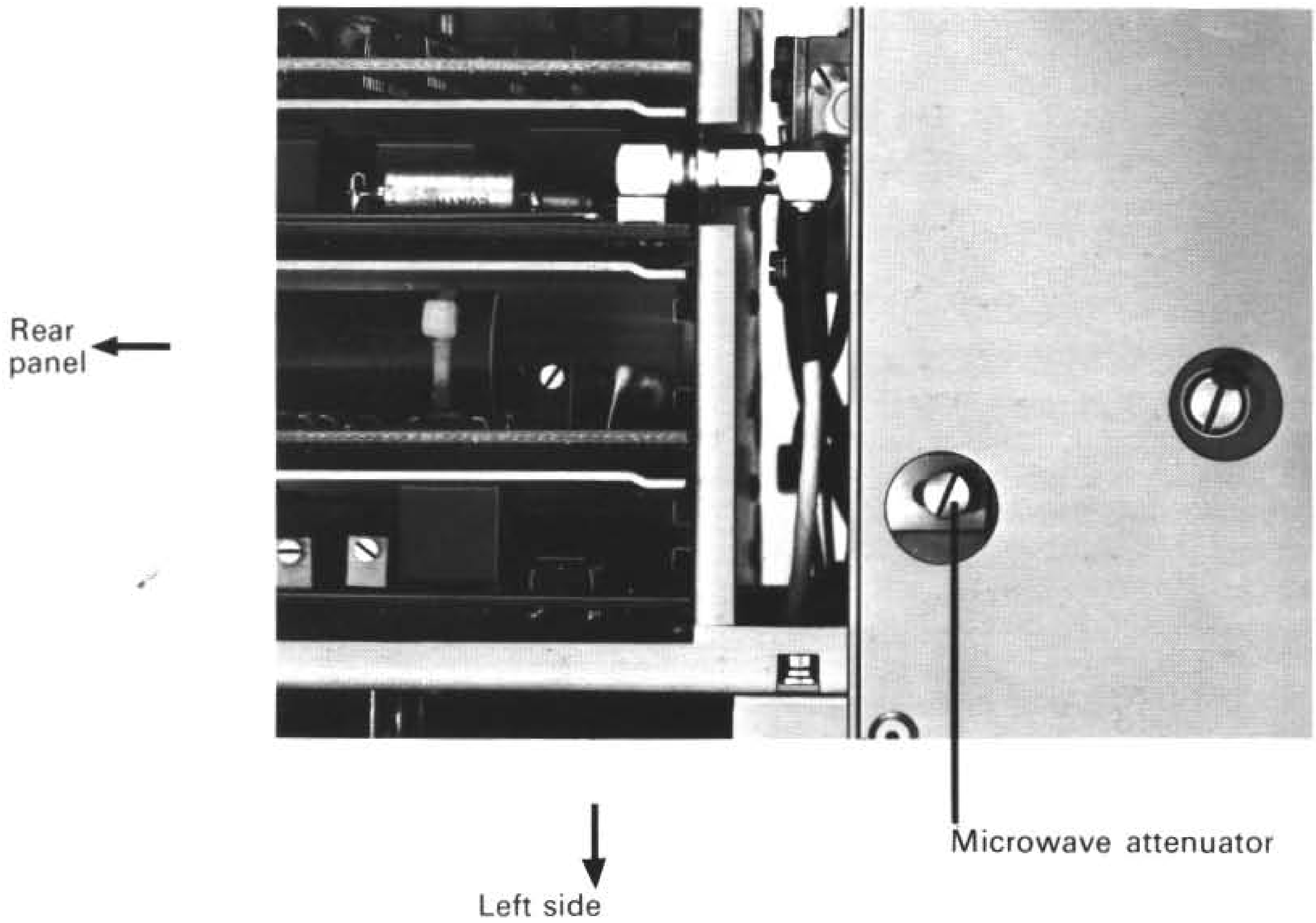


Fig. 17 Cesium Frequency Standard, Model 3200 – Partial top side view

References Fig. 18	Functions	Schematic number	PC board number
A1	Cesium oven supply	942 030 002	956 300 015
A2	Power supply +5 V, –U ionizer, 26 kHz generator	942 030 003	956 300 016
A3	Power supply +U1, +U2 C-field, EMVH regulation Pump alarm logic	942 030 010	956 300 020
A4	Buffer amplifier 5 MHz	942 030 012	956 300 022
A5	Synthesizer	942 030 011	956 300 021
A6	VCXO 12.631770 MHz	942 030 017	956 300 024
A7	Modulation generator Quadrature detector	942 030 008	956 300 018
A8	Synchronous detector Integrator Summing	942 030 013	956 300 023
A9	Pre-amplifier Servo amplifier	942 030 007	956 300 017
A10	2nd harmonic detector Alarm logic	942 030 009	956 300 019

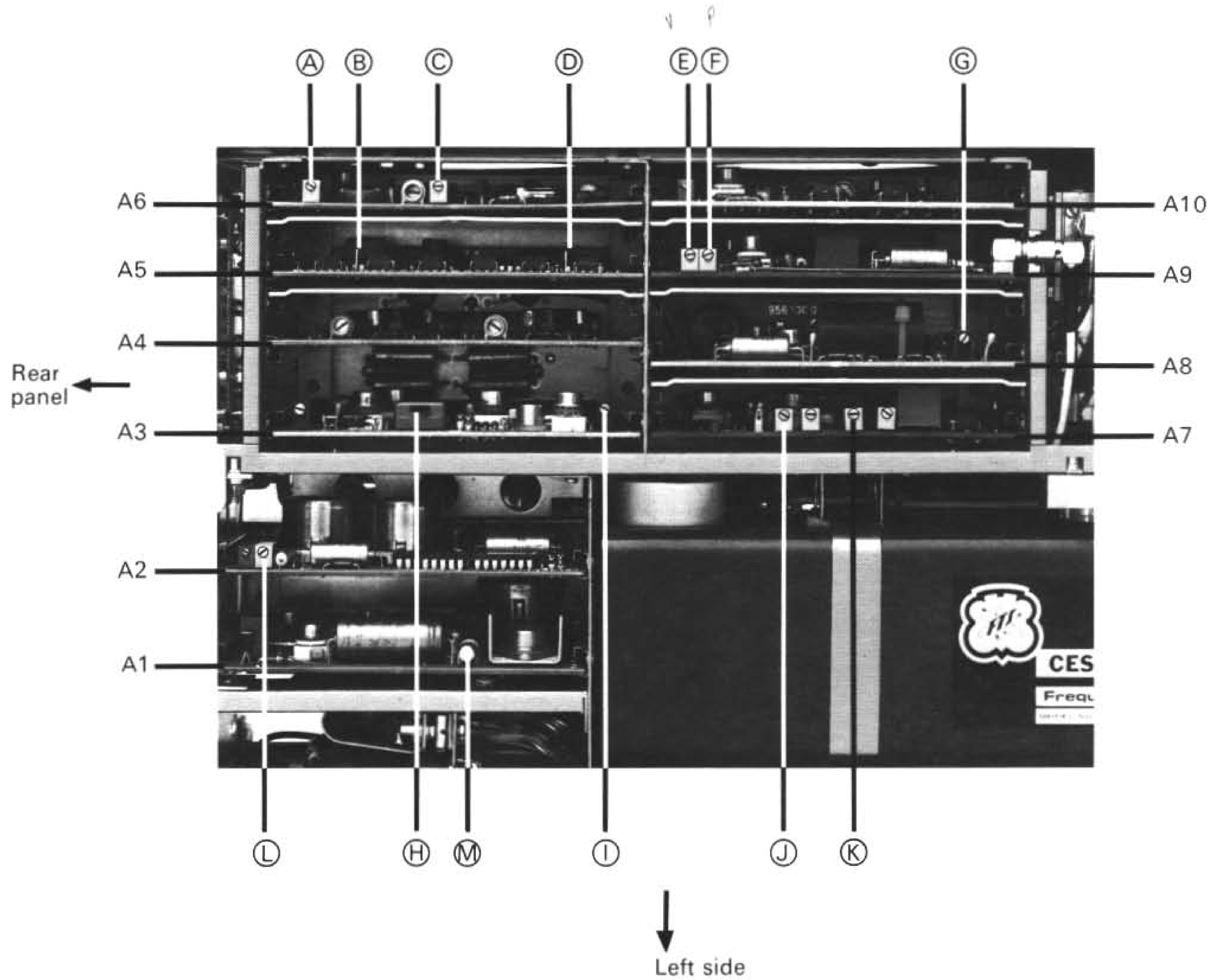


Fig. 18 Cesium Frequency Standard, Model 3200 – Circuit cards installation (top side)

Ⓐ 12.6 MHz modulation level
Ⓑ Synthesizer synchronization test point ⟨1⟩ S
Ⓒ 12.6 MHz VCXO PLL synchronization
Ⓓ Synthesizer synchronization test point ⟨2⟩ V
Ⓔ Pre-amplifier offset
Ⓕ Pre-amplifier gain
Ⓖ Integrator offset
Ⓗ Electron multiplier H.V. switch
Ⓘ C-field
Ⓙ 137 Hz modulation level
Ⓚ 137 Hz phase
Ⓛ Mass spectrometer voltage adjustment
Ⓜ Cesium oven fuse

7.5. 137 Hz modulation level setting

a) Normalize pre-amplifier and microwave as described in § 7.4.

b) Set 137 Hz modulation switch S8 (fig. 15) to position ON.

c) Adjust 137 Hz modulation amplitude (Ⓙ fig. 18, circuit diagram 942 030 008) for a pre-amplifier signal output of –165 mV when oscillator is set to central peak maximum. For this measurement, front panel monitor meter M1 (fig. 16) may be used, or a monitor meter having 300 mV full scale deflection may be connected to rear panel connector J2 as indicated in § 7.3. (fig. 14).
This setting of 137 Hz modulation amplitude should be rechecked after the 137 Hz phase adjustment (see § 7.6. below).

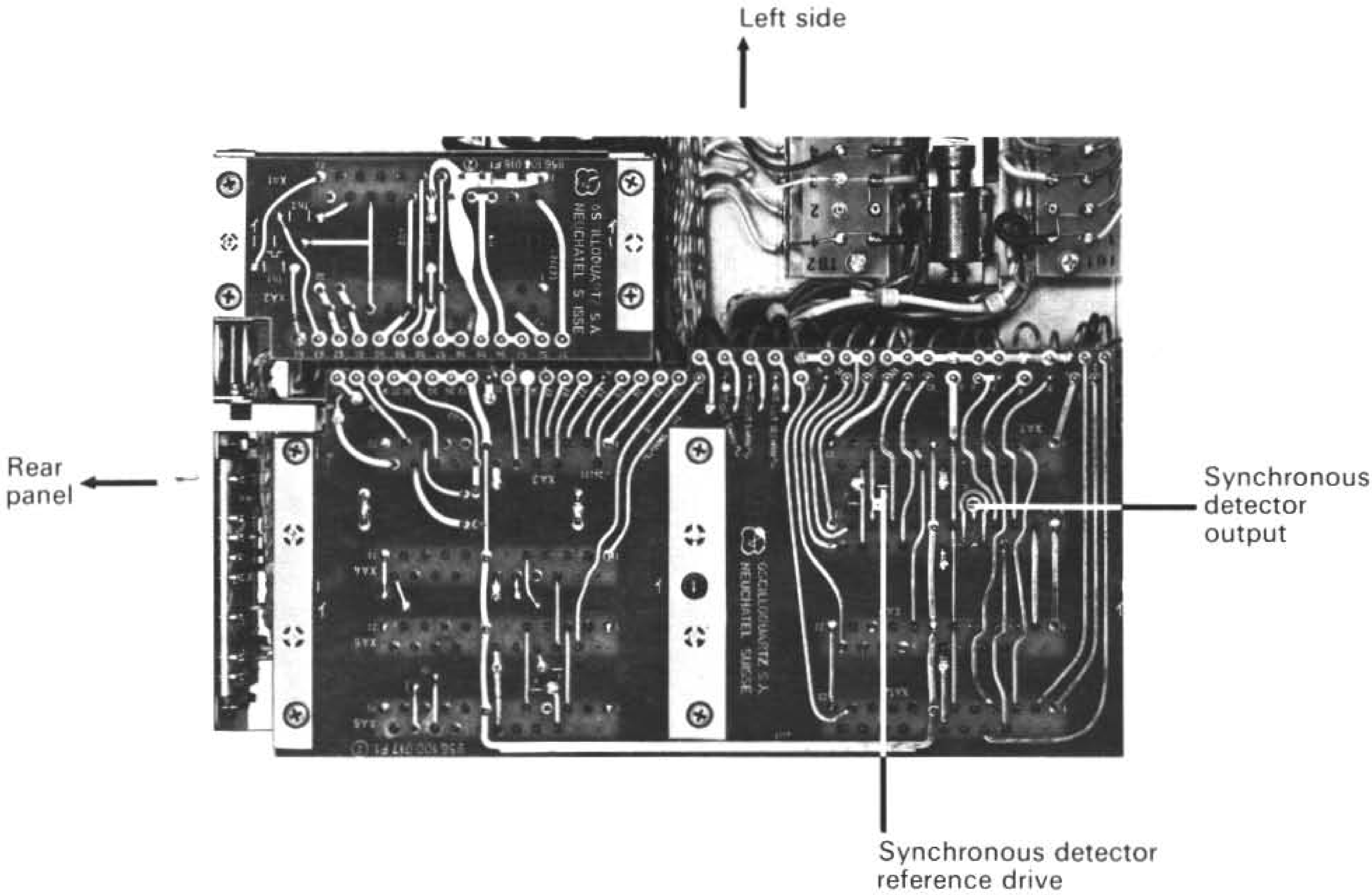


Fig. 19 Cesium Frequency Standard, Model 3200 – Circuit cards connecting board (bottom side)

7.6. 137 Hz phase adjustment

a) Turn the Frequency Standard on its right side and remove the bottom cover and the cover plate of the electronic section.

b) Connect an oscilloscope to the synchronous detector output and its synchronizing input to the synchronous detector reference drive (fig. 19) with high impedance probes. (Scale setting of 2 V/cm and 2 ms/cm.)

Note: The dual trace feature of the Tektronix 422 can be used for this synchronization.

c) Place mode selector switch S1 to position LOOP OPEN, 137 Hz modulation switch S8 to position ON and auto lock switch S7 to position OFF (fig. 15). Set vertical sensitivity of scope to 200 mV/cm.

d) Adjust oscillator for small frequency offset from central peak maximum with oscillator fine frequency control R1 (fig. 15) while at the same time viewing synchronous detector signal on oscilloscope. Signal resembles a fullwave rectified sine wave (fig. 20a). The frequency should not be changed more than that necessary to obtain a suitable signal for adjustment otherwise the beam tube quadrature signal will result in a residual asymmetry in the rectified sine wave response (fig. 20b).

e) Adjust 137 Hz phase control (Ⓚ fig. 18, circuit diagram 942 030 008) to obtain correct response as shown in figure 20a.

f) Change oscillator frequency with oscillator fine frequency control R1 (fig. 15) to either side of center peak maximum to assure that the detector response is symmetric.

g) Re-check 137 Hz modulation level as indicated in § 7.5.

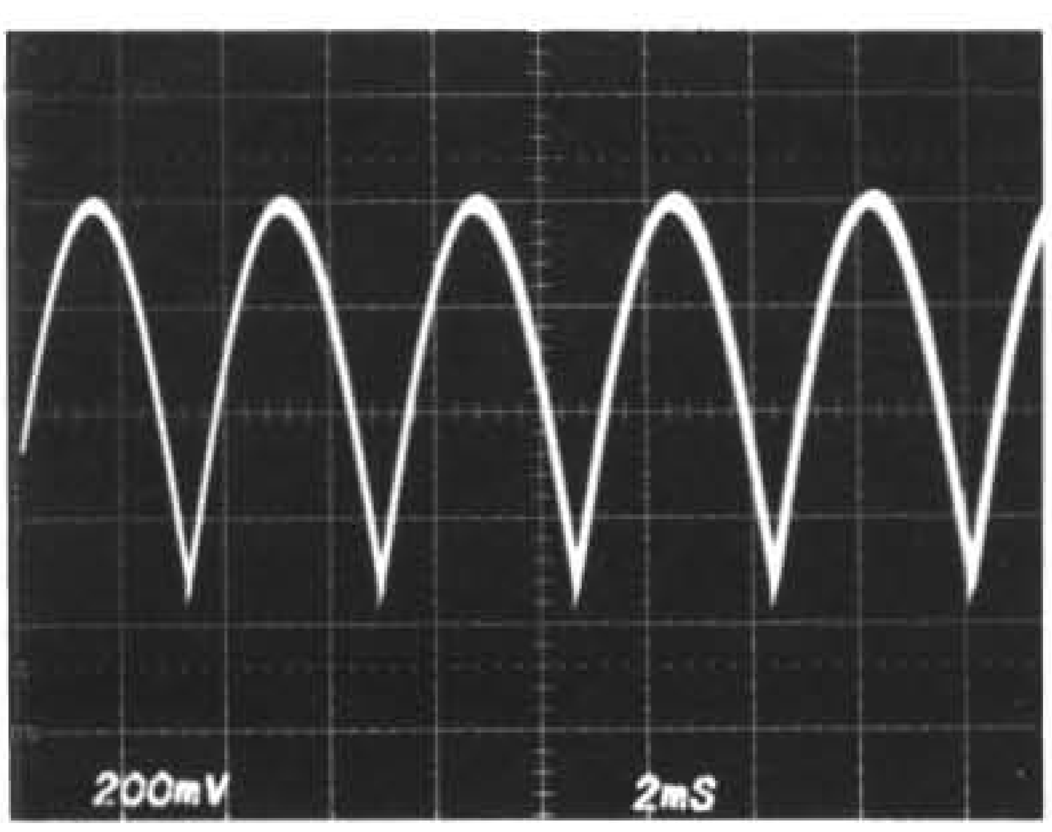


Fig. 20a Phase adjustment correct

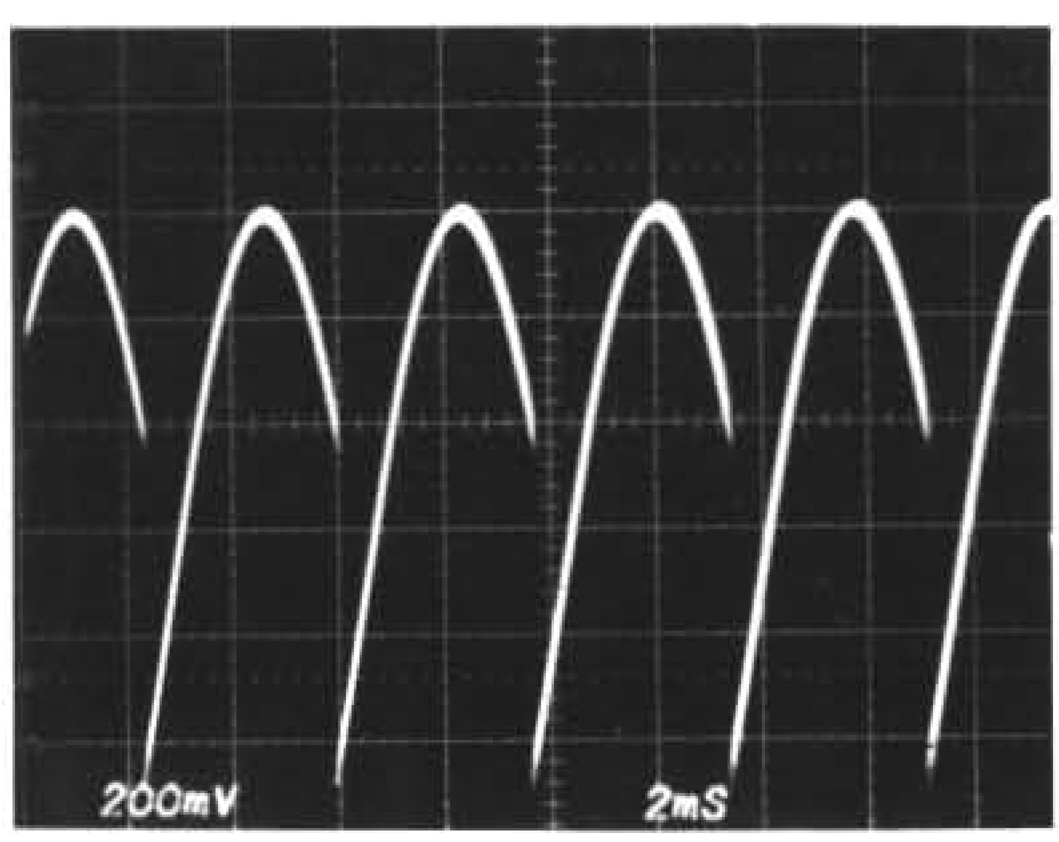


Fig. 20b Phase adjustment incorrect

Fig. 20 Synchronous detector signals during 137 Hz phase adjustment

7.7. Integrator offset adjustment

a) Place the cesium frequency standard in normal operation as described in section 5.1.

b) Set monitor meter selector switch S4 (fig.16) to position 7, INTEGRATOR or, preferably, connect a DC strip chart recorder of 100 mV full scale sensitivity to appropriate pins on rear panel monitor connector J2 as indicated in § 6.3. (fig.14). A chart speed of 2 cm per minute is convenient.

c) Adjust oscillator fine frequency control R1 (fig.15) for zero output of integrator.

d) Set auto lock switch S7 (fig.15) to position OFF and electron multiplier H.V. switch (Ⓗ fig.18, circuit diagram 942 030 010) to position OFF.

e) Observe change in DC output on recorder or the front panel monitor meter M1 (fig.16). The voltage should not change more than 100 mV in 15 minutes.

f) If integrator offset exceeds value mentioned in § 7.7. e) above, offset potentiometer of the integrator must be adjusted (Ⓖ fig.18, circuit diagram 942 030 013). The potentiometer is rotated in a clockwise direction to correct a positive offset.

g) To reset the integrator to 0 value for each adjustment and test, place auto lock switch S7 (fig.15) to position ON until integrator output gives 0, then set auto lock switch S7 to position OFF to observe integrator drift.

h) After drift rate is within specified limits, place auto lock switch S7 (fig.15) and electron multiplier H.V. switch (Ⓗ fig.18, circuit diagram 942 030 010) to position ON.

7.8. Test for phase-lock of 12.6 MHz VCXO

a) Connect scope synchronizing input to test point ⟨1⟩ (Ⓑ fig.18, circuit diagram 942 030 011) on synthesizer circuit, and scope vertical input to synthesizer test point ⟨2⟩ (Ⓓ fig. 18, circuit diagram 942 030 011).

b) A stable VCXO control synchronizing pulse should be found between 0 and 100 µs. If not, reverse connections to test points ⟨1⟩ and ⟨2⟩ and obtain pulse in view. Normal time difference observed between synch and pulse is less than 20 µs.

c) If necessary, adjust synchronizing potentiometer (Ⓒ fig.18, circuit diagram 942 030 017) to bring the pulse within the range 0 to 20 µs (fig. 21).

7.9. Measurement and adjustment of C-field

The C-field is measured and adjusted by utilizing the linearly field dependent microwave transition (4.1) ⟷ (3.1):

a) Set mode selector switch S1 (fig.15) to position LOOP OPEN.

b) Set 137 Hz modulation switch S8 (fig.15) to position OFF.

c) Set monitor meter selector switch S4 (fig.16) to position 8, PRE-AMP or, preferably, connect a monitor meter of 300 mV full scale sensivity to appropriate pins on rear panel monitor connector J2 as indicated in § 7.3. (fig.14).

d) Adjust oscillator fine frequency control R1 (fig.15) until pre-amplifier output is at the central peak maximum (fig. 11).

e) Connect a sine wave signal generator (capable of 10 to 20 Vpp into 250 Ω at 42 kHz) to external modulation connector J9 (fig.13). Measure the frequency of the signal generator (using a BNC T connection) with a counter synchronized to the frequency standard output (1 MHz or 10 MHz as appropriate).

f) Adjust the frequency and level of the signal generator (the precise frequency to be set later will be 42.794 kHz) to obtain a maximum signal and response similar to the Ramsey response already obtained in the LOOP OPEN mode of operation with the base 5 MHz oscillator (fig.11). The level of the signal generator should be adjusted to obtain maximum deviation of the signal response. This level will depend upon the characteristics of the particular beam tube, but should have peak-to-valley swings of from 20 to 100 mV.

g) The signal response to the Zeeman input signal generator should be the same as a normal Ramsey pattern (fig.11). If inhomogeneities exist in the C-field of the tube, the Ramsey pattern may be displaced from the center of the beam tube pedestal response resulting in a signal such as shown in figure 22.

Determine the displacement of the Ramsey response from the center of the pedestal as follows (steps h, j):

h) Adjust frequency of the signal generator to the center Ramsey peak maximum obtained on the pre-amplifier output.

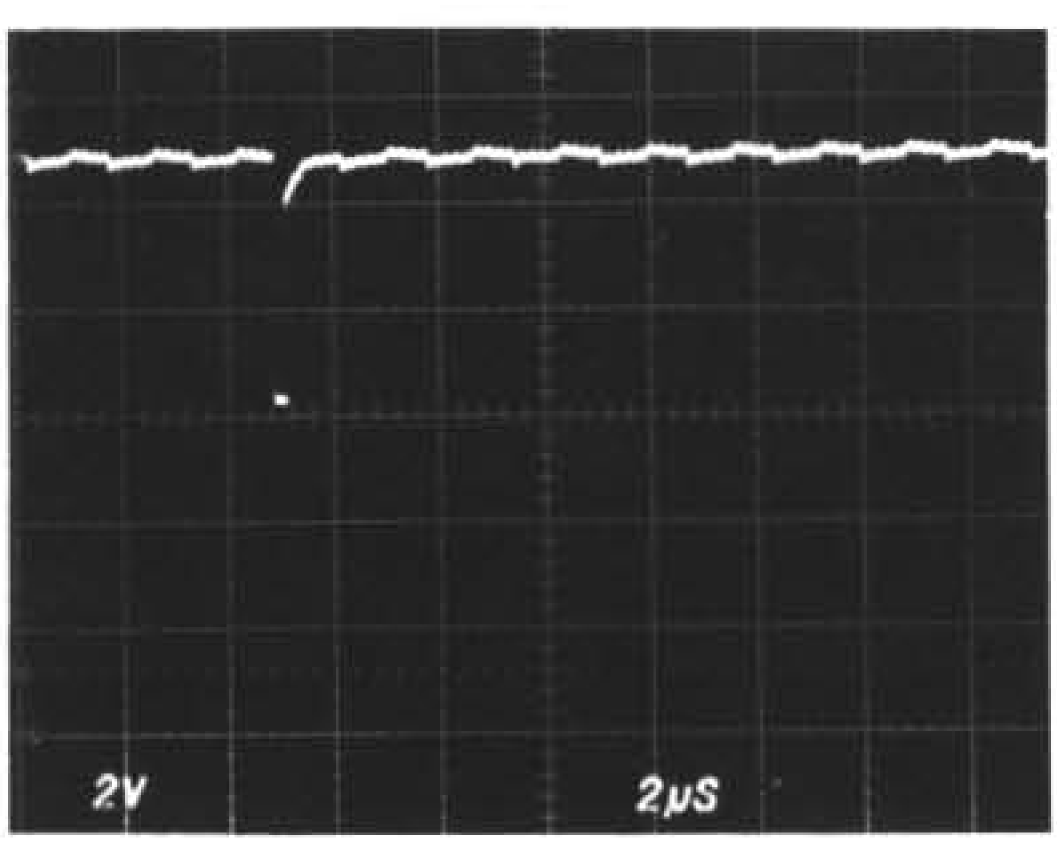


Fig. 21 Synthesizer 12.6 MHz VCXO synchronizing pulse

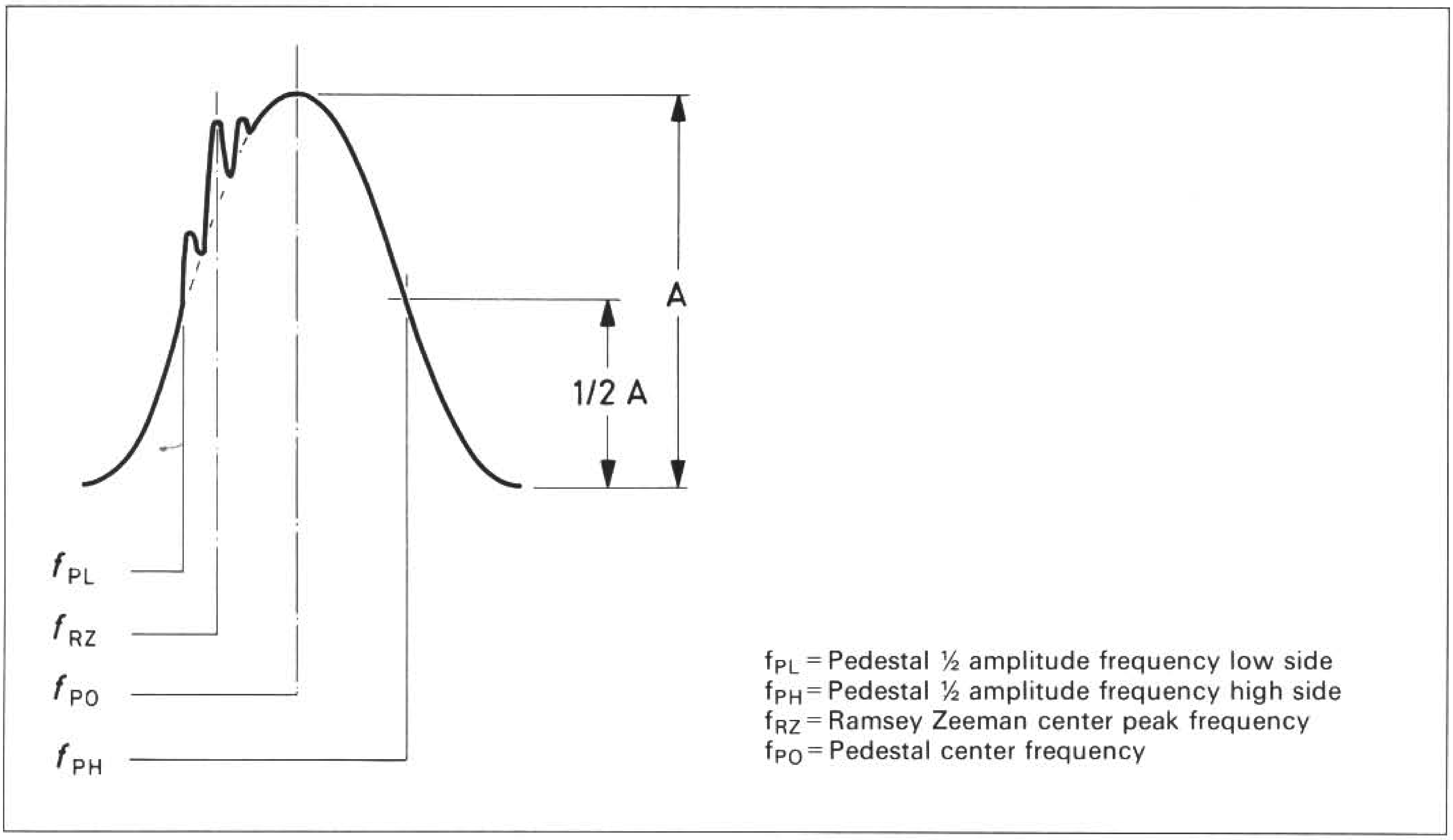


Fig. 22

Note: It is important to realize, as illustrated in figure 22, that the central peak may not be significantly higher than the adjacent peak if the central Ramsey peak is considerably displaced from the pedestal center frequency.

Record frequency of Ramsey central peak. This is the Zeeman frequency.

i) Determine the center frequency of the pedestal by measuring, with the external signal generator, the frequency of the pedestal half-amplitude (½ A) successively at the low frequency and high frequency side (fig. 22). Calculate the pedestal center frequency as $(f_{PL} + f_{PH})/2$. If the difference between the Ramsey center peak frequency and the pedestal center frequency is greater than 1 kHz, the beam tube C-field should be demagnetized according to § 7.10.

j) After assuring that the Ramsey response is centered on the pedestal, measure the Zeeman frequency of the center Ramsey peak. This frequency should be 42.7[illegible]4 ± 40 Hz.
Repeat the measurement several times to determine average Zeeman frequency.
If Zeeman frequency is not within prescribed ± 40 Hz limits at center peak maximum, adjust C-field digital potentiometer R2 (fig. 15) until correct value is obtained by repeating step of § 7.9. f) above.

7.10. Degaussing

Degaussing connections are made at the rear panel connector J2 (fig. 14) between pin 14 and pin 2. Two methods may be used to degauss the tube:

a) with a special apparatus available from Oscilloquartz SA either on loan or purchase. Degausser Model 3098.

b) with the following equipment connected as shown in figure 23.

   1) Adjustable autotransformer
   2) Line-to-6.3 V/1 A isolation transformer
   3) A.C. ammeter (1 amp. full scale)
   4) 1 Ω 5 W resistor
   5) 0–100 μA D.C. Meter
   6) Fuse 1 A normal

7.10.1. Degaussing procedure

The microammeter is connected to J2 pins 11 and 22 (fig. 14) to monitor pump current during degaussing cycle. **If the C-field winding overheats, pressure in the tube will rise due to out-gassing and pump current will increase rapidly. Should this occur, the degaussing current must immediately be reduced to zero otherwise the tube may be permanently damaged.**

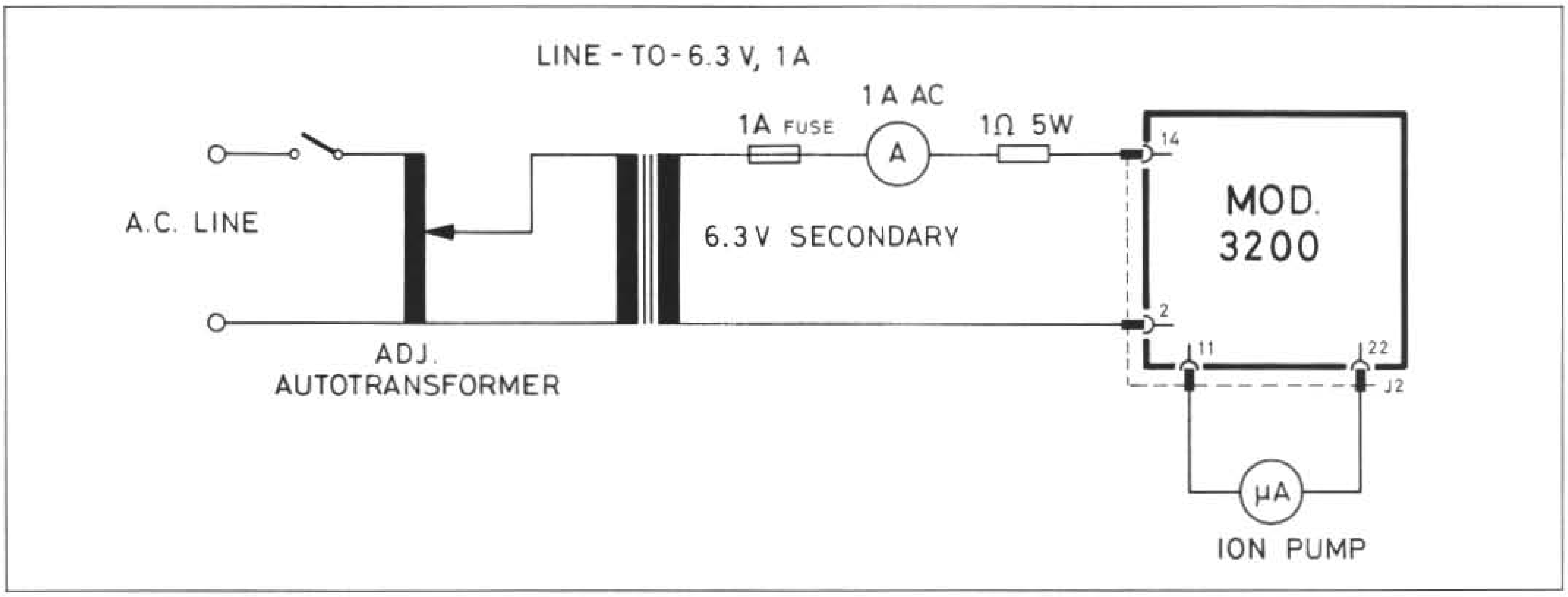


Fig. 23

a) Assure that the auto-transformer is set for zero output before connecting for A.C. line.

b) Place standard in LOOP OPEN mode.

c) With a smooth and continuous motion of the auto-transformer control increase the degaussing current to 1 ampere and reduce again to zero taking from 15 to 30 seconds for this cycle.

d) Monitor ION PUMP current during the cycle.

e) Recheck Zeeman response as described in § 7.9. g) to 7.9. j).

7.11. Adjustment of mass spectrometer voltage

If it is necessary to adjust the voltage of the mass spectrometer, proceed as follows:

a) Set standard in LOOP OPEN mode as described in § 5.1.3. c).

b) Set monitor meter selector switch S4 (fig. 16) to position 8 PRE-AMP or, preferably, connect a monitor meter having 300 mV full scale sensivity to the appropriate pins on the rear panel connector J2 as indicated in § 6.3. (fig. 14).

c) Adjust mass spectrometer voltage potentiometer (Ⓛ fig. 18, circuit diagram 942 030 003) for maximum signal on pre-amplifier output (maximum negative deviation of instrument).

7.12. Beam tube signal measure

The useful output beam current from the beam tube is a measure of the efficacity of the tube as a frequency control device when related to the noise coming from the tube at the same time. The useful signal is defined (for the tube) as the difference in level of the main peak maximum and the adjacent minimum (valley). This measure can be made directly at the beam tube output with an electronic voltmeter capable of responding to input levels in the order a few nano-amperes.

In the Model 3200, the measurement can be made at the pre-amplifier output with an instrument of 300 mV full scale. The pre-amplifier contributes noise to the measurements, but the level of this noise is much less than that coming from the beam tube.

Two tests of signal quality can be made on the beam tube, and are measures of the useful life of the tube:

Signal-to-background and signal-to-noise.

7.12.1. Signal-to-background noise ratio

Make the adjustments as described in § 7.4. a) to 7.4. g) using an external meter connected at rear panel connector J2 (fig. 14). This normalizes the gain of the pre-amplifier, and establishes a peak-to-valley voltage difference ($V_p - V_v$) of 300 mV for optimum microwave power.

a) Place electron multiplier H.V. switch (Ⓗ fig. 18, circuit diagram 942 030 010) to OFF position.

b) Adjust pre-amplifier offset (Ⓔ fig. 18, circuit diagram 942 030 007) for zero reading on monitor meter.

c) Place electron multiplier H.V. switch to ON position. **Note:** It will be necessary to change scale of the instrument to 1 V full scale.

d) Pull the 12.6 MHz VCXO circuit card (fig. 18, circuit A6, PC board number 956 300 024) from its socket thus eliminating the microwave signal.

e) Record value of meter reading. This is the beam tube background signal V_B.

f) Calculate signal-to-background ratio: $\frac{300 \text{ mV}}{V_B \text{ (mV)}}$
Value should be greater than 1.

g) Return the 12.6 VCXO circuit card to position and normalize the pre-amplifier as described in section 7.4.

h) Note value of signal-to-background in operating record Table II.

7.12.2. Signal-to-noise ratio measurement

Normalize microwave power and pre-amplifier as described in § 7.4. a) to 7.4. g). This establishes signal level $V_p - V_v$ (peak to valley voltage) as 300 mV. Set frequency to center peak maximum.

a) Connect a wave analyzer to pre-amplifier output (see connections given in § 7.3. – fig. 14).

b) Set wave-analyzer to a bandwidth of 1 Hz, meter time constant of 10 seconds, and frequency 130 Hz.

c) Set 137 Hz modulation switch to OFF position (fig. 15).

d) Record reading of voltmeter on wave analyzer. This is the noise level in a 1 Hz bandwidth. Signal-to-noise ratio is defined for noise in a ¼ Hz bandwidth. Therefore, calculate the noise voltage in ¼ Hz bandwidth by dividing the reading by 2.

e) Calculate signal-to-noise ratio by dividing signal (300 mV) by noise in ¼ Hz bandwidth. Note value in operating record Table II.

7.13. End of tube life

The life of the cesium beam tube is generally not limited by the quantity of cesium contained in the oven reservoir as long as specified oven temperature is not exceeded, and limits of storage time and temperature are observed. A small fraction of the atoms which leave the oven arrive at the detector to form a usable signal. The remaining atoms are absorbed in getter materials placed advantageously in the tube. It is the final saturation of these getters which determines the usable life of the tube.

The limits of beam tube life are somewhat arbitrary in their definition, but rest at some level of performance beyond which further degradation will exceed the equipment specifications; this level is usually fluctuations of frequency due to noise in the beam tube. For the Model 3200, the following determine the tube usable life:

7.13.1. Ion pump current

When the rate of generation of free atoms within the beam tube exceeds the pumping capacity of the Ion pump, the pressure will rise, and this pressure results in a certain pump current. The maximum allowable pressure in the Model 3200 beam tube corresponds to a pump current of 50 μA. Thus as the beam tube ages, the pump current gradually rises until this value is reached. When this occurs, the power supplies to the beam tube are shut down, and the tube must be replaced.

7.13.2. Signal-to-noise ratio

The beam tube signal-to-noise ratio determines the frequency stability of the standard when the time constants of the servo loop are such that the beam tube controls the frequency stability. The signal-to-noise ratio deteriorates with time and a minimum signal-to-noise ratio is established which maintains the frequency fluctuations of the standard within specified limits. The minimum acceptable value for the instrument is given in Table II.