Edwards

Hr. Müller

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Instructions

M18042/3
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FTM3 DIGITAL FILM THICKNESS MONITOR
MONITOR OSCILLATOR
RATE DISPLAY
TERMINATION UNIT

Codes 18-D311-26-000
18-D311-26-040
18-D311-26-150
18-D311-26-200

Associated Instructions

Water-Cooled Crystal Holder M18041/2

Edwards High Vacuum
Manor Royal, Crawley, West Sussex RH10 2LW, England
Telephone: Crawley 28844 (std code 0293) Telex: 87123 Edhivac G

CONTENTS

FTM3 DIGITAL FILM THICKNESS MONITOR

UNPACKING

The packing case contains

			Code
One	-	FTM3 Main Unit	18-D311-26-000
One	-	FTM3 Monitor Oscillator	18-D311-26-040
Three	-	Quartz Crystal	18-D311-00-083
One	-	4 m connecting cable:	
		4-core screened cable, Suhner Electronics type G4/01232-1, with:	15599-9021
		Five-pin plugs GE Electronics type 8-6973	07-D351-01-019

Included in main unit

One	-	Test lead assembly	07-D311-21-070
Three	-	500 mA fuse (mains supply) Beswick TDC123	07-D134-21-065
Three	-	1A anti surge fuses	07-D311-26-076
Two	-	Indicator lamps 12V 30 mA R.S. Components T $1\frac{1}{4}$ B1 Pin	07-D311-26-221

Check the contents of the packing case. Keep the packing materials.

DAMAGE IN TRANSIT

If the equipment is damaged in transit, it is important to notify BOTH the carrier and the supplier WITHIN THREE DAYS OF DELIVERY.

ACCESSORIES AVAILABLE

FTM3 Rate Display (with connecting leads)		18-D311-26-150
FTM3 Termination Unit (with connecting leads)		18-D311-26-200
Water-cooled Crystal Holder		18-D313-11-000
FTM3 Monitor Oscillator (additional) (with connecting leads)		18-D311-26-040
FTM3 Rack mounting adaptor (screened)		07-D354-26-000

RECOMMENDED SPARES

The following spares are available only from Edwards. Fitting them does not call for specialized electronics knowledge, but some skill is required.

Description	Code
P.C.B. Assembly No.1 (Clock)	D311-26-010
No.2 (Mixer)	D311-26-015
No.3 (Display)	D311-26-020
No.4 (Store)	D311-26-025
No.5 (Power)	D311-06-100
No.6 (Mother)	D311-26-030
FTM3 Monitor Oscillator	D311-26-040
4-button switch	D311-26-035
Transformer	D311-26-036
Display glass (main unit)	D311-26-039
For the Rate Display	
P.C.B. Assembly (rate)	D311-26-160
Display glass (rate)	D311-26-165
For the Termination Unit	
P.C.B. Assembly (termination)	D311-26-210

INSTALLATION

This section should be read in its entirety before starting the installation.

Inside the vacuum chamber, the installation is simple in principle, but not always in practice. The object is to mount the monitor crystal where it will receive the evaporant in the same way as the substrates to be coated, but careful precautions may be needed to achieve this reliably and without hazard to the apparatus or operator.

The accessory Water-cooled Crystal Holder (or a closely equivalent holder), is necessary for the proper operation of the FTM3. The crystal is mounted in a metal enclosure which is cooled by water flowing at about 0.25 litre/min. An aperture (6.4 mm diameter) defines the area of the crystal which is exposed and receives the evaporant. This face of the crystal is earthed via the enclosure. The crystal and the connecting leads from the back of the crystal are completely screened by the enclosure and the copper tubing which encloses the lead to the base-plate lead-through, where the screening is completed by a vacuum-tight coaxial connector.

The film thickness monitor, with the rate display and termination unit when used, may be mounted up to 4 m away from the vacuum chamber, this being the length of the connecting cable provided.

HAZARDS

The Edwards water cooled crystal holder gives excellent protection against the electrical and thermal hazards discussed below.

Electrical

Some vacuum chamber accessories, for example, an HT glow discharge cleaning device, a sputtering device or an external RF heater used to heat the evaporation source, could induce voltages into the monitor crystal and its leads sufficient to burn out the protective devices in the monitor oscillator.

A further possible cause of induced voltages is the inadvertent short circuiting to earth and resultant arcing of any HT supply within the chamber. It is important to maintain the HT insulation in good condition and to keep HT leads well spaced from metal objects.

Thermal

Most vacuum coating chambers use at least two sources of heat, for substrate and evaporant heating. Heat from any source in the chamber can affect the monitor crystal frequency and steps should be taken to minimize temperature changes during the deposition process. The best way is to use a water cooled enclosure around the monitor crystal. This ensures that the heat acquired from the deposited film is quickly absorbed. It also largely protects the crystal from radiant heat from the evaporant source and the substrate heater.

An evaporation source heater shield is also useful and can be fabricated from thin molybdenum or stainless steel sheet which can usually be supported by the heater clamp nut. Two holes will be needed in the shield: a fixing hole and another immediately above the evaporant. The diameter and position of the latter hole must be determined so that the passage of the evaporated vapour to both crystal and substrate is unobstructed. The shield should preferably be in good thermal contact with the chamber base.

Monitor Crystal Installation

For the water-cooled crystal holder, see Instructions No. M18041/2. The crystal support should in all cases meet the following requirements:

1. The crystal must be located in a definite, reproduceable position relative to the evaporant source and the substrates, preferably at the same distance as the substrates from the source.

2. The crystal position should preferably be adjustable over a small range to facilitate setting up.

3. The holder should be accessible so that the crystal can easily be inserted or withdrawn.

4. The face of the crystal should preferably be at right angles to the line of sight to the evaporant source.

5. The cooling water pipes and the electrical connexions should be securely supported.

Crystal Position

If reproduceable results are to be achieved, the crystal must be mounted in a fixed position relative to the evaporant source and the substrates, so that when a new crystal is fitted the geometry is not changed.

The position chosen should, as far as possible, be representative of the positions occupied by all the substrates in each batch to be coated.

The distance from the evaporant source is important, because the mass deposited (on a given area) is inversely proportional to the square of the distance from the source. An increase of 5% in the distance will therefore cause a decrease of 10% in the mass deposited.

The crystal face should also be at right angles to the line-of-sight to the evaporant source, because the effective area of the crystal presented to the source is proportional to the cosine of the angle of incidence of the evaporant.

Electrical Connexions

The crystal has two connexions, 'live' and earth. The centre conductor of the coaxial lead is live, the sheath is earthed.

The side of the crystal which receives the evaporant must be earthed. This condition is satisfied by the Edwards water-cooled crystal holder.

Monitor Oscillator

Dimensions	76 mm long x 32 mm diameter
Weight	60 g

This small cylindrical unit must be mounted immediately below the baseplate of the vacuum chamber, so that the 15 cm flexible lead on the water cooled crystal holder can be connected.

The other end of the oscillator receives the multi-pin plug of the 4 m cable.

The oscillator must be mechanically supported. The 4 m cable should also be cleated.

FTM3 Film Thickness Monitor

This main unit may be mounted in any accessible position within the range of the 4 m cable provided. The panel should be kept within about 25° of the vertical and free air circulation is necessary, especially over the heat sink on the back of the unit.

The monitor is free standing but is also suitable for rack mounting.

It occupies a half-rack space on a special 19 in rack module, leaving the other half for the rate display and the termination unit.

Voltage Adjustment — Insert the multi-pin plug so that the arrow points to the voltage of the supply mains.

Connexions — Mains - The 3-core mains lead is attached. A good earth connexion is required.

Crystals - Plug the lead from the monitor oscillator into Xtal 1 (and the second into Xtal 2 when two crystals are in use).

RATE DISPLAY

The unit is free standing and also suitable for rack mounting. It occupies a quarter-rack 19in module. It must stand close beside the main unit to the right.

Connexions. Connect the display to the main unit by means of the 7-core cable provided, using the Rate connexion block on the back of the main unit.

TERMINATION UNIT

The unit is free standing and also suitable for rack mounting. It occupies a quarter-rack 19in module. It stands to the right of the main unit, with the rate display between.

Connexions

(a) Connect the unit to the main unit by means of the 7-core cable provided, using the Term connexion block on the back of the main unit and the lower connexion block on the back of the termination unit.

(b) Connect the termination relay to the evaporation control apparatus of the coating plant by way of the upper connexion block on the back of the termination unit. The diagram below the block shows the internal connexions to the relay contacts, which will make or break IA at 250V a.c. or d.c.

The apparatus should be arranged so that when the relay is energized, a shutter closes over the evaporant source and the evaporant heater is switched off.

RACK MOUNTING ADAPTOR

The special 19in rack adaptor should always be used when the FTM3 is to be fitted together with the Rate Display and/or the Termination Unit. The adaptor provides the necessary electrostatic screening for the interconnexions. It occupies height of 133mm on a standard 19in rack; the depth is 350mm.

DIGITAL FILM THICKNESS MONITOR FTM3

DESCRIPTION

The film thickness monitor is a vacuum coating plant accessory used to monitor the thickness and the rate of deposition of thin films. It can also provide an electrical signal to stop the evaporation when a pre-set thickness is reached.

An oscillating quartz crystal is positioned inside the coating chamber. As deposition proceeds the frequency of the crystal changes as the result of the evaporant deposited upon it. This frequency is compared with a reference frequency and from the difference the rate of deposition and the film thickness can be found.

The frequency change is determined by the mass of evaporant deposited on the crystal, and is therefore related to the thickness of the film deposited on the substrates being coated.

The frequency comparison is made by stable electronic circuits. Small, high-speed, integrated circuit logic units operate the thickness display and generate rate of deposition information for the rate display.

The instrument is equally suitable for use in the research-and-development area and in mass production, for it combines very high sensitivity with great stability and reliability together with extreme simplicity of operation.

The main unit contains the reference crystal oscillator and the electronics which extract and display the change of frequency of the monitor oscillator. Power and signals are also generated for the monitor oscillator(s), the rate display and the termination unit. The main unit also includes the panel selector switch for operating two crystals each with its own monitor oscillator. This system permits two materials to be independently monitored, or doubles the maximum thickness when working with one material.

Water-cooled Crystal Holder. This provides the best possible housing for the monitor crystal. The water cooling protects the crystal from heat and the complete electrostatic screening gives protection from electrical interference.

The crystal is mounted in a water-cooled metal enclosure supported on a swan-neck which contains the coaxial electrical connexions and the cooling-water pipes. The connexions are all carried through the baseplate by one leadthrough with an O-ring seal.

Spare monitor crystals will be needed from time to time. They must conform to the Edwards specification 18-D311-00-083.

SPECIFICATION

FTM3 DIGITAL FILM THICKNESS MONITOR with WATER-COOLED CRYSTAL HOLDER

DISPLAY	Six-digit, bright orange, seven segment planar
Range	1 - 999,999 Hz Leading zeros are suppressed
SENSITIVITY	Approximately 300 Hz per microgram Approximately 10^{-8} g/cm^2, or 1 Å thickness at unit density, per hertz
MAXIMUM CHANGE	Damping of the crystal normally restricts the useful change to about 150,000 Hz for most metallic, unstressed films, and down to 20,000 Hz for highly stressed films of metallic compounds.
STABILITY	Reference crystal. Drift less than 10 Hz in 8 hours normal operation, after 15 minutes initial warm-up. Monitor crystal. Drift normally less than 30 Hz in 8 hours operation.
Temperature effect	20 to 60°C, change less than 300 Hz. Thermal shock may cause a larger transient change in the monitor crystal frequency.
RESPONSE TIME	The display is up-dated once per second. The set zero operation occupies three seconds.
INPUTS	Two inputs at 6,000 KHz nominal from monitor crystal oscillators. One oscillator is supplied as standard. A second oscillator may be added.
SET ZERO	Set zero pushbutton to set reading to zero at the current monitor oscillator frequency. Lamp indicates that zero is being set.
FRONT PANEL CONTROLS	1 Mains on/off switch and indicator lamp 2 Two pushbuttons with indicator lamps select crystal 1 or crystal 2 3 Crystal check pushbutton. Displays total frequency difference between monitor oscillator and reference oscillator 4 Set zero pushbutton with indicator lamp
OUTPUTS	1 Power and signals to operate Rate Display via rear connector 2 Power and signals to operate Termination Unit via rear connector
POWER SUPPLY	100-125 and 200-250V 50 - 60 Hz 1 ph 50VA Fuse 500mA anti surge Fuse 1A anti surge
DIMENSIONS	
Main Unit	133 mm high x 222 mm wide x 293 mm deep
Monitor oscillator	76 mm long x 32 mm diameter
WEIGHT	Main Unit 5.3 kg Monitor Oscillator 60 g

MOUNTING	Main Unit half-rack series 70 module Monitor Oscillator beneath vacuum chamber baseplate
Restriction	The main unit panel must be within 25° of vertical. Free air flow is necessary over the heat sink on the back of the unit.

WATER-COOLED CRYSTAL HOLDER

This accessory is necessary for the proper operation of the FTM3 film thickness monitor.

Crystal Enclosure	Nickel plated copper with stainless steel cover. Crystal plugs in. Aperture 6.4 mm diameter defines exposed area of crystal.
Leak rate	Less than 10^{-8} torr-litre/sec.
Water connexions	Plain sleeves for 9.5 mm bore hose Internal water filter 0.75 mm mesh
Water temperature	30°C maximum at inlet
Dimensions	Length in vacuum chamber 515 mm approx. Length of external water tubes 100 mm approx. Diameter of insertion aperture 27.08 mm
Weight	450 g

OPTIONAL ACCESSORIES

RATE DISPLAY	Displays the rate of change of film thickness in hertz per second
Ranges	1 - 999 Hz/s and 1 - 9990 Hz/s
Mounting	Series 70 quarter-rack 133 mm high x 111 mm wide x 141 mm deep
TERMINATION UNIT	Operates two light-duty change-over contacts for terminating deposition at a pre-set value of frequency shift
Controls	6 digit decade switch for selection of termination value Indicator lamp Reset switch
Mounting	Series 70 quarter-rack 133 mm high x 111 mm wide x 277 mm deep

ORDERING DETAILS	Code
FTM3 Digital film thickness monitor	18-D311-26-000
FTM3 Monitor oscillator	18-D311-26-040
FTM3 Rate display	18-D311-26-150
FTM3 Termination unit	18-D311-26-200
Water-cooled crystal holder	18-D313-11-000
FTM3 Rack mounting adaptor	07-D354-26-000

OPERATION

OPERATING PRINCIPLE

The sensor on which the film thickness measurements depend is the monitor crystal, which is mounted in the vacuum chamber so that, as vapour is deposited on the substrate, it is also deposited on a defined area of the crystal surface.

The crystal is of the kind used in radio systems to control their frequency. It is a mechanical resonator, somewhat analogous to a spring with a mass on the end. When the mass is increased (by the deposition of evaporant) the frequency of vibration falls.

In the FTM3, the frequency of the monitor crystal is compared with that of a reference crystal in the main unit. Electronic circuits extract the difference; its value in hertz (cycles per second) appears on the six-digit display.

The system is extremely sensitive. The displayed value increases by about 300 Hz per microgram of material deposited on the crystal. Using the standard crystal holder, this corresponds to 1 Hz for 10^{-8} g/cm^2 or 1 Hz per Angstrom unit at a density of 1 g/cm^3.

Quartz crystals

The specification and behaviour of the crystals is as follows:

Type	18-D311-00-083
	AT Cut 0.5 in (12.5 mm) square
Electrodes	Gold. Diameter 7/32 in (5.55 mm)
Frequency	Reference crystal: 6,400 KHz
	Monitor crystal: 6,000 KHz
	Accuracy: 0.01% at 25°C
Temperature effect	Over the range 20 to 60°C, max. change of frequency 300 Hz.

AT cut crystals are used because they have a high sensitivity to mass loading, a low temperature coefficient of frequency, and are readily available at a reasonable price.

The crystal vibrates in the thickness shear mode; the movement is like that of a book with its pages being slid back and forth over each other. The frequency is determined by the elasticity and mass of the crystal. Adding material to one face of the crystal increases its mass and so reduces its frequency.

Sensitivity to added mass

It is essentially the total mass of added material which determines the change of frequency. The relationship is almost exactly linear over the working range of the FTM3. The frequency of the monitor crystal drops by approximately 300 Hz per microgram of evaporant deposited on the crystal.

Calculation of film thickness

Given the area covered by the deposit and the density of the material, the thickness of the film can be calculated from the frequency change.

In convenient units, the result for a circular area is approximately

$$\text{Thickness } t = 42\ N/d^2D$$

where t = thickness (Å) (10^{-10} m)

N = frequency change (Hz)

= the number shown on the thickness display

d = diameter of area (mm) $d^2 = (6{,}4\ mm)^2 = 40{,}96\ mm^2$

D = density of material (g/cm^3)

The standard crystal holder has an aperture 6.4 mm in diameter, so the above relationship becomes simply

$$t = N/D \cdot 1{,}025$$

For accurate work, the thickness calibration should be determined by experiment.

Densities of common evaporant materials in bulk

(gram per cubic centimetre)

Aluminium	2.7	Silicon	2.4
Bismuth	9.8	Silver	10.5
Gold	19.3	Tin	7.3
Selenium	4.8		

Very thin films. The structure of a very thin film differs from that of the same material in bulk, being less closely packed. The density of such a film is lower than the bulk density. When the FTM3 is used to monitor such films, it continues to respond normally to the mass deposited, but the thickness of the film will be greater than that calculated from the bulk density. The magnitude of the effect depends upon the material and the conditions of evaporation. A film must usually be a few hundred Angstroms thick before its structure becomes continuous and its density approaches the bulk value.

Experimental evidence

The numerical factors (300, and 42 in the equation on page 11) agree well with values calculated theoretically but several approximations are involved in the theory so it is better to use empirical values based on actual experiments using the precise set-up which is to be monitored. Those quoted above are taken from calibration runs in which many successive evaporations were made, the film thickness and mass being determined independently for each measured frequency change.

PRELIMINARY RUN

When the FTM3 is first installed, it is advisable to gain familiarity with the instrument by making a preliminary run before embarking on a working evaporation. This can also give an overall check of the monitor system under working conditions, including a comparison of the FTM3 reading with the measured thickness of the film deposited on a test substrate.

Preparing the monitor crystal

Before using a new crystal or one which has been cleaned to monitor a working evaporation, it is advisable to deposit a thin layer (say 2000 A) of aluminium upon it. This covers the exposed part of the crystal with a metal which is readily dissolved and so makes it easier to remove subsequent deposits. Copper may be used instead of aluminium if it will be less affected by subsequent deposits.

This preparation of the crystal can obviously be combined with the preliminary run, or a repetition of it at any time.

Procedure for preliminary run

Set up the coating unit for depositing aluminium on a glass substrate and start to pump down.

Switch on the FTM3 and immediately press the crystal check button. Check that a reading of about 400 000 is obtained. Press the set zero button. Watch the display. The reading is likely to change even though no evaporation is taking place, because the crystal is subject to changes of pressure and perhaps temperature.

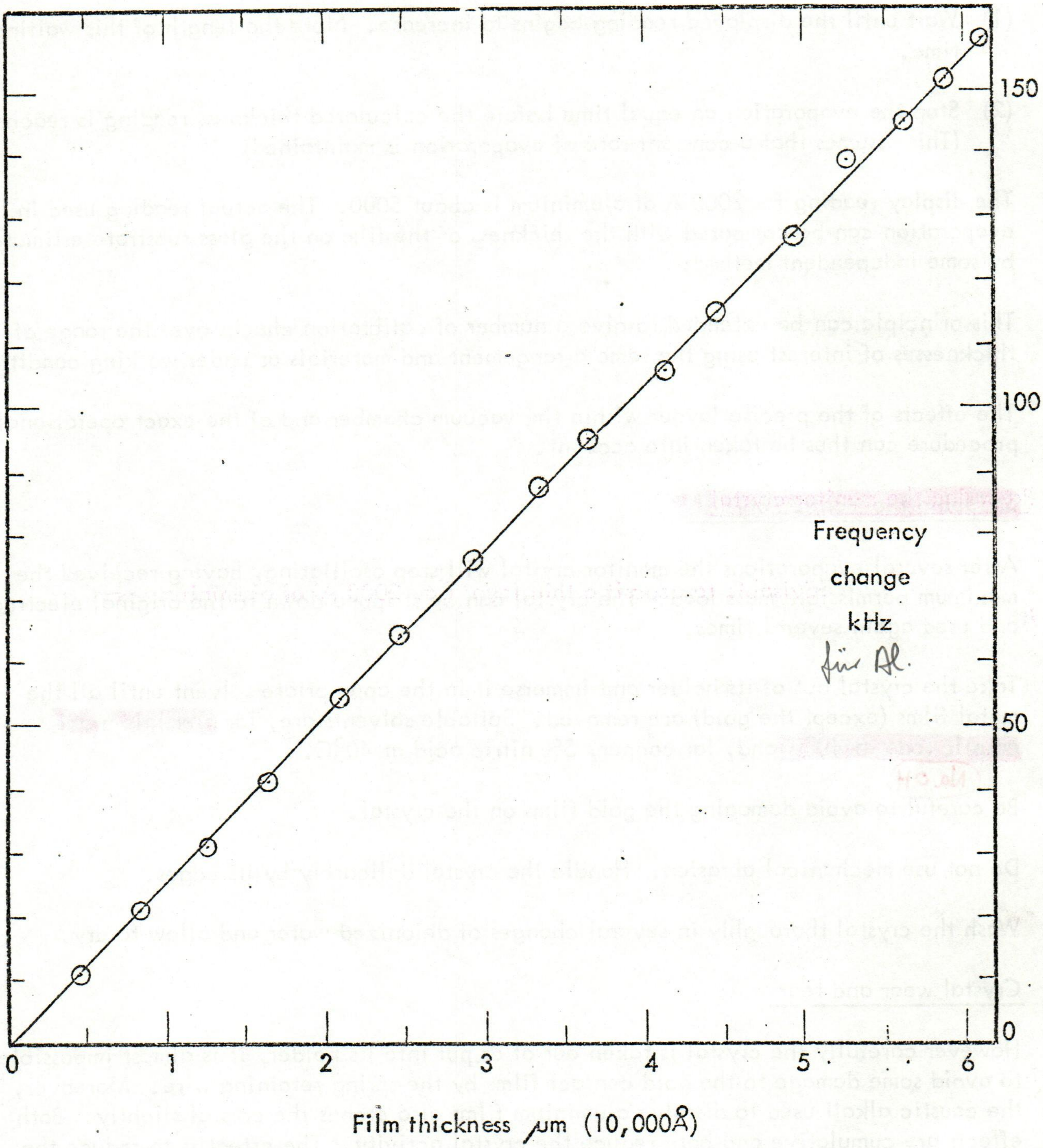
In evaluating these changes of reading, remember that 10 corresponds to only 4 A of aluminium, a layer less than two atoms thick.

Allow 15 minutes for the FTM3 to warm up, then set zero again.

Start the evaporation and again watch the display.

During the first few seconds of the evaporation, the radiation from the evaporant source may cause a frequency change which may be greater than that produced by the mass of material deposited and in the opposite direction. The display will then remain at or near zero, being unable to show a negative value. To reduce the small consequent error, in operation the following procedure may be adaopted.

Experimental calibration results



The graph shows the results of a typical calibration run. Aluminium was evaporated on to the monitor crystal through the standard 6.4 mm diameter aperture. The evaporation was interrupted from time to time; the frequency change shown by the film thickness monitor was recorded and the thickness of the aluminium was measured by optical interferometry. Each plotted point represents one such pair of measurements.

(1) Wait until the displayed reading begins to increase. Note the length of this waiting time.

(2) Stop the evaporation an equal time before the calculated thickness reading is reached. (This assumes that a constant rate of evaporation is maintained).

The display reading for 2000 A of aluminium is about 5000. The actual reading used in the evaporation can be compared with the thickness of the film on the glass substrate estimated by some independent method.

This principle can be extended to give a number of calibration checks over the range of thicknesses of interest using the same arrangement and materials as under working conditions.

The effects of the precise layout within the vacuum chamber and of the exact operational procedure can thus be taken into account.

Stripping the monitor crystal

After several evaporations the monitor crystal will stop oscillating, having received the maximum permissible mass load. The crystal can be stripped down to the original electrodes and used again several times.

Take the crystal out of its holder and immerse it in the appropriate solvent until all the metal films (except the gold) are removed. Suitable solvents are, for aluminium 5% caustic soda at 40°C and, for copper, 5% nitric acid at 40°C.

NaOH

Be careful to avoid damaging the gold films on the crystal.

Do not use mechanical abrasion. Handle the crystal delicately by its edges.

Wash the crystal thoroughly in several changes of deionized water and allow to dry.

Crystal wear and tear

However carefully the crystal is taken out of or put into its holder, it is almost impossible to avoid some damage to the gold contact films by the spring retaining wire. Moreover, the caustic alkali used to dissolve aluminium films also etches the crystal slightly. Both effects are cumulative and both reduce the crystal activity. The effect is to reduce the mass load of evaporant which the crystal will accept and still oscillate. When the reduction becomes significant the crystal must be discarded.

FTM3 FILM THICKNESS MONITOR CONTROLS

The controls consist simply of one switch and four pushbuttons.

Mains on/off switch

Select crystal No. 1

Select crystal No. 2

Check crystal activity

Set zero

Crystal Check

On pressing this button, the display should show a reading, between about 400000 for a new monitor crystal and up to 550000 for a fully-loaded crystal.

If the display stays blank, the monitor crystal is disconnected or not oscillating.

Set Zero

This button clears the display register so that the display returns to zero. The operation takes about 3 sec., during which the indicator lamp stays on.

Thereafter, the display shows the total change in monitor crystal frequency since setting zero. The display is updated once per second.

OPERATING NOTES

Warm-up

Switch on the FTM3 at least 15 min. before starting to use it. It may be left switched on all day or continuously for much longer periods; after the initial warm-up period any drift is negligible in practice.

Vacuum chamber set-up

The arrangement of all the working parts inside the vacuum chamber must be kept precisely unchanged if reproduceable results are to be obtained from run to run and day to day.

Crystal life

Before starting an evaporation, check that the crystal is capable of receiving the prospective additional material. Press the crystal check button and note the display reading. For a new, unloaded monitor crystal the value will be about 400000. As evaporation proceeds the value will rise. The crystal will cease to oscillate when the reading reaches about 550000 for an unstressed film (i.e. most metals). Check that there is enough margin to cover the new evaporation. For highly stressed materials the limiting reading is lower, perhaps much lower, and should be established in each case by experience.

Two crystals

Continuity of operation can be assured by using two monitor crystals in the chamber. When one has received nearly its maximum deposited load, the other can be brought into use. The first crystal can be removed for cleaning, being replaced meanwhile by the third crystal supplied.

The change-over between the crystals in the chamber is made simply by pressing the appropriate 'Select Xtal' button, provided each crystal has its own monitor oscillator. With only one monitor oscillator, the changeover must be made by moving the coaxial plug under thebaseplate from one crystal connexion to the other.

Rate display and crystal check

When using the rate display, do not press the crystal check button during an evaporation because the flow of rate information to the rate display is interrupted while the button is depressed.

LITERATURE REFERENCES

A.W.Warner and C.D.Stockbridge.

Mass and thermal measurements with resonating crystalline quartz.
Vacuum Microbalance Techniques 2,71,(1962)

W.Steckelmacher, J.English, H.H.A.Bath, D.Haynes, J.T.Holden and L.Holland.

Deposition and monitoring apparatus for preparing passive microcircuits.
Electronic Components, 5,405 (May 1964)
495 (June 1964)

W.Steckelmacher.

Thin film monitoring techniques
Thin Film Microelectronics (Ed. L.Holland)
Chapman and Hall, London (1965) p.204.

C.D.Stockbridge and others.

Several papers on fundamental questions.
Vacuum Microbalance Techniques 5,147-245 (1966)

T.I.Putner, J.English and R.Lincoln.

Recently developed instruments for control of vacuum deposited thin films.
Vacuum, 21,529 (1971).

F.Wehking, K.Hartig and R.Niedermayer.

Precision measurements of film thickness with a quartz crystal oscillator.
Progress in Vacuum Microbalance Techniques 1,25 (1972).

ELECTRONICS

The electronics of the instrument maintain the monitor crystal and reference crystal in oscillation, mix their outputs, extract the difference between their frequencies and process this difference to drive the thickness display, the rate display and the termination unit. Power for all these functions is derived from the mains supply.

Measuring circuits: outline (Figure 1)

The 6.4MHz reference oscillator output is divided down by the clock generator to produce reference clock pulses at 1 Hz repetition frequency.

The output of the monitor oscillator is mixed with the 6.4MHz reference frequency to produce a difference frequency which is gated by the clock generator to provide a discrete train of pulses each second lasting for virtually the whole second. This difference frequency is counted and compared with the initial value stored in the set zero memory. When it reaches that value the thickness gate is opened and any increase over the initial value is counted by the thickness counter and displayed.

The initial frequency is stored in the set zero memory at the start of a deposition cycle by pressing the set zero push button.

The value counted during one second is stored on the thickness latches for the following second and displayed as a steady reading during that time.

The new value being counted is compared with the previous value in the rate comparator. When it reaches the previous value the rate gate opens and any increase is transferred to the rate display unit. There it is counted, stored and displayed.

The thickness count is also passed to the termination unit where it is counted and stored. The value is compared with that selected on the thumbwheel switches and when it reaches the latter value the termination relay is energized.

The two crystal oscillators are sinusoidal so they and the mixer use linear circuits which are described in more detail below. The digital circuits employed to process the signals after the difference frequency has been extracted use a more highly specialised circuit technology and are not described in these instructions.

There are no adjustable controls in the signal circuits: every function is self-regulating. As far as possible without undue complication, the functions are also self-checking through the indicator lamps and displays.

All the active components are solid state devices and the whole system is operated before despatch for long enough to eliminate early-failing items. The reliability is therefore inherently high: apart from accidental damage, the most probable cause of breakdown is the unpredictable catastrophic failure of some component after thousands of hours of operation.

Sub-assemblies: function and location

Main unit (Figure 2)

The FTM3 main unit chassis and rear panel carry the mains-frequency circuits including the mains transformer and also one power supply (+5V). Supported horizontally on the chassis is the mother-board (PCB6) into which the other printed circuit boards plug. In order from the rear panel forwards, the boards are

(1) PCB5 (Power) (2) PCB1 (Clock) (3) PCB4 (Store) (4) PCB2 (Mixer) (5) PCB3 (Display)

Power supplies

+5V supply (Figure 2) On main unit chassis. Supplies the logic circuits including those in the rate and termination units. See footnote.

The 10V mains transformer secondary feeds a rectifier bridge. The output is regulated by the 5V regulator (LM 309K). This is supplemented by a shunt transistor (TIP 2955) to increase the available output current by about 20%.

The regulated +5V output is connected to:

Rate connexion block terminal 1
Termination connexion block terminal 1
PCB6/4 and thence through PCB6 to
PCB1/5 clock supply
PCB3/29 display supply
PCB4/24 store supply

+180V supply (Figure 2) On mother board PCB6. Supplies the digital displays.

The 200V mains transformer secondary feeds a rectifier bridge. The output is regulated by three zener diodes in series and is connected to

PCB6/40 and thence to
PCB3/18 display supply
Rate connexion block terminal 3

+12V and -12V supplies (Figure 3) On PCB5. Supply the two crystal oscillators and associated linear circuits and also the indicator lamps and crystal selection relay.

The two supplies are similar; in each, a 16-0-16V mains transformer secondary feeds a full wave diode rectifier, followed by a series regulator. The output voltages can be trimmed by the pre-set potentiometers.

Note: Crowbar trip. A crowbar SCR is connected across the +5V supply and short circuits it if a voltage high enough to damage the integrated circuits should develop. The trip will reset when the supply is switched off and on again, if the fault has been rectified.

The outputs are connected as follows:

+12V Source PCB5/6
connected to:

PCB2/21 mixer supply
PCB6/15 and thence to Termination connexion block terminal 3
Xtal selection relay and thence:
via PCB6/17 to Xtal 1 socket contact 5
and via PCB6/18 to Xtal 2 socket contact 5
through Xtal select relay coil to PCB6/12 and thence to Xtal 1 select button contact 6

-12V Source PCB5/10
connected to:
PCB2/2 Mixer supply
via PCB6/30 to Termination connexion block terminal 4
via Xtal 1 pushbutton contact 4 to Xtal 1 lamp
via Xtal 2 pushbutton contact 4 to Xtal 2 lamp

Monitor Oscillator (Figure 4)

The monitor crystal, in the vacuum chamber, is connected by the 15 cm coaxial lead to TR22e (e = emitter). TR22c (collector) is coupled to TR21b (base); TR21c is coupled back to TR22b to complete the positive feedback loop which maintains the crystal in sinusoidal oscillation at its series resonance frequency.

The level of oscillation is kept constant, independent of the crystal loading over a wide range. The signal at TR21c is rectified by D19, D20. The smoothed d.c. signal is applied via TR24 to TR23b to complete the ALC loop.

The ALC level can be checked at Pin 3 at either end of the 5 way cable.

The signal from TR21c is amplified by TR20 and TR19 and coupled by T2 to the balanced output connexions.

The 5-pin plug connects the monitor oscillator to the FTM3 main unit.

Normal conditions

Voltages relative to Pin 4

Power supply	Pin 5	+ 12V
Output	Pins 1 and 2	each 400 mV p/p 6 MHz sine
ALC level	Pin 3	new crystal about + 0.15V end of life about + 0.3V

Reference oscillator and mixer On PCB2 (Figure 5)

The reference oscillator circuit is similar to that of the monitor oscillator. Its output, from TR4c, is converted to a clean square wave by IC17.

TR1 and TR2 form a long-tailed pair which combines the two balanced inputs from the monitor oscillator in use. The output from TR2c is added to the reference oscillator signal on TR3c; the sum is rectified by D3 and D4. The difference frequency is amplified by TR8, filtered, clipped to an approximately square wave by D5 and D6 and converted to a clean, sharp square wave by IC16. Test points TP1 to TP6 are provided.

Normal conditions

Voltages relative to contact 19 (0V)

TP1 and TP2 inputs from monitor oscillators each 400 mV p/p 6MHz sine.

TP3	sum of monitor oscillator 6MHz and reference oscillator 6.4MHz signals. Almost 100% beat at about 400KHz visible.
TP4	reference oscillator 1 to 1.2 V p/p 6.4MHz sine.
TP5	difference frequency with about 10% r.f. ripple.
TP6	difference frequency 1.2V p/p 400KHz clean square wave.
PCB2/22	difference frequency about 3.5V p/p 400 KHz very sharp square wave.
PCB2/23	reference oscillator about 2.5V p/p 6.4MHz very sharp square wave.

FIRST LINE SERVICE

If the instrument should develop a fault, Edwards' world-wide service facilities are at your disposal as described below, but meanwhile it will often be possible to bring the instrument back into operation if the recommended spares are available.

Fault location

A fault in the electronics can usually be located by working through the following three-stage procedure.

1. Self-checking facilities

The indicator lamps and displays check the power supplies and some of the current functions as follows:

Mains indicator lamp Checks the power supply mains, mains filter, fuse, on/off switch, mains voltage selector and wiring up to the mains transformer.

Set zero indicator lamp Checks the +12V supply.

Xtal selector lamps Check the -12V supply.

Digital displays If any digit glows in either of the displays, the +180V supply is functioning.

If either the thickness or the rate display works, the +5V supply is functioning.

2. Voltmeter checks without opening the case

A high resistance multi-range voltmeter (10,000 ohms per volt or more) with probes can check the power supplies at points on the back panel, accessible from the outside. All the voltages should be very close to the nominal value.

0V The common ground line is connected to

Rate terminal block	terminal 2
Term terminal block	terminal 2.
Xtal 1 socket	pin 4
Xtal 2 socket	pin 4

+12V is connected to

Term terminal block	terminal 3
Xtal 1 or Xtal 2 socket whichever is switched in, pin 5	

-12V is connected to

Term connexion block terminal 4

+5V is connected to

Rate connexion block terminal 1
Term connexion block terminal 1

+180V is connected to

Rate connexion block terminal 3

3. Voltmeter and oscilloscope checks inside the case

Refer to the circuit descriptions and diagrams.

WARNING Dangerous high voltages exist within the main unit case. The unit should not be switched on (with the cover removed) except by a competent engineer.

Voltages Additionals checks on the supply voltages and their internal distribution connexions can be made inside the case. The monitor crystal activity can also be checked by measuring the ALC voltage.

Waveforms An oscilloscope capable of displaying signals of a fraction of a volt at frequencies up to at least 6MHz is required to check the linear circuits. To check the digital circuits requires much more sophisticated equipment.

Diagnosis The above checks in conjunction with the circuit description will usually indicate which part of the instrument has developed the fault. All parts except the mains-frequency circuits and the +5V supply are contained in the recommended spares.

Replacement of fault board

The faulty unit can be replaced by the spare and returned to the supplier for repair.

Note: If any of the supply voltages is found to be appreciably higher than its nominal value, this fault should be cleared before inserting any spare board (apart from the one carrying the faulty power supply).

In particular, a marked rise in the +5V supply, which could conceivably occur due to a failure in the 5V regulator, might damage the integrated circuits of the logic boards.

Repairing printed circuit boards

It is usually better to return the complete board to Edwards than to attempt to repair it.