# Optical Film thicknes measuring Instrument

# GSM 210

A Product of BALZERS AG, Balzers

Operating Instruction No. A 11-3995 e

| | | |
|---|---|---|
| Valid for Serial Nos. | GSM 210: | 111—1200 |
| | WLL 201: | 111—1200 |
| | WLE 201: | 111—2500 |
| | WLU 201: | 111—1000 |

BALZERS

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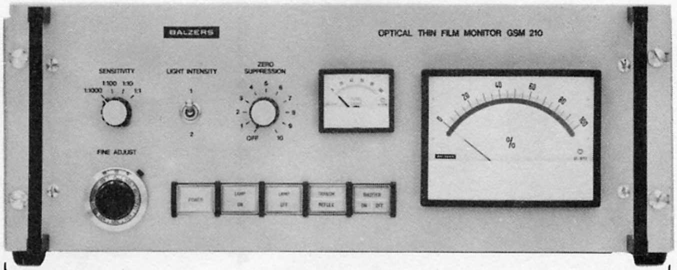
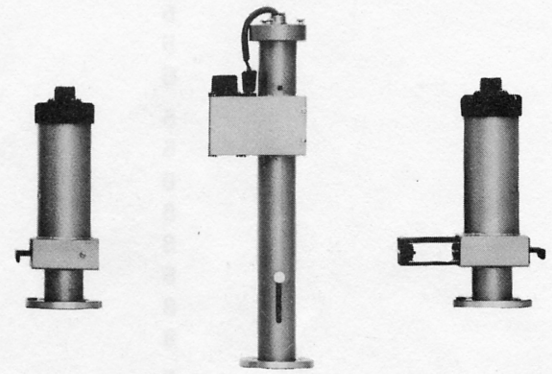
## 1. APPLICATION

The film thickness measuring equipment GSM 210 illustrated in Fig. 1, is designed for measuring vacuum deposited films during coating, making use of thin reflection or transmission.




GSM 210



WLE 201 WLL 201 WLE 201

Fig. 1 GSM 210

| | |
|---|---|
| GSM 210 | Control and measuring instrument |
| WLE 201 | Modulated light receiver for transmission and reflection |
| WLL 201 | Modulated light source |

## 2. MEASURING PRINCIPLE

(See Fig. 2 and Fig. 3)

The modulated light source (WLL 201), which is powered by a stabilised voltage, produces a light beam, which is modulated or chopped to 80 Hz by a rotary chopper disc. This light beam enters the vacuum chamber through a window, and reaches a test glass mounted in the plane of the specimen to be coated. The light is transmitted through the test glass or is reflected by it.

Using two separate receivers (for transmission and reflection) the modulated light transmitted or reflected from the test glass is converted into a proportionate alternating current and amplified. This signal is transmitted to the control and measuring instrument GSM 210, where it is amplified once more and indicated. To ensure that the light from the evaporation source and from the room lighting etc. is not included in the measurements, the amplifier is selectively matched to the modulation frequency (phase sensitive discriminator).

**Measuring arrangement of the GSM 210**

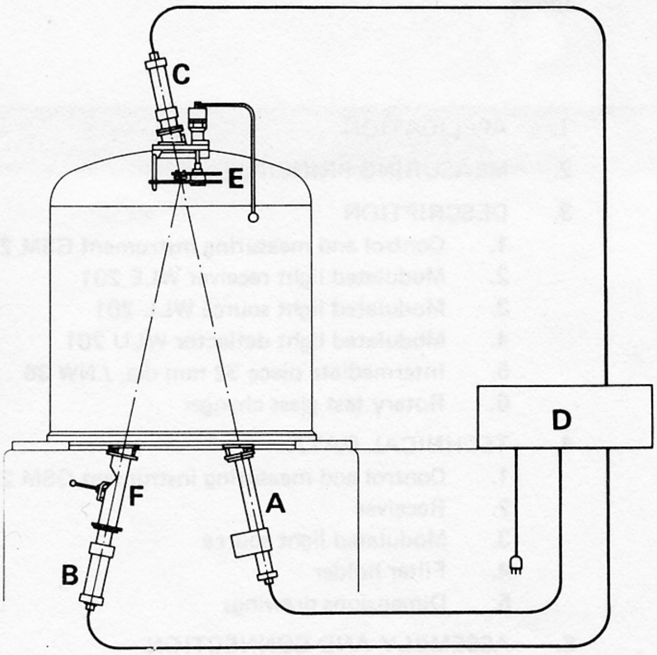



Fig. 2 Two-beam principle

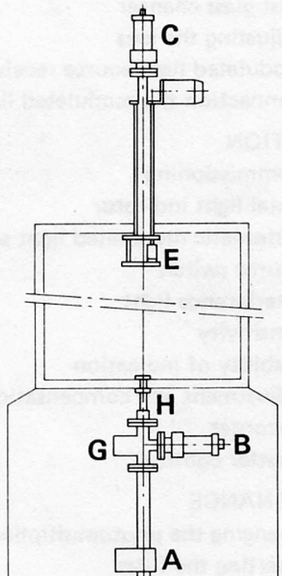



Fig. 3 Mono-beam principle

| | |
|---|---|
| A Modulated light source | E Test glass changer |
| B Receiver Refl. | F Light beam deflection |
| C Receiver Transm. | G Deflector |
| D Indicating instrument | H Intermediate-piece |

## 3. DESCRIPTION

(See block diagram Fig. 4)

### 3.1. Control and measuring instrument GSM 210

All components necessary for operating the equipment are contained in the control and measuring instrument GSM 210.

**Principle diagram GSM 210**

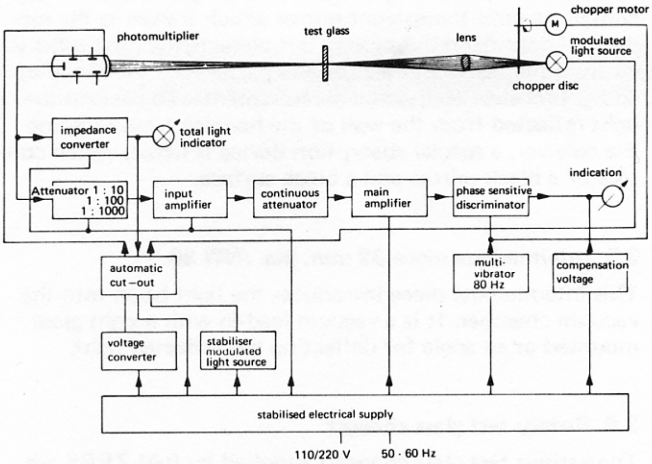



Fig. 4

**Modulated light source stabiliser.** For energising the modulated light source WLL 201. The stability and thus the sensitivity of the entire measuring equipment is largely dependent on this component.

**The Multivibrator 80 Hz** produces the necessary square wave voltage for the chopper motor and also for the phase discriminator. The frequency is not dependent on the power supply, so the GSM 210 can be connected to an electrical supply with either 50 Hz or 60 Hz.

**Total light indicator MI 1.** The signal produced by the photomultiplier is transmitted to an indicator via an impedance convertor. Thus, the total quantity of incident light (measured light and interference light) can be measured. By this means, any over-loading of the photo-multiplier, whereby linearity is lost, can be checked and the ratio of usable light to interference light can be determined.

**Automatic cut-out.** Excessive light input to the photomultiplier affects the photo-cathode and reduces its sensitivity, at least temporarily. In such event, the automatic cut-out interrupts the current supply to the modulated light source and the photomultiplier. The current can only be switched on again after the light intensity has been appropriately reduced by the use of optical filters.

**Decade attenuator.** The measuring signal produced by the photomultiplier first reaches the decade attenuator where it can be attentuated in the ratio 1 : 10, 1 : 100 or 1 : 1000 to satisfy requirements.

**Input amplifier, continuous attentuator and main amplifier.** The measuring signal is amplified in the low noise level input amplifier so that it can be transmitted to another, continuously adjustable attenuator. This attenuator consists of a precision potentiometer with calibrated scale. With the aid of this and the decade switch the measuring signal can be adjusted to suit the subsequent main amplifier.

**The phase sensitive discriminator** is controlled by the multivibrator and thus acts as a filter for any voltages of a different frequency which may enter the amplifying channel. The discriminator converts the measuring signal into a direct current.

**Indicating instrument and compensation voltage.** The direct current produced from the measuring signal (alternating current) in the discriminator is transmitted to the indicating instrument. The compensation control allows the signal effective at the indicating instrument to be suppressed up to 4 times full scale.
Thus the indicated changes in transmission and reflection are correspondingly extended, so that the reverse points which occur with certain measurements can be more unequivocally detected. (See section 9.)

Mounted on the front panel are the switches and controls for:

- Measuring instrument ON – OFF, push-button POWER
- Selector switch for 4 sensitivity ranges (SENSITIVITY)
- Sensitivity fine adjustment (FINE ADJUST)
- Electrical zero point suppression (ZERO SUPPRESSION)
- Selector switch for light intensity (LIGHT INTENSITY)
- Push-button for selecting the measuring method (TRANSM.-REFLEX.)
- Push-button for the modulated light source (LAMP ON, LAMP OFF)
- Moving coil instrument for indicating the total light incident at the photomultiplier (TOTAL LIGHT)
- Moving coil instrument with a scale from 1 – 100 % for indicating the measuring signal.

Mounted on the rear panel are the following connections:

- Power supply socket MAINS
- Socket for connecting another BALZERS instrument MAINS-INTERPANEL-CONN.
- Two RECORDER connections, for 10 mV and for 100mV
- One socket TRANSMISSION and one REFLECTION for connecting the modulated light receiver WLE 201
- Three sockets for the synchronising signal
- One socket LAMP for connecting the modulated light source WLL 201
- One socket SHUTTER for connecting a shutter

The mains power supply fuses are also on the rear panel.

## 3.2. Modulated light receiver WLE 201

The modulated light source receiver WLE 201 for transmission and reflection measurement is of very compact construction and is provided with a 4-stage blue photomultiplier as standard equipment. We also supply a red photomultiplier as an accessory, which is interchangeable with the blue one (bayonet type fastening). The incident light signal is converted into an alternating light proportional A.C. voltage and amplified. The measuring range of the blue photomultiplier is approximately 350 mμ to 700 mμ and that of the red photomultiplier approximately 450 mμ to 1100 mμ.

The receivers are each provided with a filter holder in which suitable filters can be fitted, for example, an interference filter for measuring with monochromatic light or a neutral light density filter to keep the light density within permissible limits. A neutral light density filter (20 % absorption) and an interference filter (450 mμ – 480 mμ) are provided with the standard equipment. A double Mumetal shield protects the receivers from the effects of magnetic fields.

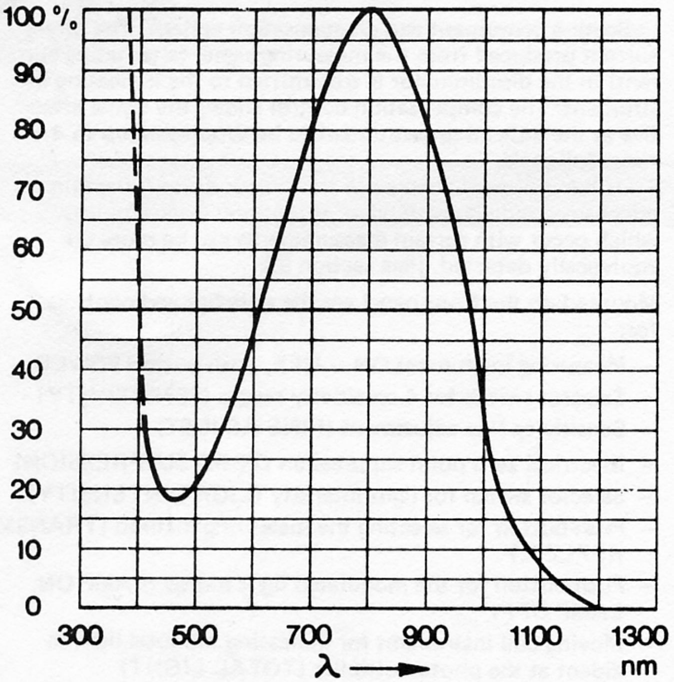



Fig. 5 Spectral sensitivity photomultiplier "red"

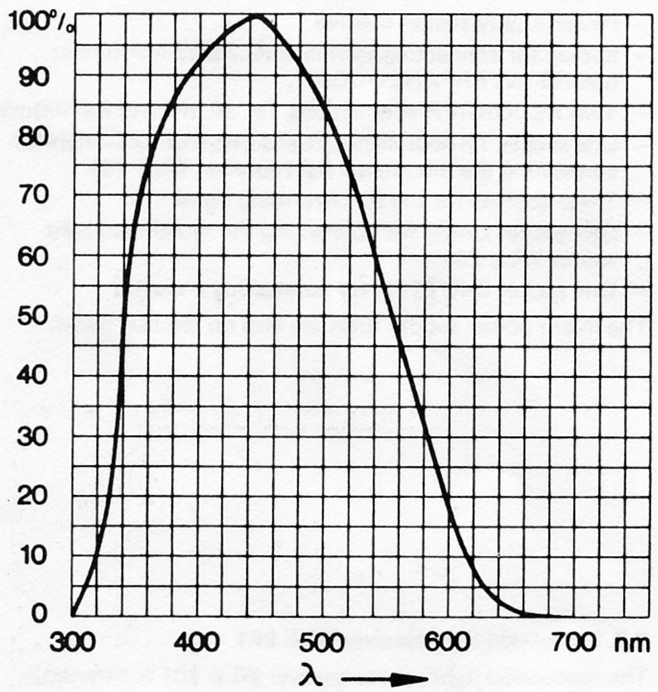



Fig. 6 Spectral sensitivity photomultiplier "blue"

### 3.3. Modulated light source WLL 201

The modulated light source WLL 201 is very compact and its mounting angle is adjustable to allow the light beam to be set. It contains the following components:

- Incandescent lamp
- Chopper motor with perforated chopper disc for modulating the light (slow running with very long life)
- A lens system which produces an approximately parallel light beam of minimum diameter (permissible distance between source and test glass approximately 370 to approx. 1000 mm.)

### 3.4. Modulated light deflector WLU 201

In box coaters measuring is by means of the mono-beam principle (Fig. 3). This method requires the modulated light deflector WLU 201 (Fig. 14). The housing of the WLU 201 contains a semi-transparent mirror which transmits the modulated light from the source, but deflects the light reflected from the test glass changer and passes it to the modulated light receiver (reflection measurement). To prevent the light reflected from the wall of the housing from entering the receiver, a special absorption device is fitted, which consists of a black mirror and a black surface.

### 3.5. Intermediate piece 32 mm. dia. /NW 36

This intermediate piece introduces the light beam into the vacuum chamber. It is a vacuum lead-in with a sight glass mounted at an angle for deflecting the reflected light.

### 3.6. Rotary test glass changer

The various test glass changers supplied by BALZERS are described in the enclosed leaflets. Appropriate selection of the test glass changer for your application ensures maximum utilisation of the film thickness measuring instrument.

## 4. TECHNICAL DATA

### 4.1. Control and measuring instrument GSM

**Amplifier without receiver**

| | |
|---|---|
| Sensitivity (full scale deflection) | approx. 0.1 mV |
| Amplification max. | 10 000 |
| Linearity | better than 0.5 % |
| Attenuator max. | 1 : 10'000 |
| Accuracy of the attenuator | 1 % |
| Compensation range | 4 times |

**Stability of indication**

| | |
|---|---|
| with full compensation, max. amplification and ± 10 % mains voltage fluctuation | ± 0.5 scale divisions |
| Recorder connection, dependent on compensation | 10/100 mV/full scale deflection |
| Recorder connection independent of compensation | 10/100 mV |
| Source resistance | 100/1000 Ω |
| Shutter control | 1 selector switch |
| Loading at 220 V AC-voltage (ohmic load) | 5 A |

**Modulated light stabiliser**

| | |
|---|---|
| Stability of the light source voltage with ± 10 % mains voltage fluctuation | better than 1 ‰ |
| Stability of the source voltage in relation to the ambient temperature | better than 0.5 ‰/°C |
| Adjustment value of the source voltage | approx. 4.5 and 5.5 V |
| Life of the incandescent lamp at 4.5 V | approx. 400 hours |
| Life of the incandescent lamp at 5.5 V | approx. 65 hours |

**Automatic Off Switch**

Switch point at approx. 70 % of the max. permissible photomultiplier current

**Multivibrator for the chopper motor and phase sensitive discriminator**

| | |
|---|---|
| Frequency | 80 Hz |
| Output voltage for chopper motor | 50 V |
| Output current for chopper motor | 20 mA |
| Mains voltage supply | 115/230 V ± 15 % |
| Mains supply frequency | 50 – 60 Hz |
| Rating | 80 Watts |
| Weight | 14 kg. |

### 4.2. Receiver

| | |
|---|---|
| Anode sensitivity of the photomultiplier at 2850°K | |
| a) Type XP 1080 (blue sensitive) | 8 mA/Lm |
| Cathode material | Sb Cs |
| b) Type XP 1100 (red sensitive) | 3.5 mA/Lm |
| Cathode material | Ag - Mg - Cs |
| Anode resistance | 100 kΩ |
| Photo-cathode-diameter | min. 26 mm. |
| Spectral sensitivity see curves Fig. 5 and 6. | |
| Weight | 1,650 kg. |

### 4.3. Modulated light source

| | |
|---|---|
| Incandescent lamp, Philips | 13 353 N |
| Dimensions of the coil | approx. 1 x 1 mm. |
| Power requirement at 5.5 V | approx. 25 W |
| Frequency of chopper motor | 80 Hz |
| Weight | 1,750 kg. |
| Optics | Achromat ϕ 30 mm. |
| Focal length | 180 mm. |
| Adjustment range i.e. distance between modulated light source and test glass | approx. 370 – 100 mm. |

### 4.4. Filter Holder

| | |
|---|---|
| Construction | single and double |
| Steps | 2 |
| Size of filter | 50 mm. ϕ ◻ |
| Shape of filter | round - square |

### 4.5. Dimensions drawings

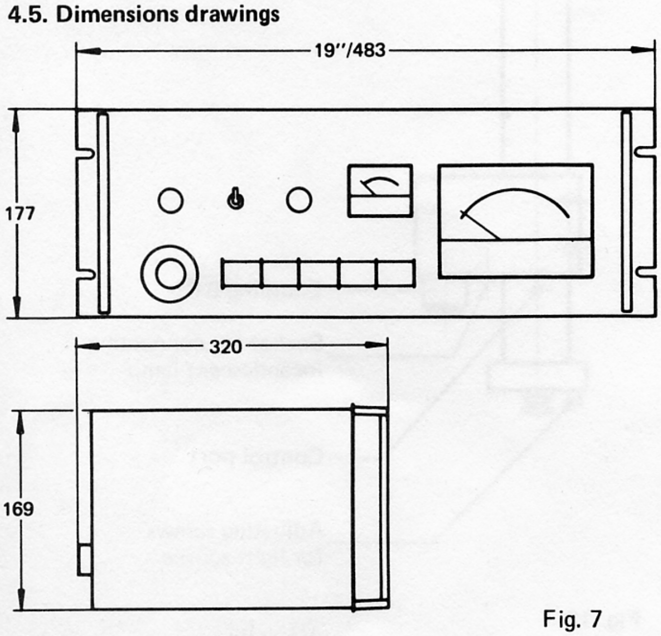



Fig. 7

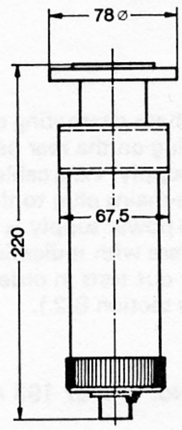



Fig. 8

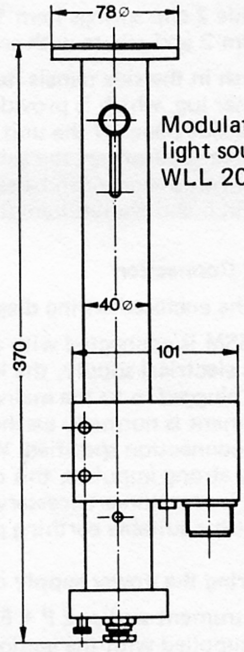



Fig. 9

## 5. ASSEMBLY AND CONNECTION

### 5.1. Control and measuring instrument GSM

#### 5.1.1. For rack mounting

The measuring instrument can be mounted in any suitable standard rack using 4 M6 or 1/4" screws.

#### 5.1.2. As bench model

If the GSM 210 is to be used as a bench model, the side panels, which are supplied as an accessory, are fitted as follows:

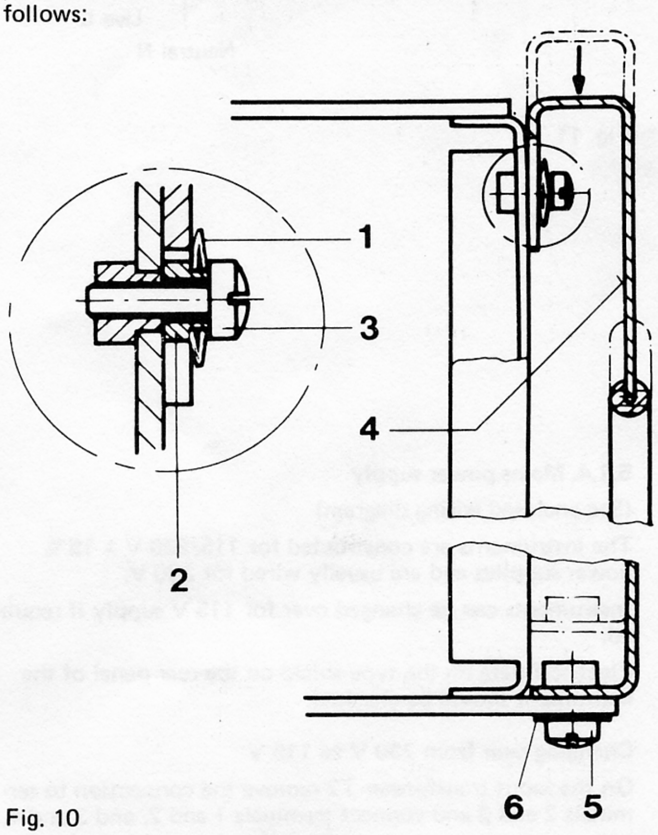



Fig. 10

1. Slide 2 cup springs item 1 onto the neck of the sleeve item 2 and secure with screws M4, item 3.
2. Push in the side panels item 4 from the rear so that the inner lug, which is provided with slots, slides between the side panel of the unit and the cup springs item 1. When the front of the side panel rests on the front panel, the components can be secured in place with screw M6, item 5 and washer item 6.

### 5.1.3. Connection

(See the enclosed wiring diagram)

The GSM is connected with a single phase alternating current mains electrical supply, the MAINS plug on the rear panel being plugged in to the mains power supply, via a cable. The instrument is normally earthed via the mains plug to the earth connection specified. Where the power supply is subject to strong impulses, this can interfere with indication, and it is sometimes necessary to carry out tests in order to establish a suitable earthing point (see section 8.2.).

**Preparing the power supply cable**

1 instrument socket 2 P + E Order No. B 4707 193 A is supplied with the equipment.

Because different countries have different sockets and different regulations concerning lead color, only Europa apparatus plugs are delivered with the instrument. A three-lead cable (3 x 1.5 mm$^2$) is to be introduced and connected to it according to Fig. 11.

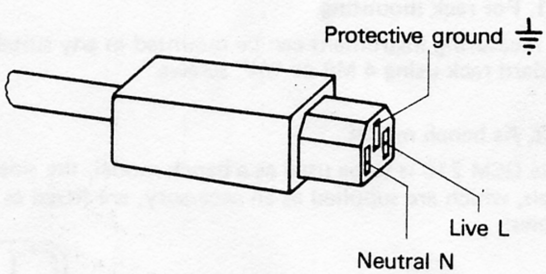



Fig. 11

### 5.1.4. Mains power supply

(See enclosed wiring diagram)

The instruments are constructed for 115/230 V ± 15 % power supplies and are usually wired for 230 V.

Instruments can be changed over for 115 V supply if required.

Electrical data on the type shield on the rear panel of the instrument should be checked.

**Changing over from 230 V to 115 V**

On the input transformer T2 remove the connection to terminals 2 and 3 and connect terminals 1 and 2, and 3 and 4.

| Fuses for | 115 V | 230 V |
|---|---|---|
| F1 | 1,2 A | 1,2 A |
| F2 | 2 A | 1 A |
| F3 | 2 A | 1 A |

The fuses should be cartridge type 5 mm. $\phi$ and 20 mm. long with a time delay. The GSM 210 can be operated at power supply frequencies of either 50 or 60 Hz without switching over.

Reference should be made to the spare parts list when ordering fuses and connections.

### 5.2. Modulated light source WLL 201

#### 5.2.1. Assembly

**a) Plants with a vacuum chamber baseplate**

The modulated light source is fitted on the rear sight glass below the vacuum chamber base. Flange A (see Fig. 13) is at an angle of 15$^{\circ}$ with the vacuum chamber base. The light beam is thus directed onto the centre of the test glass in the top of the vacuum chamber.

The modulated light source is mounted as follows:

Screw flange B to the bolts on flange A. Before fitting, turn back the three setscrews (see Fig. 13), which serve for adjustment, so that they are flush with the intermediate collar i.e. they do not project.

Using the three lock screws, assemble the modulated light source. Make sure that the setscrew for the optical system (see Fig. 12) remains accessible, by turning the modulated light source into the required position before tightening the lock screws.

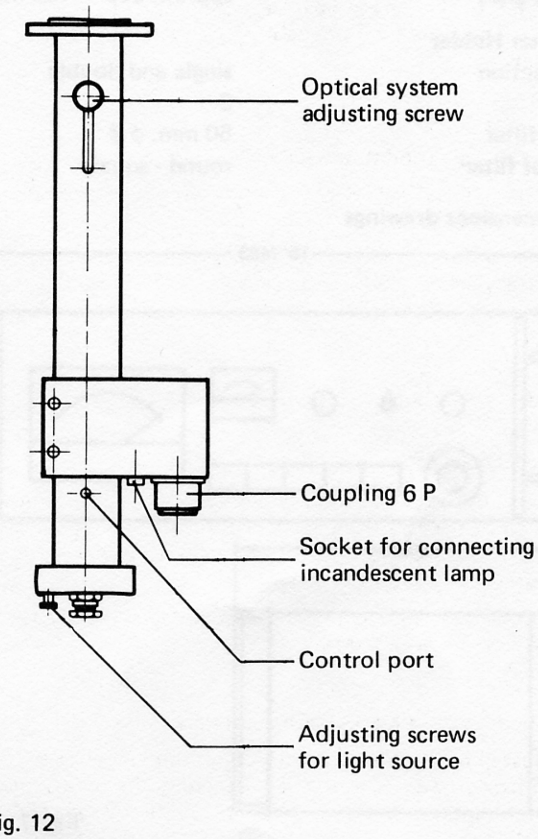



Fig. 12

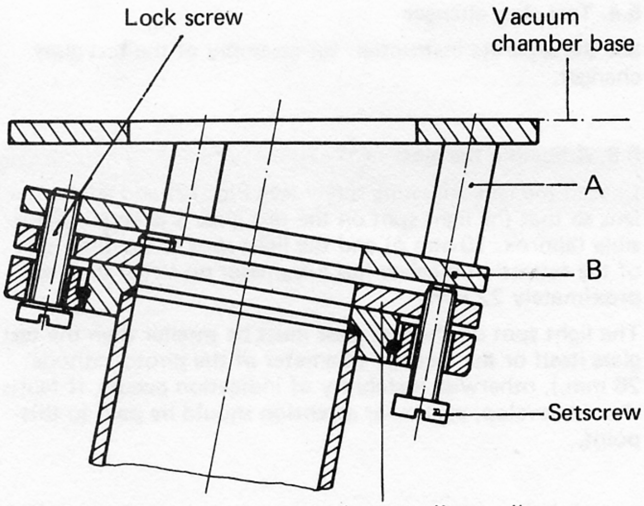


Fig. 13

**b) Plants with a cubic vacuum chamber**

Instead of the central blank stopper, the intermediate piece is mounted on the vacuum chamber baseplate. The deflector WLU 201 can then be mounted on the bottom flange of this intermediate piece (inside the stand) and the modulated light source attached to it (see Fig. 14). When assembling the modulated light source, make sure that the setscrew for the optical system (see Fig. 12) is accessible. See also the separate instruction on ''Producing BALZERS standard flange and small flange connections''.

**Note:** With the mono-beam arrangement, it is essential to make certain that the angle of the sight glass to the horizontal is a minimum of 15°, otherwise stray light can enter the receiver.

### 5.2.2. Connection

The 6-pole plug of the modulated light source (see Fig. 12) is connected to the socket ''LAMP'' of the control and measuring instrument via the cable supplied 51-9068 R3 (3 m. long).

### 5.2.3. Putting the modulated light source into operation

Press push-button POWER to put the control and measuring instrument GSM 210 into operation.

Press the push-button LAMP ON and switch on the modulated light source. A control port on the modulated light source (see Fig. 12) allows a visual check to see whether the lamp is on.

### 5.2.4. Adjusting the incandescent lamp

Lift the vacuum chamber and hold a piece of white paper in the light beam of the modulated light source.

By turning the three adjusting screws under the modulated light source (see Fig. 12) move the source until a uniformly illustrated round light spot approximately 10 mm. $\phi$ appears on the paper.

The light source is adjusted in the Works and normally requires no further re-adjustment.

### 5.2.5. Aligning the modulated light source

Place a test glass, frosted on one side, in the test glass holder, with the frosted side upwards. By loosening the lock screws and tightening the set-screws (see Fig. 13) direct the modulated light source onto the centre of the test glass. Care must be taken to ensure that the light beam does not come into contact with the test glass holder. The optical system setscrew should be adjusted so that the light spot is rather smaller than the test glass. Final setting of the modulated light source optics takes place after the receiver for reflection is assembled.

The three setscrews mentioned above provide a three-point support so that the modulated light source can be moved in any direction. When adjustment is completed, all screws should be tight to avoid subsequent movement of the source.

Maximum care must be exercised in making the adjustment and also to see that the vacuum chamber is correctly placed, otherwise it will move during evacuation and adjustment will be incorrect. For this reason it is advisable to rough out the vacuum chamber before adjusting the modulated light source.

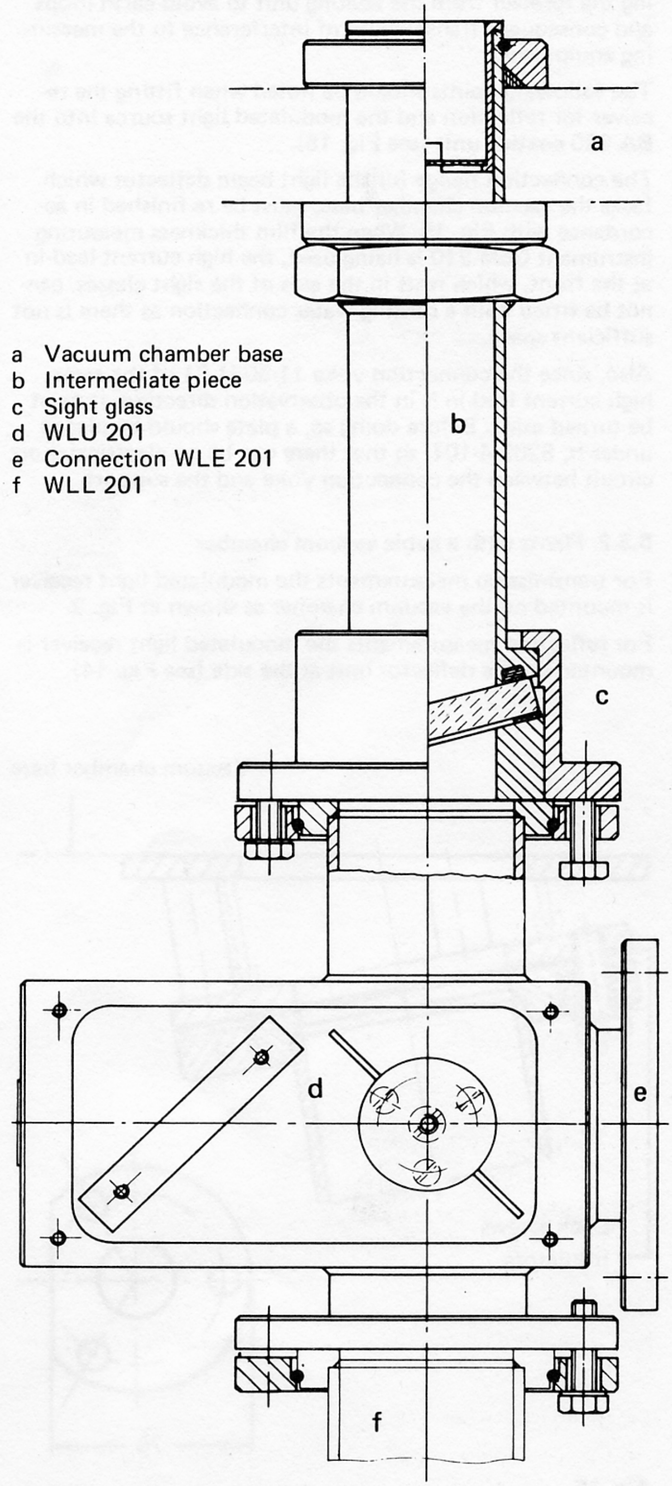


Fig. 14

### 5.3. Modulated light receiver WLE 201

#### 5.3.1. Plants with a vacuum chamber baseplate

The modulated light receiver for reflection WLE 201, together with the filter holder, is mounted on the flange under the vacuum chamber base, opposite to the modulated light source. This flange is fitted at an angle of 15$^{o}$ to the vacuum chamber base. A light beam deflector which is fitted between the receiver and the connection flange, allows visual observation of the test glass.

Before tightening the lock screws, rotate the receiver so that the filter holder is accessible. With the double filter holder, care must be taken to ensure that when it is pushed right in, it does not touch any other fittings. The insulation components (see Fig. 15) have the function of electrically insulating the receiver from the coating unit to avoid earth loops and consequent transmission of interference to the measuring equipment.

The following points should be noted when fitting the receiver for reflection and the modulated light source into the **BA 360 coating unit** (see Fig. 15).

The connection flange for the light beam deflector which faces the vacuum chamber base, must be re-finished in accordance with Fig. 15. When the film thickness measuring instrument GSM 210 is being used, the high current lead-in at the front, which rests in the axis of the sight glasses, cannot be fitted with a cooling water connection as there is not sufficient space.

Also, since the connection yoke 11-5031 P1 of the same high current lead-in is in the observation direction, it must be turned aside. Before doing so, a plate should be placed under it, 8203-4-101, so that there can be no electrical short circuit between the connection yoke and the support.

#### 5.3.2. Plants with a cubic vacuum chamber

For transmission measurements the modulated light receiver is mounted on the vacuum chamber as shown in Fig. 3.

For reflection measurements the modulated light receiver is mounted on the deflector unit at the side (see Fig. 14).

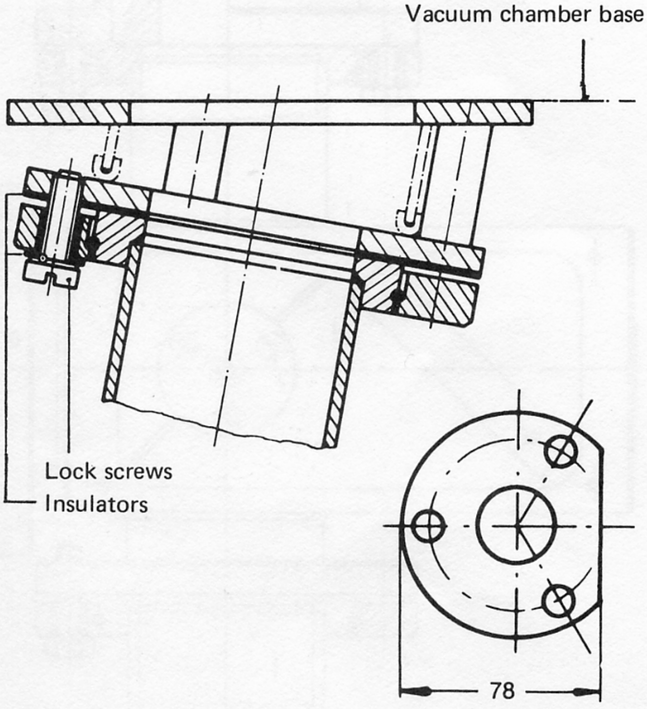



Fig. 15

### 5.4. Test glass changer

See the separate instruction for assembly of the test glass changer.

### 5.5. Adjusting the lens

Loosen the lens adjusting screw (see Fig. 12) and adjust the lens so that the light spot on the test glass is as small as possible (approx. 10 mm $\phi$) and the light spot in the filter slot of the reflection receiver has a diameter no larger than approximately 22 mm.

The light spot on the test glass must be smaller than the test glass itself or the receiver (diameter of the photo cathode: 26 mm.), otherwise instability of indication occurs. If faults should develop, particular attention should be paid to this point.

### 5.6. Modulated light source receiver WLE 201 (Transmission)

Similarly to the receiver for reflection, the transmission receiver is mounted on the flange of the test glass changer on the vacuum chamber. Special adjustment is not necessary, but care should be taken to ensure that the direction of the receiver corresponds with the optical axis of the modulated light source. The centreing and diameter of the incident light beam can be similarly checked by means of a test paper as described in the previous section. Any irregularities can be corrected as described in paragraph 5.2.5. and 5.5. It is advisable to test the beam path, modulated light source – test glass – receiver once again, very accurately because the entire functioning of the instrument is strongly dependent on this adjustment.

It should also be noted that the stray light shield supplied is specified for mounting between the test glass changer and the receiver for transmission.

### 5.7. Connecting the modulated light source receiver

The receivers for reflection and transmission are connected to the sockets REFLECTION and TRANSMISSION of the control and measuring instrument GSM 210 via the cable 51-9067 R3 (3 m. long) provided, as shown in Fig. 2.

## 6. OPERATION

### 6.1. Commissioning

Switch on the control and measuring instrument by pressing the push-button POWER. Select the required method of measuring on the push-button contact REFLECTION/TRANSMISSION.

Switch on the modulated light source by pressing the push-button LAMP ON.

### 6.2. Total light indicator

The small indicating instrument shows the total quantity of light reaching the receiver i.e. measured light and interference light. If full scale deflection is indicated when the modulated light source is switched on, there is immediately a certain risk of overloading, and the quantity of light entering the filter should be appropriately reduced by fitting a filter. To what extent the quantity of light must be reduced depends on the measuring signal in the subsequent coating process, whether it decreases or increases (see Section 9.3.). In the former case, the indicator can be virtually full scale in the initial stages of the coating process (see the following section).

It is our experience that with a normal test glass (reflection approximately 8 %), the receiver is fully loaded. If interference filters are used (i.e. monochromatic light), the measuring signal produced is determined by the sensitivity of the photomultiplier at the wave length utilised.

The measuring signal which can be anticipated can be roughly determined by the sensitivity curves (see section 6.6.1.).

## 6.3. Automatic modulated light source cut-out

If the quantity of light reaching the photomultiplier exceeds approximately 70 % of the permissible limit, the modulated light source and the current supply to the receiver is automatically switched off.

The modulated light source can only be switched on again after the quantity of light has been reduced in accordance with section 6.2.

## 6.4. Source switch (LIGHT INTENSITY)

The LIGHT INTENSITY switch has two positions, 1 and 2 so that the voltage to the modulated light source can be switched on to either 4.5. or 5.5. volts.

Normally the switch is left in position 1 and the source then operates at 10 % below nominal voltage. By this means the life of the coil is extended considerably because there is very little evaporation of the tungsten coil.

For measurements in the UV-range it is sometimes necessary to operate the source in switch position 2. In this position it operates 10 % over nominal voltage so that a considerably greater intensity of light is obtained in the UV-range. However, the life of the source is reduced considerably because of quicker evaporation of the tungsten coil. For this reason, operation of the source in switch position 2 should be kept to a minimum, and also because coated incandescent lamps have a very high absorption in the UV-range.

## 6.5. Interference light

If there is over loading of the receiver, there is always a possibility that this is caused by interference light, so that basically, the ratio of measured light to interference light should be high as possible. As the interference light is not indicated by the measuring instrument (%), this ratio can be determined by making a comparison between the voltage indicated by the total light indicator and the value indicated by the measuring instrument.

The sensitivity of the total light indicator is approximately 1000 mV (full deflection) and that of the measuring instrument approximately 0.1 mV for full scale deflection with maximum sensitivity.

To determine the information signal, the attenuators SENSITIVITY and FINE ADJUST are adjusted until the indicating instrument is exactly at full scale deflection. During adjustment care should be taken to ensure that the potentiometer ratio of the FINE ADJUST potentiometer is not greater than 1 : 10.

Information signal = total attenuation factor x 0.1 (mV)

**Example**

| | |
|---|---|
| Deflection of the total light indicator approx. 50 scale divisions | = 500 mV |
| Attenuator SENSITIVITY | = 1 : 1000 |
| Attenuator FINE ADJUST | = 1 : 2 |
| Total attenuation factor | = 2000 |
| Information signal | = 2000 x 0.1 = 200 mV |
| The ratio: Information signal/Interference signal is thus 200/500 | = **0.4** |

Determination of this value can only be carried out with the relatively large quantities of light that can be indicated by the total light indicator.

Fundamentally, stray light, provided that it is "direct light" has virtually no effect on measurement, but in the case of "light intensity variations", for example, fluorescent tubes, a large alternating voltage signal exists in the receiver, and phenomena of interference can occur. This results in cyclic fluctuations of indication.

The evaporation source (boat), which is itself a modulated light source with mains power supply frequency, is a very important factor. The degree of modulation depends on the thermal capacity of the evaporation source used. For this reason, the boat material should, in principle, be as thick as possible. If problems of this nature arise, it is sometimes necessary to provide an optical screen for the evaporation source, or to move it to another position.

## 6.6. Sensitivity

With photo-optical instruments it is customary to utilise the sensitivity i.e. the signal emitted, per unit of light intensity in "Lumen". In the case of the GSM 210, the detection limit is of interest i.e. the signal which is still clearly indicated. Therefore, this sensitivity data relates to the most sensitive range and to a still readable needle deflection of 10 scale divisions.

Here, the theoretical sensitivity is approximately 10 scale divisions / 5 x $10^{-9}$ Lumen (at 2850°K).

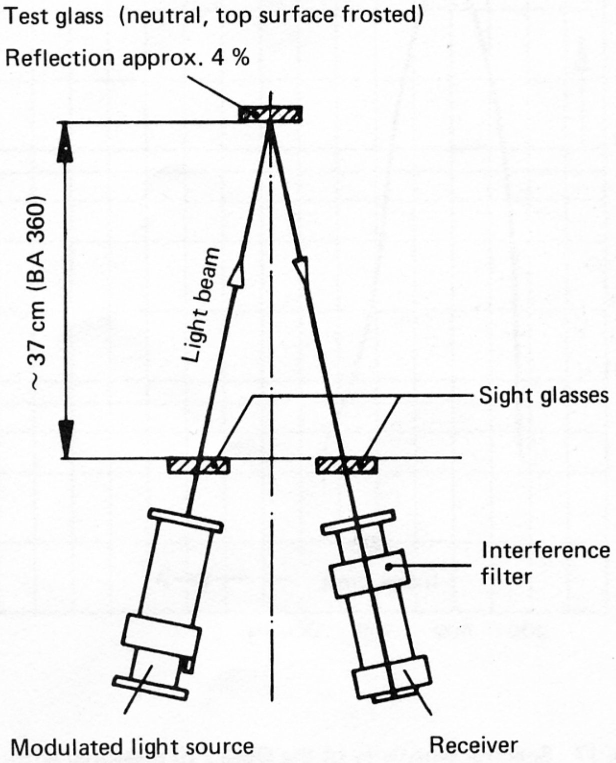



Fig. 16

In practice, these figures are of little value because the data refers largely to white light. Interference filters, which have the effect of monochromatic light are virtually always used with the GSM 210. The producer of thin films will thus be interested in the spectral sensitivity which is shown in the curves in Fig. 17 for the blue sensitive photomultiplier and in Fig. 18 for the red sensitive photomultiplier.

The curves where obtained with a BALZERS BA 360 coating unit in the position "Reflection" in accordance with Fig. 16. In this exercise interference filters with half band widths between 10 – 15 mμ were used. The test glass used was frosted on one side (reflection approx. 4 %) and the incandescent lamp was new (uncoated).

In each case the scale deflection resulting with the various filters was calculated for a transmission of 100 %. Therefore, in reality the scale deflections, corresponding to the transmission of the filter used are smaller, at the minimum 25 % of the value shown in the curves.

Using the photomultiplier XP 1100 (red) and λ = 450 mμ, the detection limit is approximately 10 scale divisions / 0.04 % reflection.

### 6.6.1. Spectral sensitivity of the GSM 210

Measuring arrangement corresponds to coating unit BA 360 in the position "Reflection".

For measurement results see Fig. 17 and 18.

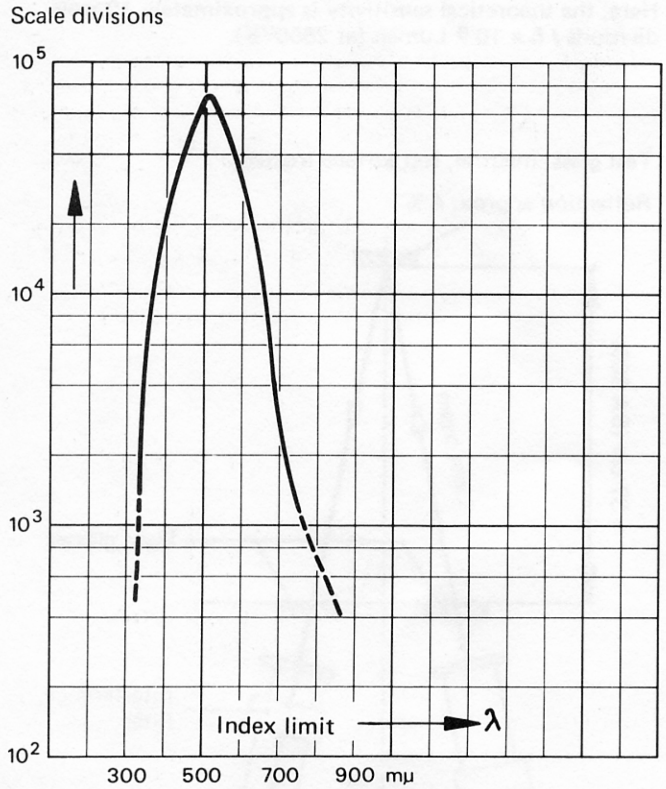



Fig. 17 Spectral sensitivity of the GSM 210 measured with a photomultiplier XP 1080 (blue) with a reflection of 4 % and interference filters, with T = 100 % and half band width values between 10 and 15 mμ

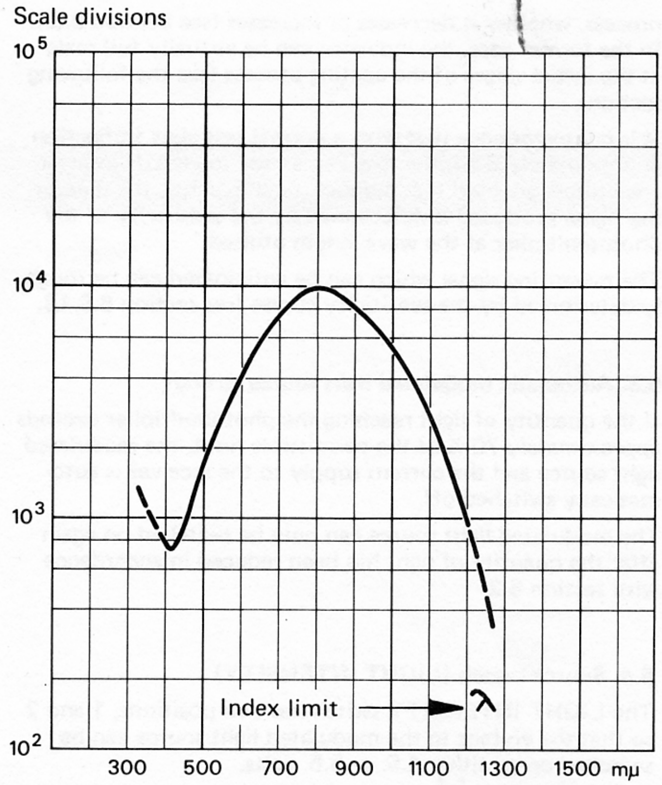



Fig. 18 Spectral sensitivity of the GSM 210 measured with a photomultiplier XP 1100 (red) with a reflection of 4 % and interference filters, with T = 100 % and half band width values between 10 and 15 mμ

### 6.7. Stability of indication

Accuracy of measurement largely depends on stability of indication, which is mainly affected by the following factors.

#### Stability of the light source

The light source is designed so that with a fluctuation of ± 10 % in the power supply voltage, with full compensation, indication varies by not more than 1 scale division at the maximum.

#### Interference light transmission

This has a great affect on stability of indication, especially if the light is produced by a greatly modulated alternating current light (for example fluorescent tubes) or greatly modulated evaporation sources.

#### Electrical supply transients

Power supply transients vary from place to place. Sharp peaks have a particularly bad affect on stability of indication. In such cases an improvement can sometimes be obtained by phase selection (from three phase supply) and by moving the earthing point. If this problem arises the receivers must be electrically insulated from the coating unit.

#### Noise and humming from the photomultiplier and the amplifier

The photomultipliers are shielded against magnetic fields, which can affect the electron mean paths, by a double walled Mu-metal tube. Despite this protection, care should be taken to see that the high current lines are not laid in the vicinity of the receivers.

Where light signals are very weak, stability of indication depends largely on the volume of interference light i.e. on the noise voltage produced in the photomultiplier. Fundamentally, this noise voltage increases with increasing light signal. Where there is considerable interference light, a small information signal can be drowned in the noise voltage originating from the interference light.

Therefore the information signal should not be less than 0.5 mV (500 scale divisions) (see section 6.5.).

### 6.8. Adjustment and compensation of the electronics

This section is tuned in the Works, and normally requires no further readjustment. However, a certain ageing effect on the semi-conductors must be anticipated, so that it sometimes becomes necessary to carry out the following re-adjustment:

**Adjusting the chopper-phase**

- Remove cover plate from the modulated light source.
- Loosen the chopper motor lock screws.
- Give the measurement signal to one of the two receivers and set the instrument deflection at maximum by turning the chopper motor.
- Re-tighten the chopper motor lock screws.
- This adjustment only becomes necessary if the chopper unit was defective or if a component had to be replaced.

### 6.9. Recorder

#### 6.9.1. Choice of recorder

Any potentiometric recorder with an input sensitivity of 10 or 100 mV and symmetrical or non-earthed input can be used.

#### 6.9.2. Recorder connection

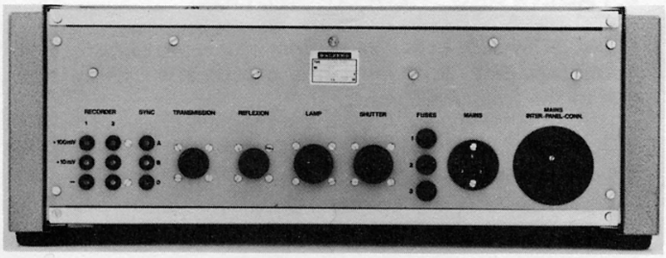



Fig. 19

The instrument has two recorder connections, RECORDER 1 and 2. The signal at the outlet RECORDER 2 behaves similarly to deflection on the indicating instrument i.e. it is also affected by the compensation voltage ZERO SUPPRESSION.

The signal at RECORDER 1, however, is unaffected by a continuous compensation voltage. This is desirable if the recorder is used for subsequent control in the reverse point method.

#### 6.9.3. Synchronisation

If reflection and transmission are to be measured simultaneously during a coating process, a control and measuring instrument GSM 210 must be provided for each receiver WLE 201. In these circumstances the modulated light source WLL 201 can only be operated from one of the two instruments (transmitter). In order that the phase sensitive rectification of the measuring signal can take place in the instrument which is being operated without a modulated light source, this must be synchronised with the transmitter. To do this, the sockets on the rear panel of the instrument (SYNC A, B and O) must be connected together, A with A, B with B and O with O.

### 6.10. Shutter control

The function of the push-button SHUTTER on the front panel of the instrument is to release a rapid closing shutter. The contacts of this switch are led to the socket SHUTTER on the rear panel (contacts, A, B and C). These contacts are wattless and can be connected in any current circuits as required. At 220 V alternate current voltage the load on the contacts is 5 A (Ohmic load).

Depending on the construction of the electrical shutter, the following circuits are available:

With the circuit in Fig. 21 the shutter is opened by electrical current, and in the de-energised state, it is closed by a spring. In the circuit shown in Fig. 22, the shutter is opened manually, and is kept open by a catch. When the current is switched on a solenoid is energised and releases the catch, and the shutter is closed by a spring.

Two solenoids are provided in the circuit in Fig. 23 for opening and closing the shutter. The appropriate amphenol coupling should be used for connecting the relay contacts A, B and C.

BALZERS coating units fitted with a shutter as per Fig. 22 are provided with a release solenoid which is not designed for being switched on all the time. Therefore, the push-button SHUTTER (step switch) must be pressed again upon releasing the shutter in order to interrupt the power supply to the release solenoid.

The actual operating condition is signalled by the lighting up of the sections ON or OFF of the push-button SHUTTER.

On request, an impulse contact (Code No. 331 315) can be mounted by the customer in place of the step switch.

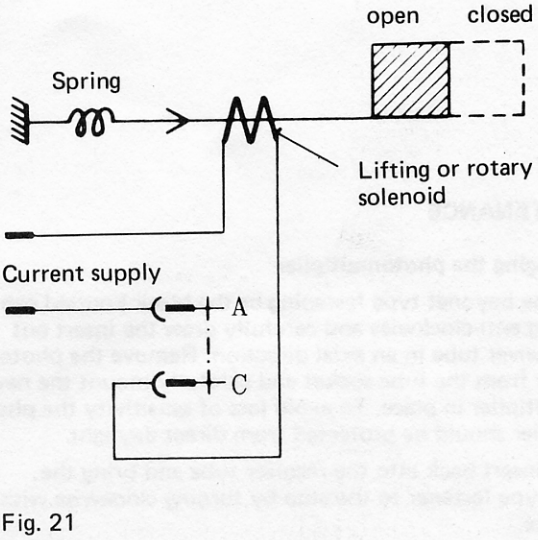



Fig. 21

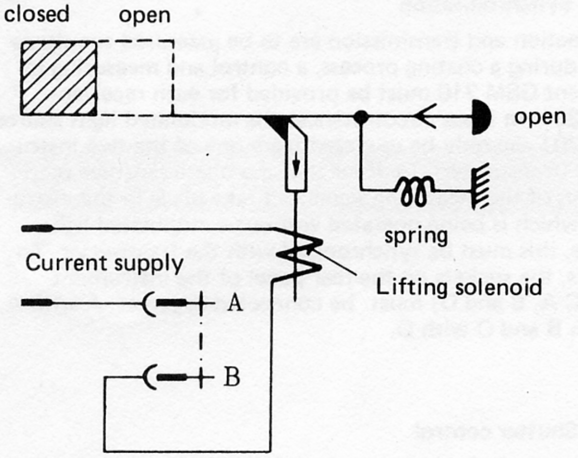



Fig. 22

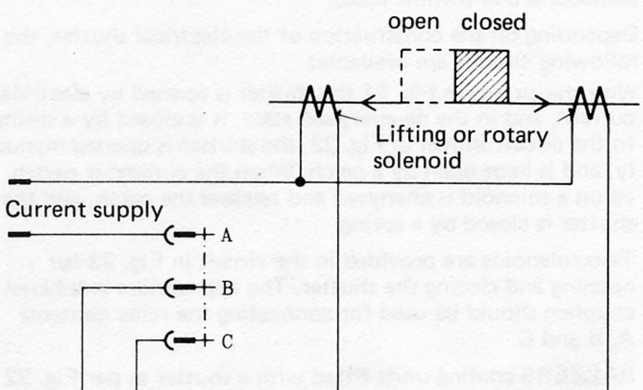



Fig. 23

## 7. MAINTENANCE

### 7.1. Changing the photomultiplier

Loosen the bayonet type fastening or the black knurled cap by turning anti-clockwise and carefully draw the insert out of the receiver tube in an axial direction. Remove the photomultiplier from the tube socket and carefully mount the new photomultiplier in place. To avoid loss of sensitivity the photomultiplier should be protected from direct daylight.

Push the insert back into the receiver tube and bring the bayonet type fastener to the stop by turning clockwise with some force.

### 7.2. Inserting the filter

Remove the filter holder from the receiver and slide the filter under the pressure spring provided. Two filters, for example, one interference and one neutral light density filter can be inserted at a time, one behind the other. Replace the filter holder back in the receiver, taking note that the holder can only be pushed against the stop in one position in the receiver.

The double filter holder which is an accessory, accomodates two or four filters, which can be moved into the beam path as required.

### 7.3. Changing the incandescent lamp

Loosen the setscrews (see Fig. 12). Withdraw the banana plug and remove the flange complete with lamp from the housing. The setscrews are captive and need not be removed. Remove the lamp from the holder and unsolde the centre connection wire. Insert the new lamp in reversed sequence, taking care that the contact sleeve is screwed firmly in place with the flange and is in perfect contact with the lamp. Check whether the terminal screws of the banana plug are tight (defective contact).

Clean the incandescent lamp with alcohol and replace the complete flange in the housing. Tighten the setscrews just sufficiently to ensure that the springs below them are fully effective.

Plug the banana plugs back into the sockets and check whether contact is being made satisfactorily. Poor contact causes fluctuations in indication.

Readjust the incandescent lamp in accordance with paragraphe 5.2.4.

## 8. FAULTS AND THEIR CORRECTION

If faults develop, in our experience this is usually due to reduced sensitivity or to instability of indication, and can be due to the following causes:

### 8.1. Inadequate sensitivity

| Cause | Correction |
|---|---|
| Incandescent lamp is coated (this is particularly apparent in the UV-range) | Replace the incandescent lamp (see paragraphe 7.3.) |
| The incandescent lamp is out of adjustment | Readjust the lamp (see paragraphe 5.2.4.) |
| The modulated light source is out of adjustment | Readjust the light source (see paragraphe 5.2.4.) |
| The optical components of the modulated light source, sight glasses or photomultipliers are dirty or coated | Clean the components or replace with new ones |
| The photomultiplier is not efficient | Replace with a new one |
| Chopper phase is incorrectly adjusted | Readjust chopper phase (see section 6.8.) |

### 8.2. Unstable indication

| Cause | Correction |
| --- | --- |
| Light signal is too weak i.e. the ratio of signal voltage to noise voltage is poor | See paragraphs 8.1. and 6.5.) |
| Defective contact in the incandescent lamp supply line | Check the lamp holder, banana plug and connection cable and, if necessary, clean the contacts |
| The receiver is not insulated against the plant | Replace defective insulators (see section 5.3. and Fig. 13) |
| Large interference peaks are superimposed on the power supply | Change the phase and use a different earthing point |
| Interference light transmission is strongly modulated (fluorescent tubes) | Check the receiver for sealing against external light |

**The adjustment data on the wiring diagram must be noted when any maintenance is carried out!**

## 9. EXAMPLE OF MEASUREMENT

### 9.1. Coating a semi-transparent chrome film (neutral light density filter with a transmission of 25 % at 550 mμ

Place a clear test glass (reflection 8 %) in the test glass holder and an interference filter 550 mμ in the filter holder of the receiver for transmission. Switch the measuring instrument to TRANSMISSION and adjust the attenuator so that the deflection of the indicating instrument corresponds to the factual transmission (100 – 8 = 92 %).

Coat until the instrument indicates 25 %.

### 9.2. Coating a semi-transparent chrome film, utilising a neutral light density reference filter, whereby greater accuracy is reached

Place a clear test glass in the test glass holder and an interference filter 550 mμ and a neutral light density reference filter 25 % in the filter holder of the receiver for transmission. Switch the measuring instrument to TRANSMISSION and adjust the attenuator so that a clearly visible deflection of, for example, 50 % is indicated on the indicating instrument.

Remove the neutral light density reference filter, after which the needle of the indicating instrument deflects to the mechanical stop.

Coat until the original value of 50 % is again reached.

### 9.3. Coating λ/4-films of dielectric materials, such as SiO, ZnS, Mg, F2 etc.

Place a test glass with one side frosted (the frosted side facing upwards) in the test glass holder, and an interference filter of the required wave length in the filter holder of the receiver for reflection.

Switch the measuring instrument to REFLECTION and set the compensation ZERO SUPPRESSION to approximately 5. By increasing the compensation voltage the λ/4 deflections are correspondingly increased.

Adjust the attenuator so that a deflection of approximately 50 % is registered. Coat until the minimum or maximum of one or more reverse points is reached, when the following relation between geometrical and optical film thickness is applicable:

$$d = x \cdot \frac{\lambda}{4 \cdot n}$$

$\lambda$ = wave length of the light used for measuring
$n$ = refractive index of the film
$x$ = the number of reflection and transmission peaks.

If the needle runs off the scale during measurement it can be brought back into the measuring range by changing the compensation voltage.

A reverse point corresponds to an optical film thickness of λ/4 of the interference filter used. Thus, reflection can increase or decrease during coating. This depends on the ratio of the refractive index of the coating material and the test glass. If the refractive index of the coating material is greater than that of the test glass, reflection initially increases to a maximum, corresponding to an optical film thickness of λ/4. However, if the refractory index of the coating material is smaller than that of the test glass, reflection decreases to a minimum, which also corresponds to the optical film thickness λ/4.

With certain coating materials, such as $MgF_2$, SiO, the refractive index of which is very different from that of the customary test glasses, the λ/4 deflections are amplified if the test glass is previously coated with an impermeable chrome film. For accurate thickness determination the rapid phase change at the chrome must be included in the calculation.

Measurement of the λ/4 deflections is affected by the volume of the compensation voltage.

**For the production of similar films we recommend the use of the following BALZERS filter sets:**

| | | |
| --- | --- | --- |
| Large filter sets | Wave lengths | 360 – 800 mμ |
| Medium filter set | Wave lengths | 400 – 700 mμ |
| Small filter set | Wave lengths | 400 – 700 mμ |

Neutral light density filter set 1 % – 97.7 %.

We also supply individual filters for any wave length between 340 mμ and 2000 mμ.

### 9.4. Coating virtually impermeable, thick metal films

Measurement is as described in paragraph 9.2., but coating is continued to approximately 1 %.

Data on the thickness of metal films can be obtained from BALZERS High Vacuum technical report No. 4 (see also data in the literature).

If a film thickness greater than 1 % transmission is required, the coating process can be interrupted for a short time by means of the shutter, and measurement continued using a new test glass. We also recommend the use of BALZERS high frequency Quartz crystal thin film monitor QSG for this type of measurement.

## 10. LITERATURE INDEX

Optische Dickenmessung von Aufdampfschichten für die elektronenmikroskopische Präparation.
R.A. Haefer, Proc. Eur. Conf. on Electron Microscopy, Delft 1960 — DN 220

Über die Herstellung Dünner Schichten durch thermische Verdampfung anorganischer Stoffe im Hochvakuum
A. Ross, Vakuum-Technik, Band 5, Seite 1-11, 1959 — DN 252

Kurze Übersicht über Methoden zur Dickenbestimmung Dünner Schichten
H. Pulker und E. Ritter, Vakuum-Technik, Heft 4, Seite 91 – 92, 1965 — DN 702

Optische Messwerte an Metall-Aufdampfschichten im Dickengebiet bis zur Grenze der Durchsichtigkeit
Dr. Hacman, Hochvakuum-Fachbericht Nr. 4 — DN 626

Reprints of these publications can be obtained under the appropriate DN-number, either direct from BALZERS or from their agents.

## 11. SPARE PARTS

The components in the enclosed Spare Parts list are available ex stock.

The descriptions in the column "S" are identical to the nomendature in the respective diagrams.

**Order Example**

1 seal, neoprene, $\phi$ 34 x 4, Code No. 406 410 as per spare parts list Z-.......... R .......... Item No. ..........

**Full data assists our service department and ensures that you obtain prompt service and receive the correct spare parts!**