2305

INSTRUCTIONS AND APPLICATIONS

Level Recorder Type 2305

AC and DC Level Recording.
Logarithmic and Linear Recording.
Polar and Rectilinear Recording.
RMS, Average and Peak Recording.
50 and 100 mm Width of Recording Paper.
Ink and Sapphire Registering.
High Writing Speed and Paper Speed.
Synchronous Drive with Scanning of
B & K Oscillators, Spectrometers, Analyzers and
Filter Sets.

Accelerometers
Acoustic Standing Wave Apparatus
Artificial Ears
Artificial Voices
Audio Frequency Response Tracers
Audio Frequency Spectrometers
Audio Frequency Vacuum-Tube Voltmeters
Automatic A. F. Response and Spectrum Recorders
Band-Pass Filter Sets
Beat Frequency Oscillators
Complex Modulus Apparatus
Condenser Microphones
Deviation Bridges
Distortion Measuring Bridges
FM-Tape Recorders
Frequency Analyzers
Frequency Measuring Bridges
Hearing Aid Test Apparatus
Heterodyne Voltmeters
Level Recorders
Megohmmeters
Microphone Accessories
Microphone Amplifiers
Microphone Calibration Apparatus
Mobile Laboratories
Noise Generators
Noise Limit Indicators
Pistonphones
Polar Diagram Recorders
Preamplifiers
Precision Sound Level Meters
Recording Paper
Strain Gage Apparatus and Accessories
Stroboscopes
Variable Frequency Rejection Filters
Vibration Pick-ups
Vibration Pick-up Preamplifiers
Wide Range Vacuum Tube Voltmeters
Vibration Programmers
Vibration Control Signal Selectors
Vibration Control Generators
Vibration Meters

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BB 2305 - 0300036

Level Recorder

Type 2305

Reprint december 1967

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Description

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General.

The Level Recorder Type 2305 has been designed for accurate recording of signal levels in the frequency range 2 Hz (c/s) to 200000 Hz (c/s). Typical fields of application are the recording of frequency response characteristics, reverberation decay curves, noise and vibration levels, spectrograms, and polar diagrams.

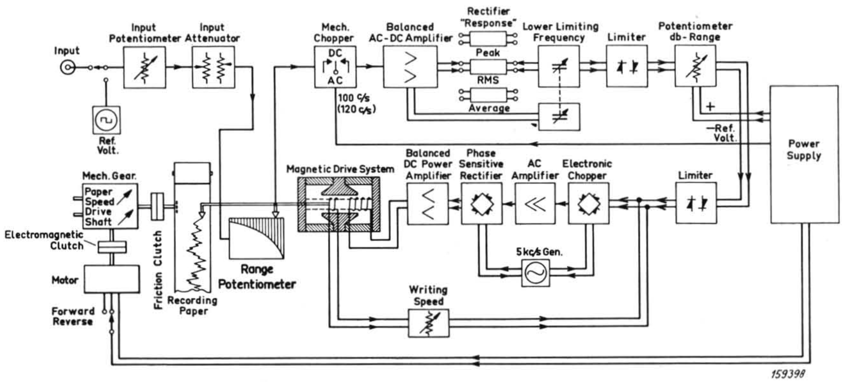

Fig. 1.1. Block diagram of the Level Recorder.

Recordings can be made by means of ink, either on lined paper or on frequency calibrated paper, or by means of a sapphire stylus on wax-coated paper. Different types of ink and preprinted recording paper are available. A synchronous motor is used for the paper drive, and by means of a gear-box 12 different paper speeds are available.

The operation of the Recorder is based upon the servo principle. When the magnitude of the voltage applied to the input terminals is changed, a current will flow through the driving coil of the writing system, thus moving the stylus, which is mechanically coupled to the Range Potentiometer. By the movement of the stylus the voltage delivered from the Potentiometer to the input amplifier will be altered until a stable condition is regained. In this way it is possible to obtain recordings for different ranges of voltage variations by employing different Range Potentiometers.

Electronic System.

Electronically the Recorder Type 2305 mainly consists of an input circuit, a Range Potentiometer, a direct-coupled AC input amplifier, the special B & K signal rectifier arrangement, and an unconventional DC output amplifier section which drives the electrodynamic writing system (see block diagram Fig. 1.1).

Input Circuit. The input of the Level Recorder is unsymmetrical. If desired it can be made symmetrical by a special Input Transformer, see chapter Accessories. The signal is first fed to the continuously variable input potentiometer and then to the calibrated input attenuator. Great care has been taken in the design of the input circuit to obtain an approximately constant input impedance of the Recorder. The impedance varies between 16 and 18 kΩ, depending upon the position of the INPUT POTENTIOMETER, and reaches its minimum value in the middle and end positions of its 12 dB range. Due to stray capacitance in the input potentiometer the frequency response will be influenced to a small degree at the highest frequencies. Vide Fig. 1.2 where the highest deviations for the different positions of the potentiometer are illustrated.
The calibrated INPUT ATTENUATOR attenuates the input signal in six steps of 10 dB with an accuracy of approximately $\pm$ o.2 dB.

Range Potentiometer. From the input attenuator the signal is fed to the Range Potentiometer. Different interchangeable Range Potentiometers are available, logarithmic (dB potentiometers) as well as linear, see also page 45. Each potentiometer consists of precision resistors connected between 216 silver lamellae on which the slider of the driving arm moves, again refer to the block diagram Fig. 1.1.

Chopper. The voltage developed between the slider and ground is fed to an electromechanical chopper. When it is desired to record AC signals, the chopper arm is continuously in one of its two contact positions. However, if the Level Recorder is switched to record DC levels, the chopper will operate at twice the mains frequency, giving an AC input to the following amplifier.

AC Input Amplifier. The non-chopped or chopped signal is applied to the balanced direct-coupled AC amplifier which, instead of a conventional AC amplifier has two distinct advantages; unwanted blocking of the amplifier due to overdriving (and thus overshoot in the recording) is eliminated, and the influence of variations in the supply voltage is decreased to a minimum. There are several other reasons why this type of circuitry is used. Firstly, the balancing enables the output from the signal rectifier, which follows immediately after the amplifier, to be symmetrical with respect to ground. Secondly, by using AC as well as DC negative feedback the lower limiting frequency of the amplifier is very easy to change. Because of the feedback arrangements the DC amplification of the amplifier is approximately 270, while the AC amplification is in the region of 4500.

Rectifier Response Circuit. The rectification circuit is the specially designed Brüel & Kjær type, which can be switched to measure the true RMS, the arithmetical average and half the peak-to-peak value of the input signal*). A bridge-type full-wave rectifier for detection of the signal allows both the positive and negative parts of the input signal to be treated in the Recorder. The three different rectifier characteristics can be selected by the switch marked "Rectifier Response". The last position of this switch is marked DC, when in this position, peak detection of the chopped DC Recorder input signal takes place.

The Rectifier Response networks are symmetrically arranged with respect to ground, whereby the output signal contains no superimposed fundamental AC component. This type of circuitry is also advantageous because of its insensitivity to mains voltage fluctuations.

The amplifiers and the Rectifier Response networks have been designed to measure the true RMS value of signals with crest factors up to 5 (crest factor = peak voltage / RMS voltage). Correct measurements of arithmetical average values are possible for signals with the product: form factor × crest factor = 5, i.e. peak voltage / average voltage = 5. The peak rectifier measures half peak-to-peak value which should be borne in mind when unsymmetrical signals are being measured. Further, as a certain amount of energy is dissipated within the rectifier circuit, the true peak value of very narrow pulses cannot be correctly measured. It has therefore been found convenient to calibrate the peak rectifier to accurately measure sinusoidal signals, whereby the peak values measured on square-wave signals (crest factor = 1) and very narrow pulses will in the first instance be slightly too high and in the second too low. Refer also to Appendix.

When non-sinusoidal signals containing important frequency components in the neighbourhood of the lower or upper limiting frequency of the recorder are being measured, the recorded peak level will be incorrect, due to phase distortion in the amplifiers. The recorded average level will only be influenced to a very small degree by the phase shift, whereas **the RMS recording is independent of any phase distortion.** Curves concerning this are found in the Appendix.

Lower Limiting Frequency Circuit. Following the Rectifier Response circuit is the Lower Limiting Frequency circuit, which allows for a first averaging of the level of the measured signal. (Refer part Appendix in this book).

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*) A thorough description of the functioning of this circuit is given in the B & K Technical Review No. 3-1958, 4-1960 and 1-1961.

This circuit determines the lowest frequency to which the Recorder responds correctly. It can be set to five values 2, 10, 20, 50 and 200 Hz (c/s) by the knob LOWER LIMITING FREQUENCY. In Fig. 1.2 can be seen the response at the five different settings. It should be noted that at the various frequency limits marked around the knob the reading is decreased by approximately 0.3 dB only. As the stability of the complete writing system is dependent on the combined setting of the LOWER LIMITING FREQUENCY, WRITING SPEED and POTENTIOMETER RANGE the reader is referred to the comments under "Writing Speed", page 10.

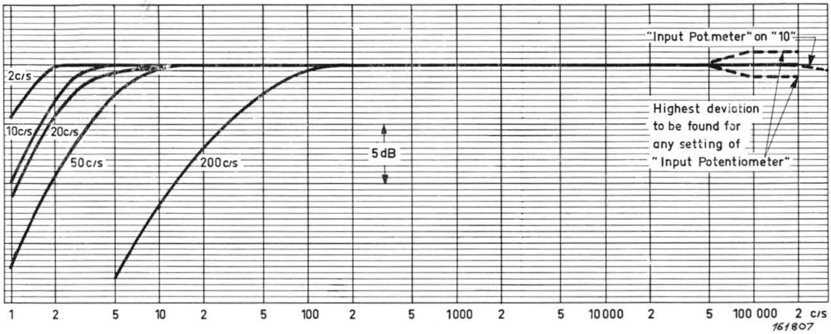

Fig. 1.2. Typical frequency characteristics of the Level Recorder for different settings of LOWER LIMITING FREQUENCY switch. The two dotted lines at the high frequencies give the greatest deviation to be found for any setting of INPUT POTENTIOMETER.

First Limiter. To avoid overdriving (heavy charging of the condensers in the Lower Limiting Frequency circuit) by high and very rapid fluctuations in the input signal level, an amplitude limiter is introduced. The threshold of the limiter is designed so that the drive system has full power when the signal fluctuations reach its limit.

Potentiometer Range. The output signal from the first limiter network, which is now DC, is compared with a built-in balanced DC reference voltage, the signal difference then being used to drive the output amplifier via a second limiter.

The difference signal obtained by comparing the rectified and limited input signal with the built-in reference voltage is attenuated in a step attenuator marked POTENTIOMETER RANGE. By the different positions of the attenuator the resolution of the Recorder is determined. (See also "Controls, Terminals, and Mechanical Drives", page 22). The resolution of the Recorder means the degree by which the Recorder is able to record the details in signal level variations. Fig. 1.3 illustrates the effect of the resolving power for different settings of POTENTIOMETER RANGE. The four measurements were made by means of a step voltage on the input of the Recorder and with a 50 dB Range Potentiometer inserted. It is seen from the figure that with a POTENTIOMETER RANGE setting of "10" the resolving power is too high for the Range Potentiometer used, thus the writing system tends to overshoot. By choosing position "50" it is seen that the "corners" of the step voltage are sharp, i.e. the correct position. In position "80" the resolving power is too low, the "corners" are thus rounded off.

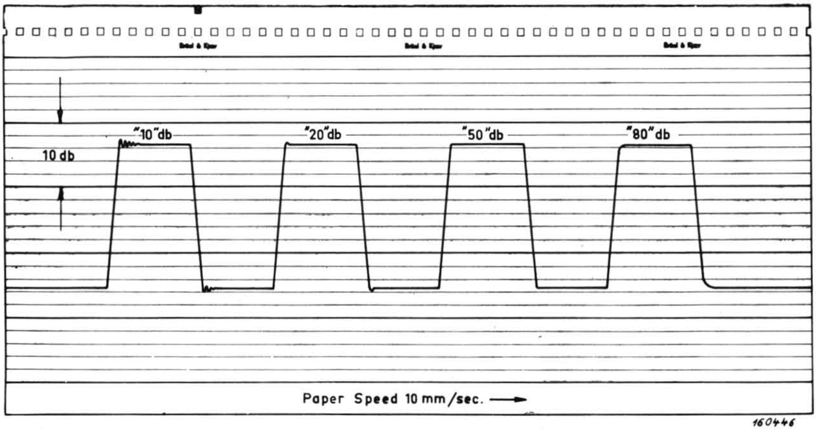

Fig. 1.3. Effect of resolving power (POTENTIOMETER RANGE setting). A 50 dB Range Potentiometer was used, WRITING SPEED on "500", LOWER LIMITING FREQUENCY "50 Hz (c/s)" and measuring frequency 600 Hz (c/s).

When employing logarithmic Range Potentiometers the signal voltage difference between any of the lamellae is equal in percent, i.e. the optimum resolving power setting will be the same for any deflection of the stylus. With linear Range Potentiometers, however, the signal voltage difference in percent between the lamellae at one end of the lamellae face is not the same as the difference at the other end, which means that the optimum resolving power will not be identical. A 10—35 mV linear Range Potentiometer requires for about full deflection of the stylus an optimum resolving power setting of "10" and for about zero deflection a setting of "25", whereas a 10—110 mV Potentiometer requires a setting of "10" and "80" respectively. In practice, the resolving power (POTENTIOMETER RANGE setting) is mostly chosen to a value between the two limits covering most deflections of the stylus, refer to part "Control, Terminals and Mechanical Drives", page 22.

Second Limiter. From the Potentiometer Range attenuator the signal is fed to the second amplitude limiter. The limiter ensures that the drive signal to the output amplifier section is independent of the magnitude of the servo error signal as soon as this reaches a certain value. That means that the signal to the output amplifier section will have a constant value.

Output Amplifier Section. This section consists of a chopper amplifier and a push-pull type DC power amplifier. The chopper amplifier is introduced to prevent zero level drift during the amplification of very small DC signals. Its chopper frequency is 5 kHz (kc/s). A balanced modulator is used as chopper, the working principle of which is illustrated in Fig. 1.4. When the chopper signal has been amplified in two stages it is rectified in a phase-sensitive rectifier circuit (i.e. balanced demodulator) and then used to control the DC power stage. This latter stage operates as a type of single-ended push-pull amplifier, thus allowing one terminal of the drive coil in the electromagnetic recording system to be grounded.

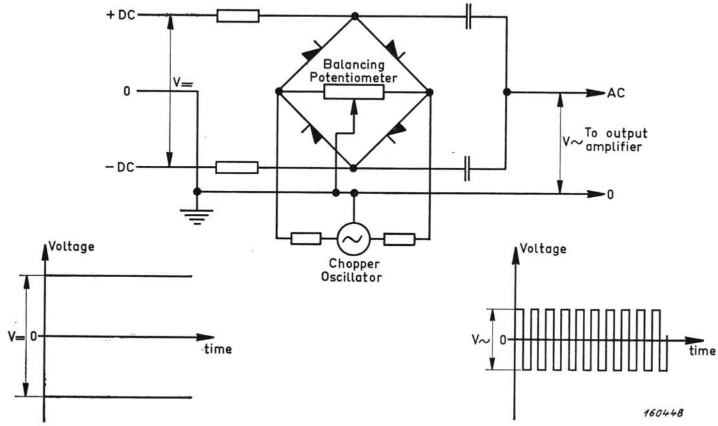

Fig. 1.4. Sketch illustrating the operation of the electronic chopper in the DC output amplifier.

Writing Speed. From a special winding on the moving coil in the electrodynamic drive system a velocity dependent signal is developed. This signal is introduced as negative feedback to the input of the output amplifier section. The feedback signal will completely control the output signal from this section as long as the signal derived from the second amplitude limiter has a constant value, which is the case when the limiter is in operation. In this way a constant speed of the writing system is obtained. The speed and thereby the damping (averaging time) of the writing system can be adjusted by means of the attenuator marked WRITING SPEED. Refer to the curves Fig. 1.5 and also to part Appendix in this book.
As mentioned under "Lower Limiting Frequency" the stability of the complete writing system is dependent on the combined settings of the WRITING

SPEED, LOWER LIMITING FREQUENCY and POTENTIOMETER RANGE. When the two first knobs are combined so that their settings correspond to points inside the hatched area in Fig. 2.2 on page 24, the writing system will always be in a stable condition, presuming that the POTENTIOMETER RANGE knob is set according to the Range Potentiometer used. For instance at "50" for a 50 dB Range Potentiometer. When settings are chosen outside the hatched area, the writing system tends to overshoot and to be unstable.

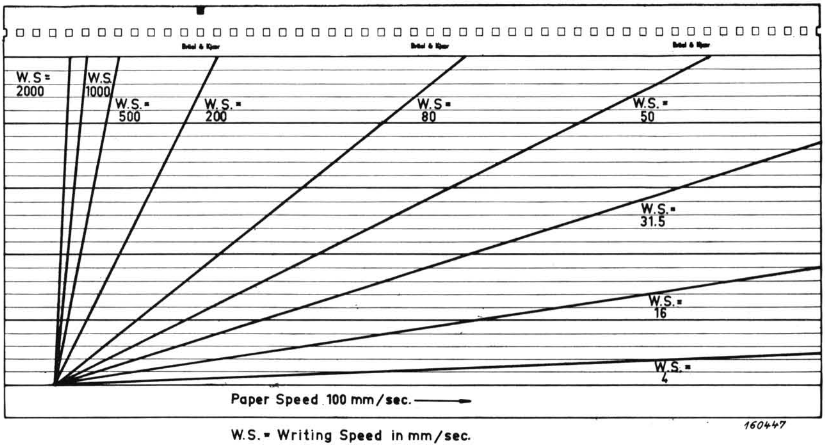

Fig. 1.5. Curves showing the influence of the writing speed upon the recording of an input step voltage on 100 mm paper.

Mechanical System.

The Level Recorder Type 2305 is designed to fulfil a number of operational requirements in combination with other Brüel & Kjær instruments and yet at the same time be remotely controlled. To carry this out, various mechanical gears, clutches and electromechanical switches are necessary.

Principle. In Fig. 1.6 the mechanical drive system is illustrated, and with the aid of this figure the working principle will be explained.

The motive power is supplied from the self-starting synchronous motor via a worm drive to the electromagnetic clutch. From the clutch the power is transferred to a gear-box via the two nylon gear wheels *1* and *2*. The gear-box (described below) has two output shafts, Drive Shaft *I* and Drive Shaft *II*, the speeds of which can be chosen by the PAPER SPEED and DRIVE SHAFT SPEED knobs respectively.

Drive Shaft *I*. This has a fixed gear wheel *3* which among others drives the reduction gear sets *4, 5* and *6, 7*. The set *6, 7* is free-running on the Drive

Shaft *I*. Two speeds (1 : 10) can be transferred to the gear wheel *9* by placing the gear wheel *8* in the position shown, or in position "in", where it will, in the latter case, be mechanically connected with the wheel *6*. The wheel *8* is shifted by the Synchronizing Gear Lever *X* (Fig. 1.8 and 2.3). When the Synchronizing Gear Lever is shifted to its "in" position (Lever *X* pulled out) a cam disc functions against a microswitch which controls the Single Chart automatic stop. The gear wheel *9* is mechanically connected with the paper drive spindle via a friction clutch.

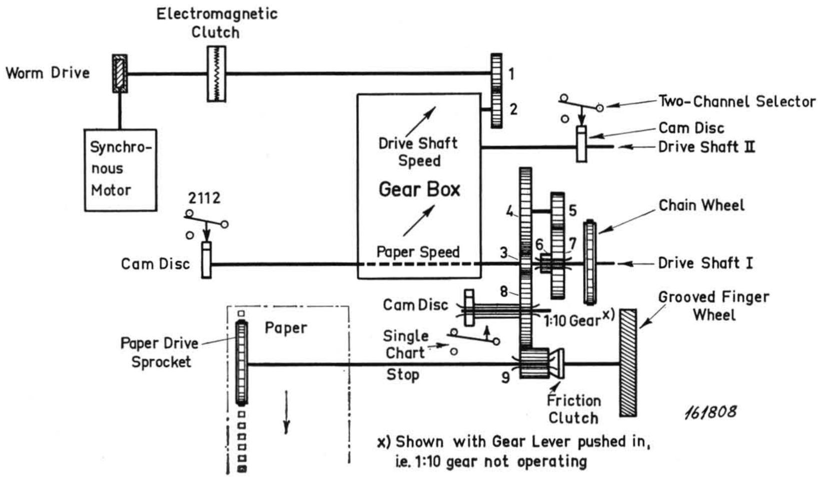

Fig. 1.6. Illustration of mechanical system outside the gear-box.

On Drive Shaft *I* a cam disc is also mounted, which provides mechanically the pulses used to control the filter switching in the B & K Audio Frequency Spectrometer Type 2112 and Band-Pass Filter Set Type 1612 when these are used in conjunction with the Recorder.

Drive Shaft *II*. This can be given any speed of revolution in relation to the paper drive sprocket by operating the knob DRIVE SHAFT SPEED.

On the Drive Shaft *II* is mounted a cam disc which operates a microswitch for the Two-Channel Selector.

Gear-Box. A number of toothed wheels mounted together in pairs and placed on two spindles enable gear ratios of 1 : 3.333, 1 : 3, 1 : 3.333, 1 : 3, etc. to be developed successively along the greater wheels on spindle *A* (vide Fig. 1.7) on which is also mounted the nylon gear wheel 2.

A moveable wheel, *B*, is used to transfer the rotation of any selected wheel on *A* to the elongated gear wheel, *C*, which drives Drive Shaft *I*. A duplication of the wheels *B* and *C* serves to drive the Drive Shaft *II*. The two moveable wheels *B* are each shifted to the various positions by means of a toothed sector operated by toothed wheels of which one is shown to the right in Fig. 1.7. The latter are directly connected with the two knobs on the top panel which are marked PAPER SPEED and DRIVE SHAFT SPEED respectively. Any change of gear can be carried out while the gear-box is operating.

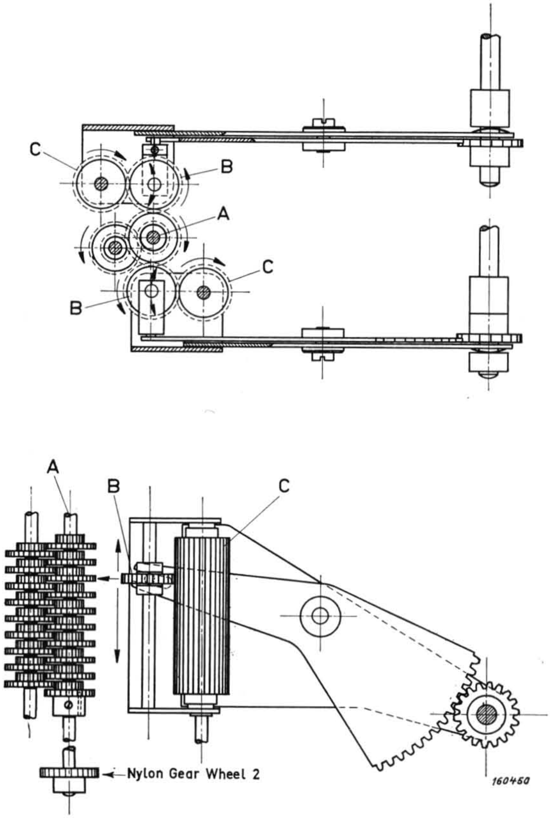

Fig. 1.7. Gear-box and shifting arrangement for Paper Speed and Drive Shaft Speed.

To give an illustration of where and how the most important electro-mechanical and mechanical parts of the Recorder are located, the reader is referred to the "exploded" view in Fig. 1.8.

Paper Speed. The paper speed can be freely chosen among 10 plus two additional values, where the highest will be 100 mm/sec and the lowest 0.0003 mm/sec. The accuracy of the speed is solely determined by the frequency of the power supply as the motive power is derived from a synchronous motor. Around the knob PAPER SPEED are printed two scales of figures, the large figures correspond to the paper speeds obtained when the Synchronization Gear 1 : 10 is not engaged, this means the Lever *X* is pushed in, whereas the small figures give the paper speeds for the opposite position of Lever *X*. The relationship between the speed of rotation of the Drive Shaft *I* and the paper speed can be seen in the table below.

Paper Speed mm/sec.	100	30	10	3	1	0.3	0.1	0.03	0.01	0.003
	10	3	1	0.3	0.1	0.03	0.01	0.003	0.001	0.0003
Drive Shaft *I* r.p.m.	120	36	12	3.6	1.2	0.36	0.12	0.036	0.012	0.0036

Synchronization Gear 1 : 10. This "extra" gear has been included in the Recorder to obtain synchronous drive of a Brüel & Kjær Oscillator or Analyzer scanning mechanism with the corresponding frequency calibrated recording paper.

The Gear Lever *X*, see Fig. 2.3 on page 26, is accessible on the right-hand side cover of the Recorder. When the Lever is pulled out, the 1 : 10 Gear is engaged. Any change can be made while the mechanical system is in operation without risk of damage.

Drive Shaft I. This mechanical drive is intended to be used in connection with recording on preprinted frequency calibrated paper. The scanning system of the respective B & K Oscillator or Analyzer is mechanically

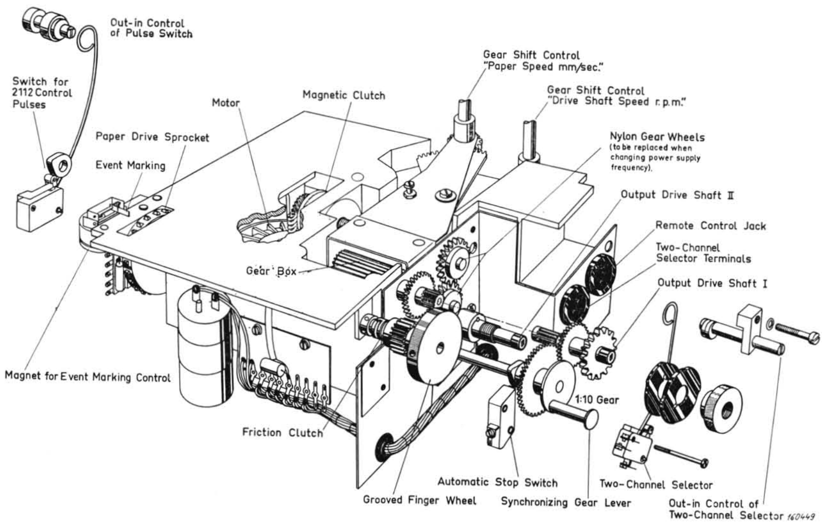

Fig. 1.8. "Exploded" view of the Level Recorder mechanical system.

connected to Drive Shaft *I* via a special Flexible Shaft UB 0040 or in the case of the combined instruments, which are mounted together in a steel cabinet, via a chain drive. When the B & K Audio Frequency Spectrometer Type 2112 or the Band-Pass Filter Set Type 1612 are employed the filter switching of these apparatuses is also controlled from Drive Shaft *I* but in this case electrically via a microswitch (vide Figs. 1.6 and 1.8). The switch can be removed from touching the cam disc by the screwdriver-operated Out-In Control *S* accessible on the plate where the pilot lamp is situated, see also Fig. 2.3. As both the speed of Drive Shaft *I* and the paper is controlled by a single knob (PAPER SPEED), the speed may be changed during the recording of frequency response curves or spectrograms without upsetting the synchronism between the Oscillator/Analyzer and the recording paper.
To avoid damage to the gear wheels, the torque supplied from Drive Shaft *I* should not exceed 2 kg cm.

Friction Clutch. With a view to giving easy and exact synchronization between the starting point of a recording on the recording paper and the scanning device of the connected oscillator or analyzer the paper drive sprocket can be moved with respect to the position of Drive Shaft *I* by means of a grooved finger wheel *Z* (vide Figs. 1.8 and 2.3). This has been made possible by the use of a friction clutch, see Figs. 1.6 and 1.8.

Single Chart. An important device which is controlled via the paper drive spindle is the automatic stop switch. This switch is operated by a cam disc on the 1 : 10 Gear axle when the Gear is engaged (Lever *X* pulled out) and activates the electromagnetic clutch after one complete rotation of the axle. Each rotation of the cam corresponds to one chart length of preprinted recording paper (250 mm). Thus, as the automatic stop switch is connected in the start-stop circuit of the electromagnetic clutch the recording of single charts is made possible.

Drive Shaft II. Since the speed of this shaft is independent of the paper speed as is mentioned previously, any frequency response curve or spectrogram can be recorded in an enlarged or compressed frequency scale, providing the Oscillator or Analyzer controlling the Recorder input signal is driven from Drive Shaft *II* instead of from Drive Shaft *I*. The DRIVE SHAFT SPEED and the PAPER SPEED have the same number of positions, that means if they are both set in the same position (example PAPER SPEED on "10/1" and DRIVE SHAFT SPEED on "12") the two Drive Shafts *I* and *II* will rotate at the same speed.
The safe torque supplied from Drive Shaft *II* is the same as specified for Drive Shaft *I*.
It is also possible to use DRIVE SHAFT II with the combined units when the accessories UT 0018 are fitted to the Level Recorder. See description at the beginning of chapter 5.

Two-Channel Selector. This selector is operated by means of interchangeable cam discs mounted on the Drive Shaft *II* and can be used for a number of purposes, such as time marking, two-channel intermittent recordings, control of external switching systems, automatic recording of reverberation curves, etc. The Two-Channel Selector can be moved out of function by means of a cam arrangement which can be screwdriver-operated through the right-hand cover plate, see Fig. 2.3.

Electromechanical System.

The electromechanical circuit consists of the drive motor, the electromagnetic clutch and the event-marking and pen-lifting arrangements.

Synchronous Motor. The motor is of the single-phase synchronous type. The rotating electromagnetic field is produced by connecting a capacitor in series with one of the three motor windings and connecting this series L-C circuit parallel to one of the two remaining windings. Dependent upon which one of the windings is paralleled by the series circuit, the motor will rotate in one or the other direction. The direction of rotation is controlled by means of the switch marked FORWARD-REVERSE on the Recorder top panel, see also Fig. 1.9.

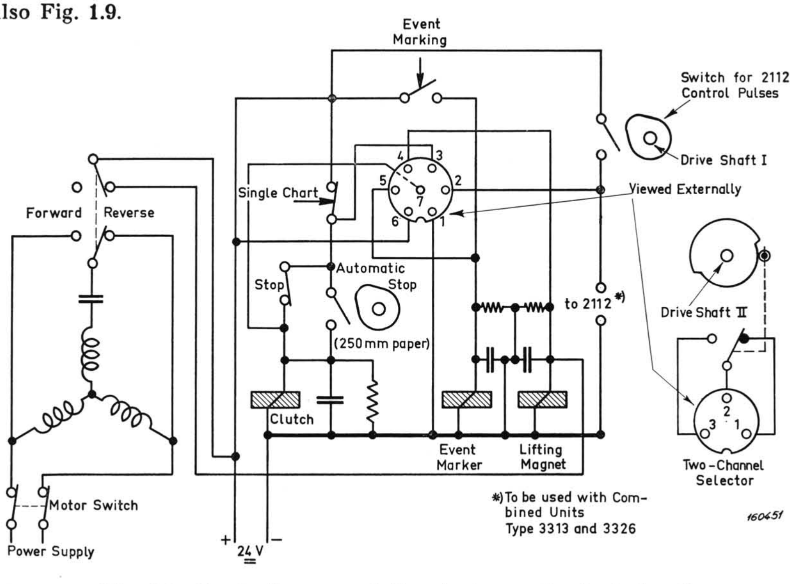

Fig. 1.9. Basic diagram of the electromechanical circuit.

Electromagnetic Clutch. To allow immediate transfer of drive power at correct speed of rotation when the recording is started, the motor can be kept running and the recording commenced by connecting the motor to the gear-box with the aid of an electromagnetic non-slip clutch. A switch marked

START-STOP on the Recorder controls the current in the electromagnet. When current flows in the coil of the magnetic clutch, the motor is disconnected from the gear-box, while with no current flowing the motor is mechanically switched in. This method of operating the clutch has been chosen to avoid the complexity of a rotating electromagnet and slip-ring arrangement.

Lifting Magnet. As the motor can be reversed, it is easy to record a number of curves on the same sheet of recording paper without losing the synchronization between the Recorder and any externally connected instrument, such as an Oscillator or Analyzer. However, to avoid the recording of a possible curve when the motor is reversed, an electromagnetic pen-lifting arrangement automatically lifts the two pens, the writing stylus and event-marker from the paper when the motor is switched to "Reverse". The Lifting Magnet can also be controlled externally via the 7-poled REMOTE CONTROL jack (see Fig. 1.9), the voltage supply for the magnet then being taken from the Recorder via the same jack.

Event-Marker. In many cases it may be convenient to mark a certain event on the recording paper during operation. For this purpose a separate marker pen has been provided, which marks the outer rim of the paper between the edge and the perforated holes that slot into the paper drive sprocket. The movement of the marker pen is operated by means of an electromagnet. The marking is controlled from the EVENT-MARKNG pushbutton on the Recorder top panel, but can also be remotely controlled via the REMOTE CONTROL jack, Fig. 1.9.

Writing System.

Magnet System. The electrodynamic writing system constitutes a most important part of the Level Recorder. It has been designed as a closed magnetic circuit producing a homogeneous field, within which the driving and the feedback coils move, vide Fig. 1.10. A max. force of approximately 1 kg is developed during operation. The coils are guided within the magnetic system by means of two metal rods and electrically connected via four brushes and slip-ring strips.

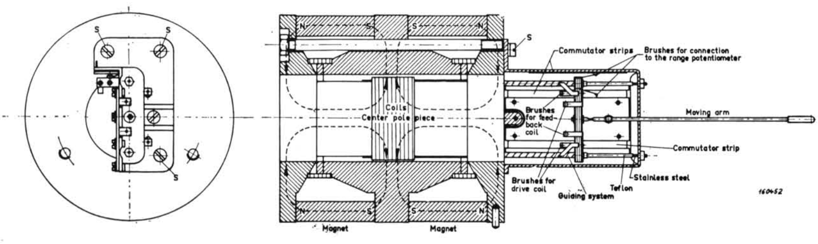

Fig. 1.10. The electrodynamic writing system.

The coil assembly is mounted in the magnet system by means of the three screws marked *S* in Fig. 1.10. If, for any reason, it should be desired to remove the coil assembly from the magnet, this can be readily done by unscrewing the screws *S* and pulling the coil assembly out, together with the center pole piece.
NOTE: During dismantling the coil assembly care should be taken that the magnetic field in which the coil normally moves, is not at any instant opened. This can be obtained by either substituting the coil assembly with an iron rod with the same dimensions as the center pole piece or by mounting an external iron tube around the magnet.

Mechanical. The driving arm of the moving coil assembly is connected to the mechanical writing system by means of a wishbone spring head, the system being so designed to give a free choice of 100 mm or 50 mm writing width. By fixing the wishbone in one of the two different holes in the mechanical writing system, the drive arm will propel the bogie with the penholder to traverse 100 mm or 50 mm paper respectively.
The penholder can hold both sapphires and inking pens. The pressure of the mounted sapphire or pen on the recording paper can be adjusted by a screw *J* (Fig. 3.1 page 31).It is pre-adjusted at the factory and will normally amount to around 15 grammes.*)

Paper Holder System.

(Refer Fig. 3.1 on page 31).

To allow accurate alignment of the zero line on the paper with the zero mark on the mechanical writing system scale, the scale which is spring-loaded is adjustable by a tension screw on the right-hand side of the writing arm unit. A cam screw *K* located on the scale varies the pressure of the paper guide clip *E*, thereby allowing a variety of paper thicknesses to be used. More details about the various methods of alignment can be found under Operation.
A demountable stainless steel cutting blade supplied with the Recorder is inserted at the front plate beneath the writing plate in order to give clean detachment of recorded paper from the roller. It is so spaced that provided one of the frequency calibrated papers QP 0123, QP 0223, QP 0323 or QP 1123 is used, and the Recorder is stopped prior to detachment in a position so that the writing system stylus rests around the 10 Hz (c/s) line on the next chart, the recording will always be detached including the format which allows object measured, paper speed etc. to be noted.

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*) For the paper types QP 0402 and QP 0423 the pressure should be readjusted to around 20 grammes.

Power Supply.

Rectifiers. The power supply section of the apparatus contains two full-wave and two half-wave rectifiers. One of the full-wave rectifiers supplies the DC for the magnetic clutch, the event marking arrangement, and the lifting magnet. The AC ripple of this rectifier is used to drive the electro-mechanical chopper in the Recorder input circuit. The output voltage is 24 volts and is also available at the 7-pin socket for remote control, see Figs. 1.9 and 2.3. External loads placed across the 24 volts DC should not draw more than 250 mA*) of current.

The second full-wave rectifier supplies the plate voltage to all the amplifier tubes with the exception of the tubes in the DC output stage. The positive reference voltage for the servo system is also supplied from this rectifier and stabilized by means of a Zener diode.

Both half-wave rectifiers are supplied from the same section of the transformer winding and act as a type of voltage doubling circuit. One of the half-wave rectifiers supplies the positive and the other the negative voltage for the DC output stage. A portion of the negative voltage is stabilized by means of a Zener diode and supplies the negative reference voltage for the balanced servo system.

100 mV Ref. The input reference voltage ("100 mV Ref.") for sensitivity calibration of the Recorder is developed across the transformer winding used for the 24 volts rectifier, the voltage being amplitude limited and stabilized by means of a zener diode. By this means a square-wave signal is produced and the input reference voltage will vary less than 1 % for a 10 % variation in the mains.

Mains Frequencies and Voltages. The apparatus should be operated from a 50 Hz (c/s) (or 60 Hz (c/s) as specified) power line. When changing the Level Recorder from 50 Hz (c/s) to 60 Hz (c/s) or vice versa, the only modification to be carried out is the replacing of the two nylon gear wheels "1" and "2" by others (See Fig. 1.6). For more details, see part Operation, page 37.

Adjustment can be made for mains voltages of 100—115—127—150—220 and 240 volts by means of a Voltage Selector on the top plate. The power consumption is 115 W (145 W with motor running). If the apparatus is to be operated from an accumulator or from other types of DC supply, the use of a DC/AC converter (for 50 or 60 Hz (c/s) respectively) is necessary. In these circumstances it should be noted that the accuracy of the various mechanical speeds is dependent on the frequency of the power supply in use.

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*) If the Level Recorder is also used to control the filter switch of the Spectrometer Type 2112, the Band-Pass Filter Set Type 1612, or the Turntable Type 3921, other external loads must not load the 24 volts supply by more than 50 mA.

Fuses.

24 volt rectifier. To avoid damage to this rectifier by external short-circuiting a fuse (1.5 Amp. medium lag) is inserted in the ground lead of the rectifier. The fuse is placed below the power transformer and is accessible from the back of the instrument when the rear plate is removed.

Main fuse. The primary side of the power transformer is fused (1.5 Amp., medium lag). The fuse is located in a fuseholder marked FUSE, SUPPLY VOLTAGE on the top panel of the instrument.

2. Controls, Terminals and Mechanical Drives

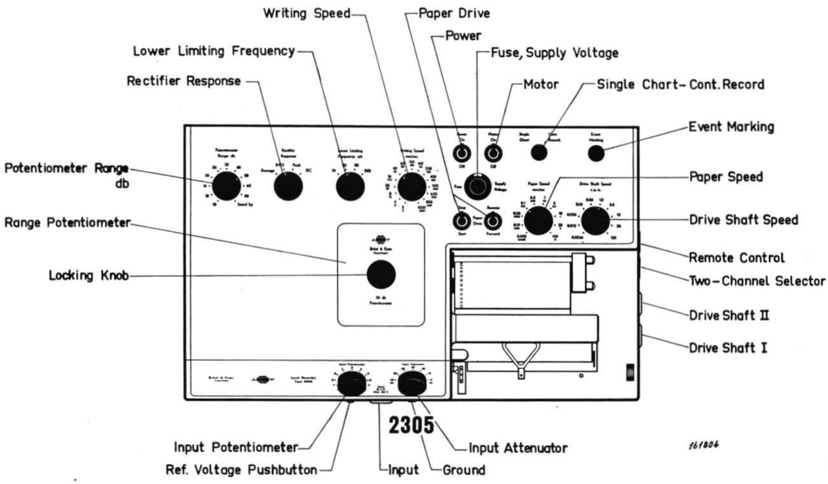


Fig. 2.1. Top view.

FUSE, SUPPLY VOLTAGE Voltage selector with fuse holder.

The mains voltage is indicated and the value visible on a disc beneath the selector lid, which itself may be lifted and turned (when the fuse is unscrewed) for selecting other mains voltages.

POWER toggle switch controls the on-off switching of the power from the power line. When the switch is in the "On" position, the pilot lamp above the recording paper will light.

MOTOR toggle switch controls the on-off switching of the motor for the paper drive system.

INPUT is a coaxial 14 mm socket for the normal B & K plugs. Banana plugs can also be used. The input voltage should not exceed 100 V.
NOTE: The Recorder Input contains no DC blocking capacitor.

GROUND socket is situated below the INPUT ATTENUATOR knob.

INPUT ATTENUATOR rotary switch attenuates the input signal in six accurate steps of 10 dB each. In position "0" no attenuation is introduced by the circuit.

INPUT POTENTIOMETER enables the input signal to be varied continuously over a range of approximately 12 dB. When in position "10", the attenuation of the input signal is zero, in position "0" the attenuation is approximately 12 dB. When signals with important frequency components around 200 kHz (kc/s) are to be recorded, the INPUT POTENTIOMETER should preferably be in position "10", see Fig. 1.2 on page 8.

100 mV REF. pushbutton is situated below the INPUT POTENTIOMETER. When pressed it causes the reference voltage (100 mV mains frequency) to be fed to the INPUT of the Recorder. May be attenuated by means of the INPUT ATTENUATOR and INPUT POTENTIOMETER in the same manner as any other input signal.

NOTE: The calibration of the Recorder by the reference voltage is correct only with RMS detection. In case of Peak detection an error of up to 1 dB may exist, whereas with Average the error is negligible. See also Fig. A7 and page 121.

POTENTIOMETER RANGE rotary switch, enables the resolving power of the Recorder's writing system to be adjusted according to the Range Potentiometer used.

Logarithmic Range Potentiometer; commonly used combinations are:—

Range Potentiometer	POTENTIOMETER RANGE on
10 dB	10
25 dB	25
50 dB	50
75 dB	80

When employing these settings the combinations for LOWER LIMITING FREQUENCY and WRITING SPEED control knob setting given in Fig. 2.2 will be valid. A higher resolving power than that according to the table may be used, but in this case the stability of the Recorder has to be considered and the WRITING SPEED reduced. The highest and lowest resolving powers correspond to the positions of the POTENTIOMETER RANGE marked "10" and "80" respectively.

Linear Range Potentiometer; combinations in practice can be:—

Range Potentiometer	POTENTIOMETER RANGE on
10—35 mV	12
10—110 mV	16

10—35 mV Potentiometer. When setting POTENTIOMETER RANGE on "12" Fig. 2.2 can be utilized for the combined setting of the knobs LOWER LIMITING FREQUENCY and WRITING SPEED.

10—110 mV Potentiometer. When setting POTENTIOMETER RANGE on "16" Fig. 2.2 can also be used, but in this instance the WRITING SPEED should be chosen two or more steps lower than that given for the limit of stability at the particular LOWER LIMITING FREQUENCY settings. If the highest Writing Speed in Fig. 2.2 has to be utilized and the stylus deflection is in the lower half of the scale the POTENTIOMETER RANGE has to be set to a value higher than "16" to obtain stable operation. For a stylus deflection in the upper half the POTENTIOMETER RANGE setting need not be higher than "16". It may in this case even be set to a lower value, ensuring a higher resolving power.

The last position of the knob POTENTIOMETER RANGE is marked "Stand by". When this position is used, the input to the output amplifier is grounded and the writing system will not respond to input signals.

RECTIFIER RESPONSE switch enables the arithmetical "Average", the true "RMS" and the "Peak" (half peak-to-peak) level of an AC signal to be recorded.

The last position of the switch marked "DC" is used when direct recordings of DC voltages have to be carried out.

NOTE: When in position "DC" the LOWER LIMITING FREQUENCY should always be kept below "200".

LOWER LIMITING FREQUENCY rotary switch allows the averaging time in the rectifier and the negative feedback of the input amplifier to be changed according to the frequencies under measurement. To ensure stable function of the Recorder and to avoid overshoot of the writing system, the positions of LOWER LIMITING FREQUENCY and WRITING SPEED should be combined so that they correspond to the hatched area in Fig. 2.2. The prescribed combinations in the figure are valid for POTENTIOMETER RANGE when set according to the Range Potentiometer employed (see under item "Potentiometer Range" above).

Example:

WRITING SPEED "500" mm/sec. and LOWER LIMITING FREQUENCY "50" Hz (c/s) will just give stable operation and negligible overshoot, whereas "500" mm/sec. and "20" Hz (c/s) respectively tends to give overshoot.

WRITING SPEED rotary switch determines the damping (averaging time) of the writing system and is chosen in accordance with the type of recording required.*) The large figure of the WRITING SPEED calibration correspond to recording on paper of 50 mm width, and the small figures to recording on

*) The settings of the WRITING SPEED which give the Level Recorder an averaging time approximately equal to the standardized meter characteristics "Fast" and "Slow" for sound level meters are 100 mm/sec. and 16 mm/sec. respectively, when the LOWER LIMITING FREQUENCY is kept at 20 Hz (c/s).

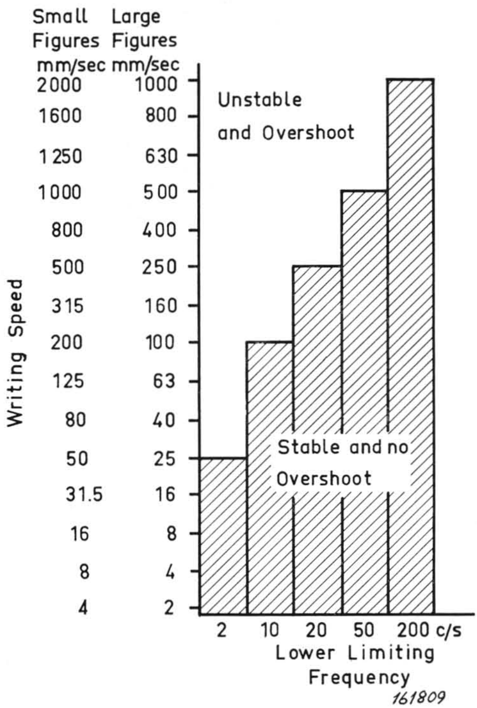


Fig. 2.2. Relation between setting of WRITING SPEED and LOWER LIMITING FREQUENCY to ensure stable function of the writing system. Combinations can be chosen within the hatched area presuming the POTENTIOMETER RANGE is set according to Range Potentiometer used.

100 mm paper width. For setting of the switch refer also previous item "Lower Limiting Frequency".

PAPER SPEED is a spring-loaded rotary selector which controls the speed of the recording paper. Twelve speeds from o.0003 up to 100 mm/sec are available. The speeds, corresponding to the inner and outer position of the Synchronizing Gear Lever *X* are indicated with large and small figures respectively. To change the paper speed lift the knob, turn it to the required position and release it again. This selector also controls the speed of Drive Shaft *I*, see below and table on page 14.

DRIVE SHAFT SPEED is a spring-loaded rotary selector which controls the r.p.m. of Drive Shaft *II*. Ten different speeds can be adjusted independent of the paper speed, granting an enlarged or compressed paper scale (horizontal) to be used in the recording. Drive Shaft *II* can be given a speed equal to Drive Shaft *I*, refer Description, page 15.

STOP-START, PAPER DRIVE switch. See table below.

Recommended Start and Stop Possibilities of Drive System.
(Valid for positions "Forward" and "Reverse" of the PAPER DRIVE switch).

Synchronizing Gear Lever *X* pulled out. (1 : 10 Gear in operation)		
How to:—	When previously	Operate as follows:—
Start	Stopped automatically by Single Chart.	SINGLE CHART-CONT. RECORD is pressed down for a fractional period*).
	Stopped by PAPER DRIVE	PAPER DRIVE on "Start"
Stop	(Unconditional)	Stops automatically by Single Chart or alternatively PAPER DRIVE on "Stop".
Synchronizing Gear Lever *X* pushed in		
Start	(Unconditional)	PAPER DRIVE on "Start" or SINGLE CHART-CONT. RECORD pressed down and held down. (Can be locked home by turning clockwise to position "Cont. Record").
Stop	Started by PAPER DRIVE	"Paper Drive" on "Stop"
	Started by locking SINGLE CHART-CONT. RECORD down in position "Cont. Record"	SINGLE CHART-CONT. RECORD turned left to position "Single Chart" whereby it springs to its upper position.

REVERSE-FORWARD PAPER DRIVE switch makes reversal of the drive motor possible when repeated recordings on the same chart are desired. When the switch is in position "Reverse", the Writing Stylus and Event Marker are automatically lifted.

*) Continuous recording can be obtained by locking the SINGLE CHART-CONT. RECORD in its down position ("Cont. Record") but in this case the paper drive can only be stopped by releasing the same button and with PAPER DRIVE on "Stop". It is recommended to make continuous recordings with the Gear Lever X pushed in.

NOTE: The changing from "Forward" to "Reverse" and vice versa can be carried out during the running of the drive system.

SINGLE CHART-CONTINUOUS RECORDING pushbutton.
Single chart recording (250 mm of paper): The 1 : 10 synchronizing gear must be engaged (Lever *X* pulled out) and the START-STOP toggle switch in position "Start", also refer to previous table.
Continuous Recording: The pushbutton is pressed down and locked home by turning to the right, see also table.

EVENT-MARKING: This pushbutton operates the Event Marker stylus (Fig. 3.1) which provides a means of marking the outer rim of the recording paper (between the left-hand edge and the perforation holes). When the pushbutton is operated, the Event Marker stylus moves towards the perforation holes.

SYNCHRONIZING GEAR LEVER X (on right hand side, Fig. 2.3).
Lever *X* in outer position: To be used for recordings on preprinted frequency calibrated paper. Both continuous and single chart recordings are possible (refer table above). The paper speed is in this instance indicated by the small figures grouped round the knob marked PAPER SPEED.
Lever *X* in its inner position: Only continuous recording can be carried out (refer also table). The ten times greater speeds are indicated by the large figures.

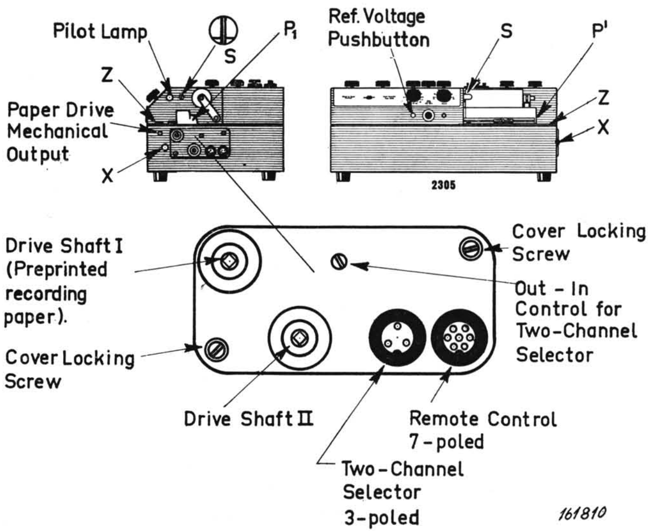


Fig. 2.3. Front and side views illustrating location of the various mechanical levers, drives and controls.

DRIVE SHAFT I is controlled by the knob marked PAPER SPEED and is mainly intended for driving the scanning mechanisms of the B & K oscillators and frequency analyzers. (For relation between PAPER SPEED and DRIVE SHAFT r.p.m., see table on page 14). When the SYNCHRONIZING GEAR LEVER *X* is in the outer position, full synchronization between the frequency sweep of the mentioned instruments and the preprinted frequency scale on the recording paper can be obtained.

DRIVE SHAFT II is controlled by the knob marked "DRIVE SHAFT SPEED. Both synchronous recording and operation with different gear ratios between paper speed and shaft speed are obtainable, according to the positions of the knob marked PAPER SPEED and DRIVE SHAFT SPEED.

FINGER WHEEL Z, see Fig. 2.3, allows the paper to be shifted manually in either direction in relation to the Drive Shaft positions due to the Friction Clutch.

MECHANICAL LIFTING CAM A (indicated in Fig. 3.1). A grooved finger cam, mounted on the right-hand side of the paper frame scale, lifts both the Writing Stylus and the Event Marker pen to the upper position when turned clockwise.

SWITCH RELEASE SCREW S (see Fig. 2.3) makes it possible to mechanically engage or disengage the switch which produces control pulses for the B & K Spectrometer Type 2112. When the niched mark on the screw slot is in the upper position, the switch is engaged. With the mark in the down position (as illustrated in Fig. 2.3) the switch is released.

TWO-CHANNEL SELECTOR (3-pin socket, Fig. 2.3) for two-channel successive recording. The socket is connected to a cam-operated microswitch equipped with a make-break transfer contact. The relative duration of the on-off periods is adjustable with the aid of interchangeable discs with different cam profiles. The discs (accessible under the cover at the righthand side of the Recorder), are mounted on Drive Shaft *II* whereby the on-off recurrence frequency can be changed by means of the knob marked DRIVE SHAFT SPEED. The cam-operated microswitch can be mechanically switched out of operation by means of a cam arrangement which can be screwdriver-operated from the right-hand side of the Recorder. Indicated on Fig. 2.3 by "Out-In Control for Two-Channel Selector".

REMOTE CONTROL. (7-pin socket, Figs. 2.3 and 2.4) gives all requisite connections for remote control of the Recorder. Pin number *1* is grounded, pin number *6* is connected to the positive side of the 24 volts built-in rectifier, and the remaining pins are connected to the "hot" terminals of the control components.

The following remote control methods are obtainable:—

Pin 2: Pulse operated components, e.g. the filter switching unit in the Spectrometer should be connected between pins *1-2*. The microswitch can be mechanically switched out of function, see item Switch Release Screw *S* above.

Pin 3: Remote Single Chart-Continuous Recording control of the Recorder: If the pins *3* and *6* are connected by means of a pushbutton similar to that mounted on the Recorder, both the single chart and continuous recording operation can be remotely controlled. For operation of the external pushbutton see item "Single Chart-Continuous Recording" above.

NOTE: If this type of remote control is used, the pushbutton SINGLE CHART-CONTINUOUS RECORDING on the Recorder must be in position "Continuous Recording".

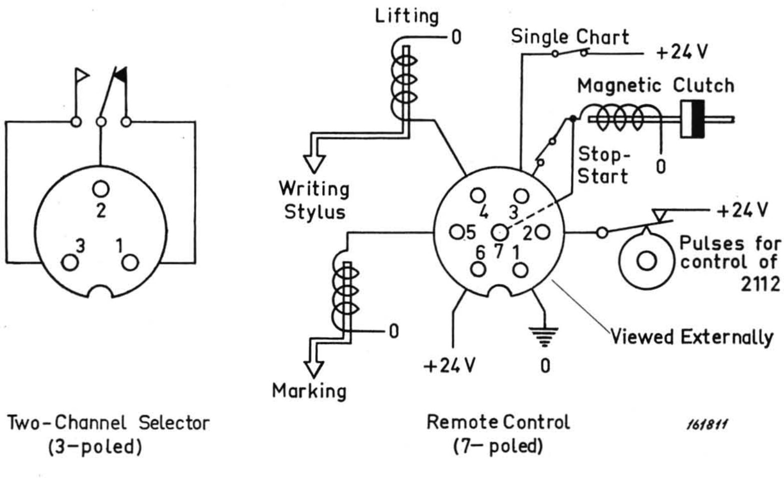


Fig. 2.4. Remote control facilities and Two-Channel Selector.

Pin 4: Remote lifting of the Writing Stylus and Event Marker can be effected by connecting the pins *4* and *6* through a make-switch e.g. through the built-in Two-Channel Selector. This lifting of the writing stylus might be found to be useful when two or three curves are to be drawn on the same chart length for later reproduction. To achieve this pins 4 and 6 of REMOTE CONTROL should be connected to pins 1 and 2 of TWO CHANNEL SELECTOR. The cam discs located on DRIVE

SHAFT II should then be adjusted to give the desired "make-brake" periods of the micro switch, the length of "on-off" time is then controlled by the knob DRIVE SHAFT SPEED independent of PAPER SPEED. (See Fig. 2.5).

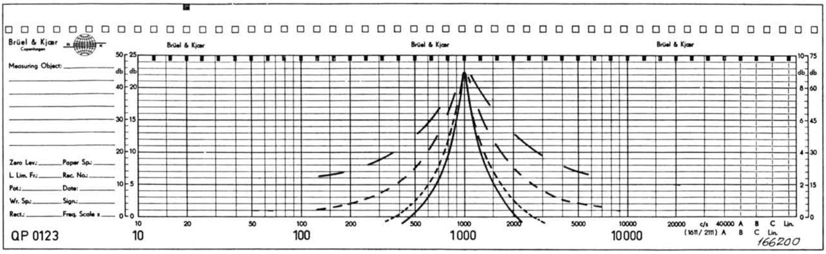


Fig. 2.5. Curves illustrating the effect of the above method.

Pin 5: Remote marking is possible when a make-switch is connected between the pins *5-6*. This switch may be operated by hand or by a timing arrangement (e.g. the built-in Two-Channel Selector).

Pin 7: This pin is connected to the electromagnetic clutch and allows complete control of the Turntable Type 3921 when this is used in conjunction with the Recorder.

POLAR RECORDING PIN enables polar recordings to be run off directly on the Level Recorder as it forms the center of rotation for the polar paper. When the Recorder is used for "normal" recordings, the polar recording pin is placed in the hole marked P_1 in Figs. 2.3 and 3.1.

Operation

3. Operation

Insertion of Recording Paper.

(Refer Fig. 3.1)

A. ROLLED PAPER.

1. Ensure stylus is in up position. This is done mechanically by moving grooved finger cam *A* at right-hand end of paper frame scale clockwise.
2. Remove spring-loaded arm *B* on the right-hand end of paper roll spindle by firmly depressing the plunger-type lock between thumb and forefinger and moving to the right.

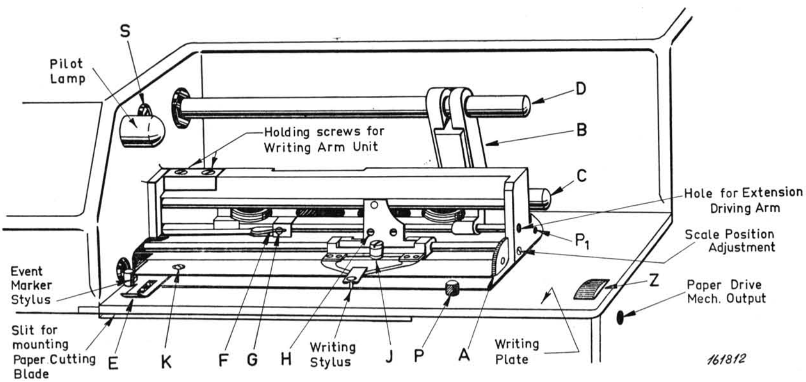


*Fig. 3.1. Paper **holder arrangement and writing system. (Cover for Writing** Arm Unit removed).*

3. Take roll of required paper (50 or 100 mm) and pull out 30 cm or 12 inches approximately. Holding roll in right hand, feed the pulled out end piece behind rear guide spindle *C* and underneath the Bottom Plate of the Writing Arm Unit at the same time placing roll on main spindle *D,* see also Fig. 3.2. Push gently to the left until stopped by guide clip *E,* which is centered above paper drive sprocket.
4. Lift guide clip *E* with finger nail, feed the perforations in the paper onto the sprocket, ensuring that the teeth are evenly engaged in the holes. Hold paper in place by lowering the clip.
5. Replace spring-loaded arm *B* over centre spindle *D* and rear spindle *C* so that it holds, with a small clearance (0.5—1 mm) the roll and the

extended piece of paper. Make certain that the paper is situated between the paper guide lip on arm *B* and rear guide spindle *C*. Vide also Fig. 3.2b.

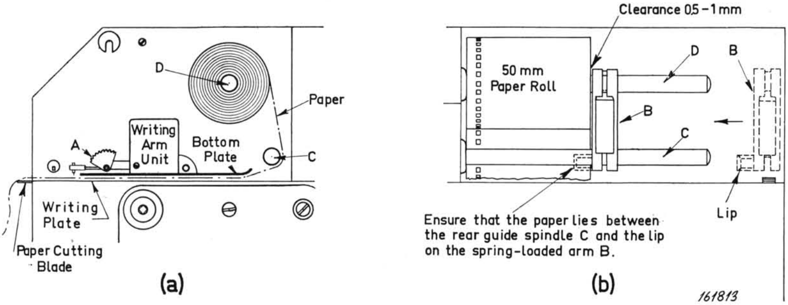


Fig. 3.2. Paper in position.
(a) Side view, spring-loaded arm B removed.
(b) Front view, spring-loaded arm B in position.

6. Test manually that the paper will run smoothly from roll, by rotating grooved thumb wheel *Z* forwards and backwards several times. Sprocket should engage in perforations without tearing or pulling.
7. Lower stylus by means of the grooved finger cam *A*.

NOTE: The pen can also be lifted electrically by setting the toggle switch marked FORWARD-REVERSE to the "Reverse" position. In practice it is, however, recommended to mechanically lift the pen during insertion of the paper as the switch may be inadvertently left at the "Reverse" position, and on switching to "Start", the paper will move backwards disengaging from the paper drive sprocket.

B. POLAR PAPER.

1. Ensure stylus is in up position. This is done mechanically by moving grooved finger cam *A* at right-hand end of paper frame scale clockwise.
2. From the front of the Recorder insert a polar chart underneath the Bottom Plate of the Writing Arm Unit. Make certain that the chart goes into the slot above and to the rear of Writing Plate, see also Fig. 3.3.
3. Lift guide clip *E* with finger nail, feed the perforation in the paper onto the sprocket, ensuring that the teeth are evenly engaged in the holes and at the same time that the center hole in the polar chart is lined up with the hole *P* in the Writing Plate.
4. Remove the Polar Recording Pin by pulling from the "stand by" hole P_1 and place it in hole *P* through the center hole in the polar chart.

5. Test manually that the paper will run smoothly by rotating grooved thumb wheel *Z* to and fro several times. Sprocket should engage in perforations without tearing or pulling.

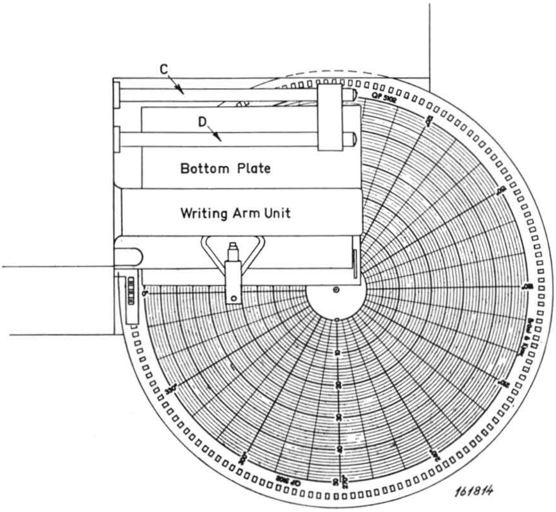


Fig. 3.3. Polar paper in position. Top view.

Alteration of Writing Width

(Refer Fig. 3.1).

The stylus is made to transcript at two widths viz. 100 mm and 50 mm respectively. The alteration has to be done mechanically and can be carried out after the cover of the Writing Arm Unit is removed. This is pulled off to the right.

A. 100 mm TO 50 mm.

1. Switch the POTENTIOMETER RANGE to "Stand by" position.
2. Lift stylus electrically or mechanically and stop paper drive.
3. To remove the driving arm with its wishbone-type head *F* from drive lug *G*, press the inner leaf of *F* gently inwards (for example by means of a pair of tweezers) extending the wishbone outer leaf, whereby the inner leaf can be disengaged by moving the bogie to the right.
4. Holding the driving arm in a forward position and at the same time resting it on the face of the lug *G*, push the bogie towards *F*. Guide the wishbone head so that it engages the two-holed lug on top of the bogie, and insert the stop on wishbone inner leaf in first hole *H*. (Second hole is for extension of driving arm when this is externally

required). Ensure that the stop is fully in hole *H* and clipped firmly.
5. Withdraw 100 mm roll and re-load with 50 mm paper as instructed in Para "Insertion of Recording Paper", item A, "Rolled Paper".

B. 50 mm TO 100 mm.

The above is carried out but reversed:—

1. Detach driving arm from bogie at point *H*.
2. Move the bogie to the right-hand end of the paper scale and insert wishbone head of driving arm in single hole drive lug *G*.
3. Load with 100 mm paper.

Writing Pens

A. SAPPHIRE.

The two Sapphire Styles for use on waxed paper are supplied in a loaded position on the Writing and the Event Marker Penholders respectively

Removing. The Writing Sapphire Stylus is removed from the Penholder by pulling gently forwards, see Fig. 3.4a.

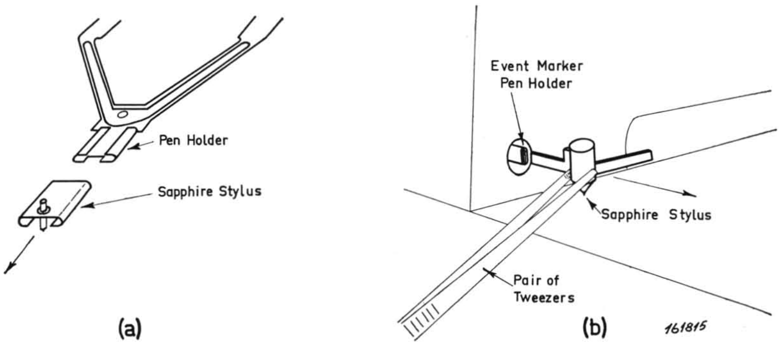


Fig. 3.4. Removing of Sapphire Styles.
(a) Writing Stylus.
(b) Event Marker Stylus.

The Event Marker Sapphire Stylus is removed by pulling gently to the right as illustrated in Fig. 3.4b. Make sure when removing that the sapphire rides free of the Guide Clip *E* (the Event Marker is lifted gently). A pair of tweezers or pliers make a good aid when removing the Event Marker Sapphire Stylus.

Replacing. The Writing Sapphire Stylus is pushed in and over the Penholder.

The Event Marker Sapphire Stylus is replaced by pushing the short fin into the vertical slot of the Penholder. The larger fin is raised by the lifting rail when the electrical or mechanical pen-lifting arrangement is allowed to function.

B. INKING PENS

Loading with Ink Cartridge. The procedure is equivalent for both the Writing Pen and Event Marker Pen.

1. Select desired pen and ink cartridge from Inking Kit QI 0001. (A separate pen is supplied for each colour in Kit).
2. Remove cleaning needle from pen.
3. Place lug on pen frame in the cup at the thin end of cartridge. Hold cartridge and pen as illustrated and press the pointed hypodermic-type needle through the "first" wall of cartridge.
4. Turn cartridge and pen upside-down and press through "second" wall.
5. When the needle is in the correct position, the cartridge should lie flush with the pen frame.

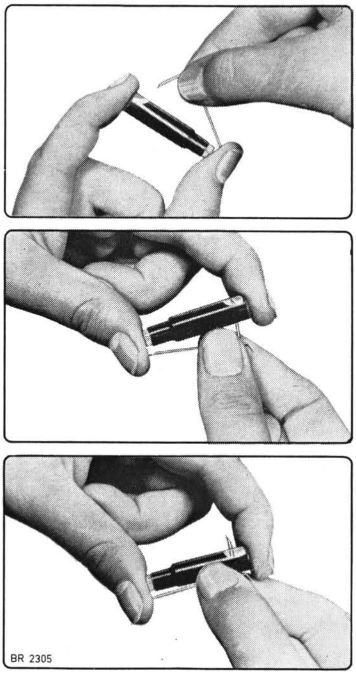


Fig. 3.5.
Placing Ink Cartridge on Pen.

NOTE: If the cartridge is held in a way so that the airlock in the cartridge is at the point where the hypodermic needle goes through the wall, no ink will flow out of the cartridge during mounting of pen.

Removement and Replacement. The Writing Pen and the Event Marker Pen are removed and replaced in the same way as described above for the Sapphire, see also Fig. 3.6a and b showing the Pens in position. After replacing any of the two Pens operate as follows:—

1. Ensure ink is flowing by cleaning the cylindrical point with the cleaning needle using an up-and-down motion, see also Fig. 3.6a and b. Then remove needle.

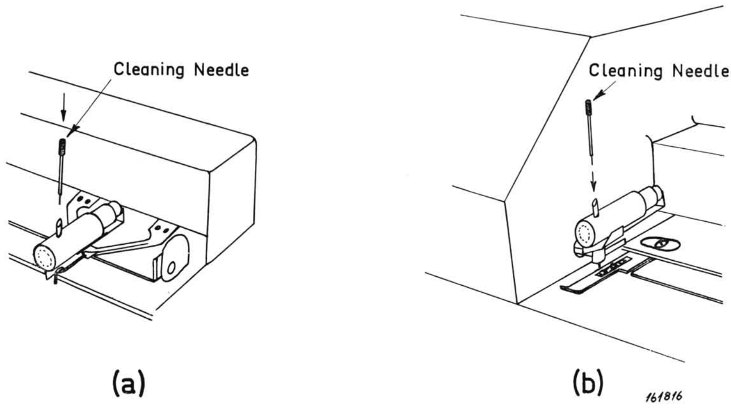


Fig. 3.6. Inking pens in position and use of the cleaning needle.
(a) Writing Pen.
(b) Event Marker Pen.

2. Lower pen mechanically onto the paper surface.
3. Test ink is flowing by moving paper forwards with Finger Wheel Z. If not, repeat cleaning process as in 1.

Changing Range Potentiometer.

To change the Range Potentiometer set the switch marked POTENTIOMETER RANGE to the "Stand by" position. The Range Potentiometer can now be easily removed by screwing its locking knob counterclockwise (see Recorder and replace it with the desired type. Always make sure when lowering a Potentiometer into the Recorder and before changing POTENTIOMETER RANGE from position "Stand by" that:—
RANGE from position "Stand by" that:—

The lamellae face the front of the Recorder.
The stylus rests in a position corresponding to about middle deflection.
The top plate of the Potentiometer lies flush with the Recorder top plate (i.e. the locking knob is properly tightened).

NOTE: Do not leave the Recorder without a Range Potentiometer inserted for any period of time without switching it off, as without the Range

Potentiometer connected the grid of the input tube is left open. Be careful not to damage the slider and do not bend it, as only a faultless and properly adjusted slider ensures correct operation.

Changing to Mains Frequency.

50 Hz (c/s) to 60 Hz (c/s) and vice versa.

The two nylon gear wheels accessible through the cover on the right-hand side of the Recorder (see also Fig. 1.8 on page 14) are replaced by another set when changing from either of the two frequencies.

50 Hz (c/s) Mains Frequency:

Both wheels should have 22 teeth (Code No. DG 0233).

60 Hz (c/s) Mains Frequency:

The upper wheel (on same spindle as the electromagnetic clutch) should have 20 teeth (Code No. DG 0232).

The lower wheel (driving the gear box) should have 24 teeth (Code No. DG 0234).

Recording of Voltage Levels.

Any voltage level between 5 mV (10 mV for DC) and 100 Volts, the frequency of which is within the range 2—200000 Hz (c/s), or which is DC, may be recorded on the Level Recorder. The Range Potentiometer used on the Recorder should be chosen according to the expected level variation in the input signal and the resolution required from the recording. Normally a 50 dB Range Potentiometer can be used for most types of recording, therefore in the following the use of this Potentiometer is assumed.

A. GENERAL.

I. Make sure that the Recorder is adjusted for the correct mains voltage, and then connect it to the power line. Details concerning adjustment to other mains voltages will be found under "Fuse, Supply Voltage", page 21.

II. Supply the Recorder with the required type of recording paper and adjust the writing width accordingly, see also "Insertion of Recording Paper", page 31 and "Alteration of Writing Width", page 33.

III. Apply the desired Range Potentiometer (in this case the "50 dB") by following instruction "Changing Range Potentiometer", page 36.

B. AC RECORDING.

I. Calibration.

1. Set INPUT ATTENUATOR to "0".
2. Set POTENTIOMETER RANGE to "50".
3. Set RECTIFIER RESPONSE to "RMS".
4. Set LOWER LIMITING FREQUENCY to "20"
5. Set WRITING SPEED to:

160 mm/sec. (large figures) with 50 mm paper.
315 mm/sec. (small figures) with 100 mm paper.

6. Set PAPER DRIVE to "Stop" and "Forward".
7. Ascertain that the SINGLE CHART-CONT. RECORD pushbutton is in its released (upper) position.
8. Set POWER to "On".
9. Set MOTOR to "On".
10. Allow a few minutes to warm-up.
11. Press the 100 mV REF. pushbutton and adjust the deflection of the Writing Stylus by means of the INPUT POTENTIOMETER until it is at the 20 dB line on the recording paper.

The Recorder is now calibrated so that a voltage applied to the "Input" will be recorded in dB re. 10 mV (0-line on the recording paper amplitude scale corresponds to 10 mV).

II. Adjustment to the Signal.

1. Lift the Pen/Sapphire by the MECHANICAL LIFTING CAM *A* (Fig. 3.1).
2. Apply the signal to be recorded to the INPUT terminal.
3. RECTIFIER RESPONSE is set to "RMS", "Average" or "Peak" as desired for the measurement.
4. LOWER LIMITING FREQUENCY and WRITING SPEED are set to positions, whichever are required for the recording. See also Fig. 2.2 on page 24.
5. INPUT ATTENUATOR is positioned so that a suitable deflection on the recording paper is achieved.

   NOTE: Do not touch the INPUT POTENTIOMETER, otherwise the calibration will be lost.

III. Recording.

1. Pull the knob marked PAPER SPEED upwards and turn to the desired position. In some cases the gear wheels may not engage properly (the PAPER SPEED will not go home when lowered) because of the relative positions of the teeth. It is then recommended to start the paper drive for a minute period till engagement takes place, or to move Finger wheel *Z* to and fro.
2. Two types of recording can be made:
   (a) Single chart recording (automatic stop of paper drive after a length of 250 mm paper has been run).
   (b) Continuous recording over any length of paper.
      (a) **Single Chart Recording:**
         1. Set the SYNCHRONIZING GEAR LEVER *X* in its outer position. Make sure that the lever is pulled completely to the out position by moving the grooved finger wheel *Z* to and fro at the same time as pulling. (The actual paper

drive speed now corresponds to the *small* figures marked around the PAPER SPEED knob).

2. Set the PAPER DRIVE toggle switch to "Start" commencing the paper to run, this will continue until the built-in automatic single chart stop switch declutches the drive mechanism (one chart length or less).
3. Lower the pen by the cam *A*.
4. Start the recording by pressing down the SINGLE CHART-CONT. RECORD pushbutton for a short while and then release it.

A chart of 250 mm length will now be recorded, whereafter the recording will automatically stop. (However, it is possible at any time to stop the recording by setting the PAPER DRIVE toggle switch to "Stop").

(b) **Continuous Recording:**

The following method is recommended:

1. Set the SYNCHRONIZING GEAR LEVER *X* in its in position (released). (The actual paper drive speed corresponds to the *large* figures marked around the PAPER SPEED knob).
2. Lower the pen by the cam *A*.
3. Start and stop the recording by means of the PAPER DRIVE, START-STOP toggle switch.

It is also possible to obtain continuous recording with the 1:10 synchronizing gear engaged (Lever *X* in its outer position). The operator should then follow the instructions outlined under (a), "Single Chart Recording", except that to start the recording it is necessary to press the SINGLE CHART-CONT. RECORD pushbutton and turn it clockwise to its position "Cont. Record". Recording will now automatically take place until the pushbutton is released and the PAPER DRIVE, START-STOP toggle switch is set to "Stop".

NOTE: Whenever the PAPER DRIVE, START-STOP toggle switch is in the "Stop" position the paper drive is completely controlled bythe SINGLE CHART-CONT. RECORD pushbutton.

IV. Reading of Absolute Values from the Recording.

The absolute values can be read from the recording by using the formula:--

The value in dB on the recording
+ the number of dB indicated by INPUT ATTENUATOR, re. 10 mV.

Example:

Deflection of stylus: 40 dB
INPUT ATTENUATOR: 20 dB

The deflection of the stylus thus corresponds to:—

40 dB + 20 dB = 60 dB re. 10 mV = 10 V.

C. DC RECORDING.

I. Calibration.

When recording DC voltage, calibration has to be done against an external calibrated DC source.

1. Set POTENTIOMETER RANGE to "50".
2. Set RECTIFIER RESPONSE to "DC".
3. Set LOWER LIMITING FREQUENCY to "50".
4. Set WRITING SPEED to:—
   400 mm/sec. (large figures) with 50 mm paper.
   800 mm/sec. (small figures) with 100 mm paper.
5. Set PAPER DRIVE to "Stop" and "Forward".
6. Make sure that the SINGLE CHART.-CONT. RECORD pushbutton is in its released (upper) position.
7. Set POWER to "On".
8. Set MOTOR to "On".
9. Allow a few minutes to warm-up.
10. Make a suitable deflection of the stylus against the external calibrated DC source by adjustment of the INPUT ATTENUATOR and INPUT POTENTIOMETER.

II. Adjustment to the Signal.

1. Lift the Pen/Sapphire by the MECHANICAL LIFTING CAM *A* (Fig. 3.1).
2. Apply the signal to be recorded to the INPUT terminal.
3. LOWER LIMITING FREQUENCY and WRITING SPEED are set to positions whichever are desired for the recording.

   NOTE: Fig. 2.2 on page 24 can be utilized when it is remembered that LOWER LIMITING FREQUENCY should always be kept below position "200", and that the highest values of WRITING SPEED, stated for the various settings of LOWER LIMITING FREQUENCY, should be avoided.
4. INPUT ATTENUATOR is positioned so that a suitable deflection on the recording paper is achieved.

III. Recording.

Refer item III. Recording on page 38 and follow the instructions stated.

The operation procedure outlined above is recommended as a guide, and whenever particular recordings are to be made, or the Recorder is used in conjunction with other B & K instruments, the reader is referred to the chapter "Controls, Terminals, and Mechanical Outputs", page 21 of this booklet and/or the instruction manual for the particular B & K instrument in question.

D. POLAR RECORDING.

The reader is referred to part Accessories, page 46, Turntable Type 3921 for Polar Recording where the operation procedure will be found.

Copying of Recorded Information.

Curves or data, whether recorded on ink paper or on the waxed transparent paper, are ideal for reproduction by photostatic copying or blue printing. The frequency range lines are outlined in a colour suitable for photostatic copying and also for blue printing or other methods where light is passed through paper. To give clear curves on the prints, it is preferable to use the black ink QI 0100 when using ink paper.

Maintenance, Service Instructions and Trouble-shooting.

The reader is referred to the separate "Parts-List and Service Instructions" for the Level Recorder Type 2305.

Accessories

4. Accessories

Recording Paper.

The Level Recorder may be adapted for either ink or stylus writing, the surface of the recording paper being treated accordingly. Paper types are available in widths of 50 and 100 mm, or as polar charts of radius 100 mm. See the table below for reference numbers for the various types of paper.

RECORDING PAPER FOR TYPE 2305

Rolls of 60 metres	White paper for ink writing Width 100 mm	White paper for ink writing Width 50 mm	White waxed paper for stylus writing Width 50 mm
Lined	QP 1102	QP 0102	QP 0402
Frequency calibrated 10 Hz (c/s) — 40 kHz (kc/s)	QP 1123	QP 0123	QP 0423
Frequency calibrated 20 Hz (c/s) — 20 kHz (kc/s) for Type 2107	QP 1130		
Frequency calibrated 2 Hz (c/s) — 200 kHz (kc/s) for Type 3328	QP 1141		
Frequency calibrated 100 Hz (c/s) — 10 kHz (kc/s) Expanded frequency scale	QP 1142		
QP 5102 Polar diagram charts. Radius 100 mm. For ink writing. Packages of 100 sheets.			

Paper for Ink Writing.

As seen from the table above, several types of paper for ink writing are available. The paper is white and to a certain degree transparent, which means that recorded curves may be reproduced by blue-print or photostatic processes, whereby both the recording and the preprinted lines are shown on the copy. It is not advisable to use the ink writing method at the highest writing speeds.

Waxed Paper.

The paper available for stylus writing is transparent with a thin coating of white wax on which the frequency calibration and level lines are printed. The waxed paper is particularly well suited for high speed writing and the stylus leaves a thin transparent line on the chart, giving a very clear definition of the recorded curves. The paper should be held up against the light for easy reading.

The waxed paper is also well suited for blue-print copying.

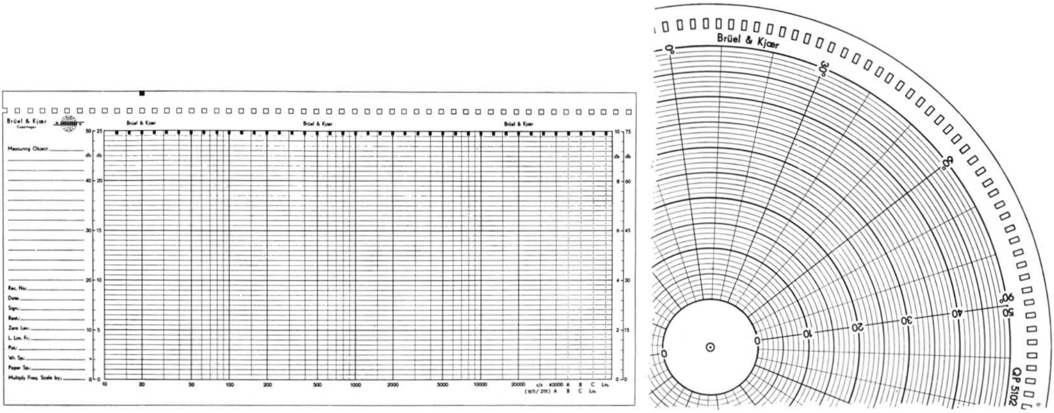


Fig. 4.1. Example of one of the preprinted frequency calibrated recording papers (QP 1123) and polar chart (QP 5102).

Ink.

The ink is available in three colours, red, green and black. The black ink is recommended for use when the recorded charts are to be subjected to reproduction.

The ink is contained in small plastic cartridges, which are mounted on a special pen. The ink cartridges can be delivered separately in packages of 100 cartridges:—

Black	QI 0100
Red	QI 0200
Green	QI 0300

Inking Kit QI 0001.

This Kit is delivered with the Recorder and contains:—

3 writing pens
1 event marker pen
4 cleaning needles
10 cartridges of black ink *and*

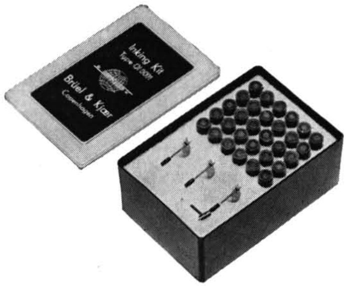


Fig. 4.2. Inking Kit QI 0001.

10 cartridges of red ink
10 cartridges of green ink

For the procedure of mounting the cartridges on the pens the reader is referred to part Operation in this book.

Range Potentiometers.

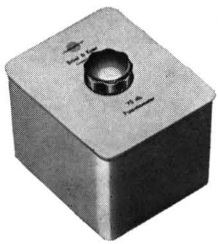


Fig. 4.3. Range Potentiometer.

The following Range Potentiometers are available:

Type	*Range*	*Accuracy*
ZR 0001	10—35 mV. Linear	2 % of full scale
ZR 0002	10—110 mV. Linear	2 % of full scale
ZR 0003*)	10 dB. Logarithmic (100 mV — 316 mV)	± o.1 dB
ZR 0004	25 dB. Logarithmic (10 mV — 180 mV)	± o.2 dB
ZR 0005**)	50 dB. Logarithmic (10 mV — 180 mV)	± o.3 dB
ZR 0006	75 dB. Logarithmic (10 mV — 56 V)	± o.5 dB

*) To maintain the wide frequency range with an approximate accuracy it has been found necessary to reduce the maximum sensitivity for this Potentiometer to 100 mV.

**) Normally delivered with the Level Recorder.

Cam Discs for Drive Shaft II

For operating the Two-Channel Selector the following cam discs are delivered with the Level Recorder.

Short cam (pointed)	OD 0060	2 pieces
2 × 90° cam	OD 0061	2 -
1 × 180° cam	OD 0059*)	2 -

Turntable Type 3921 for Polar Recording.

By combining the Level Recorder with the B & K Turntable Type 3921 a complete polar recorder is obtained allowing various types of directional characteristics to be automatically recorded. The characteristics are presented on polar paper Type QP 5102 (vide Fig. 4.1 on p. 44) which is for ink writing and preprinted in geometrical degrees (0—360°), being graduated for each **10°**. The radial width of the preprint is 100 mm. An explanation to how the paper is loaded in the Recorder is given on page 32.

Fig. 4.4. Turntable Type 3921.

Design. The table plate has a diameter of 354 mm and contains threaded holes (UNF 10-32 and M5) for fixing test specimens. Additionally it is furnished with a chuck mounted in the center, which is capable of clamping rods of diameter up to 16 mm. When it is desired to use a plain table plate the chuck can be unscrewed. The Turntable is driven by a built-in synchronous motor via an electromagnetic clutch and gear wheels giving the table an r.p.m. of o.75. When the PAPER SPEED on the Level Recorder is set to 10 mm/sec. the polar paper on the Recorder and the table are in synchronism as the synchronous motors in the Turntable and the Recorder are driven at the same line frequency. When the Turntable and the Recorder are connected

*) Mounted on the Recorder.

as shown in Fig. 4.6*) both apparatus are automatically stopped from the table after one complete revolution (see also the basic diagram in Fig. 4.5). The recording can be started again by pressing the pushbuttons SINGLE CHART-CONT. RECORD either on the table panel or on the Level Recorder. When one of these pushbuttons is locked home in position "Cont. Rec." the Table and Recorder will run continuously until the button is released.

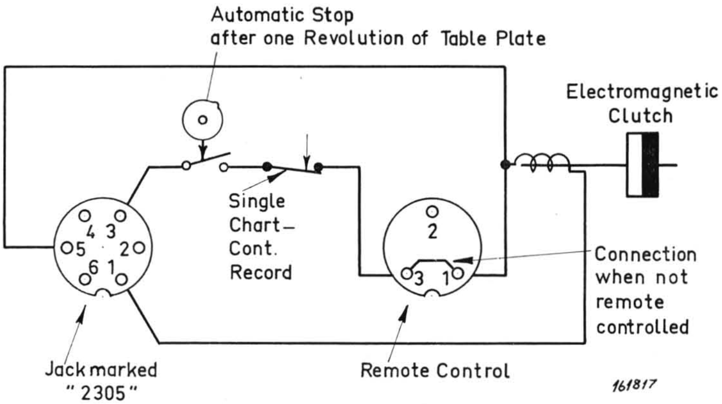


Fig. 4.5. Internal connections to jacks indicated by "2305" and "Remote Control", illustrating the working principle of the stop and start arrangement of the Turntable.

Remote Control. The start of the equipment can be remotely controlled via the REMOTE CONTROL jack on the Turntable. The interconnection between pin 1—3 of the plug inserted in the REMOTE CONTROL has in such case to be replaced by a remote switch. By opening the contacts of this switch the equipment will start on a new complete revolution.

Friction Clutch. By means of a friction clutch in the centre spindle the test specimen can, when mounted on the table, be turned to any position corresponding to the graduation on the polar paper prior to measurement.

Connections to Specimen. Two types of connections can be made from the base of the Turntable via slip-rings to the object on the table plate. One connection is intended for supplying power to any possible apparatus placed on the table. The other is a screened coaxial connection for applying signals to or from the specimen. The two connections are carefully screened from each other so that hum is negligible under normal circumstances.

*) As the length of the cable to be used will depend upon the individual circumstances, no cable has been delivered but only two plugs. In this manner the customer can freely determine the length of cable which will suffice.

Power Supply. The drive system of the Turntable can be delivered for two line frequencies of 50 or 60 Hz (c/s) respectively (specify when ordering). Alteration of the drive system from 50 Hz (c/s) to 60 Hz (c/s) line frequency or vice versa can be accomplished by changing the nylon gear wheels similar to those in the Level Recorder (refer page 37).

OPERATION

A. Start and Stop Control Cable.

The 3-cored cable to be used between Turntable and Level Recorder is mounted according to Fig. 4.6b. The figure shows the connections to be made between the respective jacks on the Turntable and Recorder but illustrates also the wiring to be made to the respective plugs delivered with the Turntable, presuming the figure shows the plugs seen from the soldering point side.

B. Setting to Correct Supply Voltage.

Check on the Turntable (bottom) that the power supply voltage selector is set to the proper voltage. If not, remove the fuse and turn the middle portion of the combined fuseholder and selector until the white mark rests opposite the desired voltage. Replace the fuse and switch MOTOR to "On". The table plate should commence to rotate when the Turntable is connected to the mains.

C. Set-up.

1. Set Level Recorder control knobs as follows:—
   POTENTIOMETER RANGE according to the Range Potentiometer employed.
   RECTIFIER RESPONSE, LOWER LIMITING FREQUENCY and WRITING SPEED to values suitable for the measurement. See also Fig. 2.2 on page 24.
   POWER and MOTOR to "On".
   PAPER DRIVE to "Start" and "Forward".
   PAPER SPEED to "10" (large figure indication).
   Gear Lever X to inner position.
   Other control knobs can be left at random.
2. Connect the Level Recorder to the Turntable Type 3921 according to Fig. 4.6a and b. The table should stop automatically after one revolution or less, (the electromagnetic clutch declutches the motor) assuming that the special plug delivered with the Turntable is inserted in the REMOTE CONTROL jack.
3. Place the object to be investigated on the table and wire it up via the jack TABLE INPUT on the base panel. The termination of this is a

coaxial jack on the edge of the table plate. Any possible power supply to the test object (when this is equal to that used for the Table) can be taken from the POWER LINE, jack OUTPUT, and supplied via the TABLE POWER input on the panel to its termination, which is also found at the edge of the table plate.

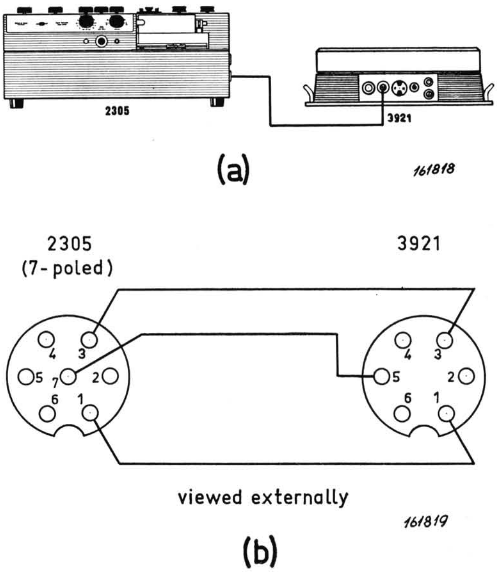


Fig. 4.6. Connection between Remote Control (7-poled) on Level Recorder and jack "2305" on Turntable.
(a) Set-up.
(b) Wiring.

4. Connect the receiving equipment to the INPUT of the Level Recorder.
5. Insert the polar paper in the Recorder. (For a detailed procedure, refer page 32).
6. Shift the polar paper by the FINGER WHEEL *Z* until the stylus rests on the 0° mark.
7. Manually turn the table plate with the object until this is situated in the required direction. This is possible due to the built-in friction clutch and is done by turning the table plate firmly in relation to the foundation.
8. Start the table plate and Level Recorder by pushing and holding in for a short period the SINGLE CHART-CONT. REC. button, either

on the table panel or on the Level Recorder. After one complete revolution the equipment will automatically stop.

NOTE: Do not switch the motor of the Turntable or the Recorder off during rotation of table, otherwise synchronization will be lost.

Stop and start of the equipment during running off one revolution can be carried out by operating the PAPER DRIVE, STOP START switch on the Level Recorder.

D. Remote Control.

For remote control starting of the equipment, connections should be made to the jack REMOTE CONTROL of the Turntable as shown in Fig. 4.7. By the opening of the remote contact the equipment will start running through a complete revolution.

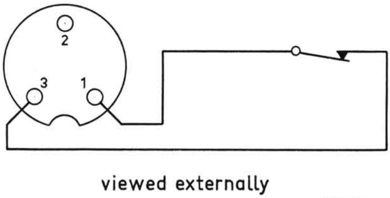


Fig. 4.7. Wiring of jack "Remote Control" on Turntable for remote controlling of "stop" and "start".

SPECIFICATION

Table Plate Diameter:	354 mm
Load (on Center):*)	Max. 100 kg
Thread for the Six Mounting Holes on Table:	UNF 10-32 or M5.
Rotation Speed:	o.75 r.p.m.
Power Supply:—	
Voltage:	100-115-127-150-220 and 240 V
Frequency:	50 or 60 Hz (c/s) (to be specified when ordering)
Consumption:	25 watt approx.
Weight:	12 kg (26 lbs.)

*) The load on the perifery can be 30 kg when the table plate is lined up perfectly horizontal.

Response Test Unit Type 4409.

Mono- and stereophonic recording and reproducing systems such as gramophone systems*), tape recorders, motion picture sound systems etc. can be automatically examined when the B & K Response Test Unit Type 4409 is

*Fig. 4.8. **Response Test Unit Type 4409.***

combined with the Level Recorder in a suitable measuring arrangement. The whole system, including the transducer (pick-up, recording/reproducing head etc.) can be examined automatically, which is a great asset in both development and production.
The Test Unit Type 4409 has three independent functions, which can be made use of separately or combined:

Synchro-starter. This starts the paper drive on the Level Recorder automatically so that the frequency calibrated recording paper will run in synchronism with the frequency sweep of a special pre-recorded test (reference) record. The start demand to the Level Recorder is given at the instant a 1000 Hz (c/s) synchronizing signal ceases. This 1000 Hz (c/s) signal is on the gliding frequency test record and immediately preceeds the frequency sweep.

Two Channel Selector. A built-in automatic selector makes it possible to record two separate signal levels "simultaneously" on the Level Recorder. It consists of a free-running multivibrator which drives a switching arrangement. The multivibrator is fully transistorized and has a frequency of approximately 1.2 Hz (c/s).

*) For investigation of gramophone systems the B & K Frequency Records Type QR 2007 (monophonic) and Type QR 2009 (stereophonic) can be used.

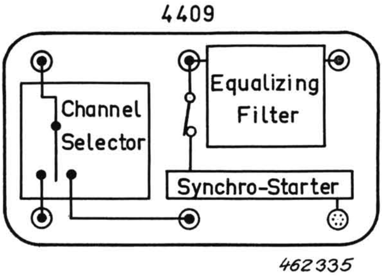


Fig. 4.9. Sketch showing the arrangement of the Synchro-starter, Two Channel Selector, and Filters in the Response Test Unit Type 4409.

Filters. These are equalizing filters. (Linear and I.E.C. curves no. 2 and 3) which are intended to be used in combination with the B & K Monophonic or Stereophonic Gliding Frequency Records Type QR 2007 or QR 2009 respectively in gramophone recording systems.

SPECIFICATION

Synchro-starter

Starting Signal:	1000 Hz (c/s) ± 100 Hz (c/s) with a voltage range 0.1 to 32 Volts (at 1000 Hz (c/s)) having a duration of at least 0.1 second.
Input Impedance:	10 kΩ during presence of the 1000 Hz (c/s). 170 kΩ paralleled by 440 pF during test.
Power Supply:	Powered from the Level Recorder.

Two Channel Selector

Switching Frequency:	1.2 Hz (c/s), 0.4 second measuring time on each channel.. Transients less than 20 m sec.
Switching Capabilities:	30 VA, maximum 100 V, 1 A.
Drive:	Free-running multivibrator, powered from the Level Recorder.
Input Capacitance:	40 pF approx. parallel capacitance on each channel including Connecting Cable AO 0018 on "Channel Output".

Equalizing Filters

Frequency Characteristic:

Linear, 20—20000 Hz (c/s).

curve 2 } of I.E.C. Recommendations 98 and 98-1
curve 3 }

All three characteristics are obtained only from a combination of the filters and the B & K Monophonic or Stereophonic Gliding Frequency Records Type QR 2007 or QR 2009.

Total Accuracy: ± 1 dB from 20 Hz (c/s) to 16 kHz (kc/s).

Input Transformer Type TI 0001.

By connecting this Transformer to the INPUT of the Recorder a symmetrical input with respect to ground is obtained. The Transformer has two input impedances which are selected by a switch INPUT IMP. The two impedances are 20 kΩ and 600 Ω. A third position of the switch allows a grounded middle point of the INPUT to be utilized. Vide Fig. 4.11.

Fig. 4.10. Input Transformer TI 0001.

To give a linear frequency response, 10—20000 Hz (c/s) ± 0.2 dB, the OUTPUT of the Transformer should be properly loaded. First, to ensure that a low capacity is connected to the OUTPUT of the Transformer the special low-capacity cable AO 0018 delivered with the Transformer should always be used when connecting to the Level Recorder. Secondly, to ensure the proper resistive load, the toggle switch on the Transformer should be set in position "Ext. Load".

Great efforts are made to make the Transformer insensitive to externally inductive stray fields. Therefore the Transformer has been furnished with a double mumetal screen. Due to this, the sensitivity to a field of 50 Hz (c/s) and 50 gauss corresponds to only 0.6 mV approx. on the OUTPUT terminal when the Transformer has an open INPUT terminal and is located in the most unfavourable position in the field.

The transformer ratio 1:1 can, if necessary, be adjusted by a potentiometer ADJUSTMENT accessible at the bottom. The Transformer is correctly pre-adjusted at the factory.

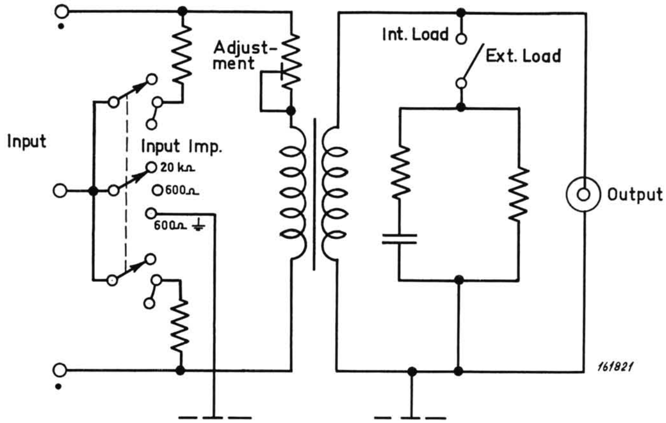


Fig. 4.11. Diagram of Transformer circuit.

SPECIFICATION

Frequency Range: 10 Hz (c/s)—20 kHz (kc/s) within ± 0.2 dB

Transformer Ratio: 1 : 1

Input Impedance: 20 kΩ approx. with INPUT IMP. in position "20 kΩ"
600 Ω ± 2 % with INPUT IMP. in position "600 Ω" or "600 Ω ⏚"

Balance: (approx.) Common mode signal rejection:
(Measured in phantom circuit)
80 dB at 200 Hz (c/s)
60 dB at 2 kHz (kc/s)
40 dB at 20 kHz (kc/s)

Maximum Input Voltage: 1.6 V / Hz (c/s) up to a maximum of:—
100 V with INPUT IMP. in position "20 kΩ"

20 V with INPUT IMP. in position "600 Ω" or "600 Ω ⏚".

Distortion (non-linear): Less than 1 % when voltage on INPUT is less than 0.8 V/Hz.

Flexible Shaft UB 0041.

To provide a mechanical connection from DRIVE SHAFT I or DRIVE SHAFT II of the Level Recorder to the scanning mechanism of other B & K apparatus.

Fig. 4.12. Flexible Shaft UB 0041.

Protractor SC 2361.

Is used in reverberation measurements for easy and quick determination of the slope of the recorded decay curves. See further under Applications in this book. The Protractor is delivered with the Recorder.

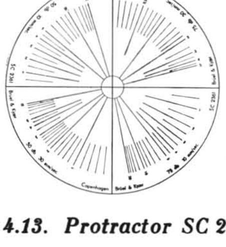


Fig. 4.13. Protractor SC 2361.

Screened Connection Box JJ 0004.

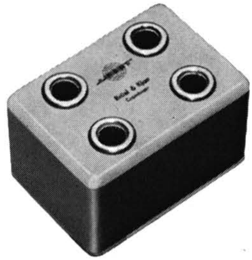


Fig. 4.14. Screened Connection Box JJ 0004.

When more complex measuring arrangements are made up from B & K instruments it is often necessary to make multiple connections. For this purpose the Connection Box is an extremely useful accessory. The Box contains four screened sockets all of which are connected in parallel (in multiples). The terminals match the normal B & K Screened Connecting Cables.

Analog Voltage Readout ZR 0021.

The purpose of the Analog Voltage Read-Out ZR 0021 is to obtain a DC voltage output from the Brüel & Kjær Level Recorder Type 2305, which is proportional to the input level (in dB). This is accomplished by utilizing the electromechanical servo system of the Level Recorder to drive an accessory slide wire.

Fig. 4.15. The Analog Voltage Readout ZR 0021.

The DC voltage output can be fed into a digital voltmeter or other type of analog-to-digital converter and the digital output so obtained may be stored on magnetic tape, punched paper tape or IBM punched cards in a standard digital code, for use in computer programs.
This system, using the B & K Level Recorder and Analog Voltage Read-Out unit, provides an output which is proportional to the log of the **true RMS, peak, or absolute average value** of the signal. Operating thus, as a log converter, it is capable of slewing rates in excess of 200 dB/sec. Also its dynamic range can be as great as 75 dB.
It is also possible to obtain an analog voltage output and use the Level Recorder for writing curves at the same time.

Description.

The Analog Voltage Read-Out consists of three parts:—

1. A linear potentiometer fixed to the shield which fits over the writing arm of the Level Recorder,
2. A contact arrangement for the Recorder's writing system, and
3. A balancing unit with a stabilizer for the voltage supply from the Level Recorder.

The linear potentiometer has 600 windings over its 50 mm working length (Level Recorder adjusted to 50 mm writing width) which gives a resolution of about 2.8 times that of the silver lamellae of the recorder range potentiometer.
In order to obtain zero output voltage with the Level Recorder writing stylus in its zero position (even though the contact point in the potentiometer is not in its extreme end position), and correct full scale output voltage with the Level Recorders writing stylus in its full scale position, a bridge circuit is employed. This adjustment of the voltage at zero and full scale (any voltage between 1 and 10 volts) is easily and conveniently carried out by the use of two high resolution, 10 turn, wire-wound potentiometers.
The power supply is obtained by smoothing and stabilizing the 24 V DC from the 7-pin socket of the Level Recorder. A socket is provided in the balancing unit so that the remote control facilities from the Level Recorder are still available. A low pass filter, cut-off frequency 100 Hz (c/s), is provided in the output leads which eliminates the contact noise which may be developed at high writing speeds.

Operation.

A. Supply Voltage:

Plug the balancing unit into the 7-pin socket on the Level Recorder.

B. Mounting of Contact and Potentiometer:

I. With the recorder's POTENTIOMETER RANGE dB on "Stand-by", remove the cover from the writing arm unit on the Level Recorder Type 2305.

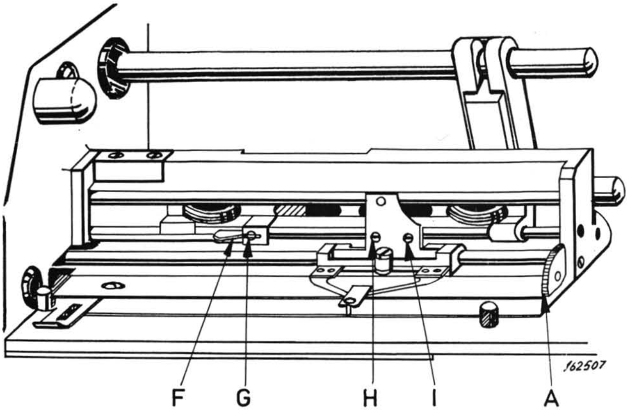


Fig. 4.16. Identification of the relevant parts in the 2305 writing system.

II. Lift the mechanical lifting cam A (Fig. 4.16).

III. Ensure that the writing mechanism is set for a chart width of 50 mm, if it is not, see "Alteration of Writing Width", page 33.

IV. Replace the standard cover by the Potentiometer, making certain that it is located over the rounded screw-head at the right-hand end, and properly bedding down on the flanges at the left-hand end.

V. Take the Contact Slider and slacken off the securing screw (see Fig. 4.17) so that the expanding collet assumes its minimum diameter. Do not remove the screw completely since it retains a ball which may be lost.

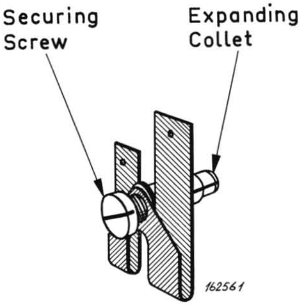


Fig. 4.17. Contact Slider.

VI. Push the expanding collet right home into the unoccupied hole I in the two-holed lug on top of the writing bogie. Make certain that the Contact Slider is bedding down nicely on the potentiometer. Tighten the securing screw just enough for it to depress the enclosed ball so that this will expand the collet and lock the Contact Slider in position.

VII. Connect the potentiometer to the balancing unit.

NOTE: The contact slider arrangement should be removed when the analog voltage read-out is not in use, to prevent unneccessary wear of the potentiometer.

C. Zero and Full Scale Adjustment.

Set the Level Recorder stylus to the zero dB position and adjust the ZERO potentiometer for zero volts output from the balancing unit. Bring the writing stylus to full scale position (50 mm movement) and adjust the FULL SCALE potentiometer for the desired full scale output voltage (1 to 10 volts). Readjust the ZERO and FULL SCALE potentiometers until the exact output voltage range is obtained.

D. Cleaning.

If needed, the potentiometer may be cleaned with a dry, fine-bristle brush. Brush the potentiometer perpendicular to its length, brushing parallel to its length tends to push the dirt between the windings and may also damage the potentiometer.

SPECIFICATIONS

Range of Output Voltage:	0—1 V, 0—10 V DC or any intermediate range.
Adjustment of Output Voltage Range:	One 10-turns potentiometer for adjustment of zero. One 10-turns potentiometer for adjustment of full scale.
Potentiometer:	Resistance 5000 Ω. 600 windings over 50 mm length. Linearity better than $\pm$ 0.2 %. Contact surface: gold. Base material: hard glass fibre plate.
Stability of Output Voltage:	10 % variation in mains voltage results in less than 0.6 % change in output voltage.
Filter for Contact Noise:	RC-filters, Cut-off 100 Hz (c/s).
Power Supply and Consumption:	25 mA from Level Recorder. 24 V DC supply.

Motor Drive UM 1018.

This unit has been designed for synchronous operation of the Level Recorder with the B & K vibration test generators. It is an external motor which is screwed onto the recorder drive shaft and driven by pulses from the oscillator which also drive the sweep motor of the generator. Complete

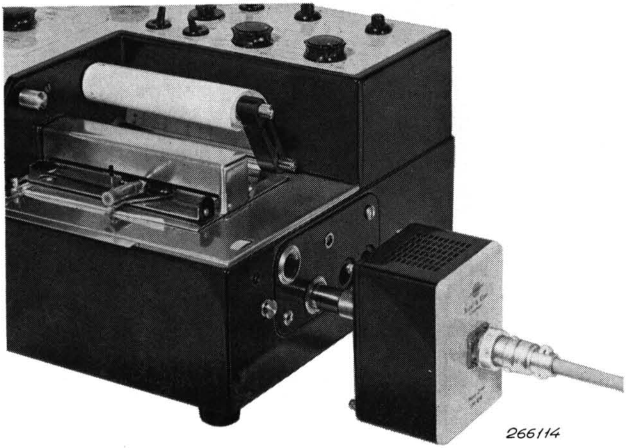


Fig. 4.18. Photograph of the Motor Drive UM 1018 mounted on the Level Recorder.

synchronism is thereby obtained in both forward and backward sweep directions, and for any number of sweep cycles.
The motor is screwed onto DRIVE SHAFT II of the Level Recorder after removal of the gear wheel shown in Fig. 4.19 and connected to the generator as shown in Fig. 4.20.

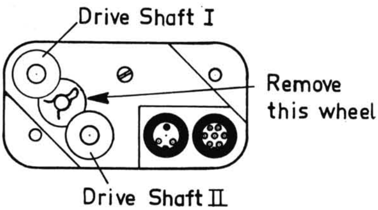


Fig. 4.19. Remove nylon gear wheel as shown.

Statistical Distribution Analyser Type 4420.

The analyser Type 4420 is basically an accessory for the Brüel & Kjær Level Recorder. Though it can also be attached to other suitable recorders and indicators including the B & K Noise Limit Indicator Type 2211.
It resolves the recorded information into twelve class intervals and presents a numerical display of the data. This is done simultaneously with the writing process of the level recorder and so a paper record need only be taken if required.
The twelve channel counters give the time distribution of the recorded level which can be used to plot a histogram as shown in Fig. 4.22.

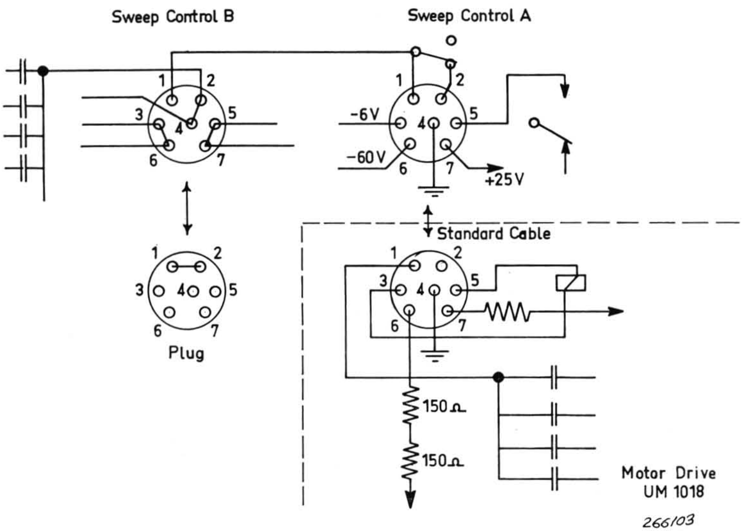


Fig. 4.20. Connection of the Motor Drive to the generator.

Fig. 4.21. Photograph of the Statistical Distribution Analyser Type 4420.

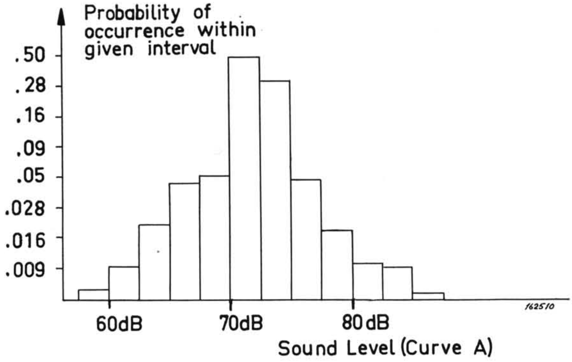
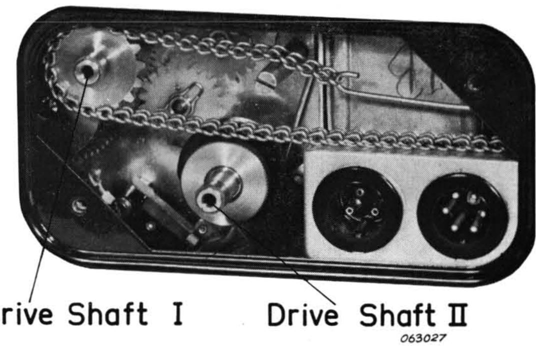


Fig. 4.22. Example of a probability distribution histogram.

5. Combined Units

Most Brüel & Kjær instruments are delivered in three versions: A, B and C.
Type A is the basic instrument with a lightweight metal casing.
Type B is the Type A instrument placed in a mahogany cabinet with front lid, giving good protection for example during transport.
Type C is the Type A instrument supplied with a frame for standard 19″ rack mounting.



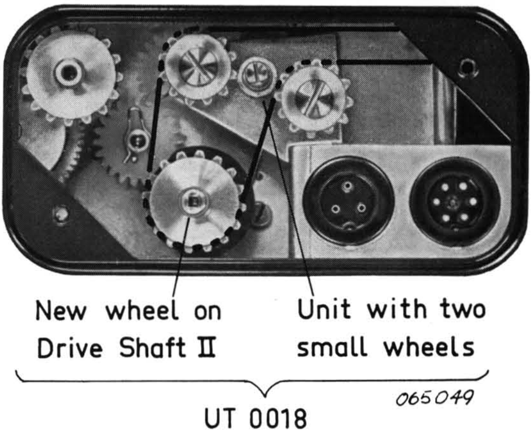


Fig. 5.1. a) Connection of chain to Drive Shaft 1.
b) Connection of chain to Drive Shaft 2.

In addition to this the Type A version of most of the instruments may be installed together with the Level Recorder in combination mounting units, for example for permanent laboratory installations. This makes the set-ups more tidy and less space consuming.

The mechanical connection between the Level Recorder and Oscillator or Analyzer is obtained with a permanent chain drive which may be connected either to DRIVE SHAFT 1 or DRIVE SHAFT 2, the latter giving the possibility of varying the relative speed between the paper drive and the chain drive for compression and expansion of the recorded curves. Connection to the two drive shafts is illustrated in Fig. 5.1.

For connection to Drive Shaft 2, screw off the wheel holding the cam discs and screw on the new chain wheel. Push the unit with the two small wheels onto the Out-In Control for the Two Channel Selector and fit the chain as shown in Fig. 5.1b.

A special recording paper QP 1142 with expanded frequency scale, covering the frequencies 100—10000 Hz (c/s) is produced, which may be used with the combined units, in addition to the other paper types. The frequency scale is doubled, so that the speed of the Level Recorder paper drive must be doubled relative to the scanning speed of the oscillator or analyzer. This is done by fitting a larger drive wheel to the oscillators. In the case of the Audio Frequency Spectrometer Type 2112 and the Band Pass Filter Set Type 1612 a relay device is connected in the control circuit, halving the number of pulses from the Level Recorder to the filter drive mechanism. The recording paper QP 1142 is shown in Fig. 5.2.

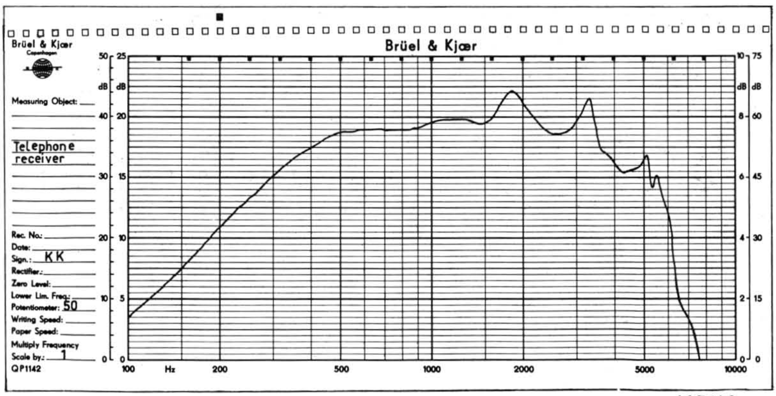


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Fig. 5.2. The recording paper QP 1142.

To obtain the speed reduction of the oscillator or analyzer the large wheel situated on the chain tightener should be interchanged with the wheel on the part screwing into the instrument. If ordinary frequency calibrated paper is to be used, the large wheel is left on the chain tightener.

Automatic Frequency Response Recorder Type 3306.

This unit contains a Beat Frequency Oscillator Type 1013 and the Level Recorder. It is designed for automatically measuring frequency response curves etc. in the frequency range af 200 Hz to 200 kHz. Recordings can be made on preprinted amplitude/frequency calibrated paper: — QP 0123 — 0423 — 1123 — 1142.

For a detailed description of the separate instruments and the operation procedure of the Unit the reader is referred to the respective paragraphs in the respective instruction books.

Fig. 5.3. Examples of combined units. (3306 and 3332).

Automatic Frequency Response Recorder Type 3307.

This combination mounting unit consists of the Level Recorder and the Beat Frequency Oscillator Type 1017, covering the frequency range from 2 Hz (c/s) to 2000 Hz (c/s). The preprinted recording paper required for this combined unit is Type QP 1123 — QP 0123 — QP 0423.

Automatic Frequency Response Recorder Type 3308.

This combination is identical to the Type 3306 with the exception that the Oscillator in this instance is the Beat Frequency Oscillator Type 1022. The frequency range covered is consequently 20 Hz (c/s) to 20 kHz (kc/s). The same types of preprinted recording paper are used as for Type 3306.

Automatic Frequency Response Recorder Type 3309.

This unit consists of the Sine-Random Generator Type 1024 and the Level Recorder Type 2305. The combination is used mainly for frequency response measurements on loudspeakers, microphones, audio-frequency amplifiers and other devices in the frequency range 20—20ooo Hz (c/s).

Narrow Band Spectrum Recorder Type 3314.

This unit consists of the Frequency Analyzer Type 2107 and the Level Recorder Type 2305. It provides narrow band continuous spectrum analysis in the frequency range 20—20ooo Hz (c/s). Special recording paper QP 1130 is used for the analysis.

Audio Frequency Spectrum Recorder Type 3315.

The combination consists of the Audio Frequency Spectrometer Type 2112 and the Recorder. With this Unit various spectrograms can be automatically recorded in bands of ⅓ or 1/1 octave in the frequency range 22 Hz (c/s) to 45 kHz (kc/s) on preprinted recording paper equal to that used by Type 3306 and Type 3308.

To facilitate automatic recording, the successive switching of the filters is accomplished by an electromagnetic drive unit which is remotely controlled from the special switch (2112) in the Recorder. The necessary wiring between this switch and the drive unit in the Spectrometer is permanent and made internally.

For a description of the separate instruments and the operation procedure for the Unit the reader is referred to the respective paragraphs in the individual instruction books.

A.F. Response Recorder Type 3328.

The A.F. Response Recorder Type 3328 has been developed to allow continuous recording of the frequency response of electrical, electro-acoustical or electro-mechanical networks in the range 2 Hz (c/s)—200ooo Hz (c/s).

The B & K combination mounting unit consists of the two Beat Frequency Oscillators Type 1013 and 1017 and the Level Recorder Type 2305.

A special preprinted recording paper, QP 1141, has been produced for use in conjunction with the Type 3328. The paper width (recording width) is 100 mm and the paper is intended for ink writing.

Automatic Frequency Response Recorder Type 3329.

This is a Unit containing three instruments, the Beat Frequency Oscillator Type 1022, the Microphone Amplifier Type 2603 and the Level Recorder. The combination is very versatile as the included Microphone Amplifier can be used to amplify weak signals before being applied to the Recorder. As an example, the Amplifier can be used as a compressor amplifier (in a servo loop) for the Beat Frequency Oscillator. A great variety of amplitude/ frequency response curves can be automatically recorded by the unit. The recording paper employed is equivalent to that used for the Units Type 3306 and 3308. For the description and the operation procedure the reader is referred to the respective paragraphs in the various instruction books for the instruments.

Automatic Frequency Response and Spectrum Recorder Type 3331.

Type 3331 consists of a Beat Frequency Oscillator Type 1022, a Frequency Analyzer Type 2107 and a Level Recorder Type 2305. The three instruments can not all be synchronized at the same time, but the unit is very versatile and may be used for many applications. When the Level Recorder and the BFO are synchronized and the Analyzer switched to its linear position (acting as a linear amplifier) frequency characteristics of electrical, acoustical or mechanical components may be obtained in the frequency range 20 to 20ooo Hz (c/s). Synchronizing the Analyzer and the Level Recorder results in an instrument which will analyze and record the frequency spectrum of vibration or sound in the audio-frequency range with the aid of suitable transducers.

A. F. Response and Spectrum Recorder Type 3332.

Three instruments are combined in this unit, the Beat Frequency Oscillator Type 1022, the Audio Frequency Spectrometer Type 2112 and the Level Recorder, which can all be driven synchronously. The paper types are equal to those employed by the Automatic Frequency Response Recorder Type 3306 and 3308.
The instrument combination contains all the necessary equipment for making automatic recording of amplitude vs. frequency characteristics and non-linear distortion on various two-pole and four-pole networks. The separate instruments can be combined in many ways, vide also Automatic Frequency Response Recorder Type 3308 and Audio Frequency Spectrum Recorder Type 3315 above.
Concerning the description of the different instruments and the operation procedure for the whole unit the reader is once again referred to the respective paragraphs in the instruction books for the instruments.

Octave, 1/3 Octave and Narrow Band Spectrum Recorder Type 3333.

This combination consists of a Frequency Analyzer Type 2107, a Band-pass Filter Set Type 1612 and the Level Recorder.

When a broad band signal is to be analyzed it is possible first to make a quick scan with the Filter Set synchronized with the Level Recorder (Paper QP 1123), then the Filter Set can be set to the octave or 1/3 octave covering the most interesting part of the curve while the Frequency Analyzer is used for scanning inside this band. (Paper QP 1130). A very high selectivity is thus obtained with extremely steep attenuation curves outside the pass-band. See the individual instruction books for further information on the Frequency Analyzer and the Band-pass Filter Set.

Automatic Frequency Recorder Type 3334.

The instruments in this unit are the Sine-Random Generator Type 1024, the Microphone Amplifier Type 2603 and the Level Recorder Type 2305. It is used for a host of different types of measurements in the fields of acoustics and vibration. The inclusion of the Microphone Amplifier makes the combination very versatile since it may be used for amplifying weak signals before they are sent to the Level Recorder.

Automatic Frequency Response and Spectrum Recorder Type 3335.

Consisting of the Sine-Random Generator Type 1024, the Audio Frequency Spectrometer Type 2112 and the Level Recorder Type 2305 this combination may be used for most frequency response measurements and frequency analyses in the frequency range 20—20000 Hz (c/s). All three instruments may be operated in synchronism, with the bandwidth of the spectrometer set to $^1/_3$ or $^1/_1$ octave, which is of great advantage where the signal to be measured has to be picked out from a noisy background.

Tape and Graphic Recorder Type 3336.

This combination consists of the Level Recorder Type 2305 and the Tape Recorder Type 7001.

Tape and Graphic Recorder Type 3337.

Consists of the Microphone Amplifier Type 2603, the Tape Recorder Type 7001 and the Level Recorder Type 2305.

Low Frequency Spectrum Recorder Type 3338.

Consists of the Frequency Analyzer Type 2107, the Tape Recorder Type 7001 and the Level Recorder Type 2305. This combination is well suited for low frequency narrow band analysis down to 0.5 Hz.

Low Frequency Spectrum Recorder Type 3339.

Consists of the Audio Frequency Spectrometer Type 2112, the Tape Recorder Type 7001 and the Level Recorder Type 2305. Type 3339 is well suited for one third octave and octave analysis down to about 0.5 Hz.

Applications

6. Applications

Spectrograms.

One of the most important applications of the Level Recorder Type 2305 when combined with one of the B & K analyzers is the automatic recording of spectrograms on preprinted frequency calibrated recording paper. Some typical spectrograms are discussed and shown in the following.

Sound.

When the B & K Audio Frequency Spectrometer Type 2112 and one of the B & K Condenser Microphones are employed together with the Level Recorder, a measuring arrangement is obtained for automatic recording of any sound spectrogram in bands of 1/3 or 1/1 octave in the frequency range 22—45000 Hz (c/s)*) and with sound pressure levels (S.P.L.) from approx. 15 dB to 160 dB, reference 2×10^{-4} μbar.

Fig. 6.1 shows the measuring arrangement. In this case the Audio Frequency Spectrum Recorder Type 3315 is used, which is a combined unit of the Level

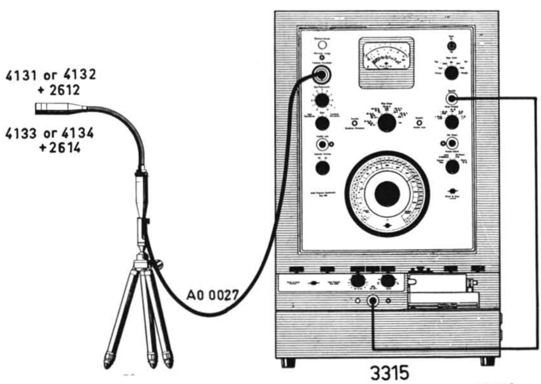

Fig. 6.1. Combination for recording of sound spectrograms in bands of ⅓ or 1/1 octaves.

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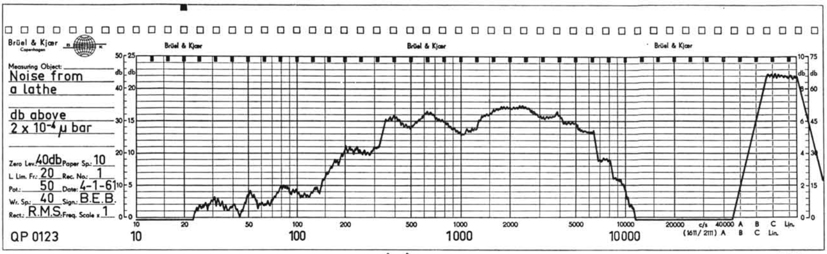
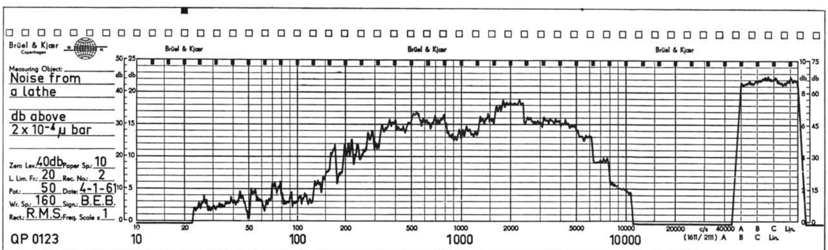
*) By adding the B & K Extension Filter Set Type 1620, the frequency range can be enlarged to 11—45000 Hz (c/s).

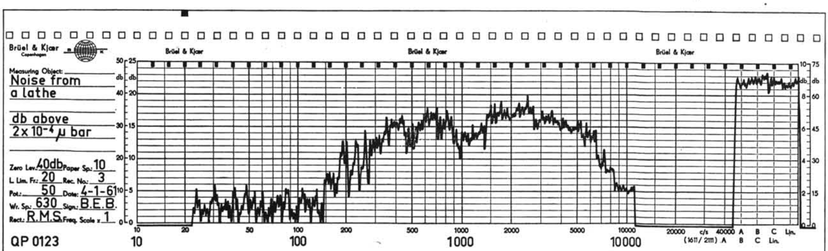
Recorder Type 2305 and the Audio Frequency Spectrometer Type 2112. In Figs. 6.2, 6.3 and 6.4 can be seen some recorded spectrograms. The ordinates are in dB (As a 50 dB Range Potentiometer is employed in the Recorder, the length of the ordinate is 50 dB) and the abscissa in frequency (logarithmic). Towards the end of the chart (right-hand side) is recorded the sound level (S.L.), as in this case noise from the various objects are weighted with the three internationally standardized weighting networks A, B and C (IEC, Helsinki 1961). In the last column marked "Lin" is recorded the S.P.L. in the frequency range 20—45ooo Hz (c/s).



(a) 161823



(b) 161824



(c) 161825

Fig. 6.2. Spectrograms of noise radiated from a lathe.
(a) Writing Speed 40 mm/sec.
(b) Writing Speed 160 mm/sec.
(c) Writing Speed 630 mm/sec.

Fig. 6.2 shows the spectrogram of the noise radiated from a lathe. The three different curves are recorded with different writing speeds on the Recorder. It is seen that the curve is considerably smoother when a low writing speed is employed. With a high writing speed all the small variations in the sound pressure level become quite pronounced.

Fig. 6.3 gives the frequency spectrum of the noise radiated from an oil burner. The high level of low frequencies is due to the characteristic sound from the flame. The high frequency noise arises from the blower.

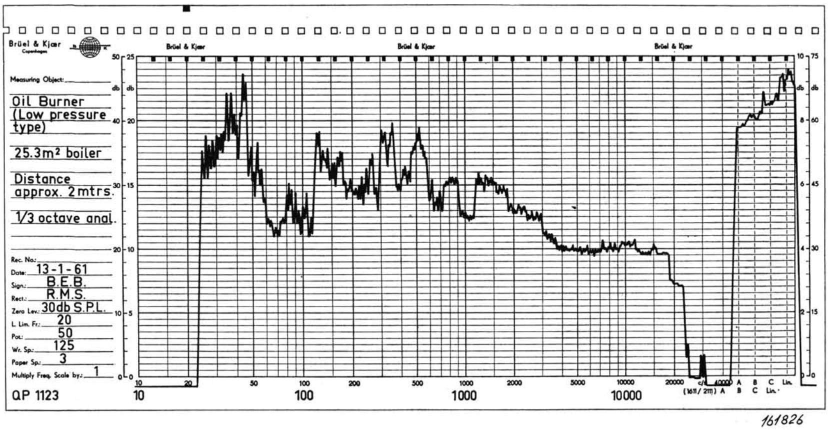


Fig. 6.3. Spectrogram of noise from oilburner.

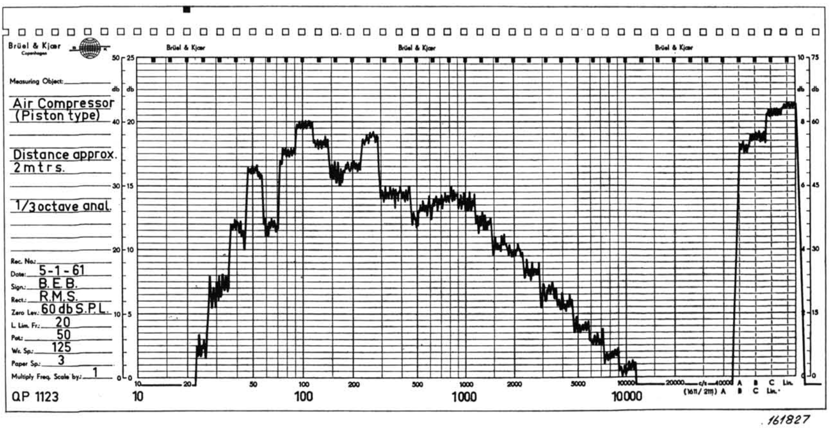


Fig. 6.4. Analysis of noise from air compressor.

In Fig. 6.4 can be seen the spectrogram obtained from measurements on a piston-type air compressor.
Another analyzer, the B & K Frequency Analyzer Type 2107, can also be employed in combination with the Level Recorder, whereby an equipment for

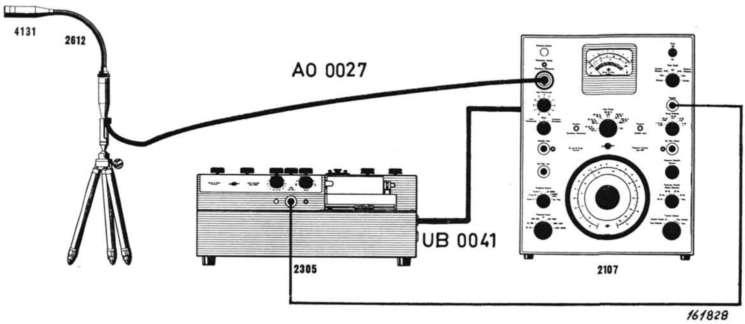
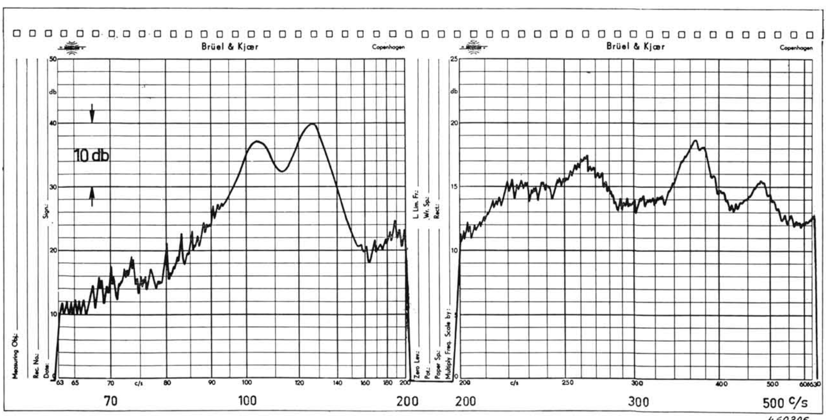


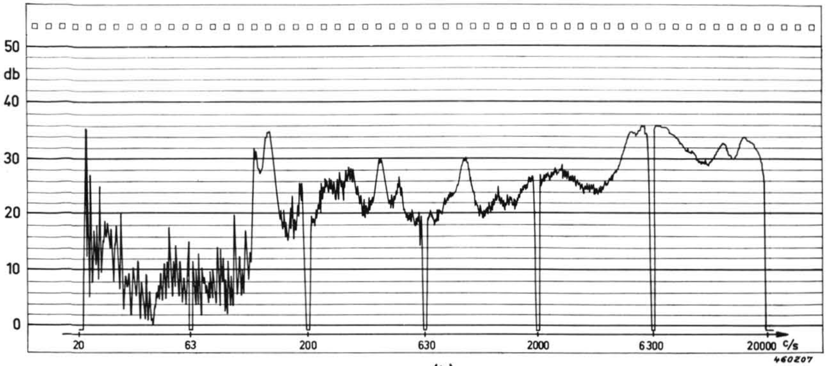
Fig. 6.5. Equipment for the automatic recording of spectrograms of acoustic noise resolved by a narrow and continuously scanned band-pass filter.

the automatic recording of electrical signals, vibration signals, and sound pressures in narrow bands is obtained. The bandwidth (3 dB) of the Analyzer is relative and selectable in six steps from 6—29 %. The Analyzer can be continuously tuned throughout the frequency range 20—20000 Hz (c/s),



(a)

Fig. 6.6a. Recording of sound spectrum produced by an electric motor. Recording on frequency calibrated paper showing part of the complete spectrogram



(b)

Fig. 6.6b. Recording of sound spectrum produced by an electric motor. Complete spectrogram with compressed frequency axis.

and the S.P.L. measurable is in the range approximately 15 dB (or somewhat lower, dependent on the bandwidth used) to 160 dB, reference 2×10^{-4} μbar. In Fig. 6.6 is shown a noise spectrogram obtained with the equipment in Fig. 6.5. Fig. 6.6a is a part of the complete spectrogram recorded on preprinted frequency calibrated paper. As the Analyzer is continuously variable, any peak and valley is precisely recorded. In Fig. 6.6b the complete spectrogram from 20—20000 Hz (c/s) is reproduced. As seen, the frequency scale is compressed compared with the frequency scale on the preprinted chart, this is easily done by employing different gear ratios between the paper drive on the Recorder and the automatic tuning of the Analyzer.

Vibration.

When objects such as machinery, buildings, ships, aircraft, rockets etc. are exposed to vibration, an equipment for automatically recording the vibra-

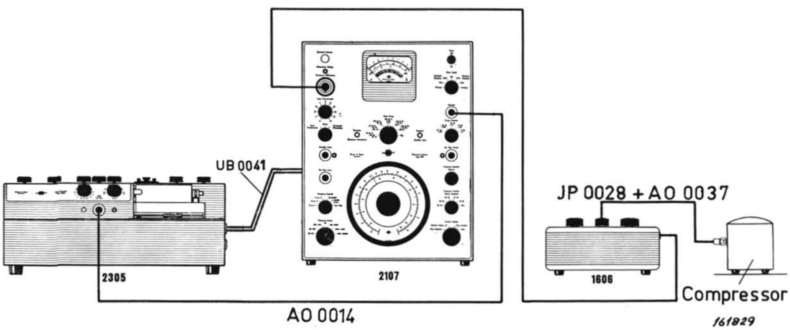


Fig. 6.7. Vibration measuring arrangement for automatic recording of acceleration, velocity and displacement spectra.

tion level versus frequency can consist of the Level Recorder and the Frequency Analyzer Type 2107 combined with one of the B & K Accelerometers and a Vibration Pick-up Preamplifier Type 1606. The frequency range covered by this equipment is limited by the Frequency Analyzer, therefore being 20—20000 Hz (c/s). Acceleration, velocity and displacement can be measured as the output from the Accelerometer can be converted by means of integrating networks within the Preamplifier.

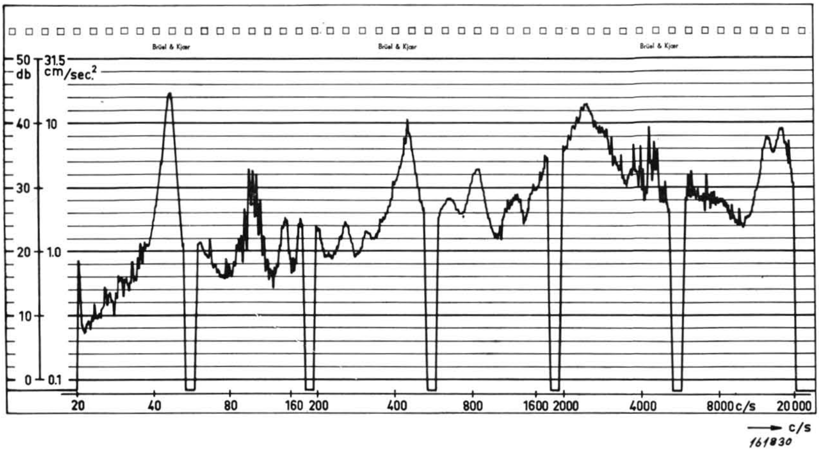


Fig. 6.8. Acceleration level measured on compressor of a 120 Liter (4.0 cu.ft.) refrigerator (2800 r.p.m.).
Condition of Level Recorder: 50 dB Range Potentiometer.
POTENTIOMETER RANGE: "50" RECTIFIER RESPONSE: "Peak"
LOWER LIMITING FREQUENCY: "20" WRITING SPEED: "200"
DRIVE SHAFT SPEED: "120".

In Fig. 6.7 can be seen a typical measuring arrangement which in this case was utilized to record the acceleration level spectrum on a compressor for a 120 liter (4.0 cu.ft.) refrigerator. The acceleration spectrum was measured on the compressor frame. In Fig. 6.8 is reproduced the spectrogram obtained, from which the various resonances and their levels can be read. The spectra were recorded with "compressed" frequency scale but can also be carried out on the preprinted recording paper similar to that in Fig. 6.6a.
When employing the B & K Audio Frequency Spectrometer Type 2112 and the Extension Filter Set Type 1620 in place of the Frequency Analyzer Type 2107 the analysis can be recorded in 1/3 or 1/1 octave bands in the frequency range 11—45000 Hz (c/s).

Electrical Signals.

A measuring set-up equivalent to that of Fig. 6.1, but in which the Microphone has been omitted, is used for the automatic analysis of electrical signals. The frequency range covered is as for sound spectrograms previously measured by the Audio Frequency Spectrometer. The signal levels can be measured between 100 μV and 1000 V (full deflection).

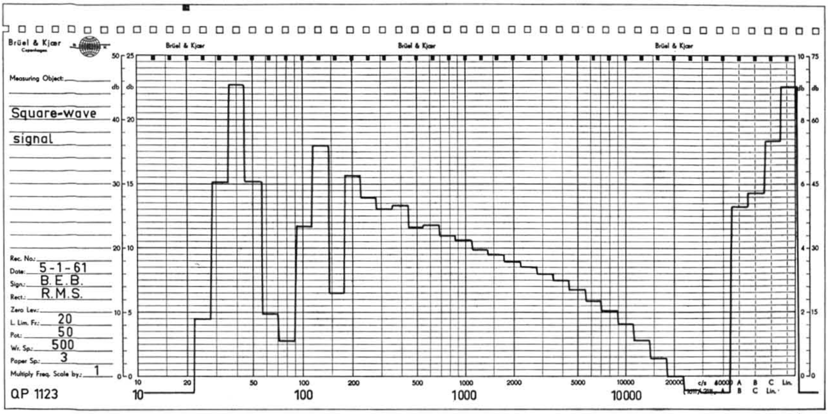


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Fig. 6.9. Spectrogram of a square-wave signal analyzed in ⅓ octave bands.

Fig. 6.9 gives as an example of the analysis of a square-wave signal.
The same type of measurement can be accomplished by an equipment consisting of the Frequency Analyzer Type 2107 combined with the Level Recorder. With this combination the frequency range is 20—20000 Hz (c/s),

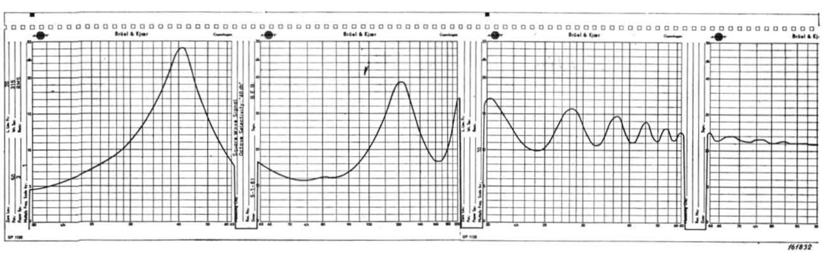

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Fig. 6.10. Spectrogram of the square-wave signal resolved by a continuously varied narrow band of approximately 8.5 % bandwidth.

and the signal levels may be between 100 μV and 1000 V (full-scale deflection).
In Fig. 6.10 is reproduced the spectrogram for the same signal as analysed with the Audio Frequency Spectrometer Type 2112.

Dynamic Strain Gage Measurements.

In dynamic strain gage investigations it may be of interest to frequency analyse the signal from the strain gage bridge. By employing the B & K

Strain Gage Apparatus Type 1516 in strain gage measurements a special output terminal facility on the apparatus can be utilized for this purpose. The dynamic signal may be directly analysed, or it may first be recorded on a tape recorder and afterwards analysed. A measuring arrangement for analysing dynamic signals from the strain gage bridge by the latter method is shown in Fig. 6.11.

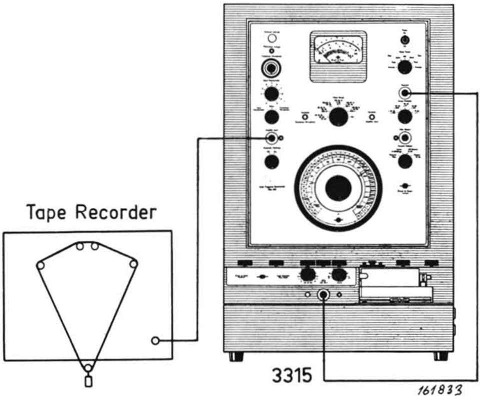

Fig. 6.11. Measuring equipment employed to frequency analyse the dynamic strain signal recorded on a tape.

The frequency spectrum obtained from measurements made on the dynamic stress of a connecting rod in a one cylinder four-stroke combustion engine is shown in Fig. 6.12. To keep all the frequency components within the range of the analysing equipment, the tape was played back with a 10 times higher speed than when originally recorded. The different magnitudes are given in dB relative to 15 μStrain.

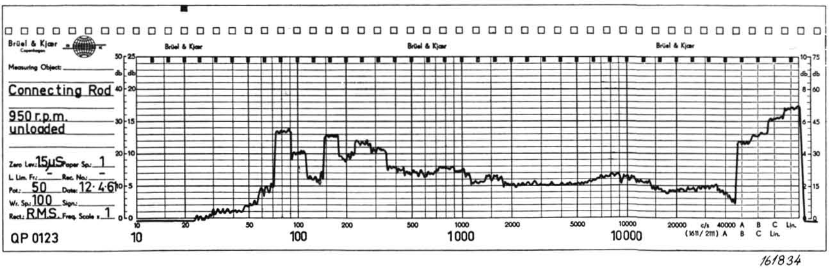

Fig. 6.12. Spectrogram of dynamic strain in the connecting rod of a combustion engine.

Automatic Recording of Frequency Characteristics.

In the production of electronic devices and components a recording of their frequency characteristic is a great asset, as it provides an accurate means of determining their quality.

When the Level Recorder is employed in combination with B & K oscillators an equipment is obtained for the automatic recording of frequency characteristics on electronic, electro-acoustic, electro-mechanical, acoustical and mechanical devices. Some examples of this type of application are given below.

Frequency Response of a Filter Circuit.

In Fig. 6.13 a measuring arrangement for the automatic recording of filter response curves is shown. The B & K Beat Frequency Oscillator (B.F.O.) Type 1017 covers the frequency range 2—2000 Hz (c/s) but substituting this B.F.O. with the Type 1022 or Type 1013 frequency ranges of 20—20000 Hz (c/s) or 200—200000 Hz (c/s) can be covered respectively.

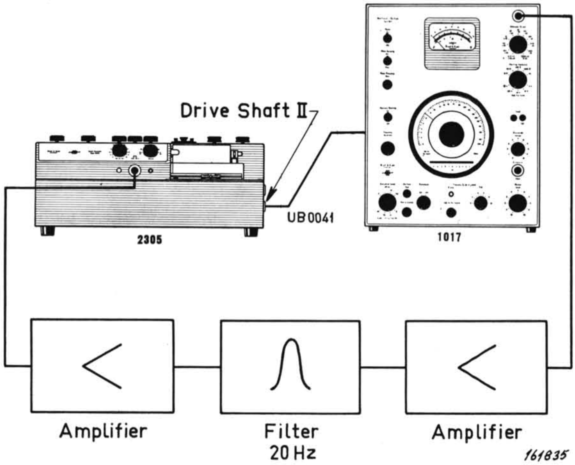

Fig. 6.13. Set-up for recording filter characteristic.

In Fig. 6.14a and b is reproduced the recorded response of a 20 Hz (c/s) filter. To be able to judge the slope of the filter the recording was firstly carried out with a 75 dB Range Potentiometer (ZR 0006), vide Fig. 6.14a. To examine the response of the transmission band, a 10 dB Range Potentiometer (ZR 0003) was then utilized in the Recorder in another measurement, refer Fig. 6.14b.

The recordings were made on non-frequency calibrated paper, and the frequency "scale" on the paper extended compared to that used with frequency calibrated paper. The extension is obtained by using Drive Shaft II on the Recorder for the mechanical connection between Level Recorder and B.F.O. instead of Drive Shaft I, which is normally connected when using frequency calibrated paper.

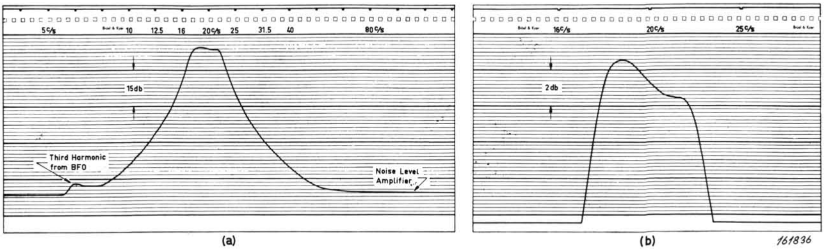

Fig. 6.14. Recording of the response of a 20 Hz (c/s) filter.
Condition of Level Recorder:—

RECTIFIER RESPONSE:	*"RMS"*
LOWER LIMITING FREQUENCY:	*"10"*
WRITING SPEED:	*"80"*
PAPER SPEED:	*"30"*
(a) Filter slope.	
Range Potentiometer:	*75 dB*
POTENTIOMETER RANGE:	*"80"*
DRIVE SHAFT SPEED:	*"12"*
(b) Filter transmission band.	
Range Potentiometer:	*10dB*
POTENTIOMETER RANGE:	*"10"*
DRIVE SHAFT SPEED:	*"3.6"*

An indication of discrete frequencies on the paper is possible by utilizing the Event-Marker, which should thus be connected for remote control as shown in Fig. 6.15. When applying the cam disc with the very short cam (OD 0060) on Drive Shaft II the Event-Marker will make indications with intervals in frequency of 1/3 octave of the frequency scale on the B.F.O.

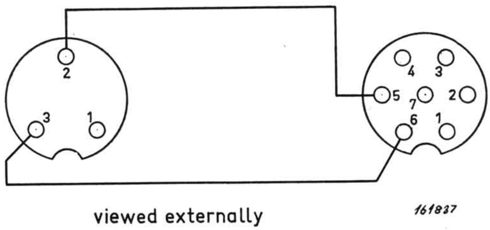

Fig. 6.15. Connections between the Two-Channel Selector (3-pin) and Remote Control (7-pin) on the Level Recorder for operating the Event Marker via the Drive Shaft II.

independent of the settings of PAPER SPEED and DRIVE SHAFT SPEED. By, for instance, adjusting the scale pointer on the B.F.O. so that an indication is achieved where the center frequency of the filter is supposed to lie, the attenuation of the filter can then be read as a function of frequency. As seen from Fig. 6.14a and b the frequency "scale" on the paper, Fig. 6.14b, is extended 3.33 times compared to that on Fig. 6.14a.

For determination of the absolute frequency between the ⅓ octave markings the reader is referred to the formula on page 90.

Frequency Response of High-Quality Amplifiers.

A measuring set-up is given in Fig. 6.16, which enables the frequency response of amplifiers to be automatically recorded in the range 2—200000 Hz (c/s). The complete recording will be presented on two charts (vide Fig. 6.17). As illustrated in Fig. 6.16, two of the B & K Beat Frequency Oscillators are utilized, the Type 1017 covering the frequency range 2—2000 Hz (c/s) and the

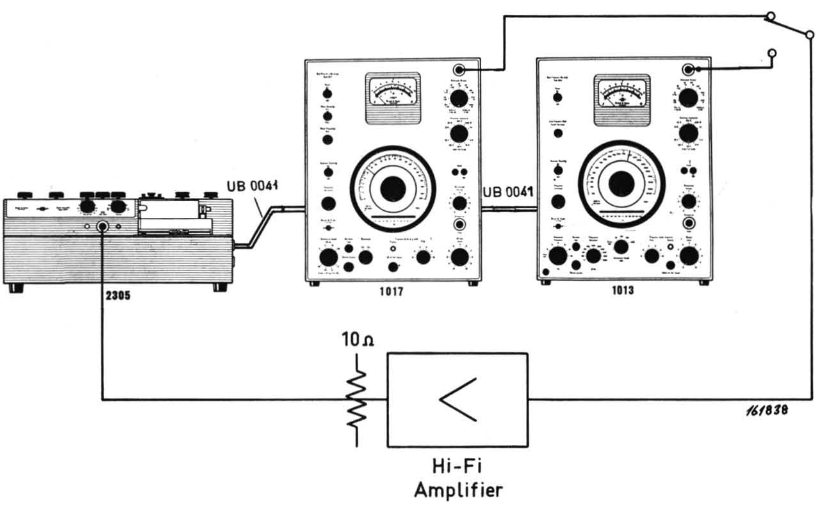

Fig. 6.16. Measuring arrangement for recording frequency response of amplifiers in the range 2 Hz (c/s) to 200000 Hz (c/s).

Type 1013 which covers the range 200—200000 Hz (c/s). As the frequency response of the Level Recorder is linear down to 2 Hz (c/s), a direct reading can be obtained for the whole frequency range. During recording the signal to the amplifier to be tested has to be switched over from the low frequency to the high frequency oscillator. This can be conveniently done in the time interval between the two charts where no signal is present.

In Fig. 6.17 is reproduced the amplitude/frequency characteristic of a Hi-Fi amplifier. As seen from the recording, the curve has an overlap of one decade. The notch recorded between the two parts is due to noise during switching over from one oscillator to the other.

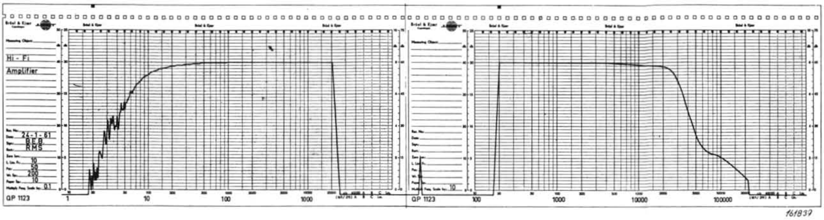

Fig. 6.17. Amplitude vs. frequency characteristic of a Hi-Fi amplifier recorded by the equipment shown in Fig. 6.16.

Frequency Response of Loudspeaker (Tweeter).

By connecting the Level Recorder with the B & K Microphone Amplifier Type 2604, the Condenser Microphone Type 4133, a Cathode Follower Type 2614 and the Beat Frequency Oscillator Type 1013 as illustrated in Fig. 6.18 a measuring arrangement for the automatic recording on frequency calibrated paper of the frequency response of tweeters is gained. To give results independent of room response the measurement has to be carried out in an anechoic chamber. The complete measuring set-up in Fig. 6.18 covers a

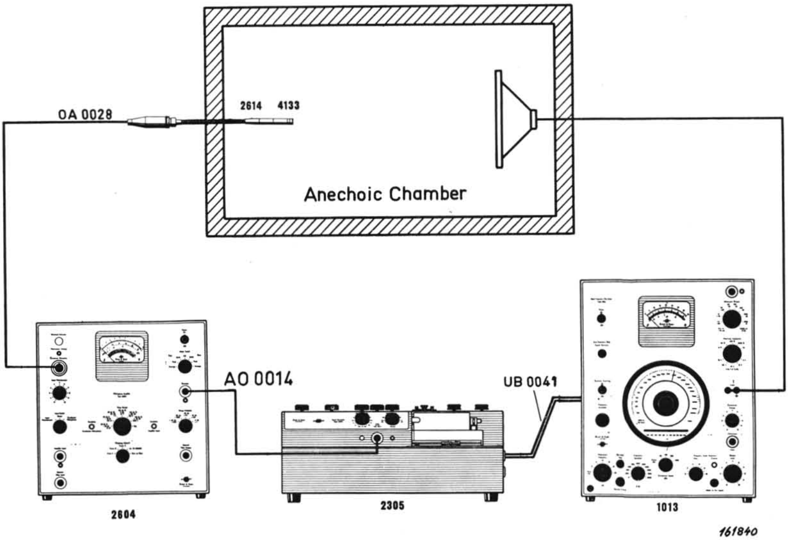

Fig. 6.18. Automatic recording of loudspeaker (tweeter) frequency response.

straight frequency range of 200—40ooo Hz (c/s). By substituting the Beat Frequency Oscillator Type 1013 and the Microphone Type 4133 by other B & K types the frequency range can be altered to cover 20 to 20ooo Hz (c/s). The range of sound pressure level is approximately 20—160 dB with reference 2×10^{-4} μbar.

Fig. 6.19 shows a recording of the free field characteristic obtained in the axis of the loudspeaker.

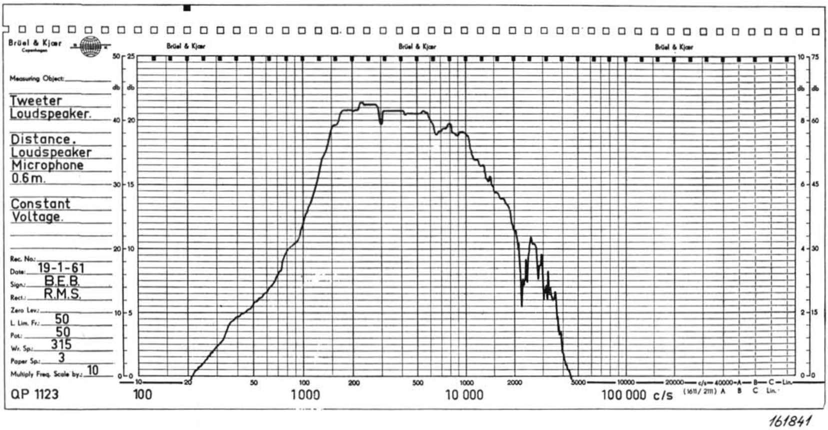

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Fig. 6.19. Free field characteristic of a tweeter loudspeaker.

Frequency Response of Hearing Aids.

By employing the B & K Hearing Aid Test Box Type 4212 along with the Microphone Amplifier Type 2603 and the A.F. Response and Spectrum Recorder Type 3332 a complete measuring arrangement is achieved for the automatic recording of frequency characteristics associated with, and also the harmonics produced in hearing aids. A measuring set-up for this purpose is sketched in Fig. 6.20.

The A.F. Response and Spectrum Recorder Type 3332 is a combined unit containing the Beat Frequency Oscillator Type 1022, the Audio Frequency Spectrometer Type 2112 and the Level Recorder Type 2305, see also part Combined Units in this book.

Measuring Arrangement. Usually the distortion produced in the electronic part of a hearing aid (the hearing aid amplifier) is small compared to the distortion caused by the electro-acoustical transducing elements. The measuring arrangement shown includes for this reason the electro-acoustical system of the hearing aid. The hearing aid is placed in the Hearing Aid Test Box Type 4212, which consists of a small anechoic chamber with a built-in loudspeaker and regulating microphone along with an artificial ear. The regulating microphone allows a constant sound pressure level to be maintained at the hearing aid microphone without influencing the practically free sound field conditions that exist in the Test Box. By placing the hearing aid earphone in the artificial ear it is possible to measure the overall characteristics of the device with relation to the acoustical input and output.

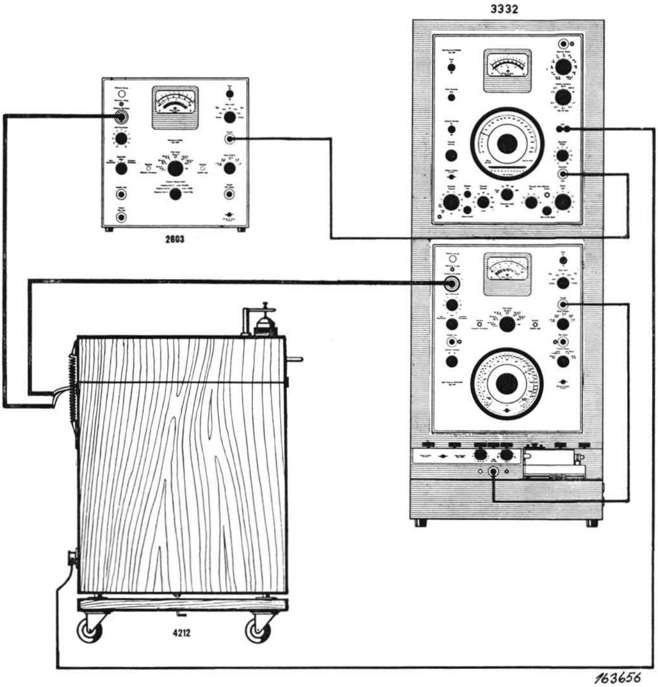

*Fig. 6.20. Measuring **equipment for measuring amplitude vs. frequency response and harmonic distortion in hearing aids.***

In the measuring arrangement shown, the Microphone Amplifier Type 2603 is used as a "compressor amplifier", i.e. it is used to amplify the output voltage from the regulating microphone and to feed the amplified signal to the compressor input of the BFO. Additionally the sound pressure level in the chamber at the diaphragm of the regulating microphone (i.e. at the microphone of the hearing aid) can be measured by means of this Microphone Amplifier.

Measurement. In Fig. 6.21 are given the recorded results of measurement of the fundamental together with the harmonics produced in a hearing aid. The harmonics are measured by setting the filter switch on the Spectrometer so that it runs ahead of the frequency scanning of the BFO, the selected space difference being in accordance with the harmonic which is going to be measured.

By means of the facility included in the Level Recorder Type 2305, which allows the recording paper to be reversed by one chart length without losing the synchronization between the BFO and the Spectrometer, the harmonics are readily recorded on the same chart as the fundamental.

More details concerning the measurement are to be found in the manual for the Hearing Aid Test Box Type 4212 (or 4217).

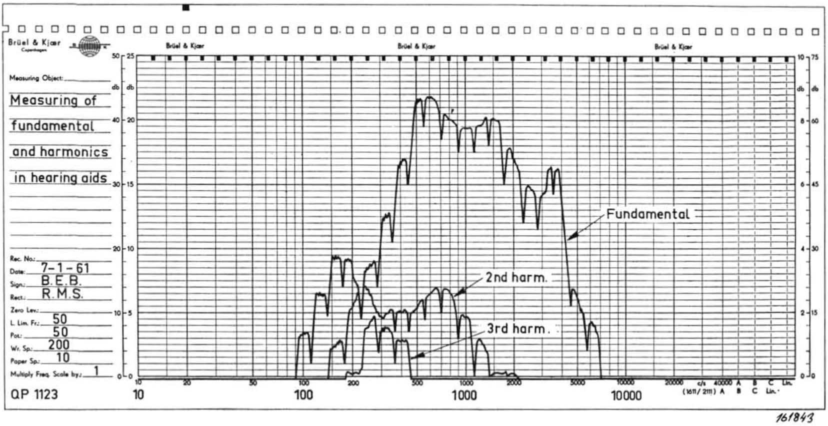

Fig. 6.21. Example of recorded chart exhibiting the response of the fundamental 2nd and 3rd harmonics in a hearing aid.

Two Channel Recording of Acoustic Signals.

Two channel recording of acoustic signals can be carried out automatically by using the B & K Two Channel Selector Type 4408 in conjunction with a B & K sound measuring system involving the Level Recorder. The two channel recording method can, for instance, be used in laboratory or field measurements of airborne sound insulation.

In Fig. 6.22 is illustrated an arrangement for automatic recording of the airborne sound insulation of a wall between two offices. By this arrangement the airborne sound insulation can be measured in accordance with the I.S.O. Recommendation R 140. The transmitting part of the measuring arrangement consists of the Random Noise Generator Type 1402, which is combined with the Band-Pass Filter Set Type 1612, and a loudspeaker. If necessary, a power amplifier can be used to obtain a signal level exceeding the background noise by the required 10 dB. The Random Noise Generator Type 1402 is a signal source generating a noise signal in the frequency range 20—20000 Hz (c/s) with Gaussian distribution up to 4 σ and with uniform spectrum density ("white"). The Band-Pass Filter Set Type 1612 contains 33 filters with ⅓ octave bandwidth and 11 with 1/1 octave. The Filter Set has in this measuring set-up been combined with the Noise Generator

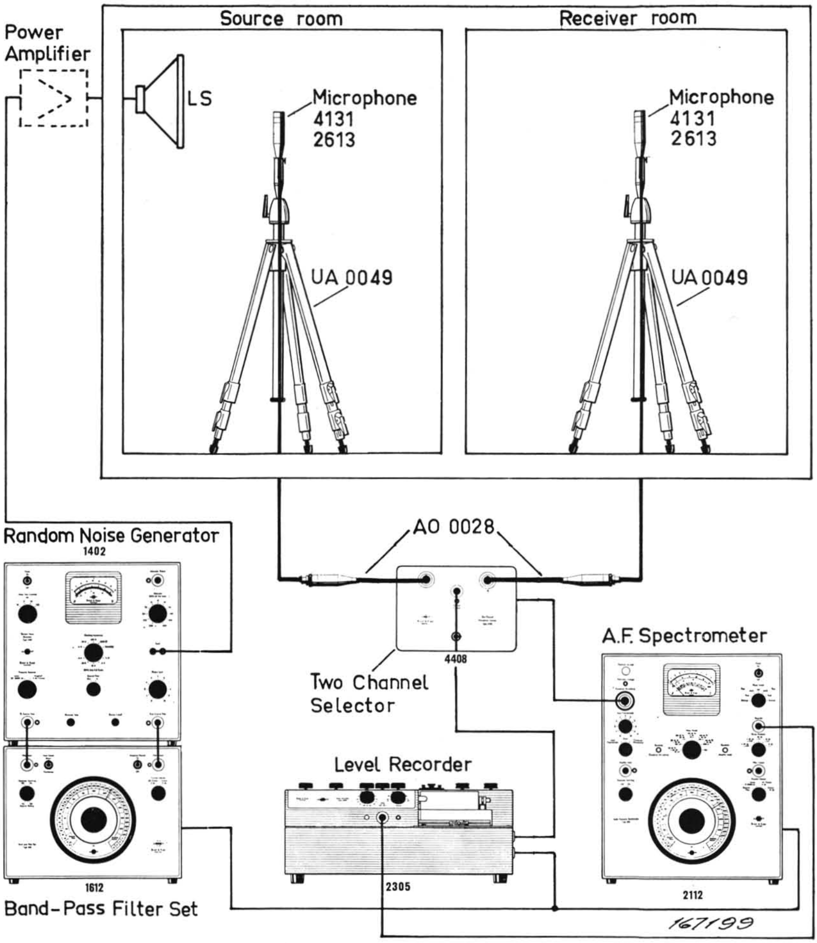

Fig. 6.22. Instrumentation for automatic two channel recording of airborne sound insulation.

and used in the ⅓ octave condition. In this manner ⅓ octave bands of noise were radiated in the transmitting room as recommended in the mentioned I.S.O. Recommendation.

The receiving system is built-up of two Condenser Microphones Type 4131 with associated Cathode Followers Type 2613, the Two Channel Selector Type 4408, the A.F. Spectrometer Type 2112 and finally the Level Recorder. With the Two Channel Selector Type 4408 the output signals from the two Microphones can successively be applied to the input of the A.F. Spectro-

meter Type 2112. The switching over can be carried out manually or remotely. The A.F. Spectrometer Type 2112 has, among other things, input facilities for the B & K Condenser Microphones, output facilities for the Level Recorder and includes ⅓ and ⅟₁ octave band-pass filters which are identical to those in the Band-Pass Filter Set Type 1612 mentioned above. As the whole measuring arrangement operates automatically the various remote switchings are controlled from the Level Recorder.
A recording from such an investigation can be seen in Fig. 6.23. All the nearly vertical lines do not belong to the measuring result as they are due to the movement of the writing pen in the switching over period, i.e. to the shifting from the level in the source room to that in the receiving room and vice versa. The upper envelope represents the sound pressure level of the radiated noise in the source room as measured in ⅓ octave bands. The lower envelope gives the ⅓ octave level radiated in the receiving room.

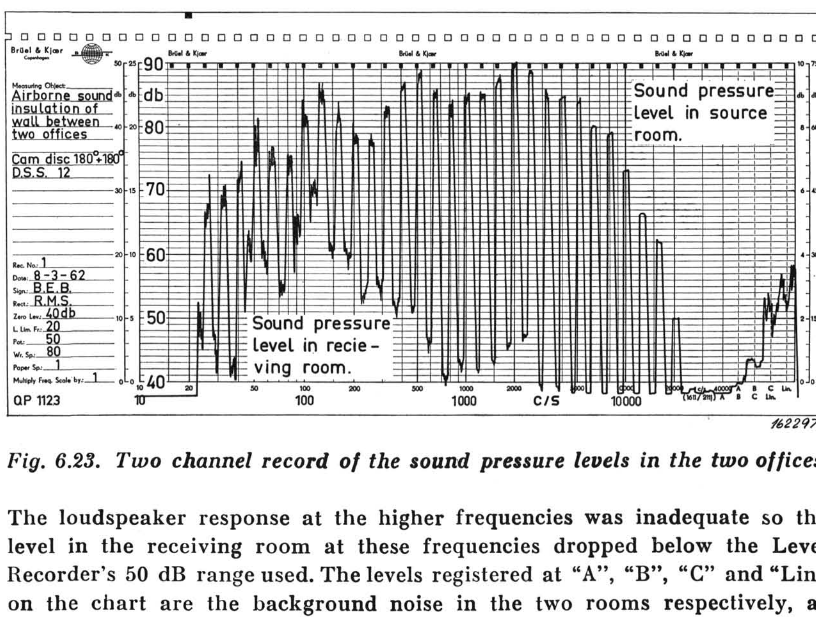

Fig. 6.23. Two channel record of the sound pressure levels in the two offices.

The loudspeaker response at the higher frequencies was inadequate so the level in the receiving room at these frequencies dropped below the Level Recorder's 50 dB range used. The levels registered at "A", "B", "C" and "Lin" on the chart are the background noise in the two rooms respectively, as measured by the "A", "B", "C" and "Lin" weighting networks.
The sound level difference between the two rooms can be read as a function of frequency directly from the recording in Fig. 6.23. For the purpose of illustration this difference is plotted in Fig. 6.24. When appropriate compensation is applied for the absorption in the receiving room, the normalized level difference can be calculated in accordance with the mentioned I.S.O. Recommendation.

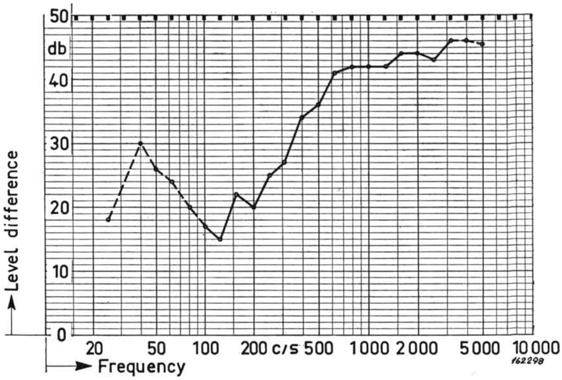

Fig. 6.24. The sound pressure level difference between the two offices plotted down manually. The values are taken from the recorded chart in Fig. 6.23.

Automatic Recording of Directional Characteristics.

When the Level Recorder is combined with the Turntable Type 3921 a complete equipment for the automatic measurement of directional char-

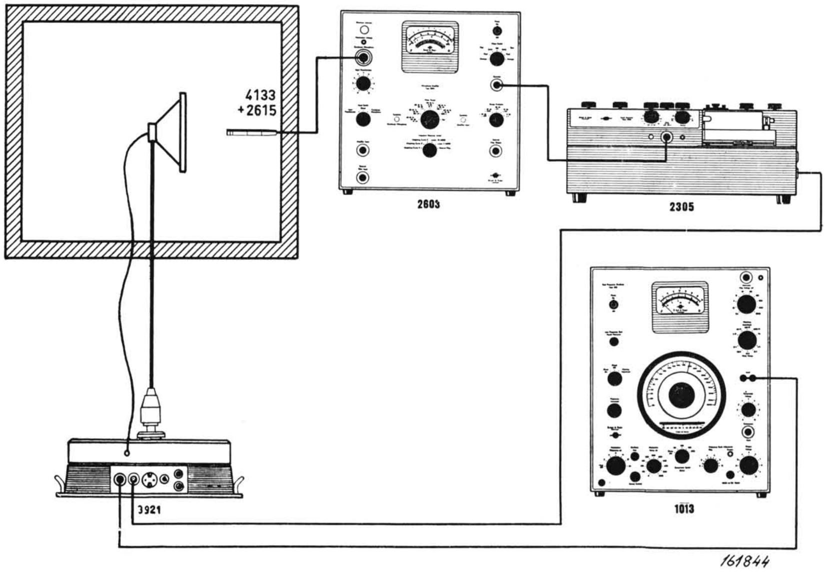

Fig. 6.25. Measuring arrangement for recording directional characteristics of loudspeakers.

acteristics is obtained. For description of the Turntable and its operation, the reader is referred to part Accessories of this manual.

In the following a few examples on the application of the Level Recorder adapted to polar recording are given.

Directional Characteristics of Loudspeakers.

With the measuring arrangement illustrated in Fig. 6.25 the directional characteristic of a tweeter was recorded at various frequencies. In Fig. 6.26 the results are reproduced.

The measuring equipment consists, apart from the Turntable and the Level Recorder, of the B & K Beat Frequency Oscillator (B.F.O.) Type 1013, the Microphone Amplifier Type 2603 and the Condenser Microphone Type 4133. With this combination a frequency range of 200—40000 Hz (c/s) is covered. When substituting the B.F.O. Type 1013 with for instance the Type 1022 a 20—20000 Hz (c/s) frequency range will be obtained. The measurements were carried out in an anechoic chamber to ensure that no reflection would influence the measured results.

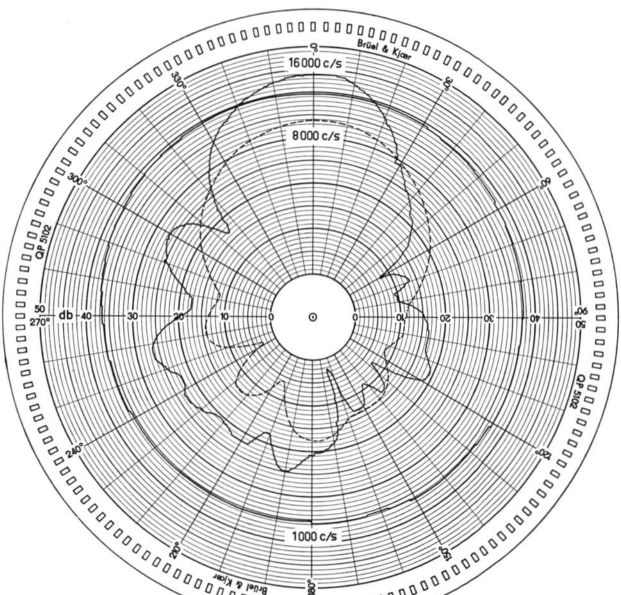

Fig. 6.26. Directional characteristics of loudspeaker measured at the frequencies 1000 Hz (c/s), 8000 Hz (c/s) and 16000 Hz (c/s). The dotted curve is obtained by utilizing the pen lifting arrangement in combination with the Two-Channel Selector.

Directional Characteristics of Antennae.

By combining the B & K Level Recorder and Turntable with a suitable signal generator and a field strength meter, directional characteristics of VHF and UHF antennae can be automatically recorded. In Fig. 6.27 is shown a measuring set-up used when measuring the directional characteristics of a six-element Yagi antenna. The antenna was horizontally polarized, designed for 210 MHz (Mc/s) and had an output impedance of 70 Ω.

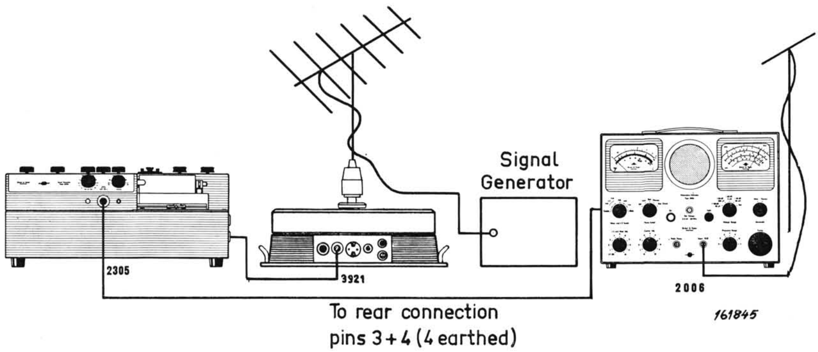

Fig. 6.27. Set-up for recording directional characteristics of VHF antennae.

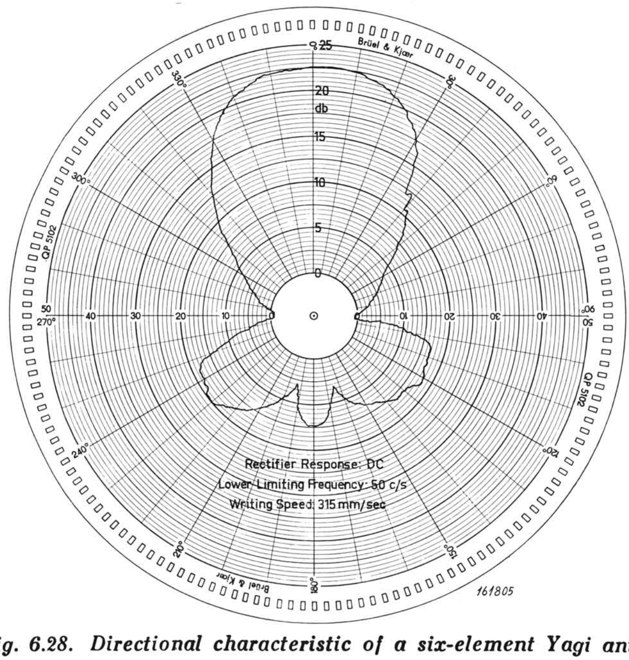

Fig. 6.28. Directional characteristic of a six-element Yagi antenna.

Fig. 6.28 illustrates the directional characteristic obtained in a horizontal plane. From the recording can easily be read the front-to-back ratio in dB and the half-power-angle (3 dB) in degrees. The Level Recorder was supplied with a 25 dB Range Potentiometer, and as the output from the field strength meter was a DC signal, the RECTIFIER RESPONSE of the Recorder was set to "DC".

Recording of Vibrations.

In the field of mechanical vibrations the Level Recorder is an ideal measuring instrument, for when combined with suitable vibration test equipment the results can be automatically recorded as functions of time or frequency.

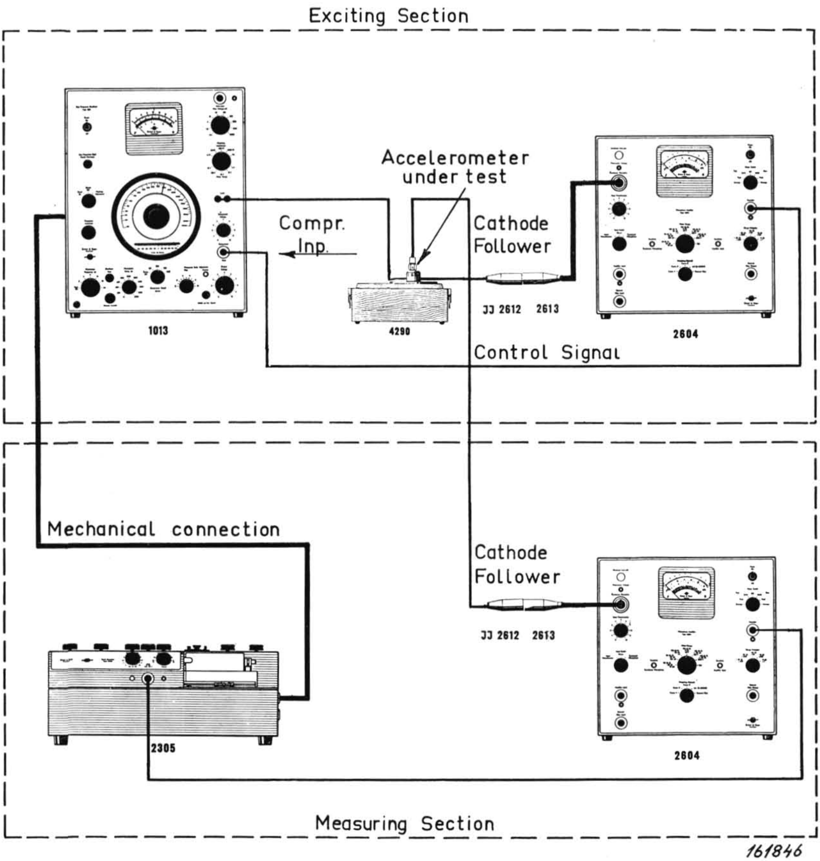

Fig. 6.29. Measuring arrangement for frequency response calibration of accelerometers.

Additional Brüel & Kjær reference literature: Technical Review, No. 4-1956, 2-4-1958, 3-1960, 3-4-1963, 2-3-1964, 3-1965 and 2-1966.

Automatic Recording of Accelerometer Frequency Response.

In the production of high quality electromechanical transducers it is an important asset to deliver with every unit an individually recorded amplitude versus frequency characteristic.

The B & K accelerometers, which are duly supplied with individually recorded amplitude vs. frequency curves, are measured on a measuring arrangement equivalent to the one shown in Fig. 6.29. The arrangement consists of an exciting and measuring section. The B & K Calibration Exciter Type 4290 is fed from the Beat Frequency Oscillator Type 1013. To keep a constant acceleration level on the table of the Exciter, the output signal from a built-in accelerometer is applied via one of the B & K Cathode Followers and the Microphone Amplifier Type 2604 to the compressor circuit of the Beat Frequency Oscillator. The output signal from the accelerometer under test is then applied to the measuring section which is comprised of another Cathode Follower and Microphone Amplifier Type 2604, and finally the Level Recorder. To derive automatic scan of the Beat Frequency Oscillator a mechanical connection is made to the Level Recorder.

In Fig. 6.30 is reproduced a typical sensitivity curve of an Accelerometer Type 4334 recorded by this set-up. From the curve is clearly seen the natural frequency of the Accelerometer.

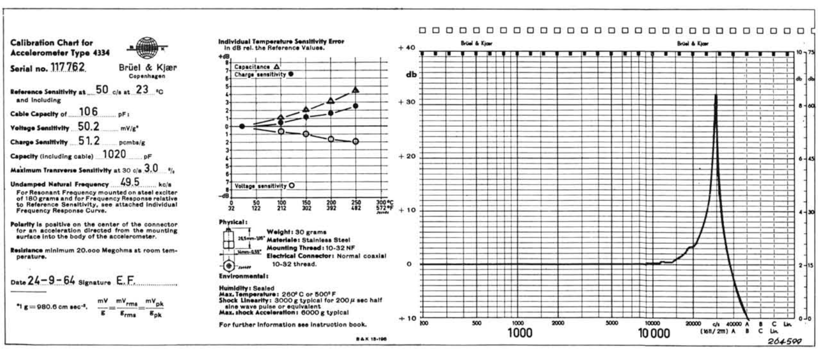

Fig. 6.30. Typical accelerometer calibration chart with frequency response curve as obtained with the above type of set-up.

Recording Vibration Sensitivity of Electronic Instruments.

In many circumstances it is important to know the response of measuring instruments exposed to vibration. By employing the Level Recorder in vibration set-ups when investigating spurious output signals from a measuring instrument which is vibrated, the output signal can be recorded as a function of vibration frequency.

An examination according to the above was carried out on the B & K transistorized Precision Sound Level Meter Type 2203. The measuring set-up employed can be seen in Fig. 6.31. It is built on the B & K Automatic Vibration Exciter Control and a vibration test system consisting of a power

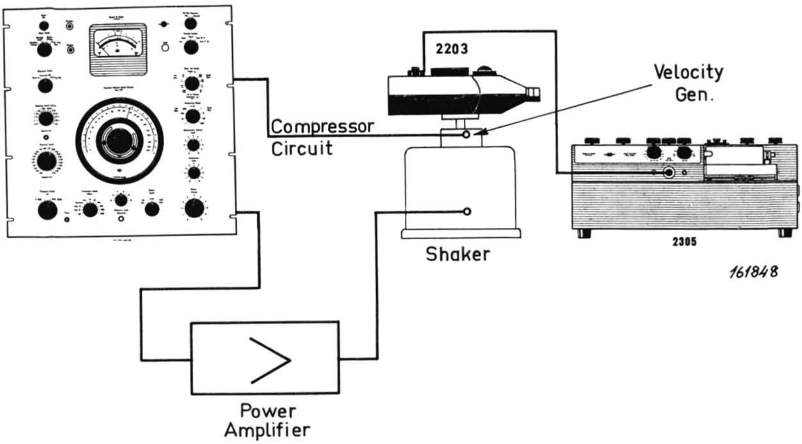

Fig. 6.31. Measuring set-up used for investigation of vibration sensitivity of the Precision Sound Level Meter Type 2203.

amplifier and a shaker table. The Level Recorder was connected to the OUTPUT of the Precission Sound Level Meter, which was situated on the shaker, as shown in Fig. 6.31. To obtain constant displacement, velocity or acceleration, as desired, on the shaker table, a servo-type system comprising a velocity generator built into the shaker table and a compressor circuit in

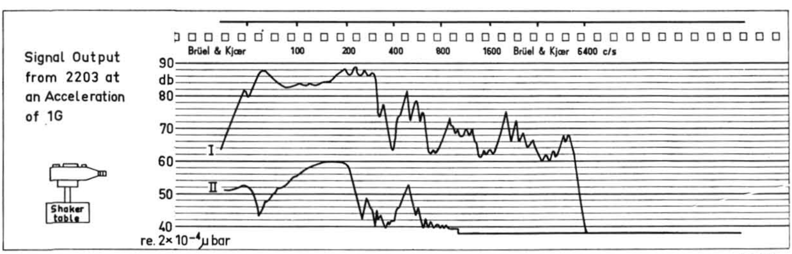

Fig. 6.32. Vibration effect on the Precision Sound Level Meter Type 2203. The acceleration has been kept constant at 1 g. The curve indicated by I is obtained with the microphone in place, while the curve II is obtained with the microphone substituted by an equivalent impedance but sound and vibration insensitive.

the Automatic Vibration Exciter Control is utilized. The Automatic Vibration Exciter Control is in principle a beat frequency oscillator furnished with an automatic frequency scan arrangement and a compressor system. The latter, by applying the output signal from an accelerometer or velocity pick-up, enables one of the three vibration quantities to be kept constant on the shaker table. The logarithmic frequency covered is 5 Hz (c/s)—5000 Hz (c/s), additionally a range 5 kHz (kc/s) to 10 kHz (kc/s) is available.

The measuring result can be seen in Fig. 6.32. For indication of the frequency the Event-Marker of the Recorder is utilized. Marking is carried out manually when the pointer on the Automatic Vibration Exciter Control during the scanning passes the 50—100—200 Hz (c/s) etc. graduations on the frequency scale. The marking can also be done automatically by the Event-Marker when this is controlled from the Frequency Marker Set NT 0100. The Market Set is a devise which has to be mounted on the Automatic Vibration Exciter Control.

If it is desired to determine the frequency f_2 to which a certain point on the recorded curve corresponds, it can be readily calculated from the formula:—

$$f_2 = f_1 \times \text{antilogarithm.*)}\ 0.3010 \frac{x}{l}$$

where

f_1 is the frequency corresponding to the nearest lower octave marking.
x the geometrical length in mm from f_1 to the point to be determined.
l the geometrical length in mm between the octave markings.

Vibration Isolation.

When employing sensitive apparatus in a vibrational environment some sort of vibration isolation is necessary. For this purpose many types of materials and devices are available. To obtain a recording of the effectivity of the type of isolation chosen, the Level Recorder combined with an adequate vibration test system will grant a quick and rational solution to the more complex problems.

Some measurements were carried out to determine the effectivity of a rubber vibration isolator. The measuring arrangement was as illustrated in Fig. 6.33. For control of the vibration test system the B & K Automatic Vibration Exciter Control was employed along with the Accelerometer Preamplifier Type 2622. The controlling arrangement is in principle equal to that described in the previous paragraph "Recording Vibration Sensitivity of Electronic Instruments", with the exception of using an accelerometer as the compressor pick-up so as to ensure a constant vibration level on the shaker table. By

*) Antilogarithm A = B when log B = A.

utilizing an accelerometer in the compressor circuit (servo loop) the Accelerometer Preamplifier Type 2622 is necessary to match the accelerometer to the compressor input. The power amplifier which drives the shaker table is supplied from the Automatic Vibration Exciter Control.

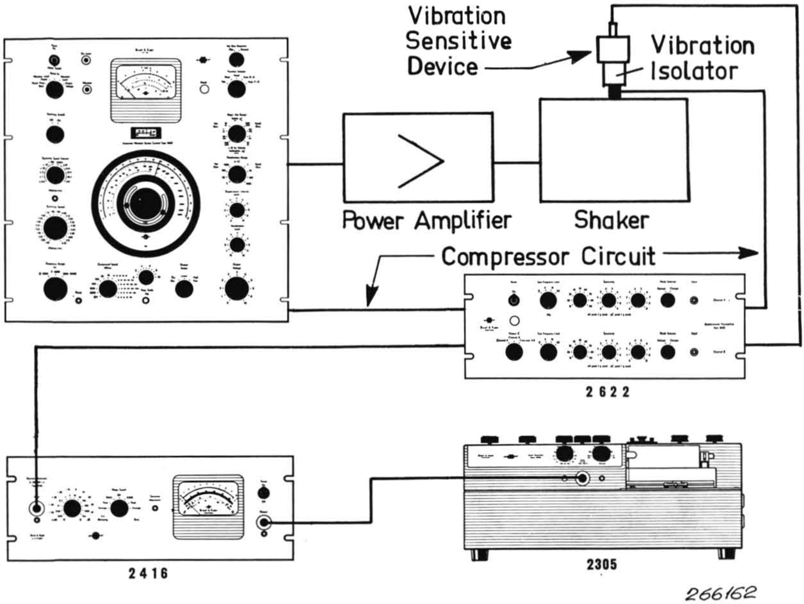

Fig. 6.33. Combination for measuring the effectivity of a vibration isolation installation as function of frequency.

A vibration-sensitive device weighing 360 grammes was mounted on the shaker table but isolated from same by a rubber vibration isolator. For measuring the vibration transferred from the shaker table to the device, a B & K Accelerometer Type 4312 was mounted on the latter. The output from this Accelerometer was applied to the Accelerometer Preamplifier Type 2622 and thence via the amplifier in the Electronic Voltmeter Type 2416 to the Level Recorder.

The equipment was set up to keep constant acceleration level on the shaker table, and the level was adjusted to 1.2 g. The automatic frequency scan was set to 15—4000 Hz (c/s). In Fig. 6.34 is reproduced the recording from the resultant measurement showing the acceleration on the device as a function

*) 1 g = acceleration of gravity.

of frequency. The resonance between the rubber isolator and the mass of the device is clearly seen. Towards the higher frequencies the suspension between shaker table and rubber isolator commenced to resonate, and also environmental as well as internal instrument noise in the employed equipment began to be perceptible. If these spurious signals did not appear, the acceleration should decrease by 6 dB per octave, provided the specimen can be considered rigid.

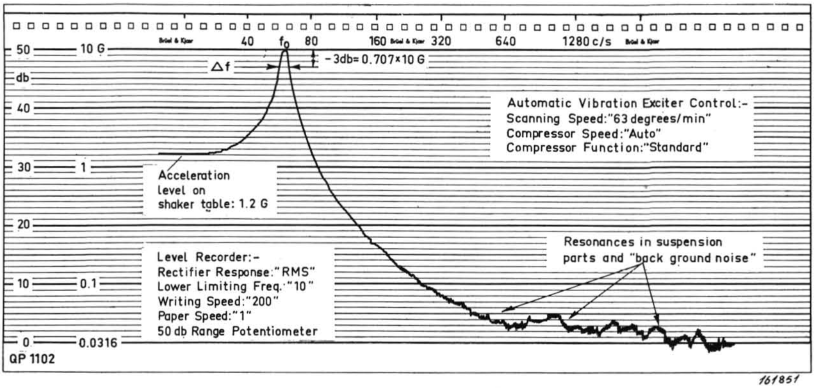

Fig. 6.34. Recorded response of the acceleration measured on a vibration isolated device.

From the recording can be calculated the magnification factor Q of the rubber isolator, presuming that the mass mounted on the isolator is rigid around and below the resonance frequency. The factor is derived from:—

$$Q = \frac{f_0}{\Delta f}$$

where

f_0 is equal to the resonance frequency of the object, and

Δf is the width in Hz (c/s) of the resonance peak at 3 dB (0.707) attenuation relative to the point of the peak, refer Fig. 6.34.

By using the formulae given on page 93 the resonance frequency f_0 was found to be 60 Hz (c/s), and the width Δf at the 3 dB points:—

$$63.8 - 56.9 = 6.9 \text{ Hz (c/s)}$$

The Q-factor was then found to be:—

$$Q = \frac{60}{6.9} = 8.7$$

When utilizing a material in the vibration isolator giving a higher Q the isolation will be better at the frequencies where the isolator is normally used (well above the natural frequency of the system), but the damping will be lower.

Measurement of Reverberation Time.

The Level Recorder constitutes a very important part in any measuring equipment intended for the measurement of reverberation time, as the decay of the sound in the room under examination will be presented as a curve with a particular slope on the recording paper. This method enables the character of the separate decays (measured at different frequencies) to be investigated.

Several methods of exciting the room can be used depending on the number of measurements to be carried out. If only a few measurements are to be made, a pistol or something similar is the simplest form of sound source. When utilizing this method the receiving part of the equipment should always contain a selective instrument which enables measurements to be carried out at different frequencies. In Fig. 6.35 can be seen a measuring arrangement together with an example of two recorded decay curves. The receiving part of the measuring set-up consists of one of the B & K Condenser Microphones, the signal from which is applied to the B & K Audio Frequency Spectrometer Type 2112, and the Level Recorder which then records the output signal from the Spectrometer. When many measurements

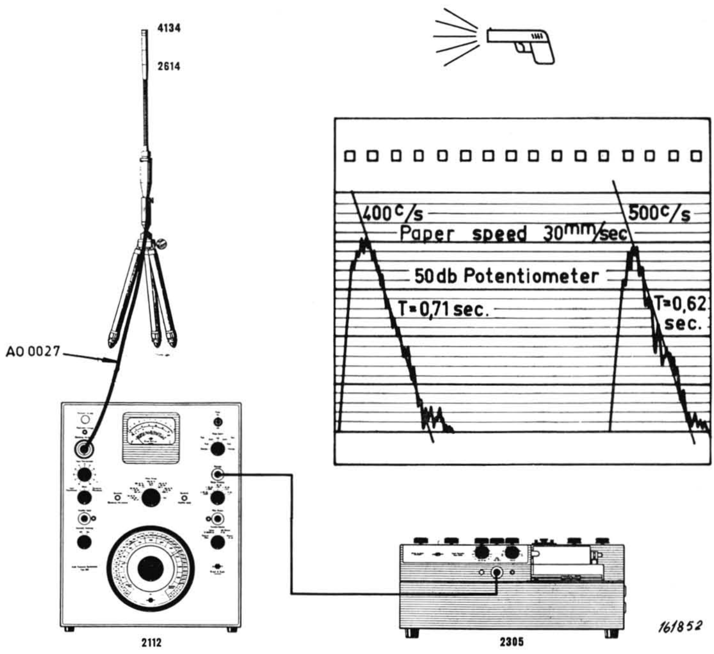

Fig. 6.35. Measuring arrangement for recording of reverberation time. Revolver used as sound source.

have to be carried out, for example in a concert hall, a measuring equipment which works automatically will undoubtedly be the most rational solution. In an equipment which works automatically the gun has to be substituted by a sound source which can be conveniently controlled. To carry this out a frequency-modulated oscillator or a noise generator is commonly used. It is recommended to employ the technique of selective signal reception. A much larger dynamic range will then be available for the decay curves due to a reduction in the system's noise level.

Automatic Measurements.

The B & K Sine-Random Generator Type 1024 is very well suited as a sound source for reverberation measurements. This generator has a narrow band random noise output with continuously variable centre frequency which may be driven in synchronism with the Level Recorder and the Audio Frequency Spectrometer Type 2112. The narrow band of random noise ensures that a great number of eigentones are excited simultaneously around the frequency

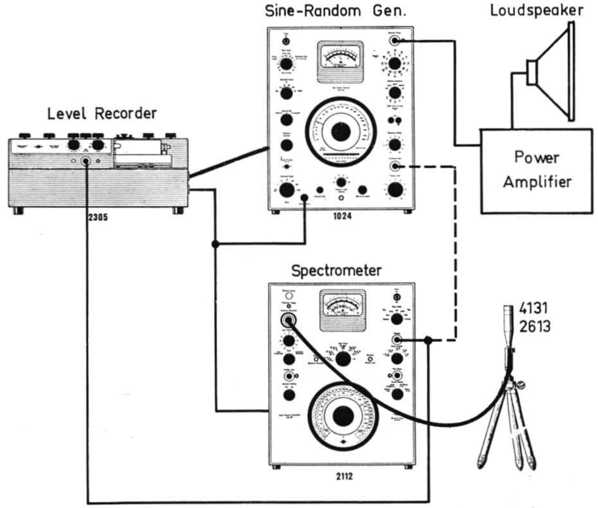

Fig. 6.36. Measuring equipment for automatic recording of reverberation curves.

of measurement. The decay curves will therefore appear with a smoother slope than would be the case with pure sine waves which produce distinct standing waves in the room.

The set-up shown in Fig. 6.36 is suitable for automatic reverberation measurements over the whole audio-frequency range. A loudspeaker is fed from the

Sine-Random Generator which is mechanically driven from the Level Recorder. The receiving section consists of a B & K Condenser Microphone, an Audio Frequency Spectrometer Type 2112 (or Microphone Amplifier Type 2603 when selective measurement is not considered necessary) and the Level Recorder.

For recording the decay of the sound in a room the source has to be disconnected at certain intervals. This is achieved by stopping the Generator. To ensure that only that part of the measurement which is of interest is recorded, the writing pen should lift from the paper in the interval between two decays, and when selective reception is used, the filter in the Spectrometer should switch in successively. The disconnecting of the sound source, the lifting of the pen and the switching of the filters in the Spectrometer can all be controlled by a special switch in the Level Recorder (The Two-Channel Selector). The necessary connections between the various instruments are shown in Fig. 6.37. The mechanical drive for the Generator should be connected to Drive Shaft II of the Level Recorder.

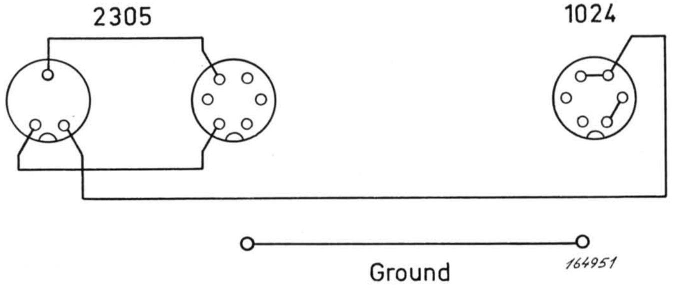

Fig. 6.37. Connections between the automatic control sockets.

Procedure. Connect the instruments as shown in Fig. 6.36 and 6.37. A power amplifier is usually necessary between the Sine-Random Generator and the loudspeaker. The compressor circuit may be employed for keeping the sound pressure reasonably constant for the whole frequency range, but is not really necessary. If a good loudspeaker is used it is better not to use the compressor in order to avoid instability in the loop. See B & K Technical Review No. 4-1955.

Make sure that the Two-Channel Selector is operating by turning the screw shown in Fig. 2.3 on page 26. The two cam discs operating the Two-Channel Selector should be situated on top of each other to give approximately equal "on" and "off" times for the Generator. See Fig. 1.8 on page 14.

Insert a roll of of non-frequency calibrated paper, 50 mm wide (e.g. Type

QP 0402) and adjust the Recorder for 50 mm writing width as described on page 33. The waxed paper and sapphire stylus are employed for best results. The SYNCHRONIZING GEAR LEVER (see Fig. 2.3) should be pushed in. Set the Generator and the Spectrometer to the same frequency, say 200 Hz (c/s), both instruments to "Scanning On" and start a trial run by switching the Level Recorder paper drive to "Forward" and Start". Fine adjust the frequency scanning of the Generator so that the switching off of the power occurs exactly at the frequency indicated by the corresponding filter in the Spectrometer. This may be achieved by setting the DRIVE SHAFT SPEED to a low value, e.g. "3.6", and stopping the Recorder exactly at the moment when the Generator cuts off. The frequency pointer of the Generator is then set to the frequency indicated by the Spectrometer, sweeping from a higher frequency to take up any slack in the driving mechanism. The instruments are now synchronized for all settings of the DRIVE SHAFT SPEED.

Keep the Sine-Random Generator scanning on and adjust the DRIVE SHAFT SPEED on the Level Recorder to give an "off" time of the Generator long enough for the reverberation decay to be measured. Usually 1—3 seconds is enough, corresponding to position "36" or "12" for the DRIVE SHAFT SPEED knob.

The PAPER SPEED knob is now adjusted until the reverberation curves have a suitable slope (about 45°) and the set-up is ready for automatic measurements. All that is required to do is to start recording at the lowest fre-

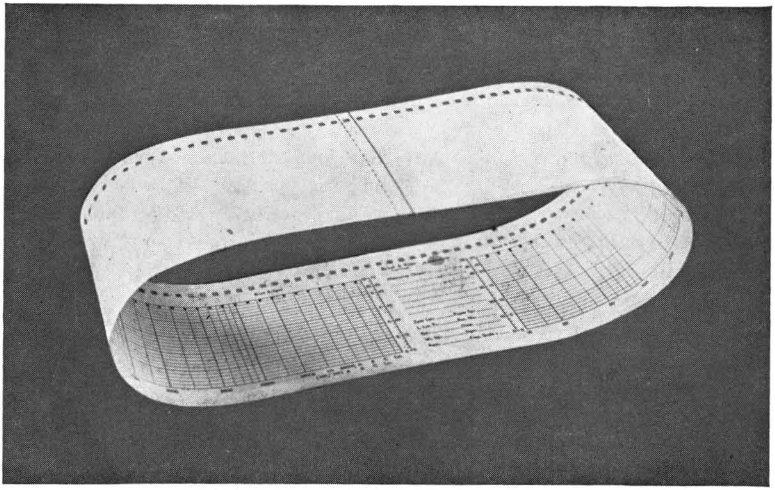

Fig. 6.38. Making up of paper loop.

quency of interest, say 100 Hz (c/s), and the set-up will proceed giving one reverberation curve for each 1/3 octave until it is stopped at the highest frequency of interest, say 8000 Hz (c/s) and all the curves will be recorded on a chart of some 1 m length.

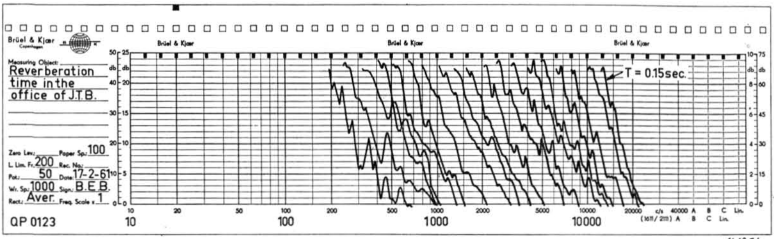

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Fig. 6.39. Example of recording of decay curves. Compressor arrangement used.

Automatic Measurement on Frequency Calibrated Paper.

It is also possible to carry out the reverberation measurements automatically on frequency calibrated paper, where the beginning of each decay curve corresponds with the frequency calibration. The instrument set-up is exactly the same as that in Fig. 6.36 above, but now the recording is done on a paper loop of exactly 495 mm (two chart lengths minus one sprocket hole). By adjusting the PAPER SPEED and the DRIVE SHAFT SPEED knobs so that the paper moves two full chart lengths (500 mm) between each successive lifting of the pen, the reverberation curves will be spaced exactly 5 mm apart, which corresponds to 1/3 octave on the paper. Suitable settings may be PAPER SPEED on "100" and DRIVE SHAFT SPEED on "12" for short reverberation times. For longer reverberation times the speeds should be correspondingly slower, keeping the same ratio between the two knob settings. Synchronizing the instruments together as described for the non-calibrated paper above results in a set-up which gives a set of reverberation curves correctly situated on the paper as shown in Fig. 6.39. Only one chart length is used for the curves.

A more detailed procedure for these automatic reverberation measurements may be had on request.

Noise Generator as Sound Source

Instead of using the Sine-Random Generator Type 1024 as signal source the Random Noise Generator Type 1402 with a suitable power amplifier can be employed, see Fig. 6.40.

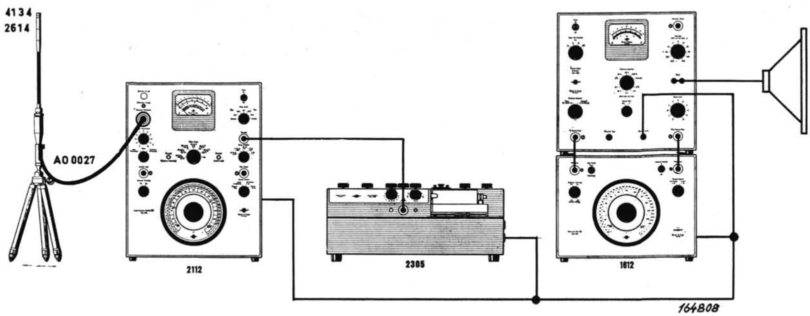

Fig. 6.40. Measuring arrangement employing 1/3 octave bands of noise as signal source.

Switching between the filters in the "transmitting" (1612) as well as the "receiving" end (2112) can be controlled synchronously from the Level Recorder. At the same time the Level Recorder can also control the on/off switching of the Noise Generator so that one reverberation curve is automatically recorded for each measuring frequency, 1/3 or 1/1 octave apart throughout the audio frequency range. The electrical connections between the instruments are shown in Fig. 6.41.

Curves similar to those shown in Fig. 6.39 can then be recorded.

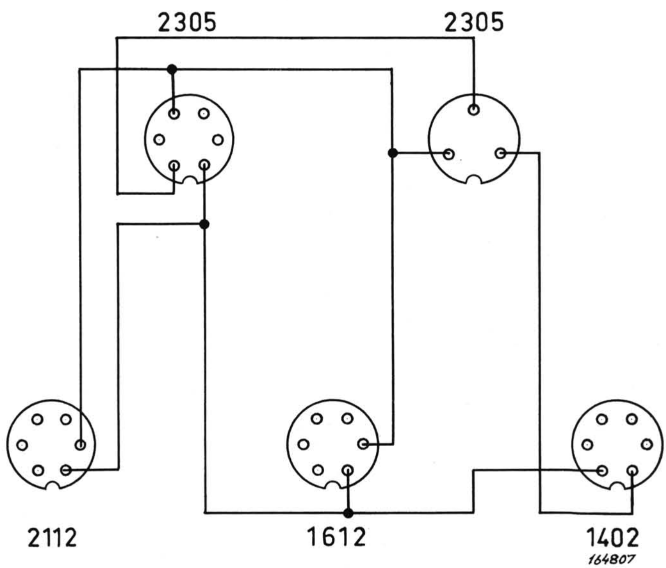

Fig. 6.41. Connections between remote control jacks.

Non-Frequency Calibrated Paper. When a larger spacing than 5 mm between the decay curves is desired (vide example in Fig. 6.42), the recording paper loop used in the Recorder has to be made accordingly shorter as the length of this determines the spacing. For example, a loop length of 490 mm gives 10 mm spacing between the curves. In such instances the recording has to be carried out on the lined recording paper, e.g. QP 0102 or QP 0402, and it is necessary to "mark" one or more frequencies on the paper. The marking can be readily done by means of the Level Recorder's "Event-Marker" arrangement.
Additional Brüel & Kjær literature: Technical Review, No. 3—1956.

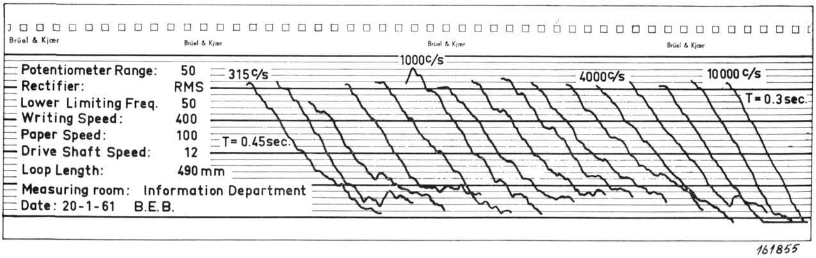

Fig. 6.42. Decay curves at 10 mm intervals recorded on a loop of 490 mm.

Use of the Protractor SC 2361.
The Protractor has been designed to facilitate the determination of reverberation time from recorded decay curves on the 50 mm width paper. It is divided into four sections marked 75 dB 10 mm/sec.; 75 dB 30 mm/sec.; 50 dB 10 mm/sec.; and 50 dB 30 mm/sec. When one of these four combinations of

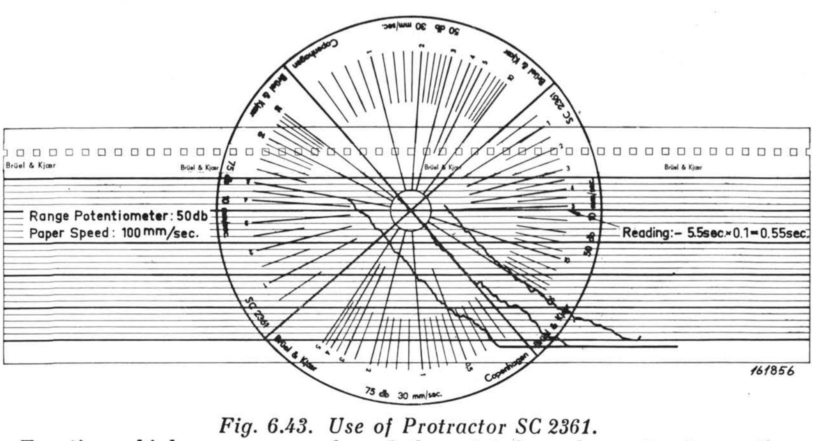

Fig. 6.43. Use of Protractor SC 2361.
Ten times higher paper speed used than stated on the protractor section "50 dB, 10 mm/sec". Reading then divided by 10, i.e. o.55 sec.

RANGE POTENTIOMETER and PAPER SPEED has been employed during the measurements the reverberation time can be read directly in seconds.

1. The Protractor is held so that the printing is readable. The proper section is chosen and its left limiting line (thick diagonal) is placed on top of the portion of the recorded decay curve to be measured, and in such a manner that the centre of the Protractor coincides with one of the horizontal lines on the recording paper. See Fig. 6.43.
2. The reverberation time in seconds is then read on the scale at the point through which the horizontal lines pass.

The decay curves should preferably be approximated into straight lines making it easier to determine the average slope.

If paper speeds other than 10 and 30 mm/sec. have been used, the determined reverberation times should be multiplied or divided by factors of 10.

Example.

50 dB Range Potentiometer.

Paper Speed 100 mm/sec.: Use the section "50 dB 10 mm/sec." and divide the measured result by 10, see also Fig. 6.43.

If the decay curves are recorded on 100 mm paper width, the results measured by the protractor have to be multiplied by 2.

Automatic Examination of Sound Recording/Reproducing Systems.

In research and production of sound systems an automatic measuring arrangement is a great asset. Development programmes for sound recording/reproducing systems can be speeded up considerably when frequency response data are immediately available, and in production it is often a demand that an individual frequency calibration chart should be delivered with a device of high quality. These requirements can be fulfilled by using the B & K automatic equipment.

The Response Test Unit Type 4409 (described under Accessories) in combination with the Level Recorder forms part of an integrated B & K measuring set-up, which makes automatic measurements on complete sound recording or reproducing systems, or parts of such including the transducers. The response is plotted on amplitude/frequency calibrated recording paper.

Frequency Response of Monophonic Tape Recorders.

In automatic frequency response measurements on tape recorders, with combined recording and reproducing head or with separate heads, the Response Test Unit Type 4409 is an important link in the complete set-up. By using various combinations of the B & K instruments, measurement can be carried out on the separate head, or at the other extreme, on the complete tape recorder system including microphone and loudspeaker. Below is given an application where a complete tape recorder is examined.

A test signal sweep is automatically recorded on the tape recorder by using

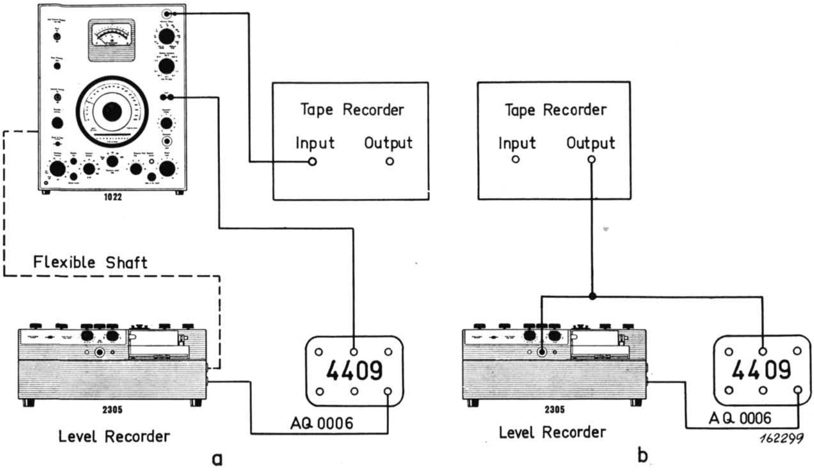

Fig. 6.44. Instrumentation for recording of monophonic tape recorder frequency response.

(a) Set-up by which the recording part of the tape recorder can be investigated.

(b) In this arrangement the recorded tape obtained under (a) is played back and the complete frequency response recorded on the Level Recorder.

the instrumentation illustrated in Fig. 6.44a. By utilizing the 1000 Hz (c/s) reference signal on the Beat Frequency Oscillator the 1000 Hz (c/s) synchronizing signal, necessary for operating the synchro-starter in the Response Test Unit, is recorded on the tape before the sweep.

The recorded tape is afterwards played back on the same tape recorder, employing the measuring arrangement shown in Fig. 6.44b. At the instant when the 1000 Hz (c/s) signal recorded on the tape ceases the Response Test

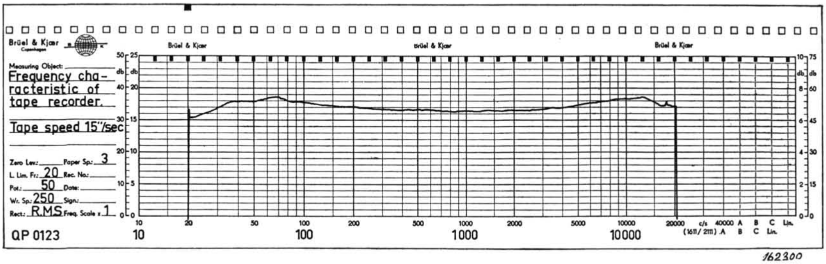

Fig. 6.45. Frequency characteristic of professional tape recorder recorded by the arrangement shown in Fig. 6.44. The peak recorded at the 20 Hz (c/s) line does not belong to the tape recorder response but is due to the 1000 Hz (c/s) synchro-starting signal.

Unit starts the Level Recorder, which now records the output signal level of the tape recorder on amplitude/frequency calibrated paper. Refer to Fig. 6.45, where the complete characteristic is reproduced.

Frequency Response and Cross-Talk Measurements on Stereophonic Systems. In stereophonic systems, automatic measurements of the frequency response of the left and right hand channel can be recorded in one sweep by utilizing a two channel method. Cross-talk between the left and right channel can also be investigated automatically. For making these measurements on, for example, a micro-groove stereophonic reproducing head, instrumentation as displayed in Fig. 6.46 can be used. The test (reference) signal source used is the B & K Stereophonic Gliding Frequency Recordings Type QR 2009 which excites the transducer under examination. The left and right hand signal is applied to the Two Channel Selector section of the Response Test Unit Type 4409. The output of this section is fed to a preamplifier, for instance the amplifier section of the B & K Electronic Voltmeter Type 2409. The preamplifier may be necessary as the input signal level to the following Synchro-starter section should be of at least 100 mV at 1000 Hz (c/s). Between the output of this amplifier and the input of A.F. Spectrometer Type 2112 are inserted the filters built into the Response Test Unit. The output of the Spectrometer, which is used in its ⅓ octave condition, is connected to the Level Recorder. Via the Remote Control Cable AQ 0006, the remote control arrangements of the Spectrometer, Response Test Unit and Level Recorder are interconnected, i.e. the filter switching on the Spectrometer is controlled from the Level Recorder.
On the record are cut several gliding frequency sweeps. A 1000 Hz (c/s) synchronizing signal is recorded before each separate sweep. At the moment where the 1000 Hz (c/s) signal ceases and the sweep commences, the paper-run on the Level Recorder is started via the Response Test Unit. In this manner the preprinted frequency calibration on the recording paper will be

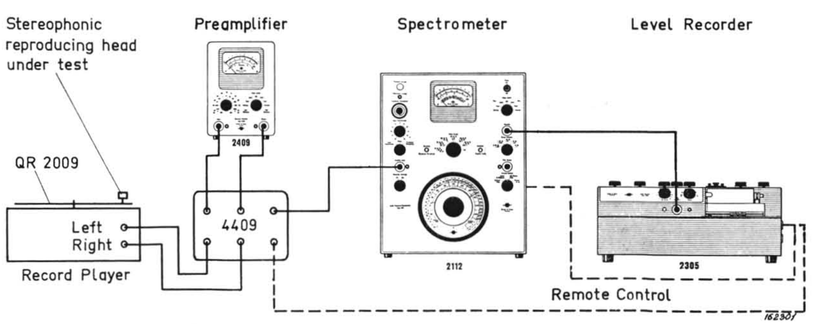

Fig. 6.46. Arrangement for automatic frequency response and cross-talk recording on stereophonic systems.

in synchronism with the frequency from the gliding sweep. Dependent on which track is used on the Record the reproducing head can be excited by four different modulation forms, i.e. 45° left (A), 45° right (B), lateral (A + B), vertical (A — B). By employing the two first tracks cross-talk measurements from channel left to channel right and vice versa can be carried out. Utilizing the third and fourth tracks, comparative frequency response measurements can be made. The desired test signal characteristic, Linear, I.E.C. curve 2 or I.E.C. curve 3 is chosen by a switch on the Response Test Unit. In frequency response measurements it is advantageous to use the Two Channel Selector of the Response Test Unit Type 4409 as the characteristics of both channels are then recorded during one sweep.
Measurements of cross-talk can be done with a selective arrangement as illustrated in Fig. 6.46 or with a non-selective arrangement which is essentially similar to that shown later for measurement on monophonic pick-ups. Selective equipment is required when cross-talk measurements are wanted on systems where the signal in the unmodulated channel is more than 20 dB below the signal in the modulated channel.
In Fig. 6.47 is reproduced a cross-talk and frequency response recording carried out on a reproducing head. The Two Channel Selector section was not working automatically here as the signal of the modulated channel (left) was recorded first. After reversing the recording paper the cross-talk signal in the unmodulated channel (right) was recorded subsequently, with the Channel Selector section in the right channel position. Owing to the

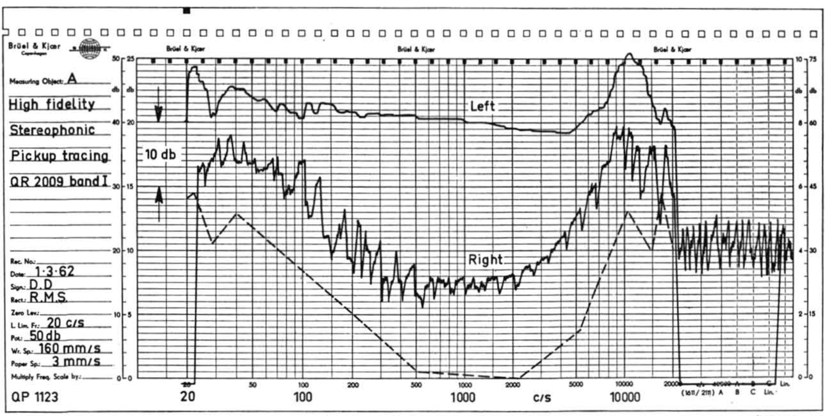

Fig. 6.47. Recording of cross-talk measurement on a high fidelity stereophonic micro-groove reproducing head. The dashed line, seen on the recording, is the limit of cross-talk discrimination measurable by the equipment. The signals above 20000 Hz (c/s) are wide band background noise levels from the Record.

characteristic response obtained when using the A.F. Spectrometer in selective measurements. employing sweeped test frequency signal, the top points of the second recording represent the signal level in the unmodulated channel.

Frequency Response of Monophonic Micro-groove Reproducing Heads.
Micro-groove monophonic reproducing heads can be tested automatically by using the B & K Monophonic Gliding Frequency Records, Type QR 2007. The measuring arrangement is mainly as described for stereophonic systems except that it need not be selective, i.e. a B & K Microphone Amplifier Type 2603 can be used in place of the A.F. Spectrometer Type 2112.

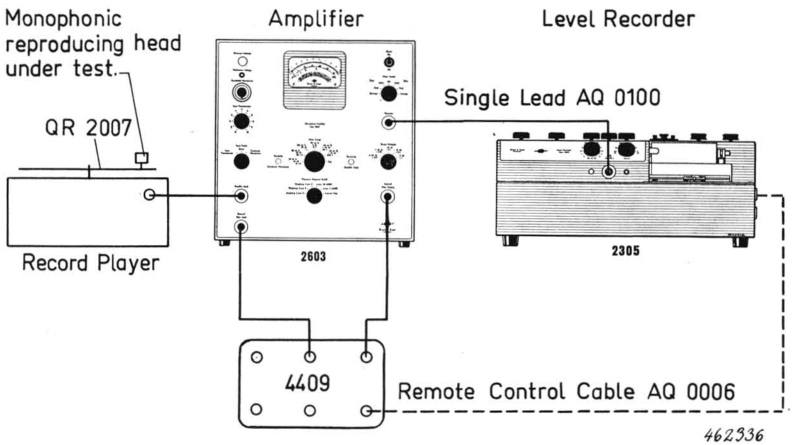

Fig. 6.48. Measuring arrangement for automatic frequency response recording of monophonic systems.

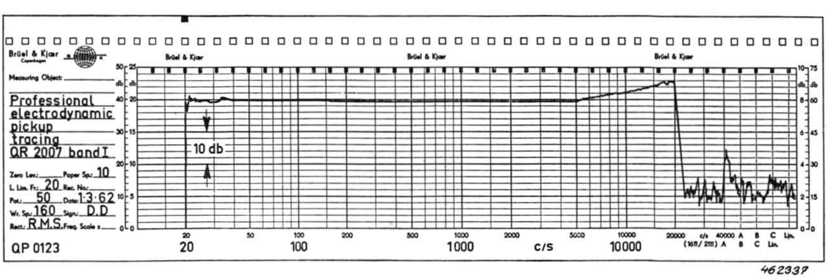

Fig. 6.49. Recorded frequency response of a professional electro-dynamic micro-groove reproducing head. The peak recorded at the 20 Hz (c/s) line does not belong to the pick-up response, but originates from the 1000 Hz (c/s) synchrostarting signal.

The frequency characteristic of a professional electro-dynamic pick-up is reproduced in Fig. 6.49. The Response Test Unit Type 4409 has been used in its linear condition, i.e. the linearity of the pick-up itself can be read from the recording in dB. The noise signal recorded above 20ooo Hz (c/s) is the unavoidable background noise generated from the record.

Complex Modulus Measurements.

In the modern production of automobiles, aircraft, railway carriages, air conditioning units, home-appliances and many other items, the war against noise and vibration is being rapidly intensified. An important step in the reduction of noise and vibrations from mechanical constructions is to cover the various metallic parts with damping materials or to construct the parts directly from high polymer plastic materials which already have high internal damping characteristics. It is obviously advantageous to be able to objectively measure the elastic properties of these materials, which are dependent upon the dynamic modulus of elasticity of the material and its damping factor, i.e. complex modulus of elasticity.

The dynamic modulus of elasticity E* differs from the static modulus*) as in the former the phase shift between the total stress and the strain has to be

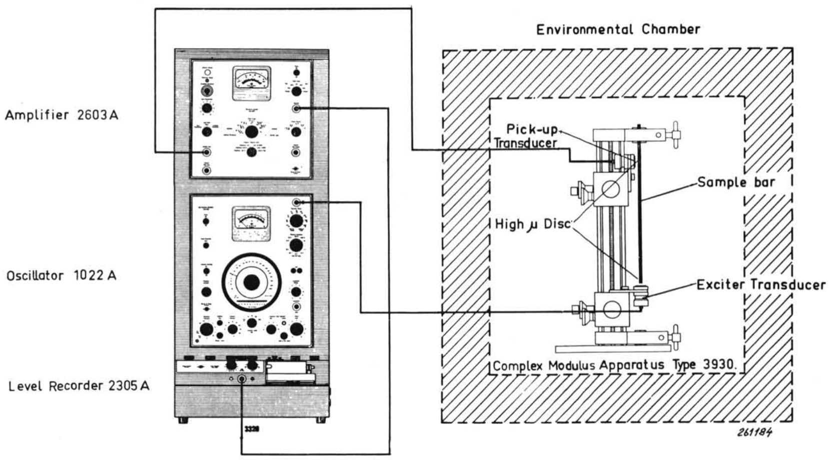

Fig. 6.50. Measuring arrangement for the determination of a material's elastic properties.

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*) Static modulus of elasticity is equal to the ratio between p and e where p is the stress kg/cm² applied to a material, and e its relative elongation (strain).

considered. The damping factor d of a material is equal to tg φ where φ is the angle of phase shift at resonance. From this it is seen that the dynamic modulus E^* can be resolved into two components, a real and an imaginary one. By means of the measuring arrangement described below the real component and the damping factor can be determined.

Measuring Arrangement. The measuring arrangement consists of a mechanical and an electronic section. The mechanical is made up of the Complex Modulus Apparatus Type 3930. This consists of a mechanical fixing arrangement in which the test material is clamped, and where two electro-mechanical transducers are positioned. A large variety of samples can be mounted in the fixture, the maximum dimensions being 12 $\times$ 12 $\times$ 220 mm. The Complex Modulus Apparatus can be placed in an environmental chamber for measurement under varying ambient conditions. It is designed for use over a wide range of temperatures from the extreme low end up to about 250°C (480°F). The electronic section, The Automatic Frequency Response Recorder Type 3329, is a combination of the B & K Beat Frequency Oscillator Type 1022, the Microphone Amplifier Type 2603 and the Level Recorder all mounted in one rack. See also part Combined Units of this book. With this equipment investigations can be carried out in the frequency range 20—20000 Hz (c/s), and the vibration response of the specimen which is clamped in the test jig can be automatically recorded on preprinted frequency calibrated paper.

Measuring Method. As an example a measurement is reproduced completed on a plexiglass bar having the following dimensions: width 0.8 cm, thickness 0.33 cm. The measuring arrangement can be seen in Fig. 6.50. The sample is suspended in the test jig at the upper end, whereas the lower end of the bar is left free. The length of the bar from suspension to free end is 15.3 cm. To enable excitation and signal pick-up from the sample, small pieces of razor blades are cemented on the bar at the points facing the transducers. The output voltage from the Beat Frequency Oscillator is applied to the exciter transducer and the vibration signal from the pick-up to the input of the Microphone Amplifier. The output from this Amplifier is then fed to the Level Recorder, in which a 50 dB Range Potentiometer has been inserted. By synchronizing the Oscillator scan, which is mechanically driven from the Level Recorder, with the frequency preprint on the recording paper, the vibration response of the sample bar can now be recorded automatically as a function of frequency. The obtained result is seen in Fig. 6.51. Five modes of resonances are pronounced at approximately 37, 205, 600, 1200 and 1950 Hz (c/s), the other shown maxima are derived from harmonics in the transducers and resonances in the suspension system. The minimum at approx. 3000 Hz (c/s) is due to the fact that a nodal point of the bar has been opposite the pick-up. From the width (3 dB = 0.707 points) of the individual resonant peaks and their frequency the elastic properties at the various frequencies can be determined.

Investigating materials having low damping, the resonant maxima will, when recorded on frequency calibrated paper, appear as relatively high and narrow peaks, resulting in an uncertain determination of the 3 dB width. By placing

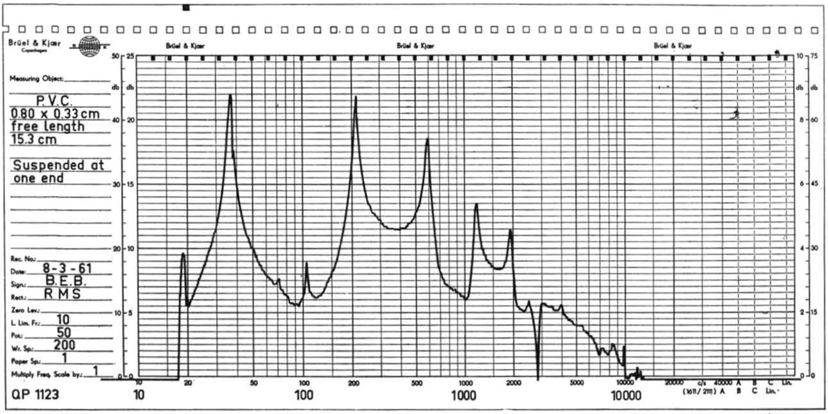

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Fig. 6.51. Recorded vibration response of a P. V. C. sample bar.

the Synchronizing Gear Lever 1 : 10 on the Level Recorder, out of operation a ten times higher paper speed results in a ten times wider resonance peak on the paper. In this case, of course, the frequency calibration of the recording paper cannot be used. If other than 10 times paper speed multiplication is wanted, the internal chain drive of the Automatic Frequency Response Recorder Type 3329 has to be connected to Drive Shaft II of the Recorder. See Chapter 5.

Damping Factor Reading with Q-Rule. A direct reading of the Q-value, which is the inverse of the damping factor d, can be carried out by employing the B & K Q-Rule Type BM 1001. This enables damping factors of approximately 0.01 to 0.3 to be determined. The Q-value of a single degree of freedom and viscously damped system (equivalent to electrical series or parallel resonant circuits) can be calculated from $\frac{f_o}{\Delta f}$ where f_o is the resonant frequency of the circuit and Δf the width of the resonant peak at 3 dB ($\times$ 0.707) below the top. $Q = \frac{1}{d} \simeq \frac{f_o}{\Delta f}$ when $\frac{\Delta f}{f_o} \ll 1$. Since the recording is made with a logarithmic frequency scanning the quantity $\frac{\Delta f}{f_o}$ is in this case dependent only on the bandwidth in mm and on the scanning-rate in octave/mm.

The Q-rule BM 1001 gives direct reading of $\frac{f_0}{\Delta f}$ from the geometrical bandwidth of the resonance curves for the following sweep rates:

scale "10/1": 10 × 15 mm/octave
scale "30/1": 30 × 15 mm/octave
scale "33/1": 33.3 × 15 mm/octave

These sweep-rates correspond respectively to a paper speed which is 10, 30 or 33.3 times the speed of synchronism between the paper graduations and the BFO frequency scale. See Fig. 6.52.

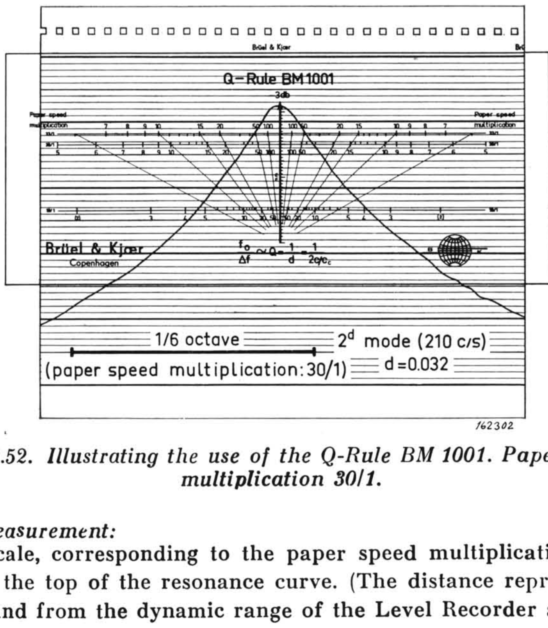

Fig. 6.52. Illustrating the use of the Q-Rule BM 1001. Paper speed multiplication 30/1.

Practical Measurement:

Place the scale, corresponding to the paper speed multiplication employed, 3 dB below the top of the resonance curve. (The distance representing 3 dB is easily found from the dynamic range of the Level Recorder and the paper width in use, e.g. with a 50 dB Range Potentiometer and 100 mm Paper: 3 dB = 6 mm).

Move the scale horizontally until the curve cuts the scale at equal values on each side.

In Fig. 6.52 is illustrated how the Rule is used on a resonant recording of the 2nd mode, 210 Hz (c/s), of the P.V.C. bar. The paper speed multiplication has been 30/1. By employing the respective scale of the Q-Rule a Q-value of 30 has been found. From the Q-value the damping factor d is easily found from $Q = \frac{1}{d}$, i.e. the damping factor equals $\frac{1}{30} \simeq 0.033$.

Damping Factor Measurement by Reverberation Decay Method. Another method of determining the damping factor is to record the reverberation decay curve of the sample. This can be made by means of the same instrumentation. In this case, however, the Beat Frequency Oscillator is adjusted to the exact frequency at which it is desired to measure the damping factor, and the pressbutton marked "Oscillator Stop" is pressed. The decay of the vibrations is then recorded on the Level Recorder and the damping factor calculated from the resultant reverberation time. This method is advantageous when measurements are made on materials with very small damping factors. The inherent losses in the measuring set-up limits the smallest measurable damping factors and are equivalent to a damping factor smaller than 0.001.

Additional Brüel & Kjær literature: Technical Review, No. 4—1957 and 1—1958.

Recording of Strain Gage Measurements.

In strain gage measurements it is often a necessity to register the results, especially when dynamic or multi-point measurements are carried out. When employing the B & K strain gage equipment, static, quasi-static, dynamic and also multi-point measurements can be carried out and recorded by the Level Recorder.

Additional Brüel & Kjær literature: Technical Review, No. 1—1957, 3—1959 and 2—1956.

Recording of Static, Quasi-Static and Low-Frequency Dynamic Measurements.

By combining the B & K Strain Gage Apparatus Type 1516 with the Level Recorder as shown in Fig. 6.53 an equipment for recording static and low-frequency dynamic phenomena is gained. The Strain Gage Apparatus which utilizes all types of resistive strain gages (10—1000 Ω) has a sensitivity (full deflection) from 25 μStrain to 30000 μStrain and covers a dynamic range of 0—300 Hz (c/s) and 20 Hz (c/s) — 100 kHz (kc/s).

For the carrying out of strain gage measurements a linear scale reading is required thus the 10—35 mV Range Potentiometer (ZR 0001) should be inserted in the Level Recorder, and it is recommended to use either of the recording paper types QP 0102 or QP 0402 (50 mm width) or the subsidiary QP 1102 (100 mm width).

As an example Fig. 6.54 is reproduced to show the recording of dynamic strain in the connecting rod on a one-cylinder four-stroke combustion engine under working conditions.

Recording of the instantaneous amplitude of signals with frequencies up to approx. 5 Hz (c/s) is possible for sine waves, when the whole width of the

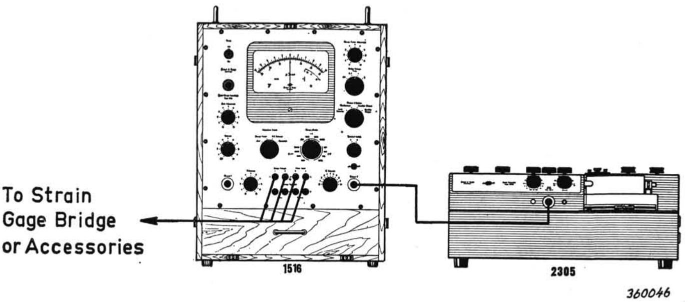

Fig. 6.53. Strain Gage Apparatus Type 1516 combined with the Level Recorder.

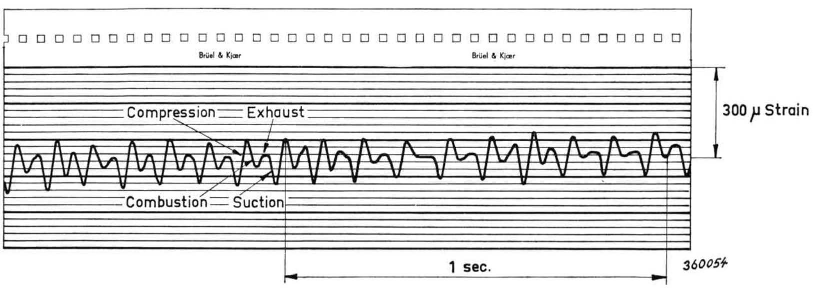

Fig. 6.54. Amplitude-time recording of strain in the connecting rod of a one-cylinder four-stroke combustion engine.

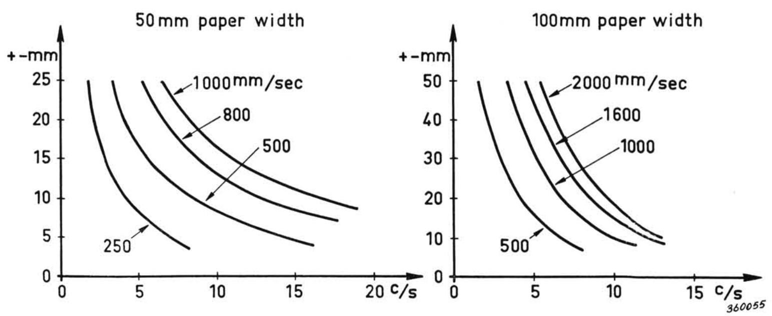

Fig. 6.55. Maximum amplitude of sine-wave versus frequency (writing speed as parameter) which can be amplitude recorded by the Level Recorder when this is connected to the Strain Gage Apparatus.

paper is utilized. When a smaller deflection on the paper is satisfactory, the frequency can accordingly be higher. In Fig. 6.55 is shown the practically distortion-free stylus deflection versus frequency for sine waves.

Recording of Multipoint Measurements.
When the B & K Automatic Selector Type 1542 and one or two Twenty-Point Panels Type 1543 are combined with the Strain Gage Apparatus Type 1516, an equipment for multi-point strain gage measurements is obtained. The combination containing two Twenty-Point Panels allows a maximum of 50 measuring points to be successively scanned. By adding the Level Recorder to this equipment, vide Fig. 6.56 a complete recorded measurement can be carried out.

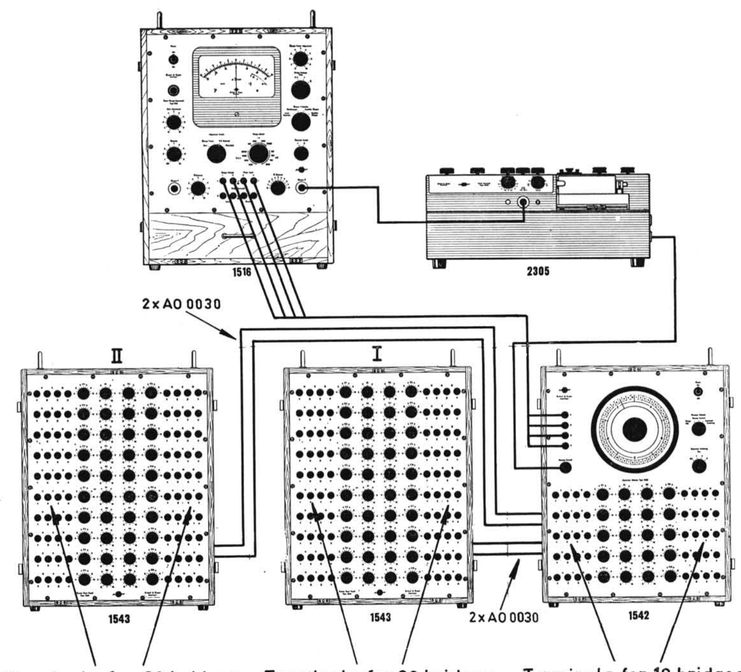

Fig. 6.56. Measuring equipment for multi-point measuring of up to 50 strain gage bridges.

Examples of Recordings. Measurements were carried out on 30 strain gage bridges, vide Fig. 6.57. In cases where not all 50 measuring points are utilized a "fast return" arrangement on the Automatic Selector Type 1542 can be placed in operation, thus ensuring a time-saving swift scan throughout non-connected points. The Position A1, Position B1 etc. stated on the recording refer to the position at a particular instant of the 50-Position Switch in the Automatic Selector.

On top of the recording are seen markings made by the "Event-Marker". One mark is given when the first strain gage bridge is switched in (A1),

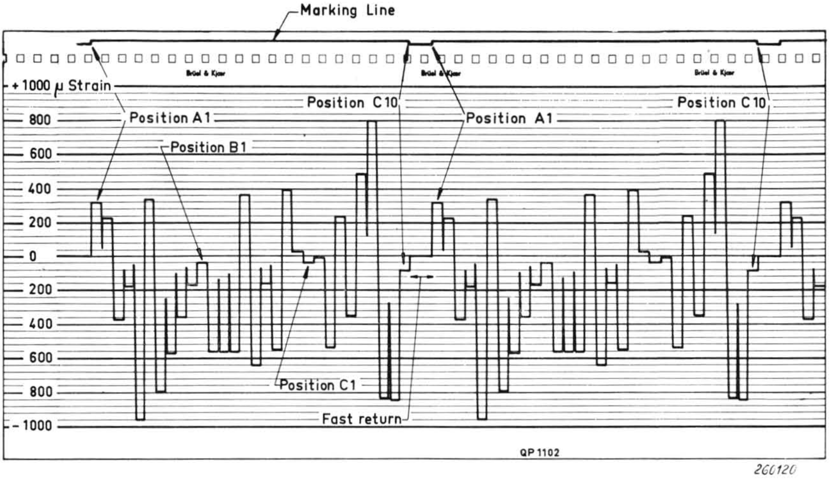

Fig. 6.57. Recording of strain at 30 different points.

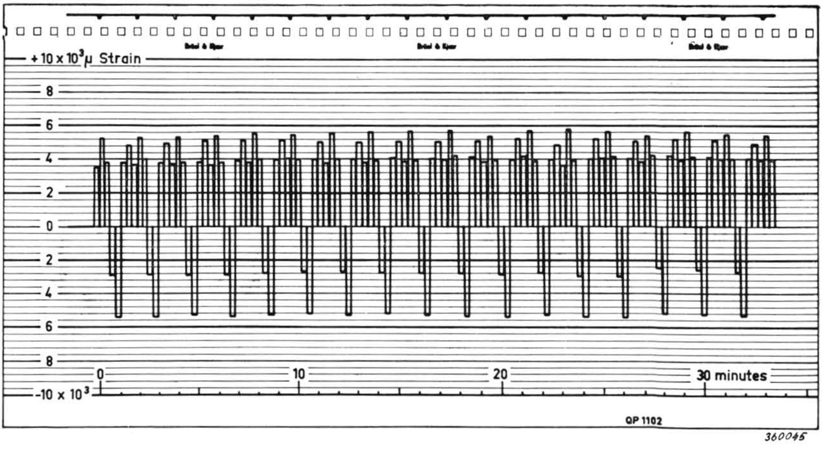

Fig. 6.58. Recording of multi-point measuring carried out over a lengthy period at 7 points.

and another when the last is switched out (in this case C10), here the fast return starts.

In Fig. 6.58 is shown a recording of measurements carried out over a longer period of time. When the Level Recorder "Paper Speed" is known, in this example 0.1 mm/sec, the paper can be time-calibrated, as illustrated by the recording. The number of measuring points (strain gage bridges) in this measurement were seven.

Frequency Analysis with Digital Readout.

The Analog Voltage Readout ZR 0021 described under "Accessories" may be used for obtaining information about the level of signals in digital form, especially when linear to logarithmic (dB) conversion is desired. A dynamic range of up to 75 dB is available. (The Level Recorder potentiometer range). Fig. 6.59 shows a sketch of a set-up which will give the results of 1/3 octave frequency analysis in digital form available on paper tape for feeding into for example a digital computer.

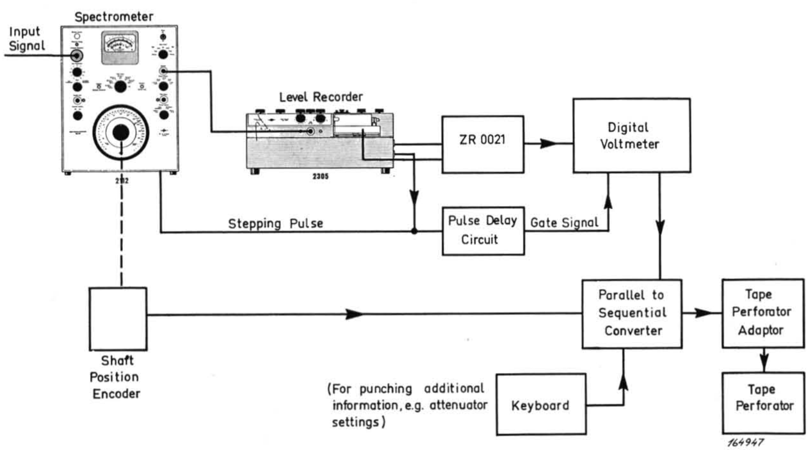

Fig. 6.59. Set-up for frequency analysis in ⅓ octave bands, with punched tape output.

The input signal, for example from an accelerometer, is frequency analysed with a B & K Audio Frequency Spectrometer Type 2112 and the output from this is fed to the Level Recorder Type 2305 fitted with the Analog Voltage Readout. The output from the Analog Voltage Readout is a DC voltage proportional to the input signal level (in dB). This voltage is fed to a digital voltmeter the output of which is sent to a perforator which punches the information on a paper tape.

The stepping pulses from the Level Recorder which are used for switching

the Spectrometer filters are also sent to a pulse delay circuit controlling the triggering of the digital voltmeter (or analog to digital converter). For fluctuating signals the Level Recorder should be set to a low writing speed and the sampling should occur near the end of the time spent in each frequency band, while for steady signals the Recorder may be set to a higher writing speed and the sampling can be taken anywhere except just after the switching over from one filter to the other, where a transient over or undershoot of the Recorder writing arm may take place. See Fig. 6.60.
It may be worth noting that it is possible to add an external voltage supply to the Analog Voltage Readout, which takes into account the attenuator settings of the Spectrometer and the Level Recorder, obviating manual punching of such data.

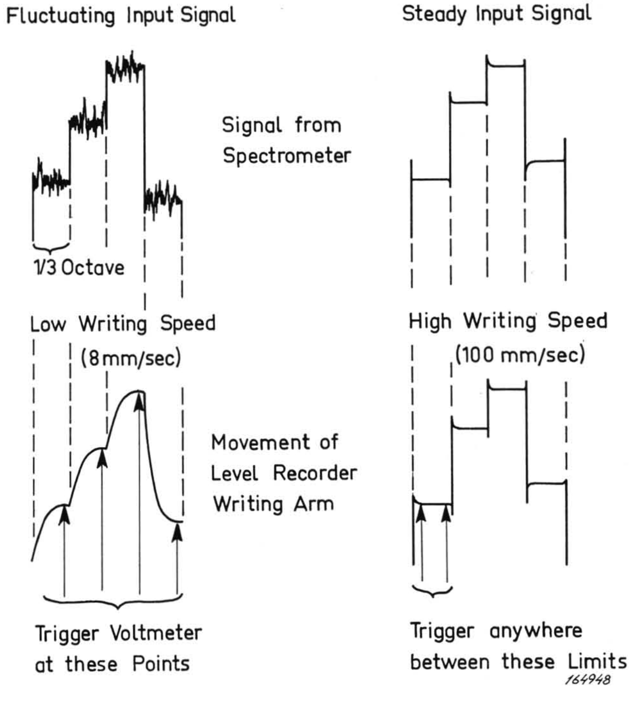

Fig. 6.60. Positioning of trigger pulse for fluctuating and for steady signals.

Appendix

Particular Recording Characteristics of Potentiometer Type Recorders.

Many physical quantities which follow the laws of nature will be more or less randomly distributed around a mean, therefore the fluctuations present in the measured quantities have to be taken into consideration. Dependent on the type of investigation it may be of interest to obtain details of the fluctuations or to smooth them out to a lesser or greater degree in relation to a certain characteristic. The following, therefore, deals with the averaging time characteristics of the Level Recorder when switched to measure the RMS value of a fluctuating input signal. Only the RMS condition of the Level Recorder is discussed as this normally is the one of greatest interest when recording and investigating complex signals. The fluctuations, which it may be of benefit to analyse in detail will mostly be those of the lower frequencies, for in such cases as noise investigations the averaging time of the human ear will limit the distinguishing of fluctuations comprising the higher frequencies.

When looking at the various types of signals which in practice will be recorded by the Level Recorder, one comes to the conclusion that bands of random noise will cover most properties of such signals.*) If a wide band of white random noise is taken the low-frequency fluctuations will contain relatively little energy and will therefore be of little or no interest. By making the band of the random noise narrower, the significance of the low-frequency fluctuations will be increased. The narrow band of white random noise can be looked upon as an amplitude modulated signal where the carrier frequency is equal to the center frequency of the band and where the modulating signal (fluctuations) contains frequencies from zero to that of the bandwidth (presuming that the filter is ideal).

Two circuits in the Level Recorder which display integrating effect mainly determine the possibility of detailing or smoothing out fluctuations in the signal under measurement. These circuits are the LOWER LIMITING FREQUENCY and the WRITING SPEED circuits.

Lower Limiting Frequency.

This circuit caters for the first integration of the signal and averages the "higher frequency" fluctuations. As the frequency of the fluctuations de-

*) See B & K Technical Review No. 4-1960.

creases an incomplete integration takes place, thereby introducing an error in the measured RMS level of the complete signal (e.g. the carrier frequency plus the fluctuations in random noise signals).

Random Noise. From Fig. A.1 can be seen the effect of incomplete integration on recording the level of random noise bands. The error is plotted against the noise bandwidth (narrower bandwidths correspond to fluctuations of lower frequency). The obtained characteristics are independent of the band center-frequency ("carrier") as long as this frequency is higher than the selected LOWER LIMITING FREQUENCY and lower than the highest limiting frequency of the Recorder. Five characteristics are shown, one for each LOWER LIMITING FREQUENCY setting 2, 10, 20, 50, and 200 Hz (c/s). If an error of 0.5 dB in the reading can be tolerated, it can be seen from the figure that in the instance of the "2 Hz (c/s)" characteristic the true RMS of the complete signal can be read corresponding to a bandwidth as narrow as 10 Hz (c/s). (The voltage on the condensers in the Lower Limiting Frequency circuit may be considered constant). Taking narrower bands than 10 Hz (c/s) for the same position of LOWER LIMITING FREQUENCY the

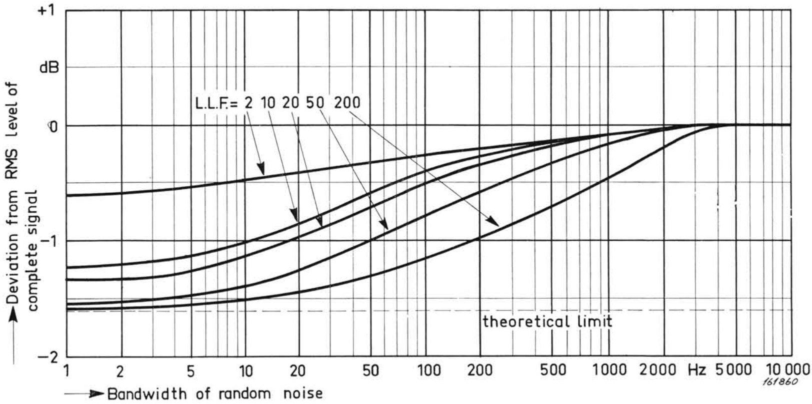

Fig. A.1. Curves illustrating the deviation from the correct RMS level of a complete random noise signal as function of the noise bandwidth. All five settings of LOWER LIMITING FREQUENCY 2, 10, 20, 50, and 200 Hz (c/s) are presented.

deviation from the true RMS reading of the complete signal will reach a value of approximately —0.6 dB*). (The voltage on the condensers in the Lower Limiting Frequency circuit then cannot be considered constant).
From the above can be seen that **when the 50 and 75 dB Range Potentiometers are employed in the Recorder, the error in recording narrow bands**

*) In this region the variation of the RMS value of the "carrier" signal will be recorded, **provided that the "Writing Speed" is high enough to follow. (See next paragraph).**

of random noise will in most measurements be of little or no importance. If necessary, corrections to the recording of the very narrow bands can readily be made by means of the above curves.

High Crest Factor periodic Signals. In measurements where the level of periodic signals with high crest factors*), e.g. pulses, have to be recorded, the averaging time of the Lower Limiting Frequency circuit has also to be considered. For, when set to a too low value (LOWER LIMITING FREQUENCY set to a too high value with respect to the signal) the signal voltage on the condensers in the Lower Limiting Frequency circuit will not remain constant between the pulses, i.e. the RMS value of the signal level will be recorded as too low a value. In order to illustrate this effect a square-wave signal with different crest factors and three different repetition frequencies was applied to the Level Recorder.
The results derived are reproduced in the curves in Fig. A.2a, b and c. From part (b) it can be seen that when an error of —o.5 dB is allowed the recorded RMS level of a signal with a crest factor as high as five will still be correct for signals with a repetition frequency which is approximately four to five times higher than the frequency indicated by the setting of "Lower Limiting Frequency".

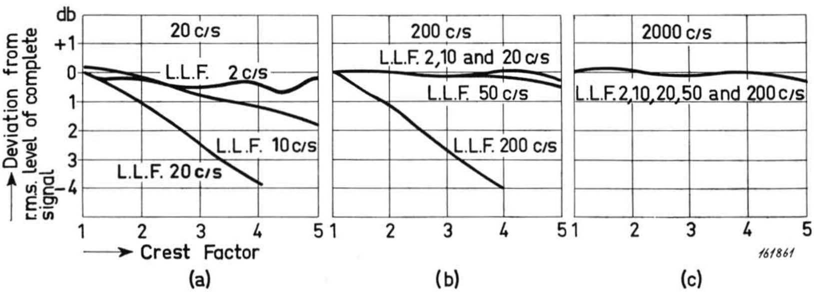

Fig. A.2. Deviation from the correct RMS level of signals as function of the signal crest factor. Measured by using a square-wave signal with various crest factors and repetition frequencies of 20, 200 and 2000 Hz (c/s).

Writing Speed.
This will influence the recording of bandwidths of random noise which are narrower than those given for the —o.5 dB points in Fig. A.1 (for example, a bandwidth narrower than 70 Hz (c/s) for the "10 Hz (c/s)" curve), whereas above this bandwidth the true RMS level of the complete signal is recorded independent of the WRITING SPEED setting. If the WRITING SPEED control is set to a high value, the Recorder stylus will try to follow the fluctu-

*) Crest factor equals $\frac{V_{peak}}{V_{RMS}}$

ation in the RMS level of the "carrier" (modulation frequency). On the other hand, if the WRITING SPEED is set to a low value it will average the fluctuations and tend to show an "average" RMS level (—1.2 dB, Fig. A.1).

In order to judge how high a "modulating" frequency (fluctuations) the stylus will follow, the modulation frequency response of the Writing Speed circuit was measured by applying an amplitude modulated 10 kHz (kc/s) carrier frequency signal to the Recorder input, while the writing system was set for 50 mm paper width. Fig. A.3 shows the response for Writing Speeds of 8, 25, 100, 500 and 1000 mm/sec. measured at four different magnitudes of stylus fluctuations versus the modulation frequency.

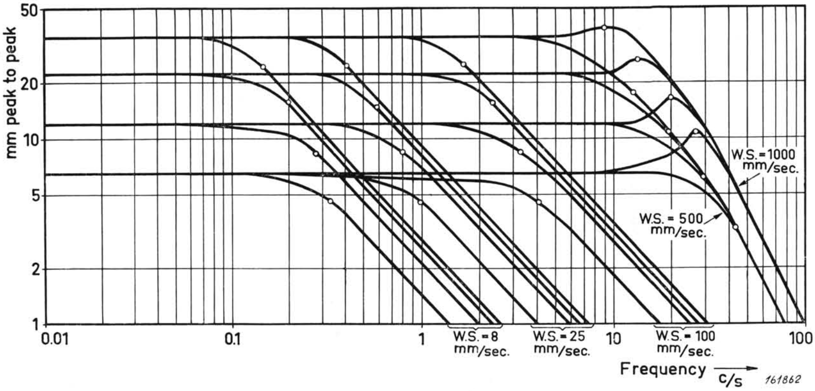

Fig. A.3. Typical frequency responses for various amplitudes of stylus deflection and WRITING SPEED settings.

From the graph it can be seen, that for example, with a stylus fluctuation of 22 mm (peak-to-peak) and a Writing Speed of 1000 mm/sec. (i.e. maximum) the stylus is capable of correctly following modulation frequencies up to around 20 Hz (c/s). By lowering the Writing Speed to 8 mm/sec., only fluctuations up to about 0.1 Hz (c/s) will be recorded correctly, while all higher frequency components at this position of the Writing Speed will be more or less averaged. This averaging effect has been investigated and curves measured of the effective averaging time of the Recorder for various settings of the WRITING SPEED control, refer Fig. A.4.

The measurement was carried out with a stylus fluctuation of approximately 1 dB (RMS) of the complete signal. As the averaging time is dependent on the stylus fluctuations the time T_0 at zero fluctuation was also calculated and is shown in the figure by a dotted line. The Recorder was set for maximum resolving power (POTENTIOMETER RANGE). In addition, on the graph is shown the positions used for the LOWER LIMITING FREQUENCY from which it can be seen that the Recorder has been working in its stable

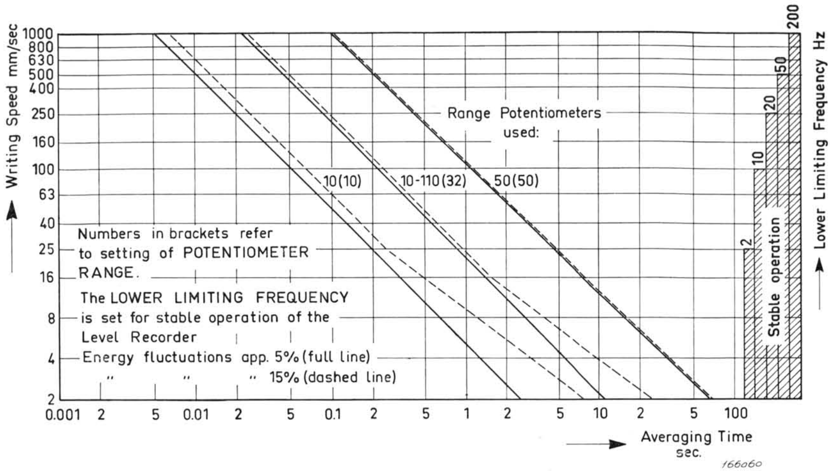

Fig. A.4. Effective averaging time of the Level Recorder Type 2305 plotted against the setting of the WRITING SPEED control knob. THE SETTINGS REFER TO THE LARGE FIGURES INDICATED AROUND THE CONTROL KNOB. The curves are given for standard resolution capabilities corresponding to the range potentiometer used and the setting of the knob marked POTENTIOMETER RANGE dB. Recommended settings of the control knob LOWER LIMITING FREQUENCY for stable operation of the Recorder are also shown.

condition. For the sake of comparison, in the same figure the theoretical effective averaging time of the Lower Limiting Frequency circuit is illustrat-

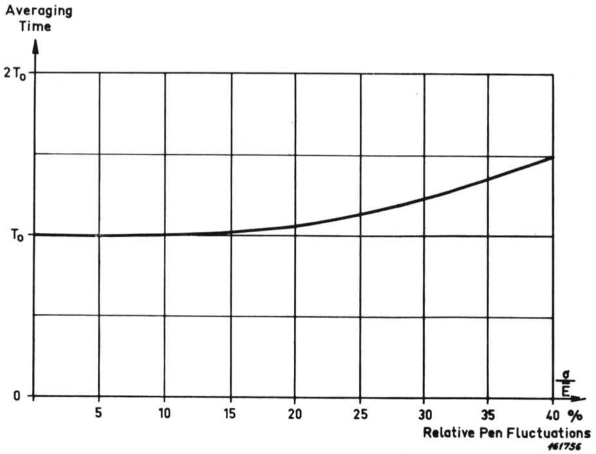

Fig. A.5. Effective averaging time as function of stylus fluctuations. Curve valid for the Recorder when adjusted to high resolving power.

ed by five vertical lines. The lines represent the averaging time for a setting of 2, 10, 20, 50, and 200 Hz (c/s) of the LOWER LIMITING FREQUENCY respectively. The height of the lines illustrates up to which WRITING SPEED setting the Recorder is stable.

In Figs. A.5 and A.6 is respectively displayed how much the integrating time T (referred to zero stylus fluctuations) changes with stylus fluctuation and resolving power (POTENTIOMETER RANGE setting).

For more details and a complete theoretical discussion on the above subject the reader is referred to the B & K Technical Review, No. 4-1960 and No. 1-1961.

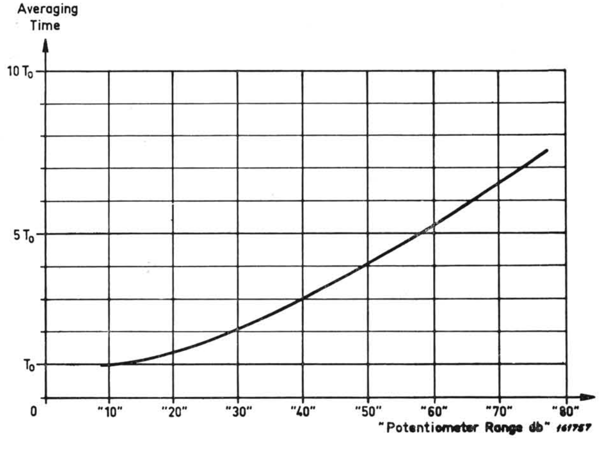

Fig. A.6. Variation of effective averaging time with resolving power. X-axis notation refers to the setting of Recorder control knob POTENTIOMETER RANGE. The curve refers to zero stylus fluctuations (i.e. dotted curve in Fig. A.4).

Influence of Phase Distortion on Complex Signals.

Common Amplifiers will always give more or less phase distortion at their low and high frequency limits. This also applies for the circuits utilized in the Level Recorder.

The phase distortion of a circuit has no influence on the majority of its applications as far as the signal is a pure sine wave or pure sine waves with no phase relation, in other words, when the distinct frequencies do not comprise the harmonics of a signal. If a signal with such a character is rectified and applied to an indicating circuit enabling measurement of true RMS, average or half peak-to-peak value of the signal, a possible phase distortion, caused by passing the signal via an amplifier creating phase distortion, will have no influence on the measured result. On the other hand, if the applied signal has a complex periodic character and thus contains harmonics with a certain phase relationship (as is the case, for example, with a square-wave or triangular signal) the signal shape will be distorted when treated in a circuit which gives phase distortion. Presuming that the amplitude vs. frequency characteristic of the circuit is practically straight in the range of the signal frequency contents the number of harmonics and their original amplitudes are unchanged in the phase distorted signal, however, the wave-shape of the overall signal will be changed. Therefore the following should be noted when the signal is applied to a rectifier circuit which detects the true RMS, average or half the peak-to-peak:—

Measuring RMS: This is by far the most important factor in the majority of investigations. When using this characteristic of the indicating circuit, the phase relationship of the different components of the signal has no influence. **Therefore, by measuring a phase distorted signal with an RMS indicating circuit, the same value will be read as for the undistorted signal.**

Measuring Average: In this case the arithmetic average value of the signal deviates from the value of the original signal when phase distorted.

Measuring Peak: When utilizing the half peak-to-peak property of the indicating circuit a considerable deviation from the original value is measureable when the signal is phase distorted.

Actual Deviation in RMS, Average and Peak Reading. To illustrate the effect of phase distortion of the Level Recorder on complex signals, measurements were carried out by applying a symmetrical square-wave signal to the input of the Recorder. The resultant frequency response at four different positions of "Lower Limiting Frequency" are reproduced in Fig. A.7. As expected the deviation in RMS reading is seen to be zero within the various frequency ranges.

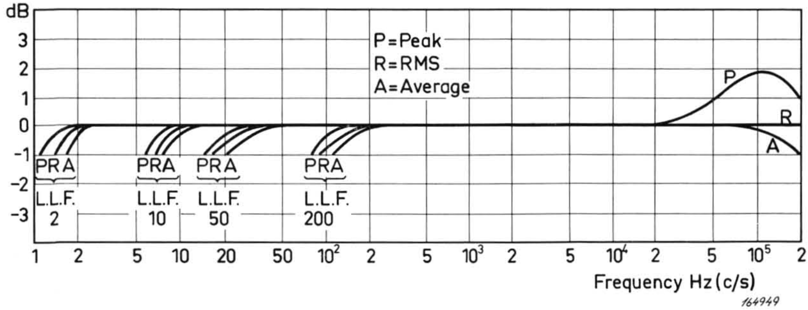

Fig. A.7. Frequency response curves illustrating the effect of phase distortion using a symmetrical square-wave signal.

Specification

ELECTRICAL

FREQUENCY RANGE:

AC:	2—200000 Hz (c/s). ± 0.5 dB (re. 1000 Hz (c/s)) for INPUT POTENTIOMETER in position around "0" and "10"*) ± 1 dB for other positions*)
DC:	Chopped at twice the mains frequency.

MAXIMUM SENSITIVITY: Minimum voltage to give zero deflection of stylus:
AC: 10 mV**) RMS approx.
DC: 20 mV approx.

DYNAMIC RANGE: Determined by the interchangeable Range Potentiometers which are available as:—

Range	Accuracy	Type
10—35 mV. Linear	2 % of full scale	ZR 0001
10—110 mV. Linear	2 % of full scale	ZR 0002
10 dB. Logarithmic (100 mV—316 mV)	± 0.1 dB	ZR 0003
25 dB. Logarithmic (10 mV—180 mV)	± 0.2 dB	ZR 0004
50 dB. Logarithmic (10 mV—3.16 V)	± 0.3 dB	ZR 0005***)
75 dB. Logarithmic (10 mV—56 V)	± 0.5 dB	ZR 0006

RESOLVING POWER: Better than
0.25 mm on scale when adjusted for 50 mm paper
0.5 mm on scale when adjusted for 100 mm paper.

INPUT CIRCUIT:

Input Impedance: 16—18 kΩ, dependent of position of INPUT POTENTIOMETER, parallel with 100—120 pF approx.

Maximum Input Voltage: 100 Volts.

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*) Refer also Fig. 1.2 on page 8.

**) The 10 mV maximum sensitivity applies to all Range Potentiometers except the 10 dB where it is 50 mV.

***) Normally delivered with Recorder.

Input Potentiometer:	Non-calibrated Covers 0—12 dB, continuous variable.
Input Attenuator:	Within ± 0.25 dB, relative to position "0". Six steps of 10 dB
RECTIFIER RESPONSE:	Selectable by a control knob:— RMS ± 0.5 dB for crest factors up to 5. Arithmetic Average. Peak (half peak-to-peak).
WRITING SPEEDS:	Selectable by a control knob. 50 mm paper: 2 - 4 - 8 - 16 - 25 - 40 - 63 - 100 - 160 250 - 400 - 500 - 630 - 800 - 1000 mm/sec. 100 mm paper: 4 - 8 - 16 - 31.5 - 50 - 80 - 125 - 200 315 - 500 - 800 - 1000 - 1250 - 1600 - 2000 mm/sec.
RECORDING SYSTEM:	Electrodynamic. Pulling force 1 kg approx. External arm connection possible.
OVERALL STABILITY:	Better than ± 0.2 dB in deflection for ± 10 % deviation in power supply voltage.
CALIBRATION VOLTAGE:	Built-in square-wave signal at power supply frequency. 100 mV RMS. Stability: Within ± 1 % for ± 10 % deviation of power voltage.
LOWER LIMITING FREQUENCY:	Selectable to 2, 10, 20, 50, and 200 Hz (c/s).

MECHANICAL

PAPER SPEEDS:	Selectable by a control knob. 0.0003 - 0.001 - 0.003 - 0.01 - 0.03 - 0.1 - 0.3 - 1 - 3 - 10 - 30 - 100 mm/sec. derived from a reversible self-starting synchronous motor.
TYPES OF RECORDING:	Rectilinear. Polar: Synchronous drive with B & K Turntable Type 3921.
TYPES OF TRANSCRIPTION:	Pens for ink writing, easily interchangeable for writing in different colours. Sapphire Stylus for writing on wax-coated paper.

PAPER:	Rolls of 50 and 100 mm paper width for ink writing and 50 mm for sapphire writing (wax coating). Various types of preprint. Polar, preprinted in degrees, radius 100 mm, for ink writing.
EVENT MARKER:	Manually and remotely operated. Suitable for ink and sapphire stylus writing.
DRIVES FOR EXTERNAL INSTRUMENTS:	Drive Shaft I and Drive Shaft II can be given speeds of rotation (independent of each other) of o.0036 - o.012 - o.036 - o.12 - o.36 - 1.2 - 3.6 - 12 - 36 and 120 r.p.m. The two shafts can, by means of a Flexible Shaft, be connected to the scanning mechanism of other instruments, e.g. the Beat Frequency Oscillators Type 1017, 1022 and 1013 and the Frequency Analyzer Type 2107. Allowable max. mechanical load on the Drive Shaft outputs: 2 kg cm. Built-in switch supplied for control of the Spectrometer Type 2112 filter selector.
REMOTE CONTROL:	Various, such as: Start-stop, single chart, lifting of pens and event marking.
TWO-CHANNEL SELECTOR:	Can be used for successive recording of two signal levels, time marking, etc.

MISCELLANEOUS

TUBES:	5 × EF94 (6AU6) — 2 × EL95 (6DL5) — ECF82 (6U8) — 2 × EL84 (6BQ5).
POWER SUPPLY:	100 - 115 - 127 - 150 - 220 - 240 Volts AC (50 or 60 Hz (c/s). Specify frequency when ordering. Power consumption 115 W approx., 145 W with motor running.
CABINET:	Steel cabinet: Type 2305A. Mahogany cabinet with handles and lid: Type 2305B. Steel cabinet for mounting in 19″ rack: Type 2305C.

DIMENSIONS (Steel cabinet):	Height: 21 cm (8½″), Width: 48.5 cm (19″), Depth: 29 cm (11½″).
WEIGHT:	25 kg (55 lbs.).
SUPPLIED ACCESSORIES:	Range Potentiometer 50 dB ZR 0005 (if other not specified). Inking Kit QI 0001 containing 3 writing pens and 1 event marker pen, all for ink. Also 10 cartridges of red, 10 of green and 10 of black ink. Writing sapphire. Event marker sapphire. 2 rolls of recording paper (QP 1102 and QP 0202). Paper cutting blade. 1 Screened plug JP 0018. 6 interchangeable cam discs for the Two-Channel Selector. Protractor to be used for reverberation measurements. Various plugs, lamp, fuses (medium lag) and power cord.

B K

ORBOE PRINT . COPENHAGEN . DENMARK

November 1967