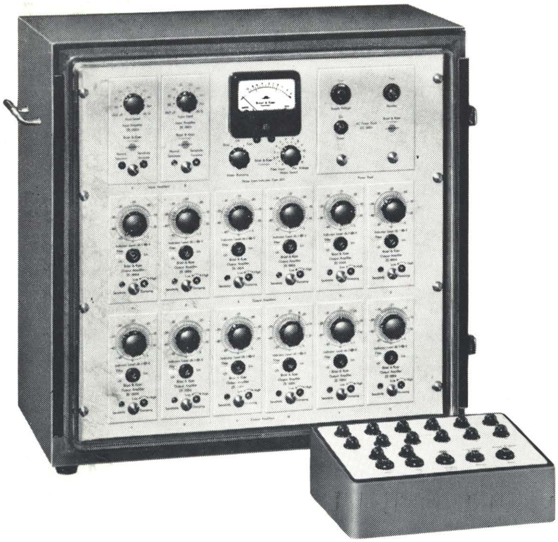
2211

INSTRUCTIONS AND APPLICATIONS

Noise Limit Indicator
Type 2211



Type 2211 Noise Limit Indicator is a noise and vibration analyzer designed to keep control on the noise or vibration produced by units leaving a production line.

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BB 2211

Noise Limit Indicator

Type 2211

Reprint April 1963

Contents

Introduction

The Noise Limit Indicator is an instrument designed to provide a rapid and accurate evaluation of the quality of products on a production line with respect to noise and vibration. This is achieved by measuring the noise and vibration of every unit leaving the production line and comparing the result with the noise and vibration level obtained from the "standard" unit.

The instrument has been designed to offer the utmost simplicity in operation. After setting-up, an unskilled worker can easily interpret the indicating panel and thereby the acceptance or rejection of the unit manufactured. Rejections are indicated by red indicating lamps. In this way the possibility of confusion or errors from meter readings is completely eliminated.

The instrument measures noise and vibration in several frequency bands (up to 12 bands) simultaneously. The operator's job is simplified to such a degree that he only presses a button and notes if any lamp lights up. If

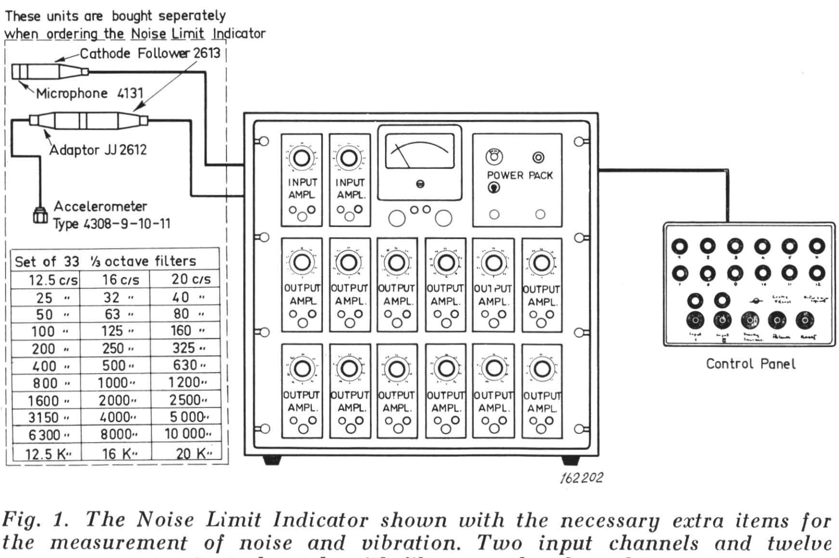

Fig. 1. The Noise Limit Indicator shown with the necessary extra items for the measurement of noise and vibration. Two input channels and twelve output channels with filters can be plugged in.

a lamp lights, the operator labels the unit just tested with a number corresponding to that of the lamp, and directs the rejected unit to the repair shop. The number of the indicating lamp informs the repair shop of the frequency at which the presset limit has been exceeded, thereby often giving the shop a hint as to which problem has to be corrected.

The total operation time for the assessment by the apparatus is extremely short. When set-up practically, the testing for noise and vibration can normally be carried out in less than ten seconds for each unit.

The apparatus is devided into units so that only the transducing elements, i.e. the microphone or vibration pick-up, need to be near the production line. The main unit containing the amplifiers and filters can be placed some distance from the production line and the control panel with indicating lamps may be placed wherever it is found most convenient for the operator. As shown in Fig. 1 the main assembly containing power supply, meter circuit, input amplifiers and output amplifiers is, together with the control panel, supplied as the basic assembly to which can be added a condenser microphone, a vibration pick-up, and as many filters as are found necessary for the measurements in question. Microphone and vibration pick-ups are readily connected by plugs on the rear of the instrument, and output amplifiers and filters are made as plug-in units which are easily interchangeable. The electrical and acoustic specification of the instrument is fully described on page 43—44.

INTRODUCTION TO NOISE AND VIBRATION MEASUREMENTS ON PRODUCTS

The measurement of noise and vibration may be carried out in several ways, depending upon the purpose of the measurement. Some of the most commonly used methods are discussed below in order to give a summary of the reasons for measuring noise from production line units in frequency bands. Noise and vibration in most respects act in a similar manner, thus the term "noise" will be used, and vibration will only be mentioned where noise and vibration act in a different way.

Some of the most common methods of measuring noise levels are:

a) wideband measurements, i.e. by means of instruments with a uniform response to all audible frequencies.

b) noise measurement with instruments that have "weighted" characteristics.

c) frequency analysis of noise.

d) measurement in selected frequency bands, i.e. with instruments that measure noise in certain pre-selected frequency bands only.

a) Wideband Measurements*

When making wideband measurements of noise levels, an instrument is used that responds equally to noise of all frequencies within the audible range, which is from 20 c/s to 20000 c/s approximately. This means that the measuring instrument gives the same indication for all sounds of equal physical "strength", whether the sound is of low, medium or high pitch. When measuring noise containing several frequencies, the wideband measuring instrument will deflect to a value which is proportional to the sum of energy contents in all the different noise frequencies represented. See Fig. 2. This type of measurement is used where it is desired to measure the overall *sound pressure level* at a certain place. (S.P.L. in db is usually with reference to the accepted hearing threshold: 0.0002 μbar).

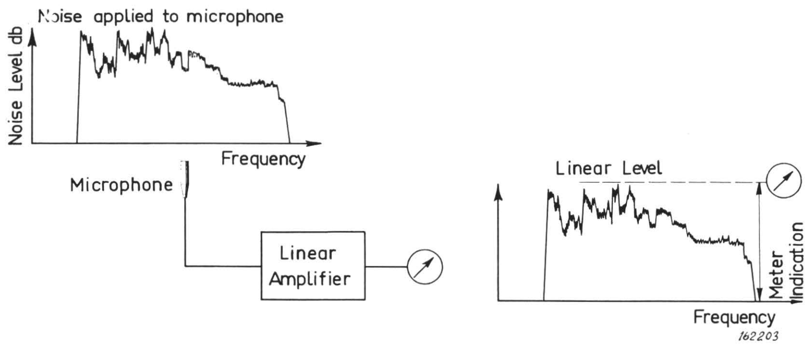

Fig. 2. Wideband measurement of noise. The meter will give an indication which is slightly above the top of the highest peak noted in the frequency spectrum. Noise of all frequencies passes unattenuated to the meter.

b) "Weighted" Measurements.

Weighted measurements are measurements taken with instruments which have response curves that, to a certain degree, follow those of the human ear. The human ear appears to be most sensitive to medium frequencies and is therefore not so irritated by low or high pitched noise. The frequency response of "weighted" measuring instruments is then shaped in such a way as to approximate the sensitivity curves of the human ear. This is normally done by insertion of one or more filters in a wideband amplifier. Three different filter characteristics have been internationally standardized for this purpose.

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*) An instrument with a **wideband** response may also be referred to as one with a response which is **linear, overall,** or **flat.**

In the measurement of noise containing several frequencies, the instrument measures the noise as the sum of the energy contents after the frequency weighting has taken place, see Fig. 3. Weighted measurements are mainly used in cases where it is desired to investigate noise interference of working conditions etc. The result read off an instrument with weighted characteristics is the *sound level* (different from sound *pressure* level) and is stated in db SL (= db de. 2×10^{-4} μbar), curve A, B or C.

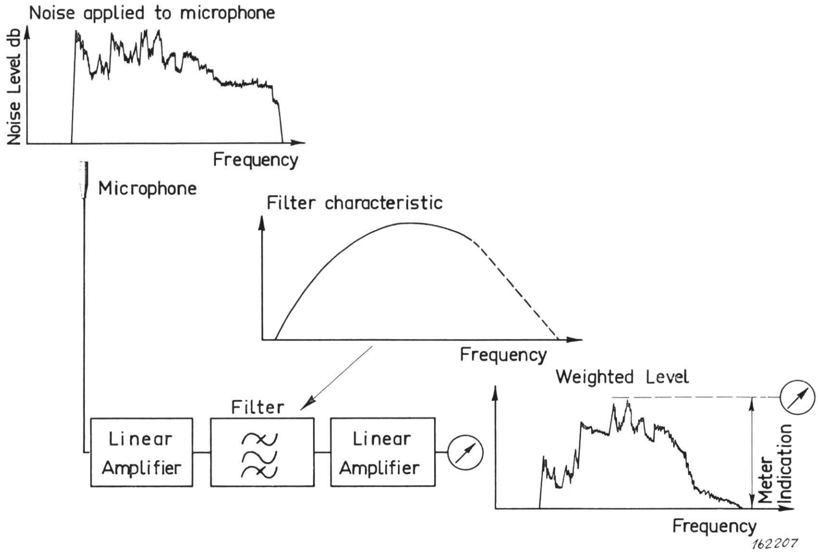


Fig. 3. Weighted measurements. As shown the noise spectrum is shaped by means of a filter so that parts of the noise is depressed and only the medium frequencies are allowed to pass unattenuated. That means that the medium frequencies have a predominant influence on the meter indication.

c) Frequency Analysis of Noise.

Frequency analysis is carried out by instruments that are capable of selecting and measuring specific noise frequency bands only, although several other noise frequencies may be present. The frequencies can be selected by means of a series of filters which are successively inserted in a wideband measuring instrument, and which make the instrument sensitive to only a certain frequency band at a time, see Fig. 4. Usually in noise measurement the audible frequency range is divided into a number of bands of equal relative bandwidth. Thus, an octave band analyzer divides the audible range into 10 bands, each with the width of one octave; a ⅓ octave band analyzer divides

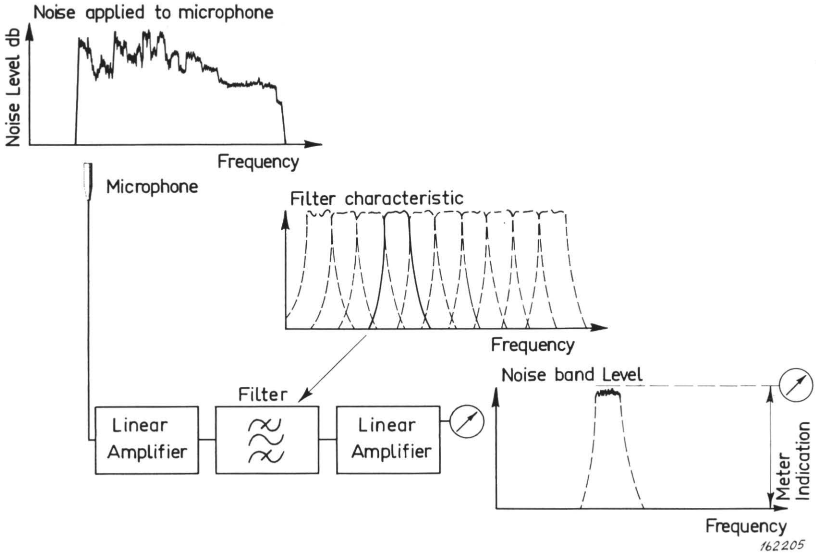


Fig. 4. Analysing noise by means of a series of narrow band filters that can be inserted successively in the amplifier. Only the noise having a frequency that falls within the range of the inserted filter is passed to the meter. The meter indication in this way becomes frequency dependant.

the range into 30 bands, each ⅓ octave wide. An example of such an analyzer is the B & K Type 2112 mentioned on page 11. With an analyzer of this type the *noise band level* can be measured at any arbitrary frequency without any disturbing influence from other (and perhaps "stronger") sounds arriving at the microphone simultaneously. In this way it is possible to investigate which frequencies are predominant, measure their "strength" and character and thereby arrive at a method for treatment of the noise problem. Bands narrower than ⅓ octave are not normally used in noise measurements; however, in the investigation of vibration, an analyzer with filters having a width of less than ⅓ octave would often be employed. The B & K Type 2107 is an example of such an analyzer.

d) Measurements in Selected Frequency Bands.

Once laboratory investigations have been carried out upon objects from a production line (or on the prototypes) and the noise and vibration generated by the objects is analysed e.g. by means of an analyzer as mentioned above, it can be calculated which of the noise frequencies must be checked in production. Often, attention may be confined to certain important frequencies only, and other bands ignored. A special instrument which measures these particular noise frequencies (see Fig. 5) can then be used to check the units from the production line. Such an instrument is the Noise Limit Indicator Type 2211. It measures noise or vibration in a number of pre-selected frequency bands simultaneously. The bandwidth can be chosen to be 1 octave or ⅓ octave, depending on the conditions.

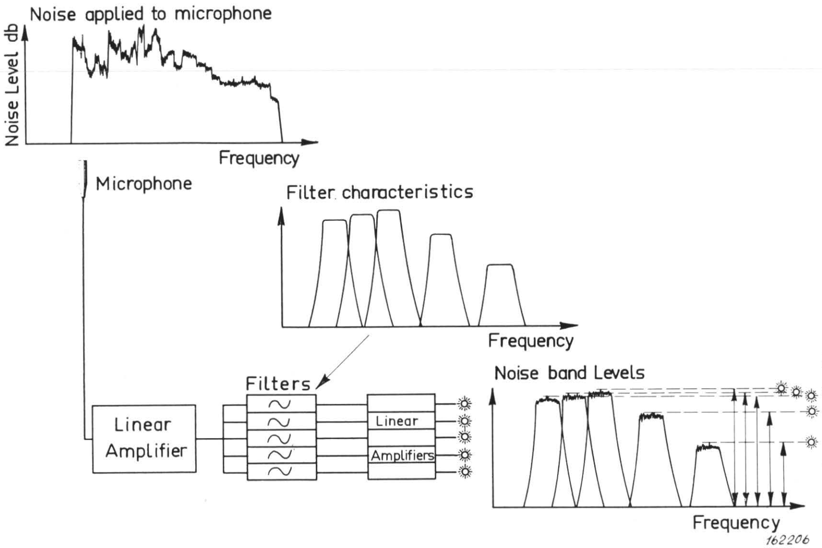


Fig. 5. This figure shows the measuring principle of the Noise Limit Indicator. Several filters are inserted. The meter is substituted by red lamps, so that there is an indicator for e a c h filter. Thereby the excess of the noise band limits of several filters can be indicated simultaneously. The filter attenuation can be adjusted for each filter individually.

The noise frequency bands and the levels set as the maximum limit for each of the bands selected should be chosen as a result of careful laboratory investigation of the object to be examined. It may also be desirable to keep a check on the overall noise level of the object by means of wideband and weighted measurements. The Noise Limit Indicator is capable of checking a number of *pre-selected frequency band levels as well as the overall noise level, both wideband and weighted, simultaneously.*

CAPABILITIES OF THE NOISE LIMIT INDICATOR

The equipment can be used for a wide range of tests, since a number of measurements can be carried out simultaneously with the Noise Level Indicator. Some af the most commonly used measurements that can be made with the instrument are:—

1) Simple "go-no go" testing for noise or vibration or both simultaneously (see Fig. 6a).

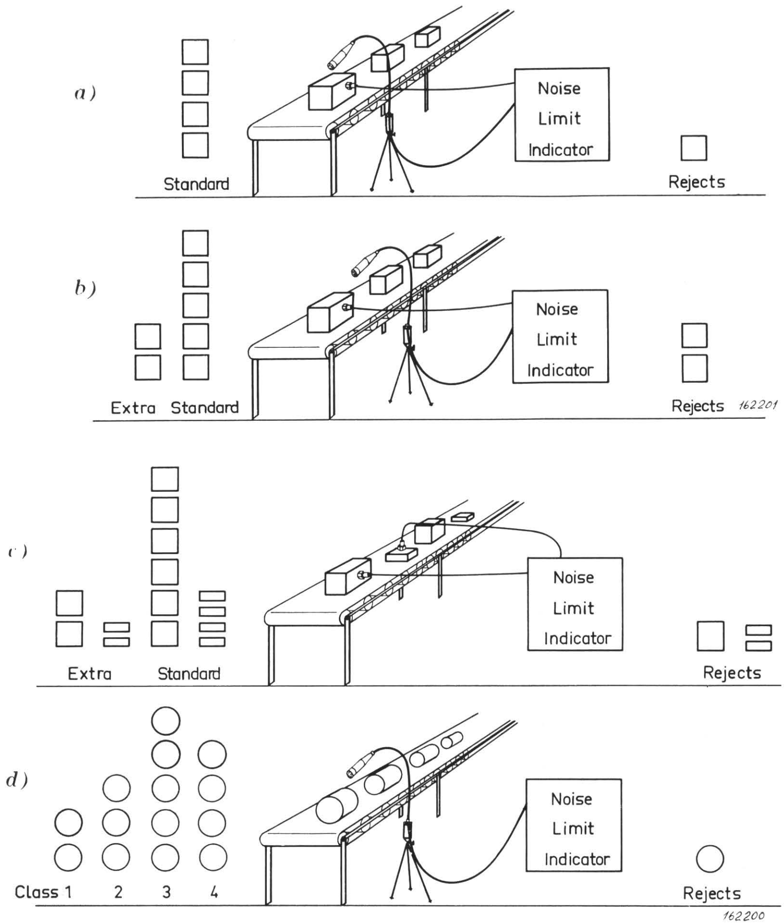


Fig. 6. Different measuring possibilities with the Noise Limit Indicator.

a) Simple testing dividing the objects from a production line in "rejects" and "standards" with respect to noise and vibration.

b) Same as a), but additionally dividing the approved objects in two classes, "standard" and "extra".

c) If only one check of the noise or vibration of a unit is required, the two inputs of the instrument may be used to serve two production lines or two kinds of products on a line, e.g. two types of motors, each with its own noise frequencies and limits.

d) When investigating the noise or vibration level of a series of units, the instrument may be used to divide the units in 3, 4 or 5 classes as regards noise or vibration.

2) Testing of units as in 1 but additionally dividing the "go" objects in two classes: "Standard" and "Extra" (Fig. 6b).
3) Dividing units into three classes, "extra", "standard" and "rejects" with respect to noise only, checking two types of units. Alternatively tests on one type of units from two directional points. (Fig. 6c).
4) Dividing units into three classes as above with respect to vibration only, checking on two types of units, or on one type of unit at two positions.
5) Dividing one type of units into 3, 4 or 5 classes with respect to noise or vibration (only one microphone or accelerometer is needed) (Fig. 6d).

Several other combinations are possible depending upon the purpose. Each of the two input amplifiers can be connected to a microphone or accelerometer, so as to employ either two microphones, two accelerometers or one microphone and one accelerometer.

Which data must be known before the Instrument is used.

As the Noise Limit Indicator is not an analysing instrument, certain investigations must be carried out before it can be used. In order to correctly adjust and use the Noise Limit Indicator the following factors must be predetermined:

I. The centre frequencies and the width of the frequency bands that must be checked.
II. The maximum noise and/or vibration limit for each band.
III. The ambient conditions under which the measurement should be carried out.

In certain cases, for instance in the production of motors, gear boxes or other items which are manufactured to customer's specification, these factors may be given by the customer as part of his specification. It is then extremely important that item III above is carefully specified. Under "ambient conditions" it is necessary to state:

1. Ambient noise or vibration level.
2. Properties of the measuring room or chamber, i.e. hard walls, non-reflecting walls, dimensions etc.
3. Exact location of object and microphone within the room.
4. Mechanical conditions of object such as:
   a) loaded or idle running.
   b) method of suspension, i.e. under simulated working conditions or on special test stand, in the latter case the stand must be described.
5. For vibration measurement, the method of fastening the vibration pick-up as well as the exact point where it must be placed.
6. Other special requirements such as temperature, prior treatment, etc. etc.

In other words, it is necessary to lay down a specification which is detailed enough to ensure that the test conditions relevant to requirements I and II can be reproduced.

In most cases the requirements for noise or vibration limits are not available in the form of well-defined specifications. The usual quality reference is a standard unit which meets the customers' requirements and which has to be reproduced within certain tolerances. The problem then is to carry out measurements on this object in order to obtain the information required in I and II. The ambient conditions for the preliminary measurements should be similar to those under which the unit was approved. Later, in production, the ambient conditions may be different, so it is then necessary to investigate what changes in the noise field the change of ambient condition has introduced.
In order to investigate the noise and vibration generated by a standard unit, an arrangement as shown in Fig. 7a can be employed.

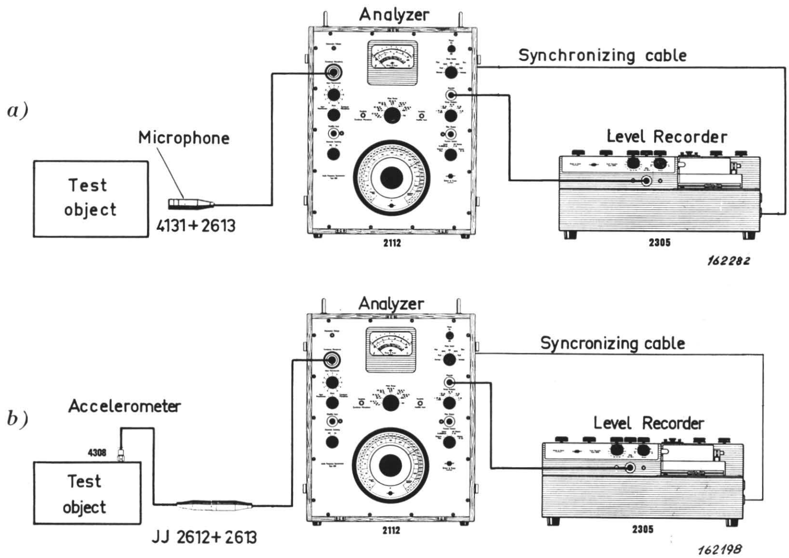
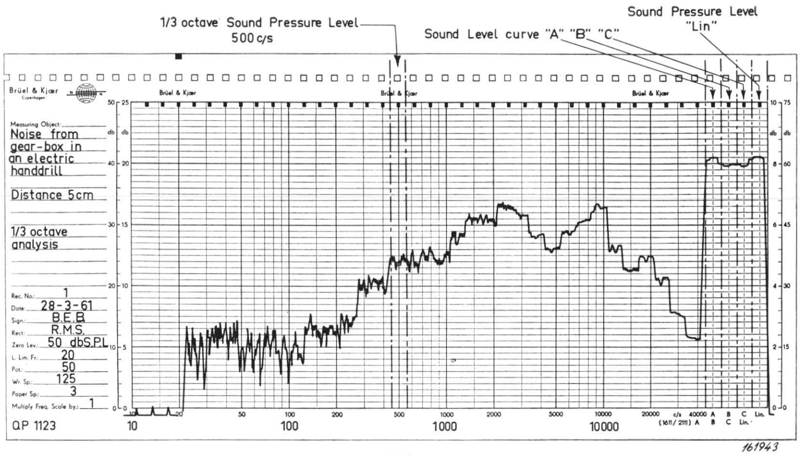


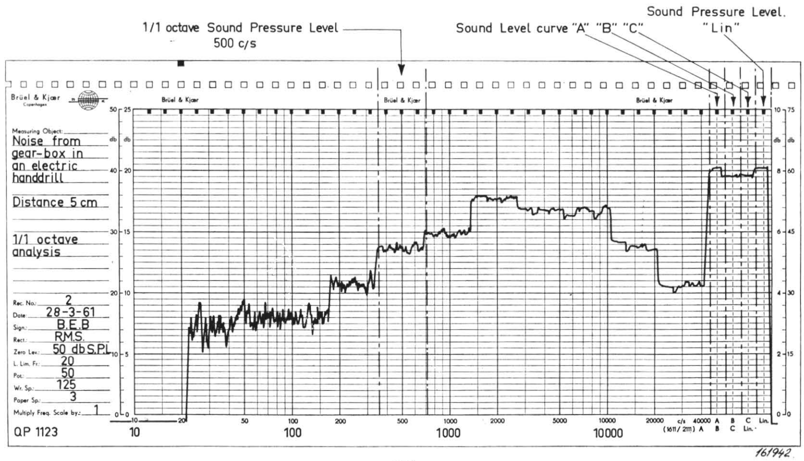
Fig. 7.
a) Analysis of noise by means of an A.F. Spectrometer Type 2112 and a Level Recorder Type 2305.
b) For Analysis of vibration, the microphone is interchanged with an accelerometer.

This "set-up" consists of a microphone, a ⅓ octave band analyzer and a level recorder. The microphone is placed near the test object so that it readily picks up the generated noise, which is then fed to the analyzer in the form of an electrical signal. The analyzer, which is synchronized with the level recorder paper drive ,is now adjusted to scan the frequency range from 16 c/s to 31 kc/s. The noise generated by the test object is measured and recorded in ⅓ octave bands and presented as a spectrogram (noise



(a)

Fig. 8. Noise spectrogram as obtained with the set-up shown in Fig. 7. ⅓ octave band analysis.



(b)

Fig. 9. Noise spectrogram obtained with the set-up in Fig. 7, but with the Spectrometer Type 2112 set for octave analysis.

curve) as shown in Fig. 8. From this curve the ⅓ octave noise level in any frequency band within the audible range can be read directly, so that a determination can be made of the noise limits to which the Noise Limit Indicator should be adjusted. The B & K Analyzer Type 2112 mentioned above may also be used for the analyses with octave bands. The recorded results will then appear as shown in Fig. 9.

This arrangement can be used for the measurement of vibration as well, if the microphone is interchanged with an accelerometer, e.g. one of the B & K Types 4308—9—10—11.

To investigate carefully the noise or vibration generated from an object several individual spectrograms or sometimes several series of spectrograms must be obtained. The microphone should be placed in several positions in relation to the test object, and spectrograms should be recorded for each position. The records are then compared in order to find the position where the microphone obtains the highest sensitivity for those noise frequencies that are considered most significant.

This multiple measurement technique is even more necessary in vibration tests. The accelerometer should be placed experimentally at several points on the test object in order to find a position where it is sensitive to vibrations of the frequencies considered most important. In some cases it may be necessary to employ more than one accelerometer for production line testing in order to obtain a distinct reading for all the vibration frequencies of interest. For instance, a motor may generate vibrations at several frequencies, but it may not be possible to find one point on the motor chassis where all the interesting frequencies are represented with sufficient strength to give a clear measurement. It is then necessary to divide the measurement, i.e. to place two vibration pick-ups at different positions and thus measure one group of the desired frequencies by means of one pick-up and the remaining group with the other pick-up. Of course, an identical method must then be used during the production control.

Where no noise requirements are set by the customer, but where it is desired to make a uniform product from the points of view of noise and vibration, the limits are often set by the average noise figure of the produced units. A sufficiently large series is measured and an average noise figure determined. The limit is then set within a suitable tolerance from the average.

The use of this limit set by the average noise figure not only ensures a uniform product but also facilitates the detection and improvement of smaller errors originating in the production system. It may then be possible to lower the noise and vibration limit of the products.

WHAT SHOULD BE MEASURED?
NOISE or VIBRATION?

Before the apparatus is used it is necessary to decide what to measure, noise or vibration, at which frequencies, and how much noise or vibration can be tolerated.

Upon the question "Noise or vibration"? noise in most cases seems to be more important. However, vibration is often easier to measure, because it is easier to isolate the test object from other unwanted and disturbing vibrations that occur in a factory than it is to isolate the object from the high level background noise which normally occurs close to production lines. As noise is always linked to mechanical vibration, it has therefore become quite common to measure vibration in the place of noise, or to measure both where the ambient noise conditions permit it. The advantage of measuring vibration instead of noise is most clearly seen in measurements where the noise generated is of the order of 30—50 db SPL. This is the normal background noise in most areas where no industrial activities are taking place. In such cases a noise insulating arrangement must be employed to shield the test object during measurement. The use of shields often involves extra problems and costs. If vibration measurements are sufficient in such circumstances, the advantage has been gained that the vibration pick-up can be placed on that part of the machinery where the vibrations are strongest, while a microphone would only measure the overall noise in general. A higher "selectivity" is thus obtained by using the vibration pick-up instead of the microphone, and thus it is easier to separate the noise generated by the test object from the background noise.

When switching from noise measurement to vibration measurement, i.e. when vibration is measured to keep control on noise, it is necessary to carry out some laboratory investigation on the relationship between noise and vibration. Of course, noise from machinery is generated by mechanical vibrations, but the predominant noise frequency is not necessarily the same as the predominant vibration frequency. Often the strongest vibration has a frequency too low to be noticed by the human ear, while a less serious vibration peak produces a more annoying noise, because it falls in a frequency range where the ear is more sensitive. Even if the frequency is in the easily audible range a serious vibration may not give rise to a high noise level because the efficiency of noise radiation may be poor.

It is therefore necessary to record one or several spectrograms of both the noise and the vibrations generated by a test object. The next step is to compare the two sets of spectrograms and after this determine what degree of vibration can be allowed in order to make sure that the noise level is kept under a certain limit.

It is also necessary to take into consideration whether the object is going to be tested under conditions that are similar to the ambient conditions at the place where it will eventually be used, or under other specified test conditions. It must be carefully investigated to what degree a possible change in ambient conditions will influence the measurement. For instance, a careful examination should be made of the change in vibration of an object when mounted on a solid fixture and afterwards tested on a spring-suspended test stand.

PRACTICAL ARRANGEMENTS WHEN "SETTING-UP" THE INSTRUMENT

The practical arrangements that are necessary when setting up the Noise Limit Indicator are often the most important factors in the installation of the equipment. In most cases where it is desired to measure noise or vibration of the units leaving a production line, a test stand for the quality control will already be provided.

Noise and vibration inspection can then be included in the normal procedure, adding only a fraction to the previous test time. However, it may sometimes be necessary to modify the existing test stand slightly, or, if no stand is provided, to make a light-weight arrangement for the noise and vibration inspection. The following gives examples of how the testing may be arranged.

Vibration Testing.

Vibration testing has one main disadvantage compared to noise testing: It is necessary to place the vibration pick-up mechanically in contact with the test object and in exactly the same position for each unit tested. In noise testing the object can pass close by the microphone without touching it.

There is one way of overcoming this problem when testing vibration. If the test objects vibrate as a whole, the vibration pick-up can be placed on the test stand. The stand should then be of a fairly light-weight construction

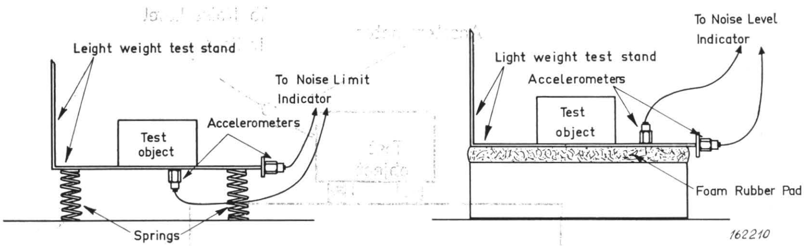


Fig. 10. Placing the object on a light-weight test stand enables vibration pick-ups to be mounted on the test stand. Vibration in two directions can be checked in one operation.

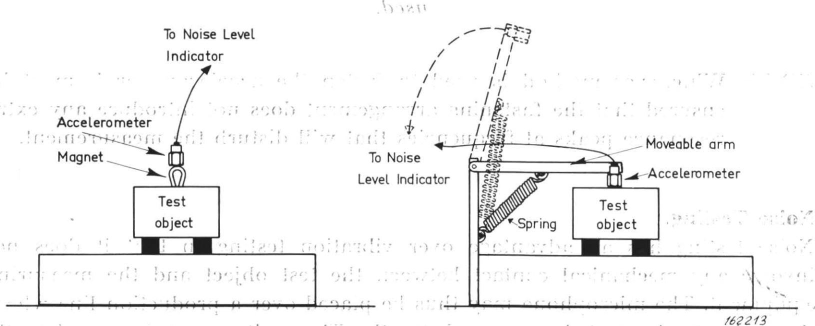


Fig. 11. The accelerometer may be fastened by means of a small magnet or with the aid of a springloaded arm.

and be placed on springs or on a piece of foam rubber as outlined in Fig. 10. The accelerometers are then placed on the stand as in Fig. 10. The two channels of the Noise Limit Indicator can now be utilized to measure vibrations in two directions, or, if only one direction is required, to serve two lines simultaneously.
Unless the test object is going to be suspended in a similar way as it will be in the place where it is to be used, the effect of the change in suspension should be carefully examined and taken into consideration before this test method is applied.
If the accelerometer cannot be placed on a test stand, or in cases where it is necessary to place the accelerometer at certain places on the machinery in order to obtain sufficient "selectivity" of the measurement, the accelerometer can often be fastened to the object by means of a small magnet, screwed onto the accelerometer as shown in Fig. 11 left. Also the use of a moveable spring-loaded arm as outlined in Fig. 11 right can often be advantageous. The common method of hand-held operation employing a test probe or rod is shown in Fig. 12.

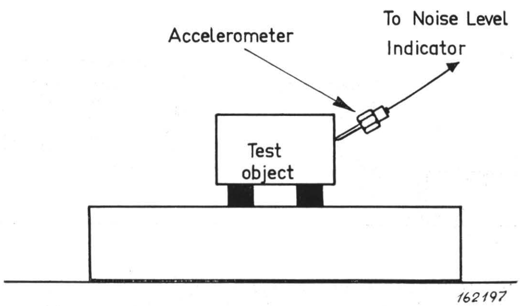


Fig. 12. Conventional hand-held operation of the accelerometer may also be used.

NOTE: Whichever method is used to fasten the accelerometer it must be ensured that the fastening arrangement does not introduce any extra resonance peaks at frequencies that will disturb the measurement.

Noise Testing.
Noise testing has an advantage over vibration testing in that it does not involve any mechanical contact between the test object and the measuring equipment. The microphone may thus be placed over a production line where the units to be tested pass underneath. The units must be consistantly positioned at the moment that the measurement is carried out, but they do not have to be touched by the measuring equipment.

On the other hand, noise measurement are more dependent upon ambient conditions than vibration measurements. When for vibration measurements the test specimen can sometimes be isolated simply by means of a piece of foam rubber beneath the specimen, it is often necessary to "screen" the object when sound measurements are carried out. Unfortunately, the screening for ambient sounds encircles the object, making measurements difficult. Testing products that are making a loud noise, such as internal combustion engines,

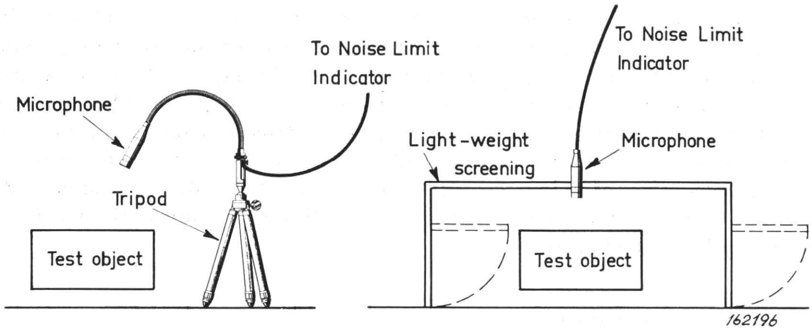


Fig. 13. Where the noise intensity generated by the test object exceeds the ambient noise to a fair degree, the microphone can be placed in a convenient distance from the object as shown left. If the ambient noise comes too close to the noise to be measured, a light-weight screen may be necessary as shown to the right.

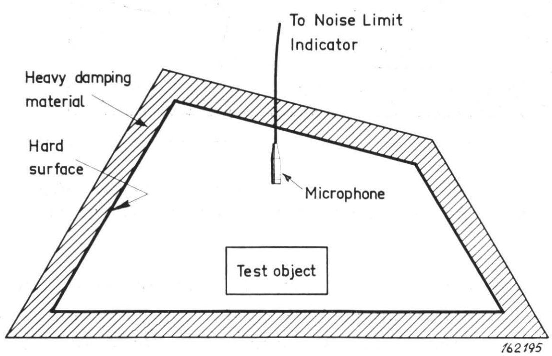


Fig. 14. Noise testing in heavy screen. The room has reasonably small outside dimensions and walls of heavy damping material. This room is not suited for directional testing, as it produces a diffuse sound field at lower frequencies.

of course creates no problems, because the test object produces more noise than is normally expected from the ambient noise sources. For such cases a microphone can be used to measure noise without any screening, provided it is placed fairly close to the object.

Objects making noise in the medium loudness range can normally be tested under a light screen, where the microphone can be placed in the screening as outlined in Fig. 13.

The problem of screening mainly arises when it is desired to measure sounds, the loudness of which are low as a whisper, and where ambient noise is conspicuous. Several methods of screening may be employed. The object may be placed in a small hard-walled chamber in order to produce a diffuse sound field for the measurement (see Fig. 14), or it can be placed in a larger silent (heavily absorbing) room to make it possible to obtain directional noise patterns (see Fig. 15). The common requirement for both rooms is that they must have a "shell" of heavy material to attenuate the disturbing sound from outside. This "shell" can be built as a brick wall, single or double, or a wooden wall with sand filling, the thickness depending upon the desired attenuation.

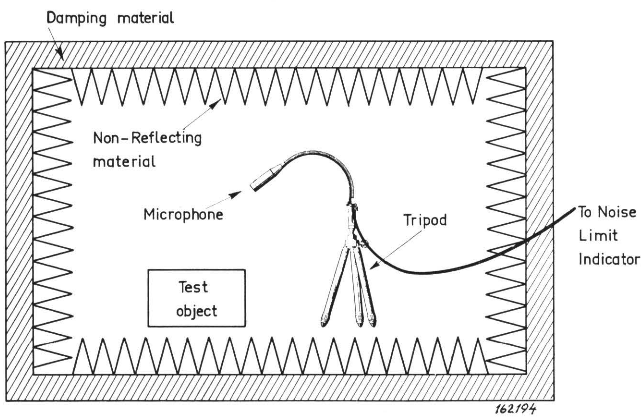


Fig. 15. Noise testing in room with absorbing walls. Directional testing is possible, but the chamber must be largely dimensioned.

In all cases it is necessary to find out, by means of laboratory investigations, what effect the protection against disturbing noise has on the sound field of the test object, compared to its sound field condition when actually in use.

It is advisable in many cases to consult an acoustical expert for the solution to the problem of test room constructions.

USE OF THE NOISE LIMIT INDICATOR

Pre-adjustments.

As already mentioned on page 10, it is necessary to predetermine the noise frequencies to be measured, as well as the noise levels to be tolerated.

When the width and the centre frequencies of the required number of frequency bands as well as the noise or vibration level for each band have been laid down, and the practical arrangements made, the instrument should be adjusted. This adjustment should be made by someone who has a fundamental idea of electrical circuits or of noise measurements in general. It should preferably be carried out in accordance with the following procedure.

Adjustment for Measurement with Microphones Type 4131—4132.

The use of the Noise Limit Indicator in its simplest form will be described first. That is, when the instrument is coupled to only one microphone, B & K Type 4131 or 4132. (Using other microphones, see page 24). It is assumed

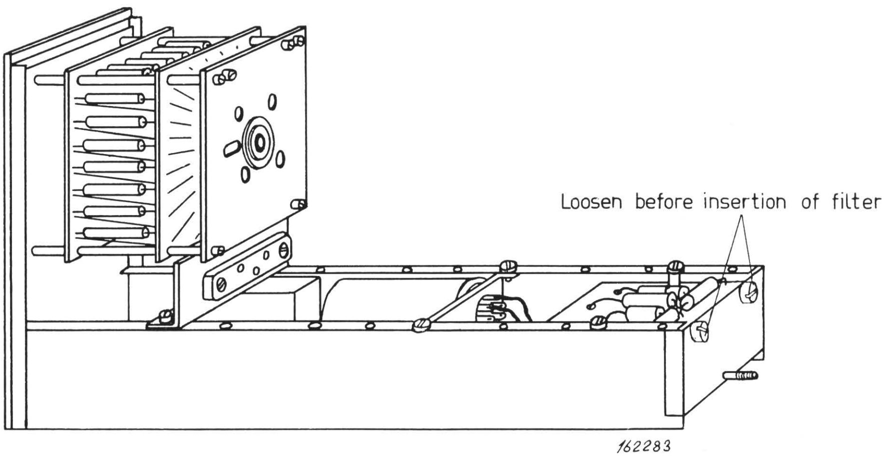


Fig. 16. An Output Amplifier withdrawn from the chassis. The screws intended for fastening the filter chassis are indicated at the rear.

that the object has to be tested for noise by means of one microphone and that the frequencies and noise limits are given.

1. The microphone is placed in its correct fixed position in relation to the test object. Then the cathode-follower cable is connected to the input socket I on the rear panel. In addition, the control panel is connected to the main chassis by the multicore cable, the power cable is connected to the power line and power switched on.

2. The filters are now chosen in accordance with the given frequencies

Example: 25 c/s — 40 c/s — 100 c/s — 250 c/s — 300 c/s — 800 c/s — 1000 c/s.

3. The filters are then placed in the first seven output amplifier units as described below:
   (a) Loosen the amplifier from the chassis by unscrewing the knurled nut at the bottom of the front plate of the output amplifier.
   (b) Pull out the amplifier unit.
   (c) Remove the small piece of paper indicating filter frequency from the clip beneath the filter (see Fig. 17).

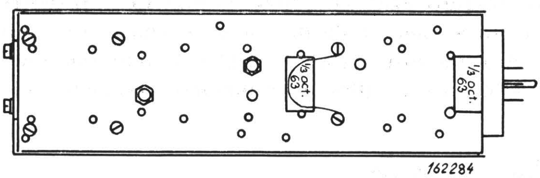


Fig. 17. Filter chassis seen from the bottom.

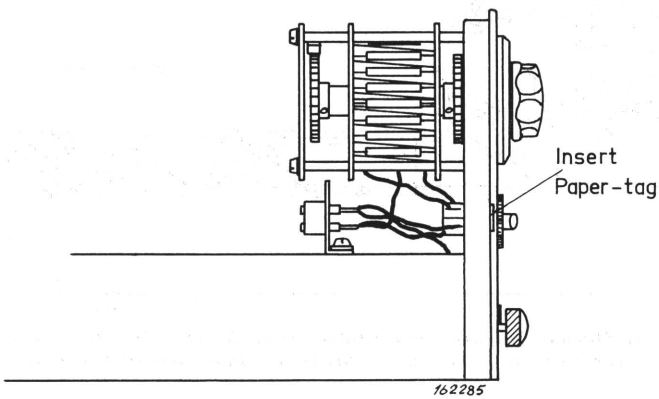


Fig. 18.

a) The paper tag from the filter is inserted in the slit behind the window as shown.

   (d) Place the paper in the slit under the window on the front plate of the amplifier, thus indicating which filter is inserted (see Fig. 18b).
   (e) Loosen the screws on the rear of the amplifier (see Fig. 16).

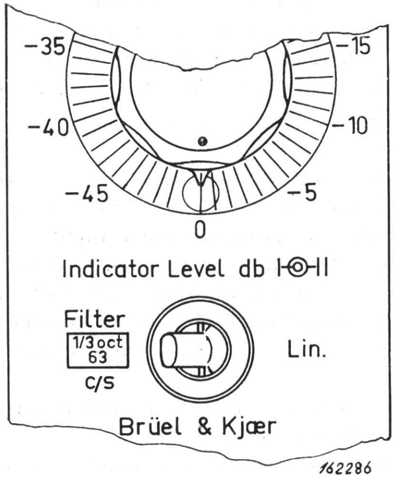


Fig. 18. b) The paper tag shown in place.

(f) Place the filter on the amplifier chassis as shown in Fig. 19.

(g) Re-tighten the screws on the rear in order to fasten the filter to the amplifier.

(h) Place the complete unit in its opening in the chassis and tighten the knurled nut on the front plate.

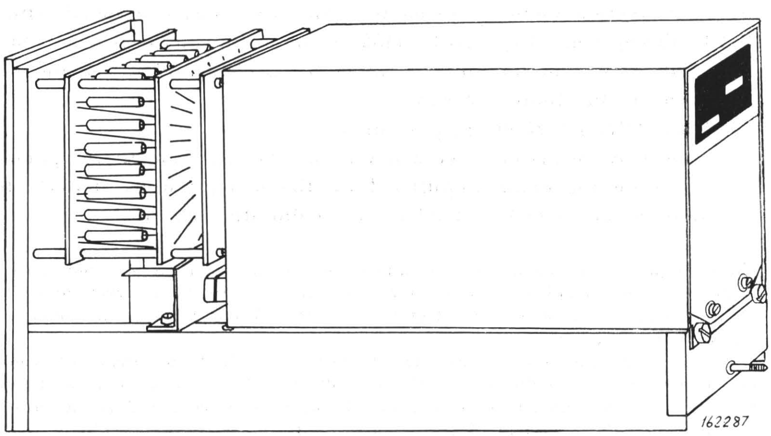


Fig. 19. The Output Amplifier mounted with the filter chassis, ready to insert.

4. Set "Meter-Switch" to position "Polarization Voltage" and check that the meter pointer deflects to the red mark (at 0 db). If it does not, adjust with a screwdriver the potentiometer at the top left corner on the rear of the apparatus until red mark deflection is obtained.
5. The gain of all the amplifiers used should now be checked and, if necessary, adjusted as follows:—
   (a) Set "Input-Level" knob on input amplifier I to its "Ref" position.
   (b) Set the "Meter Damping" knob to "Fast" position.
   (c) Set "Meter Switch" to position "Filter Input".
   (d) Press the "Input I" button on the Control Panel. The meter pointer should now deflect to the red mark at —7 db on the scale. If it does not, adjust the potentiometer marked "Normal Sensitivity" on the input amplifier I by means of a screwdriver until this condition is obtained.
   (e) Set the toggle switch on each of the output amplifiers to "Lin.".
   (f) Set the "Meter Switch" to position I.
   (g) Turn the screwdriver switch control marked "Damping" on the output amplifier I to its "Low" position.
   (h) Set both of the attenuator knobs on the front plate of the output amplifier I to their "0" positions (fully clockwise).
   (i) Adjust, with a screwdriver, the "Sensitivity" potentiometer on the output amplifier I until the meter pointer deflects to the red mark at 0 db on the scale.
   (k) Repeat items (f) to (i) for amplifier No. 2—3—4 etc. with "Meter Switch" in position 2—3—4 respectively.
6. When all the output amplifiers are correctly adjusted to red mark deflection, a correction should be made to compensate for the microphone correction factor*). From the calibration chart supplied with all B & K Microphones Type 4131—4132, a correction factor is obtained (in db). This value should now be added to the calibration of the input amplifiers in the following way:
   a. Turn "Meter Switch" to position 1.
   b. Adjust by means of a screwdriver the "Normal Sensitivity" potentiometer on the *input* amplifier I till the meter pointer deflects to a value identical to that read off the calibration chart.

---

*) The microphone correction factor mentioned under item 6 above is found from the calibration chart supplied with all B & K microphones. However, when other types of microphones are used, this factor must be calculated from the microphone sensitivity (see page 24).
The Noise Limit Indicator is calibrated in such a way that the attenuator readings, i.e. "Input Level" — "Indicator Level", show directly the sound level in db, provided that the meter deflection is 0 db, and that the microphone employed has a sensitivity of 5 mV/μbar. The correction factor, obtained from the microphone calibration chart is thus the difference in db between the sensitivity of the employed microphone and the assumed sensitivity of 5 mV/μbar.

Example:

If the correction factor is given to be + 1.5 db, the meter pointer should be adjusted to + 1.5 db. Rotating the "Meter Switch" will now result in a meter deflection to 1.5 db for all the output channels used.

NOTE: If the correction factor is between 3 and 4 db, the adjustment can be carried out as follows:

a. Set "Meter Switch" to position "Filter Input".
The pointer should then deflect to the red mark at —7 db.

b. Adjust the "Normal Sensitivity" until the pointer deflects to:
—7 db + correction factor.

Example:

Correction factor = + 3.5 db
— 7 +3.5 = — 3.5 db
The pointer should then deflect to — **3.5 db.**

7. The input and output amplifiers should now be adjusted to the correct level for each frequency band. If the level for each frequency band is, for example:

Band No.	1	2	3	4	5	6	7
Frequency c/s	25	40	100	250	300	800	1000
Max. level db	58	52	56	62	64	**48**	49

the adjustment can be carried out as follows:

(a) Set the "Input Level" knob on the input amplifier I to the nearest position higher than the highest of max. level values. In this case 70 db could do, but as 80 db is the lowest possible setting, this is chosen**).

(b) The output attenuators ("Indicator Level I" black knobs) are now set so as to obtain the desired noise limit for each frequency band as follows:
Attenuator setting = Noise Limit — "Input Level" setting.
The attenuators are then set to the values calculated.

Example:

Based on the figures given in the above example, the calculation is as follows:

For channel 1, attenuator setting = 58 — 80 = — 22 db
For channel 2, attenuator setting = 52 — 80 = — 28 db
For channel 3, attenuator setting = 56 — 80 = — 24 db
For channel 4, attenuator setting = 62 — 80 = — 18 db
For channel 5, attenuator setting = 64 — 80 = — 16 db
For channel 6, attenuator setting = 48 — 80 = — 32 db
For channel 7, attenuator setting = 49 — 80 = — 31 db
The attenuators are then set to the values calculated.

**) To prevent overdriving of the input amplifiers it should be checked that the meter pointer does not deflect higher than to the red mark at — 7 db, measured with the meter switch in position "Filter Input", and when the noise signal is applied to the microphone. This should particularly be checked when the noise spectrum contains frequencies of high amplitudes which it is not desired to measure, as for instance a 50 or 60 c/s hum signal which is accepted without measurement.

(c) The toggle switches on the output amplifiers are now placed in their "filter" position, connecting the filters.

(d) High or low damping is then chosen by means of the screwdriver-operated switch on the output amplifiers. Normally the low damping is chosen when working with frequencies above 20 c/s and with a fairly steady noise. The instrument is then ready for operation with one input channel, see page 31.

A similar procedure is used for the adjustment of Input Channel II when it is desired to use both input channels for noise measurement. A microphone is then connected to Input II on the rear panel. The setting up procedure is as just explained except that Input Amplifier II and Input II button should be used instead of the corresponding Channel I units. This time, however, the attenuators on the output amplifiers should be adjusted by means of the transparent knob instead of the black knob.
Because of the doubled output attenuator (black and transparent knob adjustment) the same output amplifiers and filters can be used with both of the input amplifiers. However, it is necessary to choose the same damping (by means of the damping adjustment on the front of the output amplifiers) for both input operations, as the damping circuit is not changed with the attenuator when changing input amplifier.

NOTE: In parallel with the red lamps of the control panel a switch circuit is incorporated. This switch closes whenever one of the red lamps is lit and may thus be used to start a buzzer or alarm bell to give aural indication of "rejects" or to control other auxiliary equipment, e.g. to remove the "rejects" from the line. The switch is connected to pin T and U on Remote Control Socket on the control panel.

Employing microphones other than B & K types the correction factor K can be calculated from the following formula:—

$$K = 20 \log \frac{5 \text{ mV}/\mu\text{bar}}{\text{micr. sensitivity in mV}/\mu\text{bar}}$$

Example:

If the sensitivity of the microphone in use is 4 mV/μbar, the correction factor is:

$$\begin{aligned} K &= 20 \log \frac{5}{4} \\ &= 20 \log 1.25 \\ &= 20 \times 0.0969 \\ &= 1.938 \text{ db or } 2 \text{ db} \end{aligned}$$

This factor should then be added in the calculation carried out under item 6b. In case this factor is higher than 4 db it should be added as described below for 1/2″ microphones.

Adjustment with ½″ Microphone.

When the B & K ½″ Microphones Type 4133 or 4134 or other microphones with a correction factor of more than 4 db are employed with the Noise Limit Indicator, the pre-adjustment is slightly different from that described above. This because the input amplifiers cannot be adjusted to compensate for a microphone correction factor higher than 4 db, and it is therefore necessary to compensate for this factor in the output attenuator setting. Adjustment to ½″ microphones is carried out as follows:

1. Choose the desired microphone and proceed as described under "Adjustment for Measurement with Microphones Type 4131—32", items 1. to 5. k.
2. Leave out item 6 and proceed with item 7. a.
3. Replace item 7. b. with the following:
   Adjust the output attenuators (Indicator Level I, black knob) in the following manner to obtain the desired noise limits:
   Attenuator Setting = Noise Limit — Input Level Setting — Microphone Correction.

   Example:

   Assume that the microphone correction factor is 14 db.
   Using the figures given in the example of item 7. a., the calculation is as follows:
   For channel 1, attenuator setting = 58 — 80 — 14 = — 36 db
   For channel 2, attenuator setting = 52 — 80 — 14 = — 42 db
   For channel 3, attenuator setting = 56 — 80 — 14 = — 38 db
   For channel 4, attenuator setting = 62 — 80 — 14 = — 32 db
   For channel 5, attenuator setting = 64 — 80 — 14 = — 30 db
   For channel 6, attenuator setting = 48 — 80 — 14 = — 46 db
   For channel 7, attenuator setting = 49 — 80 — 14 = — 45 db

   The attenuators are then set to the values calculated. The microphone correction factor is obtained from the calibration chart supplied with all B & K microphones. Using other than B & K microphones the factor can be calculated as explained on page 24.
4. Proceed with item 7. c. and d., page 24.

Vibration Measurement.

Testing products for vibration is carried out in a manner similar to that described for noise testing. However, a vibration pick-up must be used instead of the microphone, and also the calibration procedure differs slightly.

A suitable vibration pick-up is provided by one of the B & K Accelerometers Type 4308—09—10 or 11. Like the condenser microphone the accelerometers are used in conjunction with a Cathode Follower Type 2613 as shown in Fig. 1. To make the accelerometer plug mechanically fit the cathode follower the Adaptor JJ 2612 is employed.

The calibration of the instrument for vibration measurements can be carried out as follows:—

EXAMPLE

Attenuator setting. Indicator Level I = black knob Indicator Level II = transparent knob	Amplifier Number	Measurement
Indicator Level I set to correct noise level. Indicator Level II set to correct vibration level.	1	Noise Vibration
Indicator Level I set to correct noise level. Indicator Level II set to correct vibration level.	2	Noise Vibration
Indicator Level I set to correct noise level. Indicator Level II set to correct vibration level.	3	Noise Vibration
Indicator Level I set to correct noise level. Indicator Level II set to 0.	4	Noise
Indicator Level I set to correct noise level. Indicator Level II set to correct vibration level.	5	Noise Vibration
Indicator Level I set to correct noise level. Indicator Level II set to 0.	6	Noise
Indicator Level I set to correct noise level. Indicator Level II set to 0.	7	Noise
Indicator Level I set to 0. Indicator Level II set to correct vibration level.	8	Vibration
Indicator Level I set to 0. Indicator Level II set to correct vibration level.	9	Vibration
Indicator Level I set to 0. Indicator Level II set to correct vibration level.	10	Vibration
Both knobs set to 0.	11	Unused
Both knobs set to 0.	12	Unused

Fig. 20. In cases where both noise and vibration measurements are desired, the output amplifiers may be utilized as in the above example. In the cases where the frequency bands are common for noise and vibration, both of the attenuators of the output amplifiers are used. In the above example seven vibration frequencies and seven noise frequencies are checked, yet two of the output amplifiers are unused.

1. Connect the accelerometer via the adaptor and cathode-follower to Input II (presuming that Input I is occupied in noise measurements, as described above).
2. The filters are now chosen in accordance with the given frequencies.

Example:

25 c/s — 40 c/s — 50 c/s — 100 c/s — 160 c/s — 300 c/s and 600 c/s.
As four of these filters are identical to four of the filters used for noise measurement (see above Example, page 23), only three extra filters are necessary, namely 50 c/s — 160 c/s and 600 c/s.

3. Insert the necessary filters in the output amplifiers, where no filters are inserted as described on page 20, para 3.

4. Check the amplification of Input Amplifier II and the three output amplifiers as described on page 22, items 5. a. to k.

5. To compensate for the attenuation of the cathode-follower stage, a correction of 0.8 db should now be added. (N.B. When using microphones with the B & K cathode-followers, this correction factor is included in the calibration of the microphone cartridge).
   a. Set "Meter Switch" to position 1.
   b. Adjust "Normal Sensitivity" on Input II till a meter deflection of + 0.8 db is obtained.
   Rotating the "Meter Switch" will now result in a meter deflection of 0.8 db for all output channels used.

6. The "Indicator Level II" (transparent knobs), should now be set to their correct position, on all the amplifiers used, for vibration indication. Before the attenuators can be set to their proper levels it is necessary to convert the acceleration figures into decibels re. 1 μ Volt, taking into account the sensitivity of the accelerometer used. This may be carried out as follows:—

   (a) First find the input level in millivolts that may be applied to the input of the apparatus (for each of the desired frequencies) through the following formula:—
   Input Level = sensitivity of accelerometer $\times$ limit figure in G.

   Example:
   If the maximum allowable acceleration is 0.1 G and the sensitivity of the accelerometer is 50 mV/G, the input level at the apparatus is 50 mV/G $\times$ 0.1 G = 5 mV.

   (b) This value should then be converted into decibels re. 1 μVolt by means of the table below.

   Example:
   5 mV is in the table found to correspond to 74 db re. 1 μV.

   (c) The attenuators on the Input Amplifier II and the output amplifiers must now be set as to obtain lamp indication for the level calculated, in this example for 74 db. This can be done by setting the "Input Level" attenuator on Input Amplifier II to 80 db and the "Indicator Level" attenuator (transparent knob) to — 6 db (80 — 6 = 74 db).

NOTE: In order to obtain a correct setting of the "Input Level" knob the channel in which the highest acceleration level is allowed should be first calculated, and thus the "Input Level" set to the nearest higher value.

(d) The complete number of channels in which it is desired to measure vibration are now adjusted as described.

(e) Set the screwdriver operated "Damping" switch to "High" or "Low" as desired.

NOTE: When the output amplifier is used for both noise and vibration testing, the damping must be chosen so as to suit both measurements. If this is impossible an extra amplifier and filter must be employed for the vibration measurement.

mV	db/1μV	mV	db/1μV	mV	db/1μV	mV	db/1μV	mV	db/1μV
0.032	30	0.398	52	5.012	74	63.10	96	794.3	118
0.035	31	0.447	53	5.623	75	70.79	97	891.3	119
0.040	32	0.501	54	6.310	76	79.43	98	**Volts**	
0.045	33	0.562	55	7.079	77	89.13	99	1.000	120
0.050	34	0.631	56	7.943	78	100.00	100	1.122	121
0.056	35	0.708	57	8.913	79	112.2	101	1.259	122
0.063	36	0.794	58	10.00	80	125.9	102	1.413	123
0.071	37	0.891	59	11.22	81	141.3	103	1.585	124
0.079	38	1.000	60	12.59	82	158.5	104	1.778	125
0.089	39	1.122	61	14.13	83	177.8	105	1.995	126
0.100	40	1.259	62	15.85	84	199.5	106	2.239	127
0.112	41	1.413	63	17.78	85	223.9	107	2.512	128
0.126	42	1.585	64	19.95	86	251.2	108	2.818	129
0.141	43	1.778	65	22.39	87	281.8	109	3.162	130
0.159	44	1.995	66	25.12	88	316.2	110	3.548	131
0.178	45	2.239	67	28.18	89	354.8	111	3.981	132
0.199	46	2.512	68	31.62	90	398.1	112	4.467	133
0.224	47	2.818	69	35.48	91	446.7	113	5.012	134
0.251	48	3.162	70	39.81	92	501.2	114	5.623	135
0.282	49	3.548	71	44.67	93	562.3	115	6.310	136
0.316	50	3.981	72	50.12	94	631.0	116	7.079	137
0.354	51	4.467	73	56.23	95	707.9	117	7.943	138
								8.913	139
								10.00	140

Adjustment of the "Sensitivity Increase".

The "Sensitivity Increase" button on the Indicator Box is a means for quick extra check on the noise level or for further selection of the products being tested.

If a series of units has to be tested in order to check that a certain noise limit is not exceeded, it will often be of interest to know if some of the units will pass a test with even closer limits on noise and in this way classify these units as extra fine with regard to noise or vibration. The noise level, for instance, is measured as previously described, and the sensitivity increase button is then used to lower the pre-set limits by, for example, 3 db. See also Fig. 21.

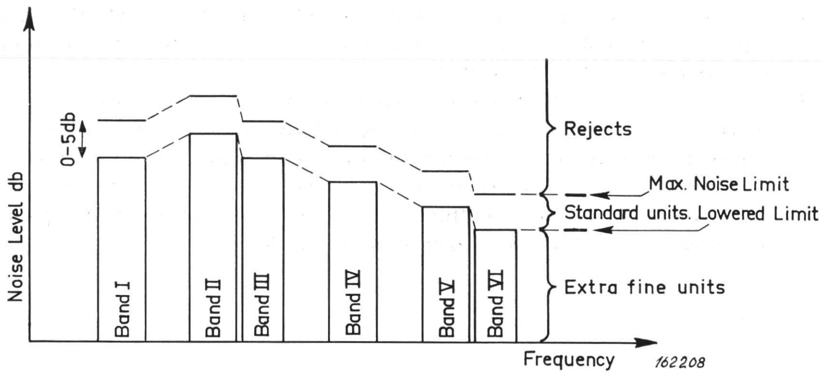


Fig. 21. Once the limits are set for all the bands in question, the limits may be lowered an equal amount of 0—5 db (preadjusted) for all the frequency bands by pressing the "Sensitivity Increase" button. Units of an extra fine quality are then selected.

When the Sensitivity Increase button is depressed, the sensitivity of the instrument is increased an identical amount for all filters. The increase in sensitivity may range from 0 to 5 db and should be preset separately for each of the two *input* amplifiers.
Before the "Sensitivity Increase" button can be used, the increase in sensitivity must be adjusted to the desired value. This should be done as follows:—

1. Adjust the instrument for normal operation as previously described under "pre-adjustments".
2. Press the "Input I" button on the Indicator Box.
3. Set the "Meter Switch" to its "Filter Input" position. (Meter Damping to "Fast").
4. Set the "Input Level" attenuator on Input Amplifier I to the "Ref" position. The meter pointer now deflects to the red mark at —7 db on the scale, plus the microphone correction factor.
5. Press the "Sensitivity Increase" button on the Indicator Box.
6. Adjust with the aid of a screwdriver the "Sensitivity Increase" potentiometer on the front of Input Amplifier I until the meter pointer deflects to as many db higher than the normal deflection as are required for the measurement.

e.g.: If it is desired to increase the sensitivity by 3 db, the meter pointer should be adjusted to $-7 + 3 = 4$ db (if microphone correction is 0 db).

NOTE: Do not touch the "Normal Sensitivity" setting.

7. The same procedure applies to Input Amplifier II. The "Input II" should then be depressed on the Indicator Box and the potentiometer on Input Amplifier II should be adjusted.
8. Set the Input Level attenuators back to their previous positions and press the "Release" button. The "Sensitivity Increase" circuit is now adjusted properly. The operator simply has to press first the "Input I" or "Input II" buttons to carry out the normal checking, and then press the "sensitivity Increase" button to see if the unit under test also passes the extra requirement. See Operators Instructions.

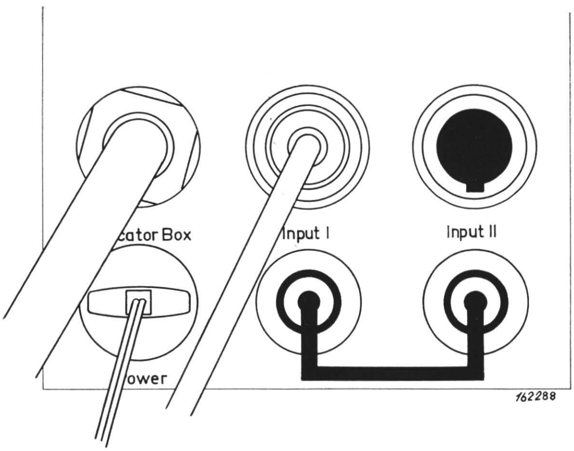


Fig. 22. Shortcircuiting the screened input sockets in order to parallel the two input amplifiers.

The "Sensitivity Increase" may also be used in cases where it is desired to divide the units from a production line in three, four or five classes with respect to noise or vibration. One useful application would be for investigating more closely the noise level of a series of recently developed products, using the first series for drawing up the quality control statistics. The noise standards for subsequent series could then be based on this information. For this sort of measurement both input channels of the noise limit indicator must be employed, while only one microphone or vibration pick-up is needed. The two input amplifiers are connected in parallel by bridging the two screened input sockets as shown in Fig. 22. Both input amplifiers utilize their normal as well as their "sensitivity increase" ranges. Fig. 23 shows how selection is obtained. Input channel I divides the objects into three classes as described above, see also Fig. 21, and then input channel II selects two additional classes (by means of "normal" and "sensitivity increase" ranges) lower than the input I divisions. The procedure for setting the required noise limits is similar to that described under "Adjustments of the Noise Limit Indicator".

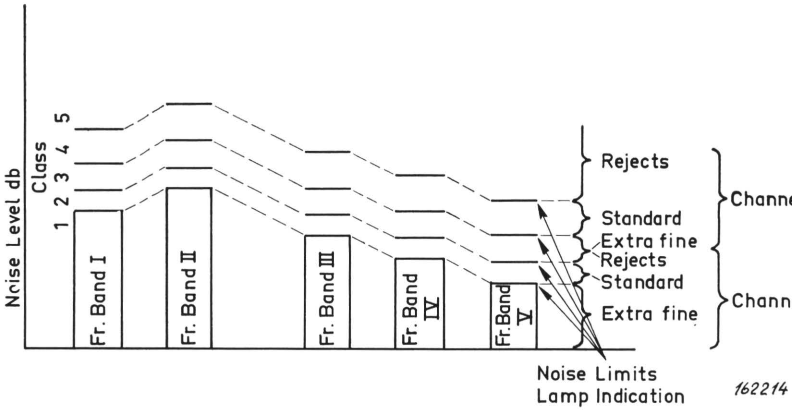


Fig. 23. Dividing objects into five noise classes with the aid of the "Sensitivity Increase" circuit of both input amplifiers.

Operator's Instructions.

The Noise Limit Indicator has been designed with a special view to simplicity of operation. The operator's only duties should be to ensure that the test object is in its proper position with respect to the microphone, to press one of the input buttons on the Indicator Box, and to see whether the lamps light.

Provided that the instrument has been properly adjusted and that the microphone or vibration pick-up has been placed in a fixed position, the operating procedure can be as follows—

Operation with one microphone or vibration pick-up:—

1. Ensure that the test object is in the correct position. For vibration measurement, place the vibration pick-up in the correct position.
2. Press the button marked "Input I", and wait 1 second.
3. If a red lamp lights up, the object is marked "reject" and labeled with the lamp number.
4. If no red lamp lights up, press the button "Sensitivity Increase" and hold it down for a short period.

5. If a red lamp lights up now, the object is marked "Standard".
6. If no red lamp lights up, the object is marked "Extra".
7. Press the button marked "Release", the red lamps will light up for as many frequency bands as are in use, which checks that lamps and relays are functioning properly.
   Bring in a new object and start again from item 1.

In cases where both input channels are used the same procedure applies to channel II.

NOTE: During noise measurements sudden disturbing noises such as the slam of a door, footsteps, etc. may sometimes cause one of the red lamps on the control panel to light. As the lamps remain lit, once the preset limit has been exceeded, this may lead to the faulty impression that the unit under test exceeds the noise limit. To save the operator from pressing first the "Release" button and then again the "Input I or II" buttons in order to make sure which noise made the red lamp light, a "reset" button has been introduced. It is a springloaded button which momentarily resets the relays controlling the red lamps, i.e. if the reset button is pressed, for example, after a door slam, the lamps are switched off as long as the button is kept depressed. Releasing it again makes the instrument work in the normal way. If the lamp then lights again it means that the noise limit has been exceeded by the test unit. This button can also be used when disturbing vibrations occur during vibration measurements.

Use of Both Inputs Simultaneously.

The input amplifier of the Noise Level Indicator can be connected in parallel, each one serving six output amplifiers. In this way two measurements can be carried out simultaneously, each with indication for six different frequencies. The instrument is then divided in two sections working in parallel as shown in Fig. 24.

This may be convenient when it is necessary to employ two microphones or vibration pick-ups, for instance to obtain better selectivity in the measurement (see also page 14).

For simultaneous operation of the two input amplifiers the following connections should be made:

1. On the Remote Control socket connect pin "R" to pin "S", and pin "V" to pin "a".
2. On the rear panel of the main unit the black shorting link should be turned from vertical position to horizontal position. See Fig. 25. The connection between the pins of the remote control socket is most readily

carried out by connecting the corresponding pins of a multi*plug* and then applying the plug to the socket when two channel operation is desired.

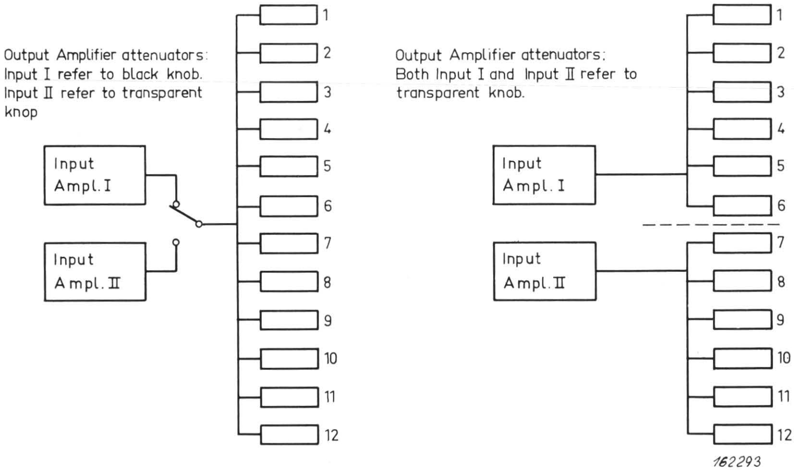


Fig. 24. The instrument can be connected for successive or simultaneous operation of the two input amplifiers.

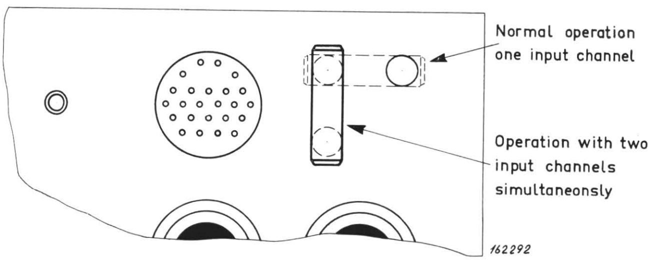


Fig. 25. Sketch of the rear panel showing the shorting link that must be changed in position when changing from successive to simultaneous operation of the input amplifiers.

NOTE: All adjustments should be carried out *before* the instrument is converted for two channel operation.

The pre-adjustment of the instrument is similar to what is described for operation with one input channel (see page 19) except for the following:

1. Both input amplifiers must be adjusted to correct amplification (red line deflection on the meter, as described under item 5. a.—d.).

2. If two microphones are to be used, the compensation in input amplifier gain for microphone correction factor must be carried out for *both* input amplifiers.
3. All settings of the output attenuators (Indicator Level) must be carried out by means of the *transparent* adjustment knobs. I.e. the transparent knobs of the first six amplifiers (upper row) should be set in accordance with the setting of the Input Level knob on Input amplifier no. I. The remaining six transparent knobs (lower row) should be set in accordance with the setting of Input Level knob on Input amplifier no. II. The adjustments are carried out as described under item 7. a.—d. (page 23).

The sensitivity increase circuit can be used in the normal way as described on page 28. The two circuits can be set to individual levels, but are operated simultaneously when the "Sensitivity Increase" button is depressed.

After the pre-adjustments have been carried out the instrument is converted for two channel operation as described above.

The operator's procedure is unchanged. The measurement is started by depressing either the "Input I" or the "Input II' button. The two buttons are paralleled when the instrument is used for two channel operation. The use of the "Sensitivity Increase", "Release", and "Reset" buttons is identical to what is described under "Operator's Instructions".

To avoid confusion during double channel operation, the instrument accessories include 6 yellow lamps to replace the second row of red indicator lamps on the control panel.

REMOTE CONTROL

In some cases it may be desirable to control the Noise Limit Indicator from a position remote from the control panel. A remote control socket has therefore been provided. By means of an external contact it is thus possible to operate remotely any one of the five push buttons of the control panel.

The control buttons can be paralleled by means of the following connections to the remote control socket:

To make "Input I" operate,	connect pin "R" to pin "a"
To make "Input II" operate,	connect pin "S" to pin "a"
To make "Sensitivity Increase" operate	connect pin "Y" to pin "P"
To make "Release" operate	connect pin "W" to pin "X"
To make "Reset" operate	connect pin "P" to pin "Z"

Additionally the Remote Control socket contains 12 pins, each of which is connected to one of the red indicator lamps on the Control Panel. Whenever one of the lamps lights-up, the corresponding pin on the remote control socket is grounded. When the lamps are not lit, the pins of the remote control socket are connected through the lamps to the 12 Volt supply for the lamps. The pins marked A to N corresponds to lamp no. 1 to 12. This arrangement facilitates the use of extra alarm bells or automatic removal of test objects on the excess of certain noise frequency limits.

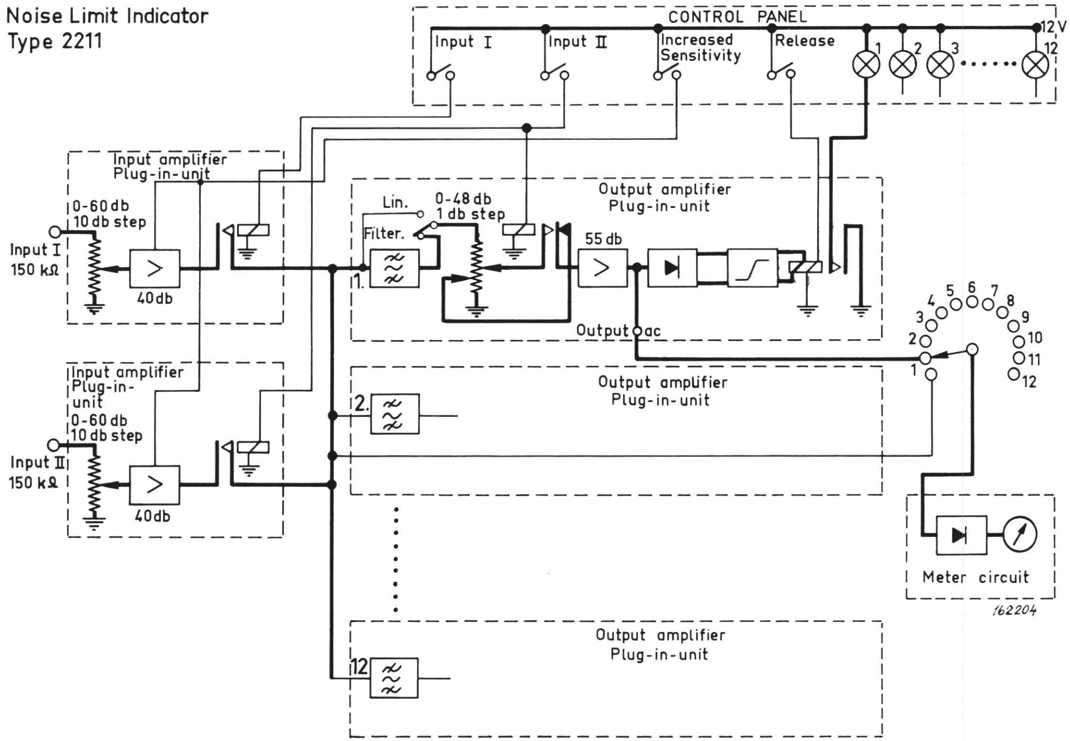


Fig. 26. Block diagram of the Noise Limit Indicator.

Technical Description

The Noise Limit Indicator consists of the following major parts.

1. Input Amplifiers.
2. Filters and Output Amplifiers.
3. Rectifier and Relay circuits.
4. Control Panel.
5. Meter Circuit.
6. Power Supply.

Input Amplifiers.

The Type 2211 contains two input amplifiers which are identical and interchangeable. Each of them contains a four-stage transistor amplifier preceded by a 60 db attenuator. The attenuator can be varied in 10 db steps and is intended to be used in conjunction with the 48 db attenuator in the output amplifier.

The first amplifier stage is designed as an emitter follower in order to obtain a sufficiently high input impedance. The input impedance is, for the least sensitive position of the attenuator, approximately 1.5 Mohms. For the next position it is approximately 0.5 Mohms, and for the remaining positions 150 kohms. The next two stages are RC-coupled, while the last stage contains two transistors in a single-ended push-pull arrangement. The output signal is fed via a relay to the input of the filters in the output amplifiers. The relay is controlled from the "Input I" or "Input II" buttons on the Control Panel and serves to break or connect the input circuits to the filter inputs. See Fig. 26. To obtain a high degree of stability and to ensure

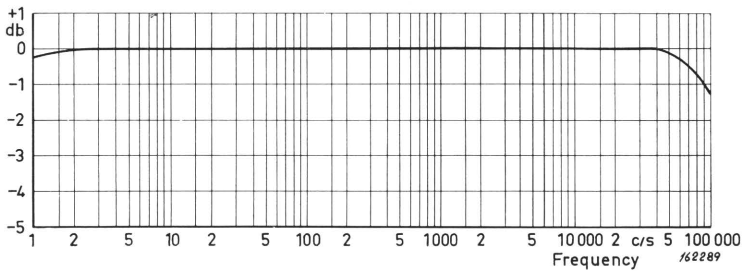
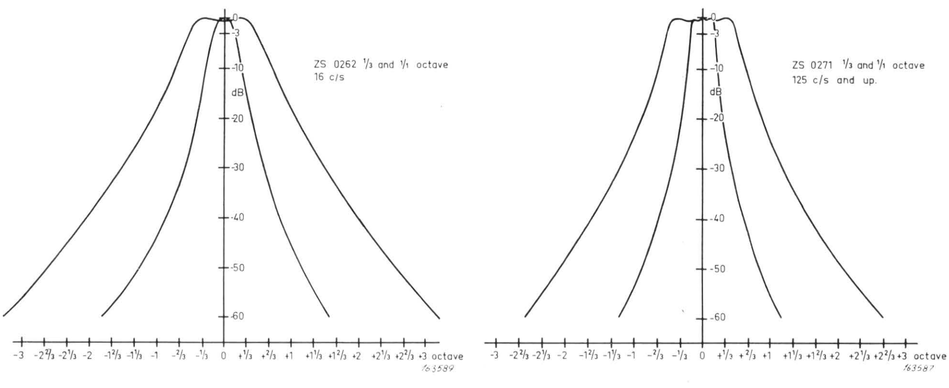


Fig. 27. Frequency Response of Input Amplifier.

a distortion of less than 0.1 %, a large amount of negative feedback is introduced in the amplifier. The feedback can be altered with a potentiometer to obtain fine adjustment of the sensitivity. A second potentiometer can be switched into the feedback circuit by means of a relay which is controlled from the "sensitivity increase" knob on the control panel. This potentiometer can be set to increase the sensitivity by between 0 and 5 db, without influencing the frequency response of the amplifier. The total amplification with increased sensitivity is 45 db.

Filters and Output Amplifiers.

Band-pass filters are used in conjunction with the output amplifiers. That is, they are filters which will allow all signals within a certain frequency band to pass unattenuated while all other frequencies will be rejected. The filters can be chosen either as octave or ⅓ octave filters.



a) *b)*

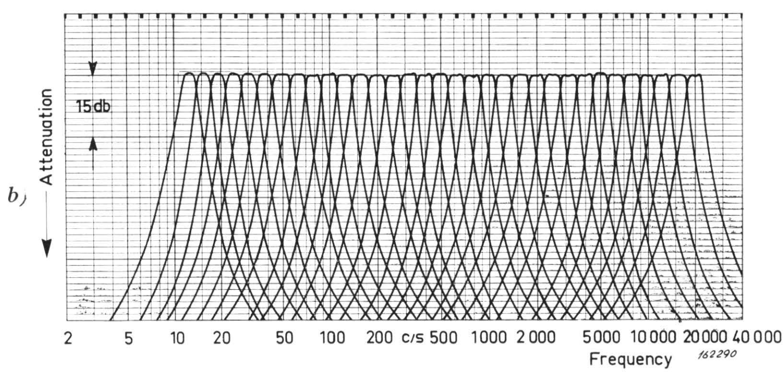


Fig. 28. Filter characteristics of Filter Set ZS 0250.
a) shows the width of a ⅓ and 1/1 octave filter relative to the center frequency.
b) shows the width of a ⅓ and 1/1 octave filter. At 125 c/s and upwards the slopes are slightly steeper than at the lower frequencies.
c) complete set of ⅓ octave filter characteristic.

The octave filters pass, as indicated by the name, frequencies within a range of one octave, i.e. half an octave on each side of the given centre frequency, while the ⅓ octave filters pass frequencies within a band of ⅓ octave, i.e. ⅙ of an octave on each side of the centre frequency of the filter, see Fig. 28a.

The filters can be by-passed by a toggle switch on the front plate of the amplifier. After filtering, the signal is fed to a 48 db attenuator with 1 db steps. Two independent tappings of this attenuator make it possible to adjust the attenuation to two different settings, one for each of the two input amplifiers. The pushbutton switches on the control panel, which are used to select the desired input amplifier, also select the correct section of this attenuator (with the aid of a relay), so that input amplifier I corresponds to attenuator tap No. 1 and input amplifier No. 2 with attenuator tap No. 2 (see Fig. 29 and block diagram).

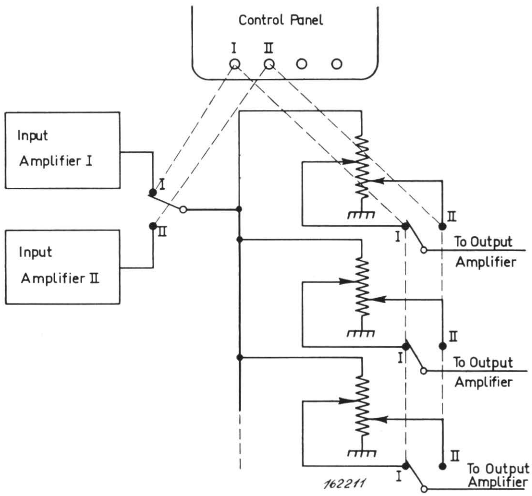


Fig. 29. By depressing one of the "Input" buttons, the correct input amplifier and also the correct tapping of the "Indicator Level" attenuators are chosen by means of relay circuits.

The first stage of the amplifier is designed as an emitter follower in order to obtain an input impedance high enough to have no influence on the attenuator. The impedance loading the filter is thus determined by the attenuator and is approximately 146 kohms which gives optimum performance of the filter. The following stages are RC-coupled amplifier stages, stabilized by negative feedback. Three feedback circuits are employed, two of which are used to shape the frequency response curve and to minimize the input capacity. The third one can be varied so as to alter the amount of amplification (this is the sensitivity adjustment on the front plate of the amplifier).

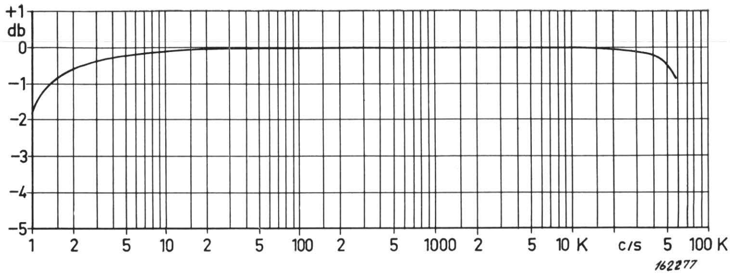


Fig. 30. Frequency response of output amplifier.

Rectifier and Relay Circuit.

Following the amplifier is a quasi-r.m.s. rectifier circuit. It provides full-wave rectification and gives accurate r.m.s. indication for sinusoidal signals as well as for white noise and other signals with complex waveforms, including unsymmetrical pulses with crest factors up to 3. By means of a switch two different damping characteristics can be introduced. "Standard" or "low damping" is meant for the measurement of steady signals with frequencies above 20 c/s, while "high damping" is meant for the measurement of fluctuating signals, i.e. frequencies below 20 c/s or measurements where fluctuating background noise would otherwise disturb the meter reading.

The signal is now capable of energizing the relay which makes the indicator lamp light-up. This relay has two stable positions. However, as even the best relays do not always operate on precisely the same amount of current-flow, another stage has been added so that the relay invariably switches over at a certain input signal voltage. This stage has a characteristic as shown in Fig. 31, and as seen the steep slope of the curve provides a large current increase for a slight voltage increase, thus making the energizing point much more consistent. To obtain a stable working point for this stage a zener-diode is introduced, and also a 20 kc/s signal is presented to give an independent bias voltage. This signal is derived from a 20 kc/s generator located in the power supply unit and thus common for all the amplifiers.

This bias is so adjusted as to make the relays operate at an a.c. input voltage of 2.24 V. When none of the "Input" buttons on the Control Panel are depressed, the relays are held in their passive position by means of a "holding voltage" of approximately 12 V dc.

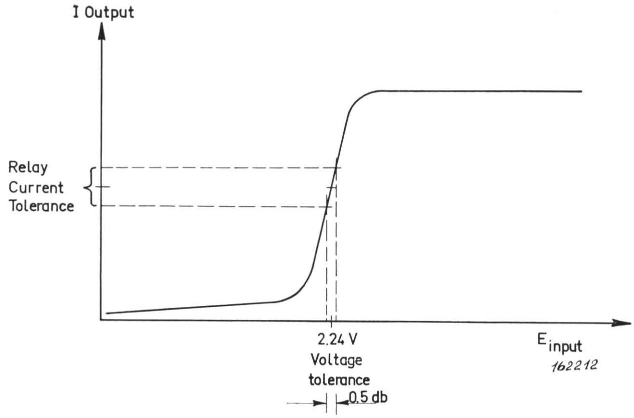


Fig. 31. E_i/I_o characteristic of the current-shaping stage just before the relay.

Before the rectifier circuit is an a.c. output lead to a multisocket on the rear panel of the instrument. The output impedance at the pins of this socket is approximately 25 ohms (to ground). The maximum voltages to be obtained are approximately 7 Volts a.c. (r.m.s.). A voltage of 2.24 Volts a.c. at this point energizes the relay.

Control Panel.

The control panel contains the five pushbuttons intended to be used by the operator as well as the indicating lamps for each channel.

The two input selectors bring the proper input amplifier into circuit and also keep the relays of the output amplifier in the passive position when not depressed.

The "sensitivity increase" button controls the two relays which influence the amount of feedback round the input amplifiers, thereby increasing the sensitivity. This button only functions while kept depressed.

The "release" button releases the other pushbuttons and thus resets the "holding" voltage used to keep the relays of the output amplifiers in the passive position. Furthermore, the "release" button serves to check the proper functioning of the output relays and the indicator lamps, as all the lamps are lit up when the switch is pressed down.

The "Input I", "Input II" and "Release buttons" operate via a relay. The two input buttons are furthermore delayed in operation, so that the "holding voltage" used to keep the output relays in their passive position is not switched off till approximately 1 second after the input amplifiers are switched in. In this way the disturbing effect of transients are avoided.

A green light indicates when the instrument is operating and at which input channel.
Parallel to the "release" button is a springloaded "reset" button which serves to momentarily reset the output relays to their passive positions without releasing the "input" or "sensitivity increase" buttons. Its purposes is to recheck the lamp indication in case of unwanted noise, e.g. footsteps, doors slamming etc.
Each of the red lamps is permanently connected to a 12 V a.c. source and is grounded through its corresponding output relay. In this way the lamps cannot be lit when no amplifier is inserted.
There is a relay in parallel with the lamps. The relay contacts change over whenever anyone of the lamps light-up. The switch so obtained is connected to pin "T" and "U" of the remote control plug (see page 34) and may be used to control remotely buzzers, alarm bells, or other auxiliary equipment. This can ensure that "rejects" are noticed or remove from the production line.

Meter Circuit.

The meter circuit of the apparatus serves mainly as an aid in the proper setting of the attenuators and to check amplification by means of the built-in reference voltage. Additionally, it can be used to check the polarization voltage for the condenser microphone and to read the input signal. The meter can be connected through a switch to any of the outputs of the amplifiers so as to read the output level before rectification. The rectifier circuit of the meter is identical to that of the output amplifiers, as is the damping circuit.
To provide aural or visual indication of the signal that reaches the meter circuit, two test bushings are placed underneath the meter. These bushings are in parallel with the meter circuit, allowing headphones, oscilloscopes or other instruments to be connected to them. With "input level" set to "Ref", the following voltages can be obtained at the meter test points:

> "Meter Switch" at "Filter Input" (deflection to red mark, left): 1 V approx. "Meter Switch" on output 1, 2, 3 etc. (deflection to red mark, right): 2.24 V approx. Same voltage on the multisocket terminals at the rear of the instrument. Full deflection of meter pointer: 3.16 V approx.

Power Supply.

The power supply is contained in one unit, the Power Unit ZG 0001. It can be operated from power lines with a.c. voltages of 100—115—127—150—220 or 240 Volts and frequencies from 50 to 400 c/s. Electrically the power unit can be divided into five main circuits: (a) the 25 V supply, (b) the polarization voltage supply, c() the 20 kc/s control voltage, and (d) the reference supply, and (e) the supply for lamps and control panel relays.

The 25 V circuit provides 25 Volts negative, for use as the colloctor voltage throughout the apparatus and also for the filament voltages of the two cathode followers that can be connected to the input amplifiers. This supply is accurately controlled by a voltage regulator circuit containing three transistors, ensuring minimum ripple and high stability.
The polarization voltage circuit supplies 200 Volts used in connection with condenser microphones and also the anode voltage for the attached cathode follower. These voltages are highly stabilized by three voltage stabilizer tubes. A position of the meter switch makes it possible to check the polarization voltage of 200 V with the built-in meter. A potentiometer, located on the back of the power supply, can be used to adjust the polarization voltage.
The 20 kc/s oscillator produces a control voltage for the final stages of the output amplifiers. It is designed in such a way that it is cut-off when a voltage of approximately 12 Volts is applied to the base of one of the transistors. By means of the relay voltage this oscillator is cut-off every time the relays are set to their passive positions, i.e. when none of the "input" buttons on the control panel are depressed.
The reference voltage is a 10 mV signal of line frequency for checking the amplification. It is kept constant by a zener diode and is applied to the input of the input amplifiers, when the input attenuator is set to the "Ref" position. The reference voltage varies by less than 0.2 % for a 10 % variation in mains voltage.

Specification for Filter Sets ZS 250 and ZS 251.

ZS 251 consists of 11 octave filters with center frequencies of 16 — 31,6 — 63 — 125 — 250 — 500 c/s and 1 — 2 — 4 — 8 — 16 kc/s.
The filters are so designed that they can be switched to have a width of 1/1 octave or 1/3 octave by means of a screwdriver operated switch. The center frequency remains the same for the 1/1 and 1/3 octave position.

ZS 250 contains all the filters mentioned under ZS 251 and additionally all the 1/3 octave filters between 12.5 c/s and 20 kc/s not contained in ZS 251.
It thus forms a complete series of 1/3 octave filters with center frequencies of 12.5 c/s — 16 c/s — 20 c/s — 25 c/s — — — — — — 16 kc/s — 20 kc/s. As every third filter can be switched to the width of 1/1 octave it also forms a complete set of octave filters with center frequencies from 16 c/s to 16 kc/s.
The frequency response of the filters appear from Fig. 28.

Specification

Frequency Range:	With the output amplifier switched to "Lin" positions the response for the entire instrument is linear to within ± 0.4 db from 20 c/s to 20000 c/s, and ± 1.2 db from 2 c/s to 35 kc/s For the input amplifiers only, the response will be linear to within ± 0.2 db from 10 c/s to 35 kc/s ± 0.4 db from 2 c/s to 35 kc/s For the output amplifiers only, the response will be linear to within ± 0.2 db from 20 c/s to 20000 c/s ± 0.8 db from 2 c/s to 35 kc/s
Sensitivity:	32—140 db re. 1 μVolt "normal" 27—140 db re. 1 μVolt with "Sensitivity Increase"
Noise Measurements.	Employing a microphone with a sensitivity of 5 mV/μbar the sound level range that can be measured is: *32—140 db S.L.* (with increased sensitivity: 27—140 db S.L.), using 1/1 or 1/3 octave filters.
Vibration Measurements.	Employing an accelerometer with a sensitivity of 50 mV/G the vibration range that can be measured is: *0.001 g to 200 g,* using 1/1 or 1/3 octave filters.
Input Impedance:	Approximately 150 kohms with input attenuator in position 80—120 db. Approximately 500 kohms with input attenuator in position 130 db. Approximately 1.5 Mohms with input attenuator in position 140 db. The input is paralleled with approximately 80 pF.
Attenuator Ranges:	"Input Level" attenuator: 60 db in 10 db steps. "Indicator Level" attenuator: 48 db in 1 db steps.
Amplification:	Maximum overall amplification: 100 db. The amplification of the input amplifiers when the "Input Level" attenuator is set to the most sensitive positions is *40 db.* When the "Sensitivity Increase" button is depressed, the amplification can be increased by *5 db* to *45 db.* The output amplifiers give an amplification of 55 db when the "Indicator Level" attenuators are set to their most sensitive position.

Output Voltage: AC output terminals: Maximum 7 V, sinusoidal waveform.
Approximately 2.24 V when relay operates.

Output Impedance: AC output terminals: Approximately 25 ohms.

Meter: Scale divisions of 1 db from — 12 db to + 3 db. Full deflection for approximately 3.16 V.
0 db deflection for approximately 2.25 V.

Type of Rectification: Rectifiers for relays as well as the meter rectifier are of the Quasi-RMS type.

Damping: The meter is provided with two degrees of damping, "Slow" and "Fast". The relay circuits also are provided with two levels of damping, "Low" and "High", which correspond to the damping of the meter.

Stability: The reference voltages vary by less than 0.2 % for a 10 % variation in power line voltage.

Power Supply: The instrument can be operated from power lines of 100—115—127—150—220 and 240 Volts, 50 to 400 c/s.
Power consumption approximately 43 Watts:
with all lamps lit, aproximately 67 Watts.

Transistors, Tubes and Diodes: Transistors: 54 × OC44, 15 × OC74, 2 × OC29, 1 × OC77, 1 × TF78/30, and 15 × SFT226.
Tubes: 2 × OA2, OB2.
Diodes: 78 germanium diodes and 14 zener diodes.

Dimensions:
(without handles):

Main Unit:	Height	Width	Depth
Centimetres	57	55	33
Inches	23	22	13
Weight	40 kg	88 lbs.	

Control Panel:	Height	Width	Depth
Centimetres	12	26.5	17.5
Inches	5	11	7
Weight	3 kg	7 lbs.	

Printed in Copenhagen, Denmark April 1963