COMPATIBLE POWER RATING
OF POWER AMPLIFIERS AND LOUDSPEAKERS
FOR SPEECH- AND MUSIC-PROGRAMME

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AUDIO ENGINEERING EXPERTS' GROUP
EXTERNAL PUBLICATION

AEEG/EP-2201
EHR 53/533/80

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Paper of the 65th AES-Convention London February 1980

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SUMMARY

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FOR SPEECH- AND MUSIC-PROGRAMME

The current power ratings for power amplifiers and loudspeakers have quite different bases.

The rated output power of an amplifier is based upon the output power which the amplifier can deliver for a sinusoidal signal at a predetermined amount of distortion. Depending upon the kind of distortion and the amount chosen (0.01% - 10%) quite different power ratings can be obtained.

The rated power of a loudspeaker is based upon a life-test using a signal, simulating normal speech- and music-programme.

Due to the different bases the current power ratings of amplifiers and loudspeakers give no true indication with respect to their power matching and to their reliable co-operation.

Work has been started recently in IEC to achieve compatible ratings for output power of amplifiers and power of loudspeakers, aiming at reliable co-operation under any condition of normal use, including overload conditions inherent to the envisaged applications.

These power ratings should be based upon a new signal, simulating normal speech- and music-programme, and should involve separate power ratings for normal up to "heavy duty" use and for overload conditions occurring for normal operation in the field of application.

COMPATIBLE POWER RATING

OF POWER AMPLIFIERS AND LOUDSPEAKERS

1. INTRODUCTION

The modern conception of audio-engineering requires hi-fi transmission of speech and music, involving true transmission of the complete frequency-range of the speech- and music-spectrum and true representation of their complete dynamic range. The latter requires that for speech- and music-programme reproduced at adequate level, neither distortion should be heard in the peaks, nor should the noise in the reproduction be heard in the background of the environmental noise of the listening-room.

To prevent peak-distortion the power amplifier in most hi-fi sound systems is so amply designed that at the adequate level for hi-fi listening the signal peaks will not intrude into the region of distortion-limited output power of the amplifier, marked by the occurrence of peak-clipping. This measure to the benefit of hi-fi listening, however, involves that the amplifier will be able to deliver considerably larger output power at higher distortion, which might still be well acceptable for less critical listeners or under less critical listening conditions e.g. in the higher environmental noise level of a house party, which tempts to adjustment of the sound system to a higher programme-level.

The loudspeaker, although with respect to distortion and power handling capacity well-designed to cope with the amplifier under hi-fi listening conditions, may not endure the higher power delivered at the less critical situations. Although the amplifier might get into trouble by overheating on the longer run, this will mostly not become manifest because the loudspeaker, due to its much smaller heat-capacity, will die first, thus relieving the amplifier of its power-load.

Because the "less critical use" may occur more or less frequently in the course of "normal use" of any hi-fi sound system, the dealer, to avoid complaints, will often advice his customers to equip his sound system with loudspeakers fit for larger power than could be expected from the power ratings stated in the catalogue-sheets of amplifiers and loudspeakers. Consequently, the power rating data, mostly given for amplifiers and loudspeakers, although inducing to guide to proper choice of a combination of amplifier and loudspeaker for a sound system, in reality leave a gap of uncertainty concerning the reliability of the combination, which can only be bridged by the experience and craftmanship of the dealer or the audio-engineer.

The uncertainty, explained for hi-fi sound systems, in establishing a proper combination of amplifier and loudspeaker, applies still more to public-address sound systems, for which less critical listening conditions may occur much more frequently (e.g. due to incidental higher noise level) or may even represent the conditions for normal operation (e.g. reproduction of background music in a noisy environment). Taking into consideration that for the latter application the music-programme will generally be subjected to rather strong compression of the dynamic-range, thus considerably decreasing its peak-to-rms ratio, and its level increased to the limit of acceptable distortion, this kind of operation requires still larger power handling capacity of the loudspeaker to cope with an amplifier with a predetermined rated output power and maintain reliable operation.

A survey of the present methods of power rating of amplifiers and loudspeakers, to which the next chapter will be devoted, will bring to light the roots of the evil, constituted by an intrinsic incompatibility of the power ratings of amplifiers and loudspeakers, the first being referred to a predetermined amount of distortion, the latter to an accellerated life-test. These power-ratings can only be related to eachother for a combination ensuring reliable operation for a restricted and well-defined kind of use e.g. hi-fi operation, normal public-address operation and "heavy-duty" public-address operation (with compressed programme under noisy conditions), excluding any incidental "less critical use" and any faulty operation, assumptions which cannot be ensured for either of the kinds of operation.

The subsequent chapter will be devoted to quite another method of power rating of amplifiers and loudspeakers for speech- and music-programme, principally based upon the fulfilling of the requirement of reliable co-operation of amplifier and loudspeakers under the "worst conditions of use", reasonably to be expected for each of the kinds of use stated above, including incidental faulty operation. Key in this new method of power rating, now under consideration in IEC/SC29B: "Audio Engineering" for international standardization, is a specific noise signal, simulating speech- and music-programme. This signal is used to establish power ratings for the amplifier in terms of output power and for the loudspeaker in terms of power handling capacity. Power ratings established in this way allow unambiguous expression of the requirements for reliable co-operation of an amplifier and a loudspeaker both for "faulty conditions", occurring during a restricted time-interval and for "worst conditions of use" occurring according to reasonable expectations for the envisaged kind of application.

These power ratings refer to the field of application for reproduction of normal speech- and music-programme, which covers the large majority of applications of sound systems. Applications, involving other signals, considerably deviating in character, such as radically processed speech- and music-programme, used for transmission into very noisy environment and howling signals in alarm-systems,require specific power rating, adapted to the specific kind of signal.

2. PRESENT STANDARDS FOR POWER RATING

1. Standards considered

In the survey, given in this Chapter, the subsequent International Standards and the subsequent National Standards and Rules, respected in international trade, have been considered.

- IEC-Standards, recommended by the International Electrotechnical Commission.
  - IEC-Publication 268: Sound System Equipment.
    Part 3 : Sound System Amplifiers.
    Part 5 : Sound System Loudspeakers.
  - IEC-Publication 65: Safety Requirements for Mains Operated Electronic and Related Apparatus for Household and Similar General Use.
  - IEC-Publication 581: High Fidelity Audio-Equipment and Systems. Minimum Performance Requirements.
    Part 6 : Amplifiers.
    The Part "Loudspeakers" is in progress of preparation but not yet issued as an IEC-Publication.
- DIN-Normen, issued by the "Fachnormenausschuss Elektrotechnik im Deutschen Normenausschuss (D.N.A.)".

- DIN 45566	: Leistungsverstärker Anforderungen	Power-amplifiers Requirements
- DIN 45500	: Heimstudio-Technik (Hi-Fi) Mindestanforderungen	Hi-Fi Technics Minimum Requirements
Blatt 6	: Verstärker	Amplifiers
Blatt 7	: Lautsprecher	Loudspeakers

- FTC-Rules, issued by the Federal Trade Commission (U.S.A.).
  - FTC Trade Regulation Rule on Amplifier Power-Output Specifications. Power Output Claims for Amplifiers Utilized in Home Entertainment Products.

  Being enforced by Federal Law, power ratings in accordance with this Rule may be expected to prevail for the future over the power ratings according to:

  - EIA-Standards, issued by the Electronic Industry Association.
  - IHF-Standards, issued by the Institute of High Fidelity.
  - AES-Standards, issued by the Audio Engineering Society.

  which for this reason have not been considered in this Chapter.

2. Power amplifiers [1)]

The distortion-limited power of speech- and music-programme, which an amplifier is capable to deliver into the loudspeaker(s) associated therewith, is expressed in terms of the Rated Output Power, referred to a predetermined distortion.

Rated output power represents the peak-power of speech- and music-programme occurring for the volume-control of the amplifier being adjusted to the limit of distortion for hi-fi listening conditions. Under these conditions the amplifier delivers the rated output power only during short and widely spaced intervals of time, the long-time average power being considerably lower.

For less critical listening conditions, allowing a good amount of peak-clipping, the volume may be put up to appr. 10 dB higher. Under these conditions the amplifier delivers the rated output during longer and more frequently occurring intervals of time and the long-time average power delivered will be up to 10 dB higher than for hi-fi listening conditions.

Apart from delivering up to 10 dB higher power to the loudspeakers under the latter conditions, the power-dissipation in the amplifier itself will be considerably higher, resulting in a rise of temperature. Because of the rather large heat-capacity of the mains transformer of the power-supply and of the output-transformer, if any, warming-up will occur gradually, but most amplifiers will reach stable temperature-conditions within one hour.

The maximum long-time average power which the amplifier is capable to deliver into the loudspeaker(s) associated therewith is expressed in terms of the Rated Temperature-Limited Output Power referred to a life-test or to the maximum-allowed temperature-rise of the amplifier-components. Requirements concerning the latter aspect, which may be more restrictive than a life-test, are generally not found in Standards for Amplifiers but in the Standards concerning Safety Requirements for Mains Operated Electronic Apparatus.

Most amplifiers will be capable of delivering a much higher power than the Rated Output Power under conditions of faulty operation, e.g. start of programme at much to high position of the volume control or occurrence of acoustic feedback howling in public-address sound systems. This will generally not harm the amplifier which mostly is equipped with an overload-protection circuit to prevent damage to the power-transistors and which has ample heat-capacity to stand the restricted time-interval of overload due to faulty operation without thermal damage to other components. This condition, however, although likely to occur only during a time-interval of some seconds, involves great danger of damaging or even burning-out the loudspeakers, which have a much smaller heat-capacity.

1) The characteristics, expressed in terms of output power, may be as well expressed in terms of output voltage.

Rated Output Power, according to IEC-Publication 268-3, is the maximum power which the amplifier is capable of delivering in the Rated Load Impedance for a sinusoidal signal at a frequency of 1000 Hz and at a stated amount of distortion.

Due to the fact, that it is left to the manufacturer to state a reference distortion, best fitting the envisaged field of application (which might be any value between less than 0,1% and 10%), the value of the Rated Output Power specified for similar amplifiers may largely vary, depending upon the envisaged application and on the manufacturer. The only restriction, put upon the manufacturer in specifying a high Rated Output Power at a high reference distortion, may come from IEC-Publication 65 conc. Safety, which requires the Temperature-Limited Output Power, if not specified by the manufacturer, to be at least 1/8 of the specified Rated Output Power for the worst conditions of normal use.

For Hi-fi Amplifiers, IEC-Publication 581-6 much further restricts the Rated Output Power by requiring the reference distortion to be less than 0,5% over the minimum effective frequency range of 40 Hz to 16000 Hz and by requiring that the amplifier shall be able to deliver the Rated Output Power for at least 10 minutes.

The DIN-Standards 45566 and 45500-7 express nearly identical requirements.

The Trade Regulation Rule concerning Power Output Claims for Amplifiers Utilized in Home Entertainment Products, issued by the U.S.A. Federal Trade Commission, and effective since November 4, 1974, expresses the following requirements concerning Rated Output Power:

- The Rated Output Power expresses the minimum continuous average output power for a sinusoidal signal and for a stated amount of distortion, which any amplifier of that type is capable to deliver into the Rated Load Impedance.
- The Rated Output Power shall be delivered for all frequencies within the rated power frequency band without exceeding the reference distortion.
- The amplifier shall be able to deliver the Rated Output Power for all frequencies within the Rated Power Frequency Band for at least 5 minutes after having been preconditioned by having delivered 1/3 of the Rated Output Power for a sinusoidal signal of 1000 Hz during one hour.

Music Power, acknowledged as an additional specification in DIN-Hi-Fi and FTC-Standards, expresses the output power which the amplifier is capable of delivering in the Rated Load Impedance for peak-signals with very short duration, e.g. due to touched strings and percussion, for which the supply voltages in the amplifier may be expected to remain at the values for zero signal.

Music Power is defined and established as Rated Output Power, but for external Power Supply, maintained at a Power Supply Voltage equal to that of the internal Power Supply for zero signal.

The Columns 1 and 2 of Fig. 1 give a global indication of the relation between the powers (voltages), mentioned in this section.

3. Loudspeakers [1)]

The power of speech- and music-programme which a loudspeaker can endure is expressed in terms of its Power Handling Capacity (PHC), established by means of a life-test.

According to IEC- and DIN-Standards the Power Handling Capacity is the maximum power of a specific noise signal which the loudspeaker can endure during 100 hours of continuous test without changing its characteristics, except its resonance frequency.

The specific noise signal, which should simulate speech- and music-programme, should have a spectral power distribution as given in Fig. 5 and should have been submitted to peak-clipping at a level 6 dB above its rms level, thus reducing its ratio peak-to-average power to 3 dB.

The limit to the Power Handling Capacity, established according to this test, can be set either by mechanical damage, due to excessive vibration, or by heat-damage, due to excessive temperature, depending on the fact to which aspect the loudspeaker is most vulnerable. Because the ratio peak-to-average power in speech- and music-programme is higher than 3 dB, heat-damage will more readily occur in the test than in normal use of the loudspeaker. In an earlier concept of the test, the test signal was interrupted in a time-ratio off/on of 2:1 and applied for 300 hours, thus being equivalent to the present test with respect to the aspect of vibration but much more representative for normal use with respect to the aspect of temperature because the higher ratio peak-to-average power of the test signal of 8 dB was much nearer to that of speech- and music-programme. Experience with power rating according to the present test reveals that for loudspeaker-types with a heat-isolated driver-system (e.g. horn-loudspeakers and tweeters) the limit to Power Handling Capacity may be set by heat-damage, not occurring under conditions of normal use with speech- and music-programme. Re-establishment of the interrupted test-signal in accordance with the earlier concept of the test is to be strongly recommended.

The nature of the test signal provides that for loudspeaker-combinations, incorporating different loudspeaker-units allotted to different frequency-ranges, the power during the test is allotted to those units in accordance with the average spectral power distribution of speech- and music-programme. For loudspeaker-units, intended to be operated within a restricted frequency-band, e.g. as a woofer, squawker or tweeter in a loudspeaker-combination, the PHC is expressed as the full frequency range power of the test signal which the loudspeaker can stand being equipped with a suitable filter, limiting the power supply to the restricted rated frequency range stated. Consequently, a 50W tweeter cannot cope with 50W power but can be used as a tweeter in a loudspeaker-combination with a PHC of 50W.

1) The characteristics, expressed in terms of power, may be as well expressed in terms of voltage.

American Manufacturers Standards involve establishment of a "Power Handling Capacity" of a loudspeaker based upon another test-signal, namely a howling sinusoïdal signal covering a restricted frequency-range within which the major part of the power of speech- and music-programme is to be expected. Obviously, this requires specific test-signals for loudspeaker-units to be operated in a restricted frequency-range, as e.g. woofers, squawkers and tweeters, intended as components for manufacturers of loudspeaker-combinations.

Speech- and music-programme involves impulse-signals due to touched strings and percussion and wave-trains with restricted duration due to organ and other wind-instruments and bowed strings, the peak-power and the short-time average power of which considerably exceeds the long-time average power corresponding to the rms value of the signal.

On the other hand most loudspeakers can readily endure signals at a power exceeding the PHC if this higher power is restricted to rather widely spaced and rather short periods of time, the restriction required depending upon the design of the loudspeaker.

This capability of a loudspeaker to handle impulse-signals, is represented by a power characteristic Music Power Handling Capacity in the DIN Hi-Fi Standard 45500-7, not appearing in present IEC-Standards. Music Power Handling Capacity ("Musikbelastbarkeit") is established as the maximum power of bursts of sinusoïdal signal in time-intervals of max. 2 seconds and for frequencies within the frequency-range between the lower limiting frequency and 250 Hz, which the loudspeaker can endure without striking distortion. This power characteristic of a loudspeaker bears analogy with the power characteristic "Music Power" of an amplifier.

The columns 1 and 5 of Fig. 1 give a global indication of the relation between the PHC and the Rated Output Power.

4. Matching a loudspeaker to an amplifier

Now, thanks to Standardization, the amplifier being labeled with its Rated Output Power, referred to a pre-determined distortion (0,1% - 10%) for a sinusoidal signal, and the loudspeaker being labeled with its Power Handling Capacity, referred to a life-test with simulated speech- and music-programme, both characteristics being expressed in watts, what should be the relation between both to ensure reliable co-operation for speech- and music-programme between the amplifier and the associated loudspeaker?

The PHC of the loudspeaker, being established by means of a signal simulating normal speech- and music-programme, quite clearly represents the upper limit for the long-time average power of normal speech- and music-programme which the loudspeaker could reliably handle. Taking into consideration that surpassing that limit will readily damage or even destroy the loudspeaker, the key to reliable co-operation could be found in expressing the required PHC of the loudspeaker to be a "safety-factor" higher, e.g. two times higher, than the maximum long-time average power of speech- and music-programme which the amplifier could deliver to the loudspeaker under the less critical listening conditions to be expected in the field of application.

Unfortunately this brings us not any further. The Rated Output Power specified for an amplifier, gives no indication at all concerning the value of the power required for the comparison just mentioned. Estimation of that power from the data known concerning speech- and music-programme are deemed to greater uncertainty the lower the distortion for which the Rated Output Power is specified,i.e. the larger the available excess of output power for still acceptable distortion for the very difficult to define "least critical listening conditions". Something like in between 3 and 6 dB below the Rated Output Power for 10% distortion (if this were to deduce from the specification) might be a fair estimate, which would require the PHC of the loudspeaker to be approximately equal to the Rated Output Power of the amplifier for 10% distortion, a "rule of the thumb" used generally for public-address sound systems, working under normal (not very noisy) conditions of use. For sound systems working in continuous noisy environment, generally involving the use of compressed speech- and music-programme, the PHC of the loudspeakers should be about double that value. It should be borne in mind, however, that continuous music-transmission under these circumstances also requires specially designed "heavy-duty" amplifiers for which the Temperature-Limited Output Power is appr. half the Rated Output Power for 10% distortion, considerably higher than required for Hi-Fi and Normal Public-Address use.

Now still remains the requirement of reliability of the sound system under faulty conditions. Unfortunately, no specification of an amplifier reveals the maximum output power which the amplifier can deliver under these conditions, nor express the specifications of loudspeakers the maximum power which the loudspeaker can endure for a restricted interval of time, corresponding to the maximum expected duration of faulty conditions, e.g. one minute. Design with respect to this reliability requirement involves the incorporation of appropriate overload protection devices.

3. COMPATIBLE POWER RATING

1. Signal, simulating Normal Speech- and Music-programme

A first requirement for compatible power-rating of amplifiers and loudspeakers is the use of a same signal for both power-ratings. Lack of compliancy with this principle is the main cause of the incompatibility of present power-ratings of amplifiers and loudspeakers.

The noise-signal, as specified in IEC-Publication 268-5, the spectral power distribution of which is depicted in Fig. 5, has proved not to give adequate representation of normal speech- and music-programme as obtained from grammophone disks and magnetic tape recordings. The representation particularly lacks in the higher-frequency range, to which the present signal allots too less power. This bears no significant consequences for the use of the signal for establishing the PHC for full frequency range loudspeakers but makes it inadequate for establishing the PHC of loudspeakers,incorporating loudspeaker-units allotted to different frequency ranges, particularly with respect to the tweeter.

The inadequate representation of the peak-to-rms ratio of speech- and music-programme, due to the present use of the uninterrupted noise-signal, has already been mentioned in Ch. 2.3.b

Consequently, elaborate investigations have been made in laboratories in different countries with respect to a signal, truly representing Normal Speech- and Music-programme. The result of these investigations is a new noise signal, the spectral power distribution of which is depicted in Fig. 6. This signal, which is a compromise between the mutually not significantly deviating proposals of the laboratories, participating in the investigations, has found sufficient preliminary international support to be circulated as a Six-Month's Rule document IEC/TC29B (Central Office) 85 for approval by the National Committees of IEC, after which approval it will be published as a Supplement to IEC-Publication 268-1: General in the series of IEC-Publication 268.

For establishing the Power Handling Capacity of a loudspeaker this signal should be submitted to peak-clipping at a level 6 dB above its rms value and be interrupted with an on/off ratio 1:1.

The procedure followed to obtain this signal is explained in detail in the Appendix to this paper.

2. Requirement with respect to conditions of normal use [1)]

As mentioned earlier in Ch. 2.4, the basis for compatible power rating, aiming at reliable co-operation of an amplifier and associated loudspeaker(s) for speech- and music-programme has to be found in the "least critical listening conditions", expected to occur in the envisaged field of application, supposing that in course of normal use the volume, adjusted by the user, will not surpass the limit of just acceptable distortion of speech- and music-programme under these listening conditions.

Investigations made by listening tests with a large variety of music-items have indicated that under the conditions stated above the long-time average power, delivered by the amplifier to the loudspeaker, representing the Rated Load Impedance, will generally not surpass 50% of the Rated Output Power $P_{10\%}$, established for a sinusoidal signal with a frequency of 1000 Hz at 10% distortion, and only very rarely will approach its full value.

This justifies that the requirement for reliable co-operation of an amplifier and the associated loudspeaker(s) for normal use can be expressed as:

$$\text{PHC lsp.} \geqslant P_{10\%} \text{ amp.}$$

thus confirming the existing "rule of the thumb".

1) Proposal of the Netherlands National Committe, still under consideration in IEC.

3. Requirement with respect to faulty conditions[1)]

Under faulty conditions of any kind the source e.m.f. of the amplifier may amount to many times its value under normal conditions of use, thus creating a situation of extreme overload, in which the amplifier may deliver a power,far exceeding the Rated Output Power established for 10% distortion. Taking into consideration the much higher loudness level and the extreme distortion occuring in this situation it is to be expected that on short notice measures will be taken to restore the situation to normal or to put the sound system out of operation. The faulty condition consequently can be expected to exist only during a restricted period of time. This will generally be very short, not longer than some seconds, but might be much longer, even one minute.

The overload is unlikely to harm the amplifier, but may damage the loudspeaker,both by excessive vibration and by excessive temperature, which (mechanical) damage may accumulate for multiple overload-events.

The power P_{max}, delivered by the amplifier during overload can be established by measuring the output power of the amplifier due to one minute of input voltage of standard noise-signal, equal to 10 times the input voltage for rated output power at 10% distortion.

The power P_{max}, which the loudspeaker can endure in bursts of one minute, can be established by a life-test, involving 10 bursts of standard noise, each lasting one minute,adequately spaced to prevent accumulation of temperature-rise.

For reliable co-operation of the amplifier with the associated loudspeaker(s) the following requirement should be fulfilled:

$$P_{max} \text{ lsp.} \gg P_{max} \text{ amp.}$$

The value of P_{max} amp. may be up to 5 dB higher than the Rated Output Power $P_{10\%}$, the instantaneous peak-value may be up to 10 dB higher.

P_{max} lsp. has been found hardly to exceed PHC for small loudspeakers but for most loudspeakers to be at least 3 dB higher.

The columns 3 and 4 of Fig. 1 give a global indication of the relation between P_{max} amp. and P_{max} lsp.

1) Proposal of the Netherlands National Committe, still under consideration in IEC.

4. Variabele loudspeaker connection

Theater sound systems and public-address distribution systems, designed for audio power transmission over 70/100V lines, may be operated with widely varying load on the audio power line. Loudspeakers may be switched off, leaving only a few connected, representing for the amplifier near to zero load. Under these conditions the amplifier may be able to effect a much higher output voltage than for rated load, resulting in much higher power delivered to the few loudspeakers connected.

Unless the amplifier is equipped with a limiter circuit, preventing the output voltage to surpass the rated output voltage (70/100V), the output voltages U_{max} amp. and $U_{10\%}$ should not only be specified for rated load but also for the range of rated down to zero load.

5. Other kinds of signal

According to the Appendix, the new test signal, interrupted at a ratio on/off 1:1, represents Normal Speech- and Music-Programme with respect to spectral power distribution and with respect to dynamic behaviour.

Measurements and tests on loudspeakers with this signal, therefore, may be expected to be representative for establishing limiting characteristics, valid for use with Normal Speech- and Music-Programme, with respect to damage due to excessive vibration and due to excessive temperature, for full-frequency range as well as for multiple frequency range loudspeakers and loudspeaker-combinations.

The test signal, however, is not representative for other signals, widely deviating from Normal Speech- and Music-Programme, either with respect to spectrum or with respect to dynamic behaviour, nor will characteristics obtained with the test signal be valid for use with these other signals.

This e.g. applies to:

- Strongly compressed Speech- and Music-Programme
- Sinusoïdal or other periodic signals at constant or varying frequency
- Impulsive signals

for which appropriate limiting characteristics (e.g. PHC of loudspeakers) will have to be established or appropriate protective measures should be taken.

4. SHORT SURVEY AND CONCLUSIONS

According to the present Standardization, the power-characteristics to be specified for amplifiers and loudspeaker have quite different bases:

- The Rated Output Power of an amplifier, referred to a stated amount of distortion of a sinusoïdal signal.
- The Power Handling Capacity of a loudspeaker, referred to a life-test for a noise-signal, simulating Normal Speech- and Music-Programme.

These characteristics allow no judgment concerning reliable co-operation of an amplifier and a loudspeaker for Normal Speech- and Music-Programme, because at normal use and the more at faulty operation the power delivered by the amplifier to the loudspeaker may largely exceed the Rated Output Power specified.

To put an end to this most unsatisfying situation, IEC/SC29B: Audio Engineering has taken steps to arrive at Compatible Power Ratings of Amplifiers and Loudspeakers, aiming at Reliable Co-operation for Use with Normal Speech- and Music-Programme.

As a first result a new Simulated Programme Signal for Audio Measurement has been established, now up to final decision for IEC Standardization, which adequately represents the Spectral Power Distribution of Normal Speech- and Music-Programme and, if interrupted in a ratio on/off 1:1, also adequately represents its Dynamic Behaviour.

Further a Netherlands proposal has been submitted within IEC/SC29B for two sets of power characteristics for amplifiers and loudspeakers, the first set representing conditions of normal use with Normal Speech- and Music-Programme, including "worst-case normal use" and the second set representing conditions due to faulty operation, supposed to be maintained only for a restricted period of time, set at one minute.

The first set involves the following characteristics:

- Rated Output Power $P_{10\%}$ of an amplifier for 10% distortion.
- Power Handling Capacity PHC of a loudspeaker, based on a 200 hours test with Simulated Programme Signal, interrupted in a ratio on/off 1:1.

The second set involves the following characteristics:

- Maximum Output Power P_{max} amp. of an amplifier for Simulated Programme Signal, to be delivered for a period of time of one minute.

- Maximum Power P_{max} lsp. of a loudspeaker, endured for 10 pulses of "interrupted" Simulated Programme Signal, each lasting 1 minute.

Expressed in terms of power $P_{10\%}$, PHC, P_{max} amp. and P_{max} lsp. the characteristics apply to impedance-defined matching.

For voltage-defined matching they may be expressed in terms of voltage $U_{10\%}$, VHC (Voltage Handling Capacity), U_{max} amp. and U_{max} lsp., $U_{10\%}$ and U_{max} amp. referring to termination of the amplifier with the Rated Load Impedance.

Because for partially loaded amplifiers, as frequently occurring for voltage-defined Public-Address sound systems, the output voltages $U_{10\%}$ and U_{max} amp. may considerably exceed the values for rated termination, the specifications of $U_{10\%}$ and U_{max} should adequately cover the range of terminations from rated termination down to zero load for amplifiers intended for this field of application. For amplifiers, intended to be used in home sound systems, the specification may be restricted to a narrower range of termination.

A loudspeaker will be considered to allow reliable co-operation with an amplifier for use with Normal Speech- and Music-Programme for all conditions expected to occur in course of normal operation if the following requirements are fulfilled:

For impedance-matching	For voltage-matching
PHC lsp. $\geqslant P_{10\%}$ amp.	VHC lsp. $\geqslant U_{10\%}$ amp.
P_{max} lsp. $\geqslant P_{max}$ amp.	U_{max} lsp. $\geqslant U_{max}$ amp.
	$U_{10\%}$ and U_{max} amp. to be taken for the highest value of the load impedance of the amplifier to be expected in the field of application, for public-address applications to be set at zero load.

The IEC-Standard for Compatible Power Rating of Amplifiers and Loudspeakers and the Requirements for Matching with Respect to Reliable Co-operation of Amplifier and Associated Loudspeaker(s) for Normal Speech- and Music-Programme, still under consideration in IEC/SC29B, may be expected to be within the scope of the principle of the proposal.

The Power Rating refers to use with Normal Speech- and Music-Programme. Use with signals, widely deviating from this, either with respect to Spectral Power Distribution or with respect to Dynamic Behaviour, such as radically compressed speech- and music-programme, howling sinusoidal and impulsive signals, will require power rating, matching the particular character of the signal.

The Simulated Programme Signal has now been in use for four years for establishing the PHC of full frequency range loudspeakers, multiple loudspeaker combinations and woofers, squawkers and tweeters, intended to be used in such combinations.

APPENDIX

SIMULATED PROGRAMME SIGNAL

1. Normal Speech- and Music-Programme

Speech and music are transient phenomena that with respect to their physical aspects can be characterized by their spectral power distribution and by the statistical distribution of the power levels in the spectrum.

By a procedure of averaging on one hand the spectral power distributions established for a large number of samples of different speech and music and on the other hand their statistical distributions of the power levels in the spectrum an average spectral power distribution and an average statistical distribution of the power levels can be obtained. These distributions together characterize a signal, indicated as Normal Speech- and Music-Programme.

The procedure is not unambiguously defined. Speech and music have different characteristics and differences also exist between male and female speech. The Normal Speech- and Music-Programme, therefore, will reflect the rather arbitrary choice of the weight of male speech, female speech and music in its composition.

This signal can be approximated by a weighted gaussian noise. The spectral distribution can be approximated as closely as desired by proper weighting. The statistical distribution of the power levels, however, is that of a gaussian noise and differs from that of Normal Speech- and Music-Programme. Appropriate correction of that distribution were possible by subjecting the noise signal to dynamic reshaping by means of a non-linear element. For the envisaged use, however, it is sufficient only to correct its peak-to-long time average power ratio, which can be done, either by decreasing that ratio by means of appropriate peak-clipping or by increasing it by means of interruption in an appropriate duty-cycle.

An example of a simulated programme signal, obtained in this way, is the noise-signal specified in IEC-Publication 268-5 for establishing the Power Handling Capacity of a loudspeaker.

Because this signal requires correction (see Ch. 3.1), investigations have been made to establish a new Simulated Programme Signal.

2. The new Simulated Programme Signal

The Netherlands proposal for the new Simulated Programme Signal has been established according to the following procedure.

Acknowledging that grammophone records are the main source for music-reproduction, the samples of speech and music have been taken from grammophone records, offering an adequate diversity of programme.

Samples of 32 seconds have been taken from each programme-item. The 1/3-octave band power spectrum has been taken from each sample by means of a Real Time Analyzer. Examples of the spectra obtained for the samples are shown in Figs. 2, 3 and 4 for characteristic programme-items.

Then the envelope-curve of the spectra pro programme-item has been established, representing for that programme-item the worst-case signal for loudspeaker life-test. For that worst-case signal the power distribution between the lower- and the higher-frequency range has been established as a function of the cross-over frequency. These power-distribution curves are shown on the lower diagrams of the Figs. 2, 3 and 4. These curves enable computation of the power-distribution in a two-loudspeaker combination. So e.g. Fig. 2 shows, that for that programme-item for a cross-over frequency of 700 Hz 60% of the power goes to the low-frequency range loudspeaker and 40% to the high-frequency range loudspeaker.

Before further explaining the procedure for establishing the new signal let us first consider the existing noise test signal, specified in IEC-Publication 268-5, for which Fig. 5 shows the spectrum-curve and the power distribution curve. Fig. 6 shows these curves for the test signal, together with the envelope spectrum curves and power distribution curves for a number of programme-items, including those given in Figs. 2, 3 and 4. Fig. 6 clearly shows that the existing test signal lacks representation of the speech- and music-signal for the higher frequencies. The lower diagram reveals that with cross-over at 700 Hz the test allots appr. 13% of the power to the higher-frequency range loudspeaker whereas for the programme-items this is up to 56% !

Returning to the procedure for establishing the new signal, the next step again aims at worst conditions for testing. From the power distribution, shown in the lower diagrams of Fig. 6, the power distribution is deduced irrespective of the programme-item, i.e. for each cross-over frequency the maximum share for the lower- and for the higher-frequency range is computed. This leads to the dotted curve in the lower diagram of Fig. 7 from which the dotted spectrum-curve is deduced, that constitutes the spectral power distribution for the new noise signal, as proposed by the Netherlands.

The Netherlands proposal thus concernes a "worst worst case" test signal, aimed at obtaining from the PHC-test a PHC-rating for a loudspeaker,ensuring the maximum reliability of operation, but significantly deviating from true representation of the Normal Speech- and Music-Programme.

The proposals by other countries aimed at true representation of the Normal Speech- and Music-Programme, showing the mutual deviations to be expected from somewhat different conceptions of choice and origin of the programme-material. The drawn curve, shown in Fig. 7 has been accepted as a basis for international agreement and now is subject of the IEC Six Month's Rule document 29B (Central Office) 85, circulated for international approval by the IEC National Committees.

Comparison of the power spectrum curves and the power distribution curves of the existing noise test signal and of the new proposed Simulated Programme Signal, both shown in Fig. 7, reveals the large difference concerning spectrum and "testing capacity" between the existing and the new signal.

The spectrum of the test-signal ensures appropriate distribution of the power of speech- and music-power over the loudspeakers in a multiple frequency-band combination. To be representative with respect to causing damage of the loudspeakers due to vibration,the test-signal should also represent the dynamic behaviour of Normal Speech- and Music-Programme.

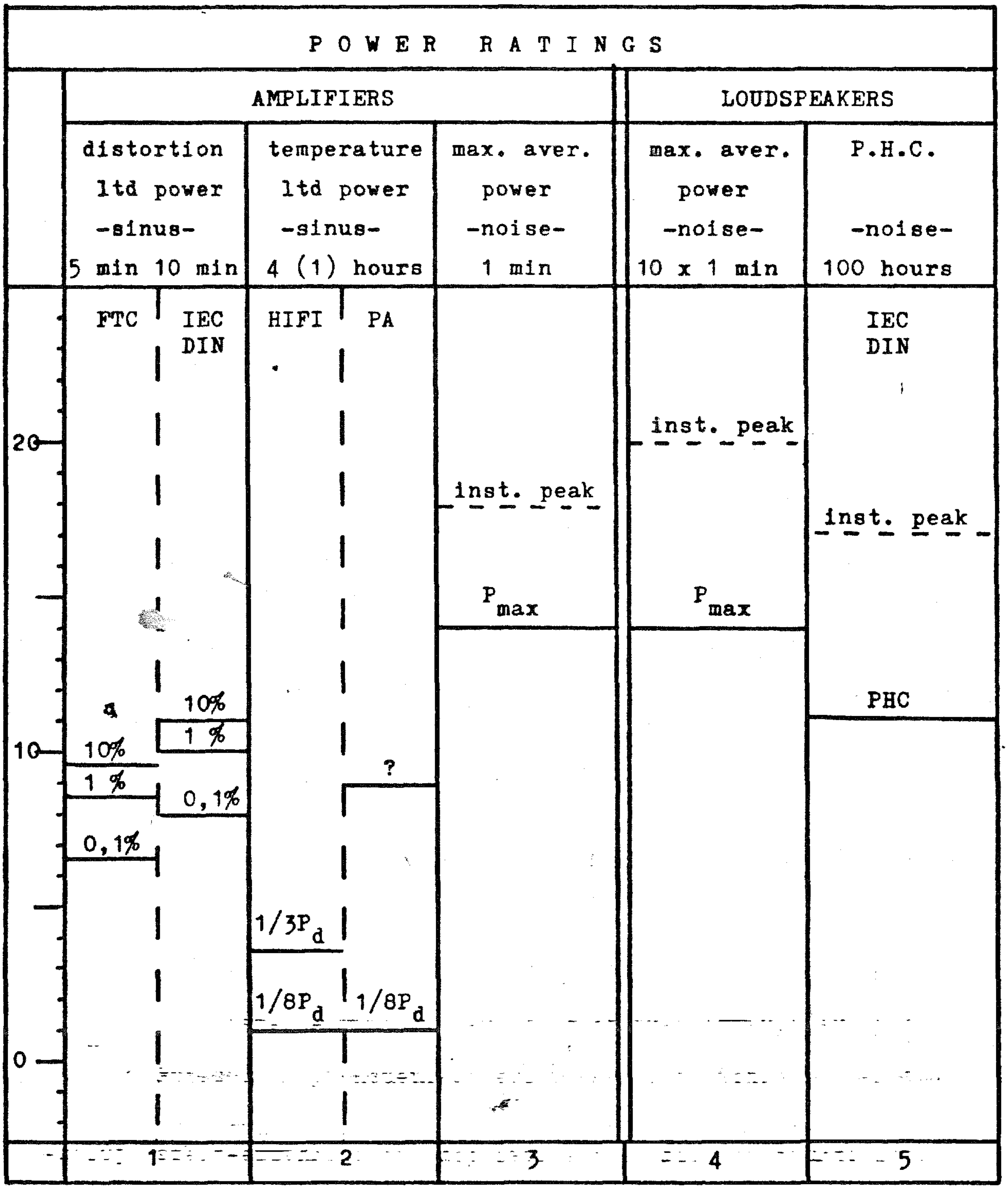
To check, to what extent a gaussian noise signal can represent the statistical distribution of power levels of Normal Speech- and Music-Programme, investigations have been made concerning that distribution for the speech- and music-samples, used in the investigation with respect to the spectrum, and for the new test signal. The investigations involved measurements to check how long and how frequently the instantaneous value of the signal surpasses a pre-determined level.

In Fig. 8 the abscis represents the trigger-level, the rms level of the signal being taken as the 0 dB reference. The ordinate represents the total period of time, expressed in ms per minute, that the instantaneous signal level surpasses the trigger-level. The curves refer to the different programme-items considered. Fig. 8 shows that e.g. a level, 6 dB above rms level, is surpassed by the instantaneous level of the programme-items during a period of time of 700 up to 2000 ms per minute.

Fig. 9 shows in an analoguous representation how many times per minute the instantaneous levels of the programme-items surpass the trigger-level and indicates that e.g. a level, 6 dB above rms level, is surpassed 2000 up to 15000 times per minute.

Fig. 10 shows both data for the new test signal, interrupted with a ratio on/off 1:1 . Interruption has been introduced because it has been found that the peak-to-rms ratio for the continuous test-signal is appr. 3 dB less than for the programme-items. The total period of time that a pre-determined level is surpassed and the frequency of surpassing for the test signal is appr. twice that for the programme-items. Interruption with a ratio on/off 1:1 of the test signal reduces its rms value with 3 dB, maintaining its peak-value, and will halve the period of time and the frequency of surpassing a pre-determined level, thus bringing the test-signal into line with the dynamic behaviour of the programme-items.

Fig. 1 Diagram, indicating globally the relations between the different power levels mentioned in this paper.

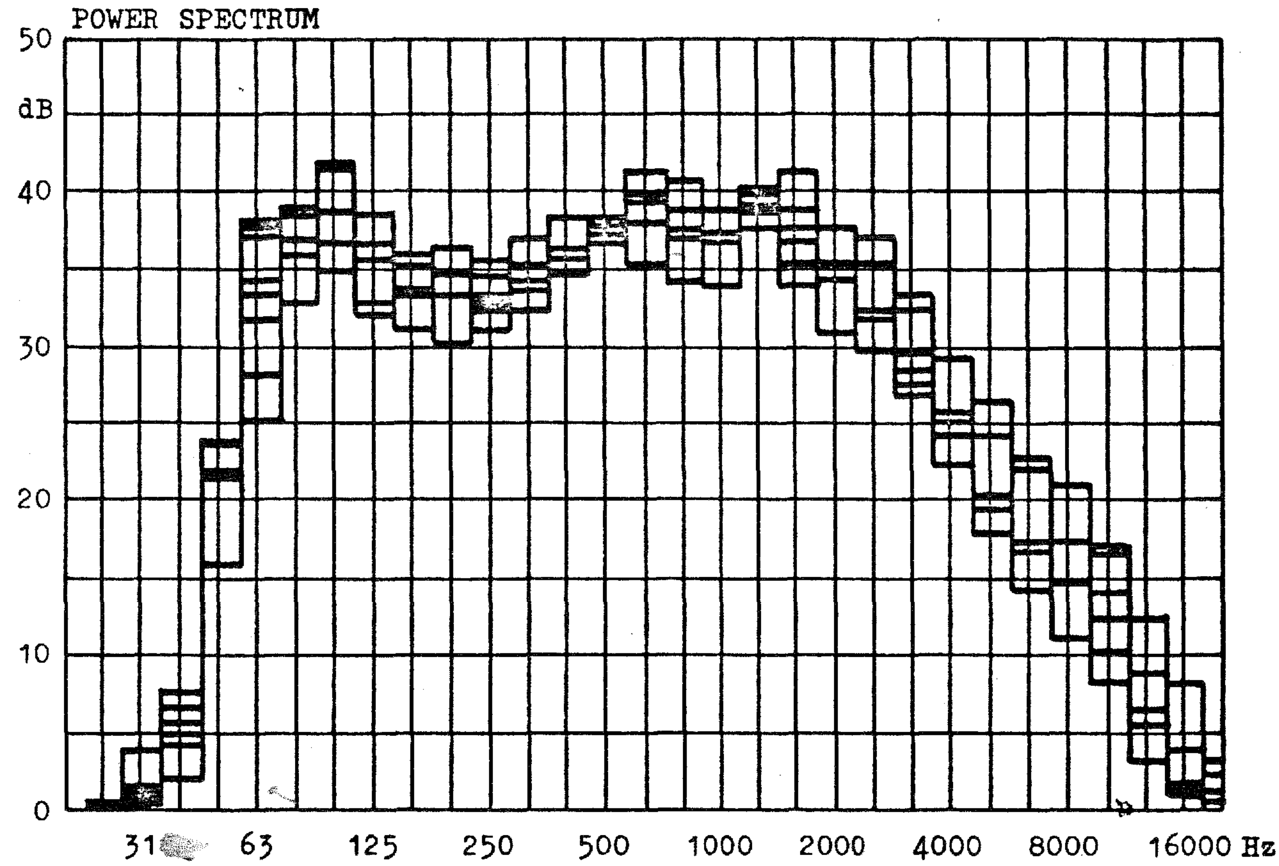


Reliable combination of amplifier and loudspeaker is obtained if :

$$P_{max}\ lsp \geqslant P_{max}\ amp$$

$$PHC\ lsp \geqslant P_{10\%}\ amp$$

Fig. 2 DGG 138 804 SLPM, Symphony N° 5, Beethoven.
H. von Karajan, side 2, middle 1/3 part.
large orchestra



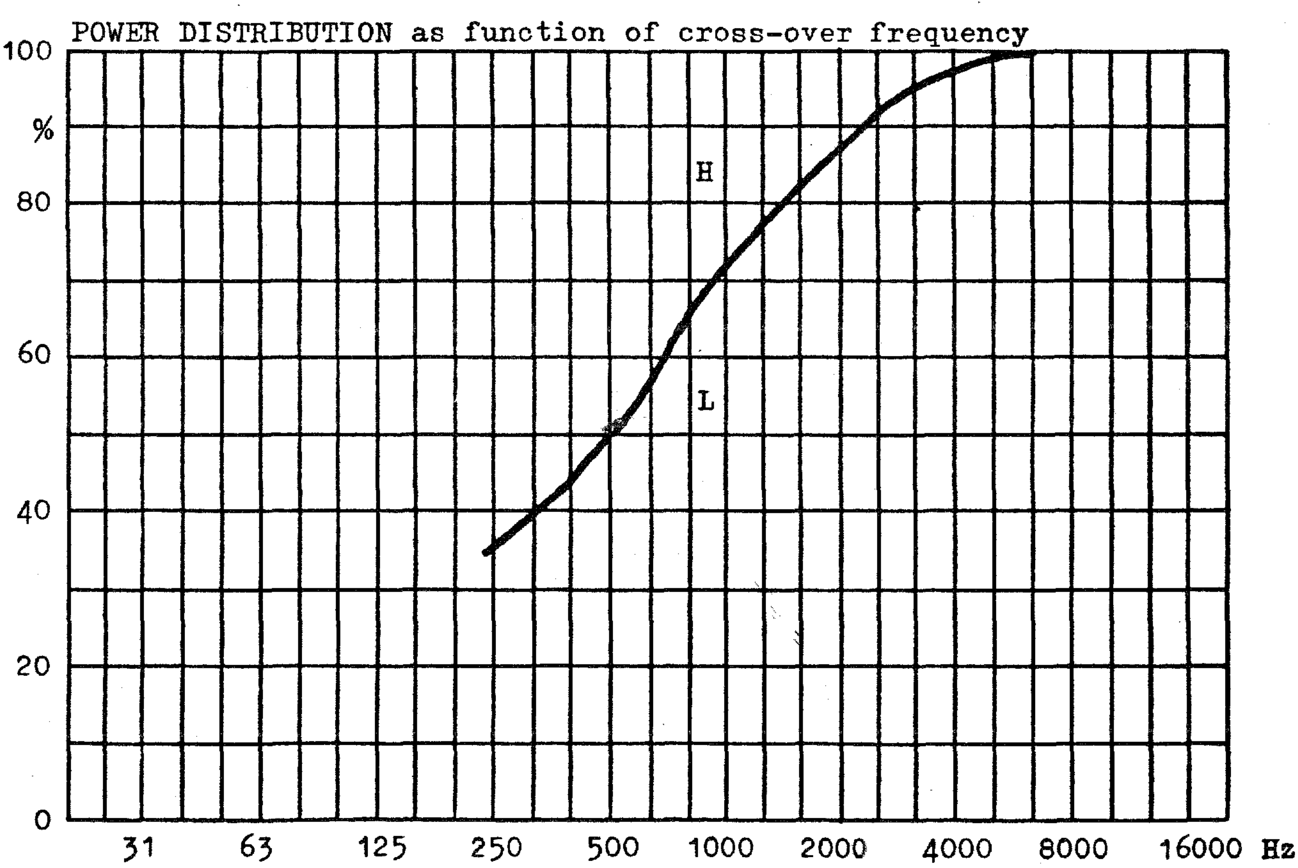
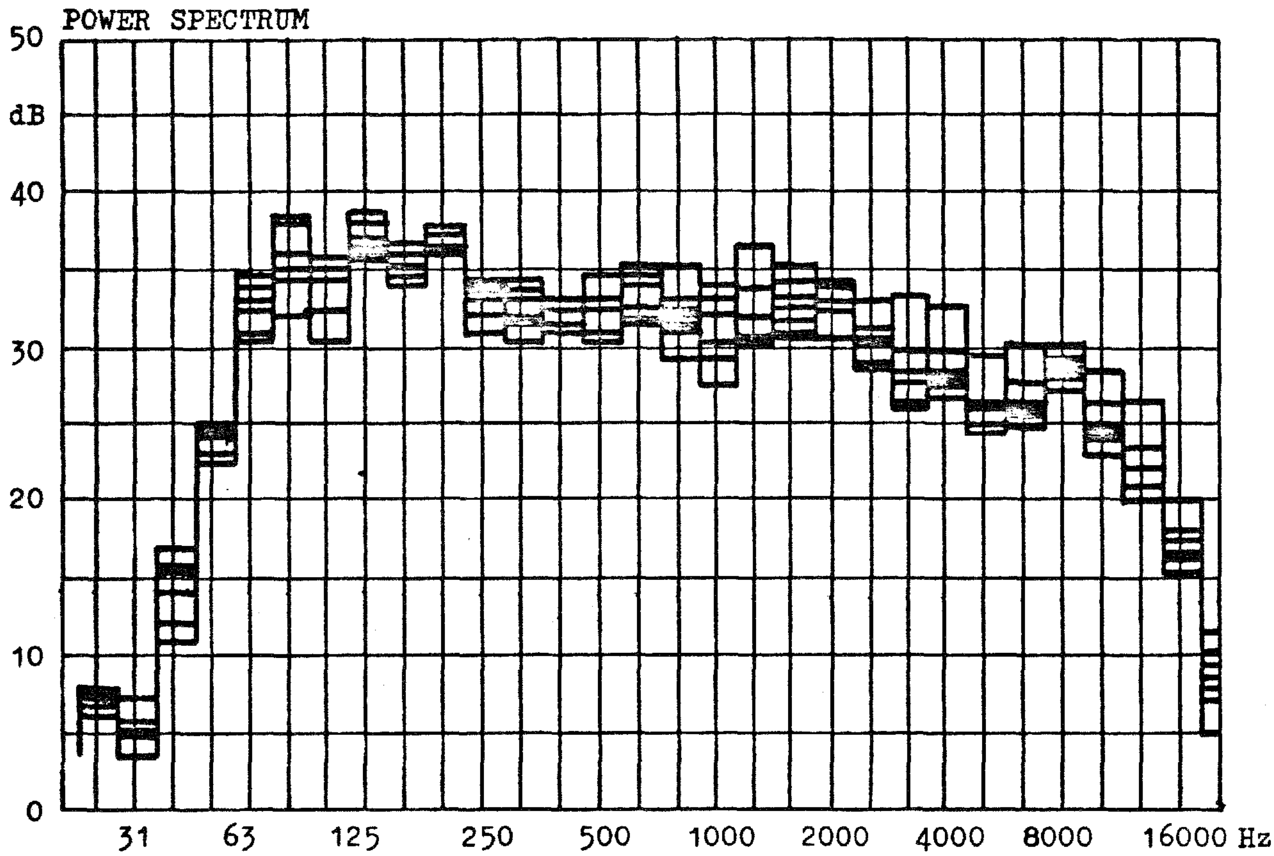


Fig. 3 Polydor 249 160, Non stop dancing 67/2
James Last, Pleasant Valley Sunday, side A, track 1
modern popular orchestra



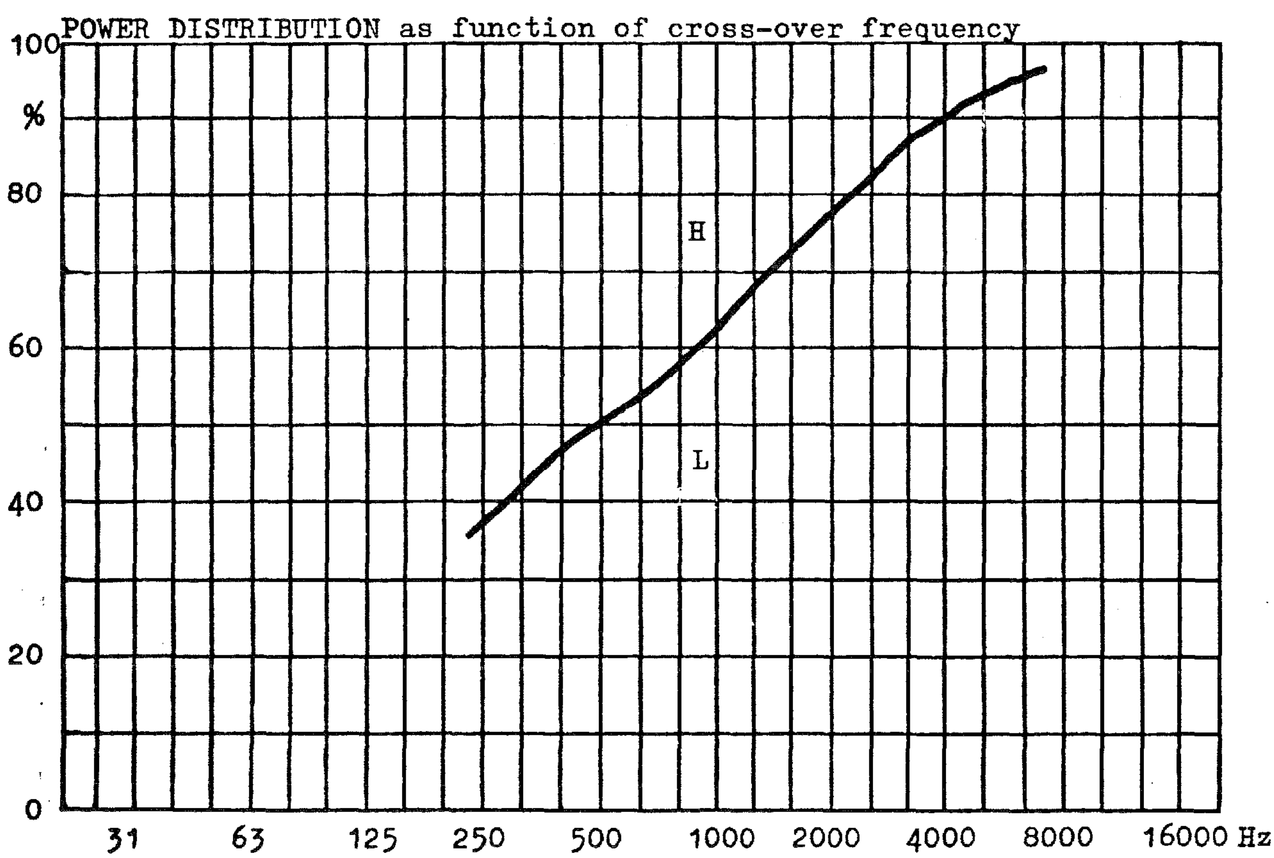
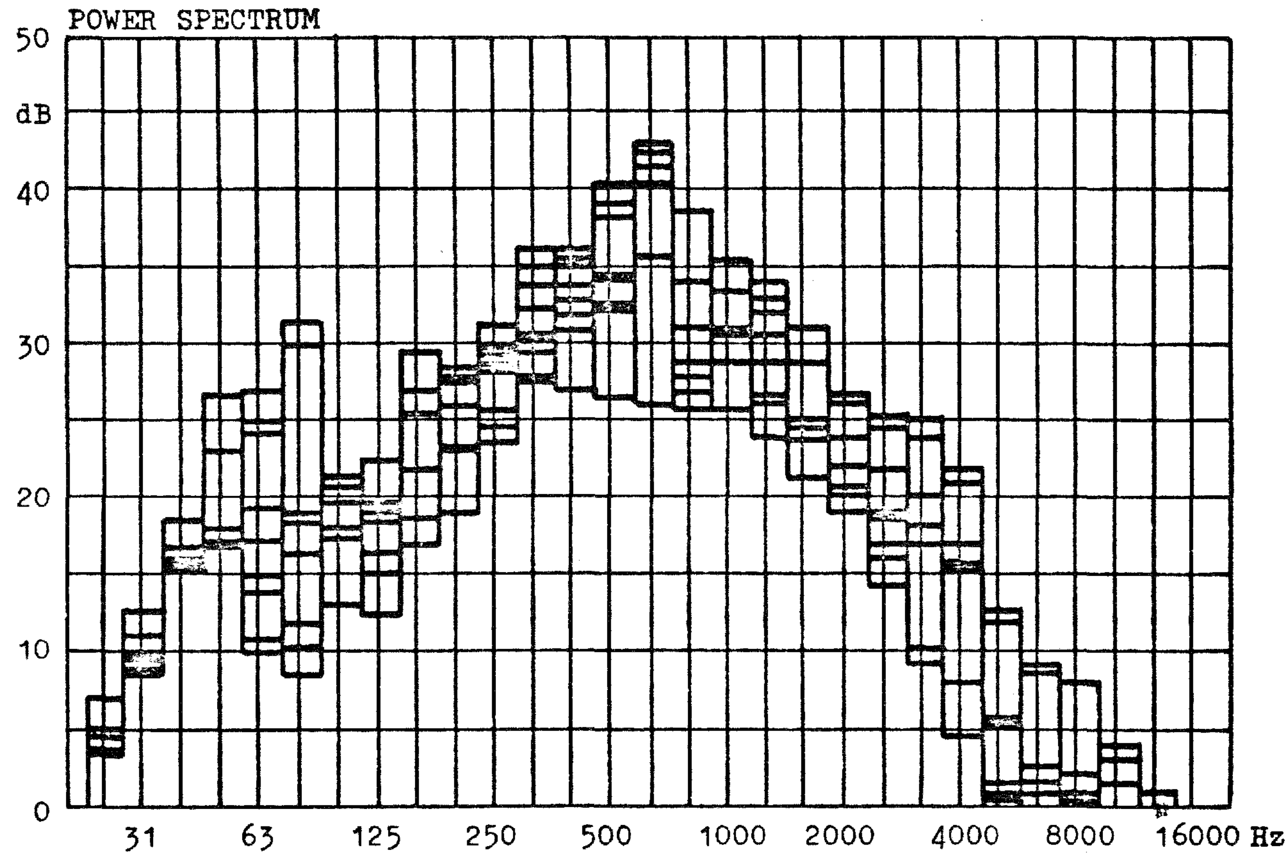


Fig. 4 CBS 72480, Bless this house
Mormon Tabernacle Choir, Oh Lord most holy
mixed choir with accompaniment



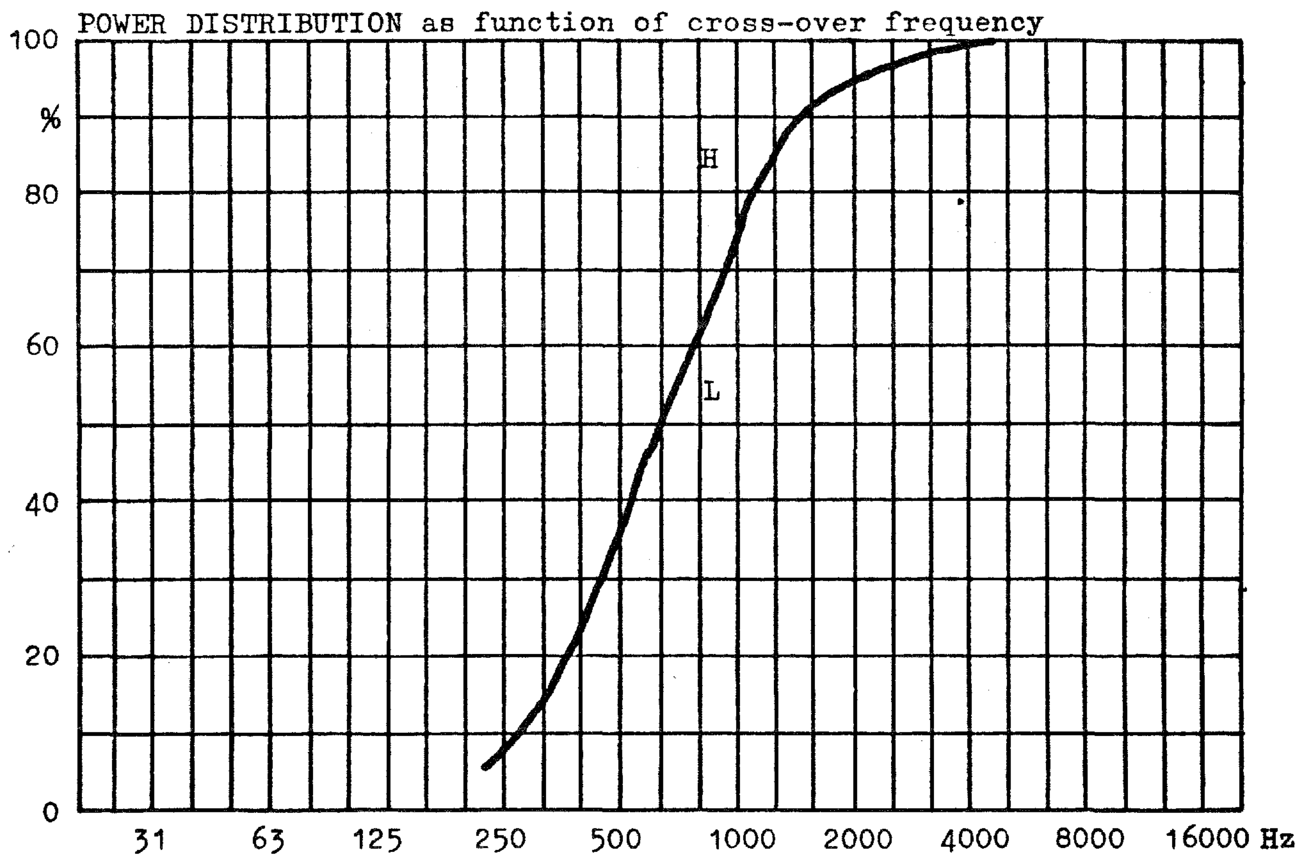
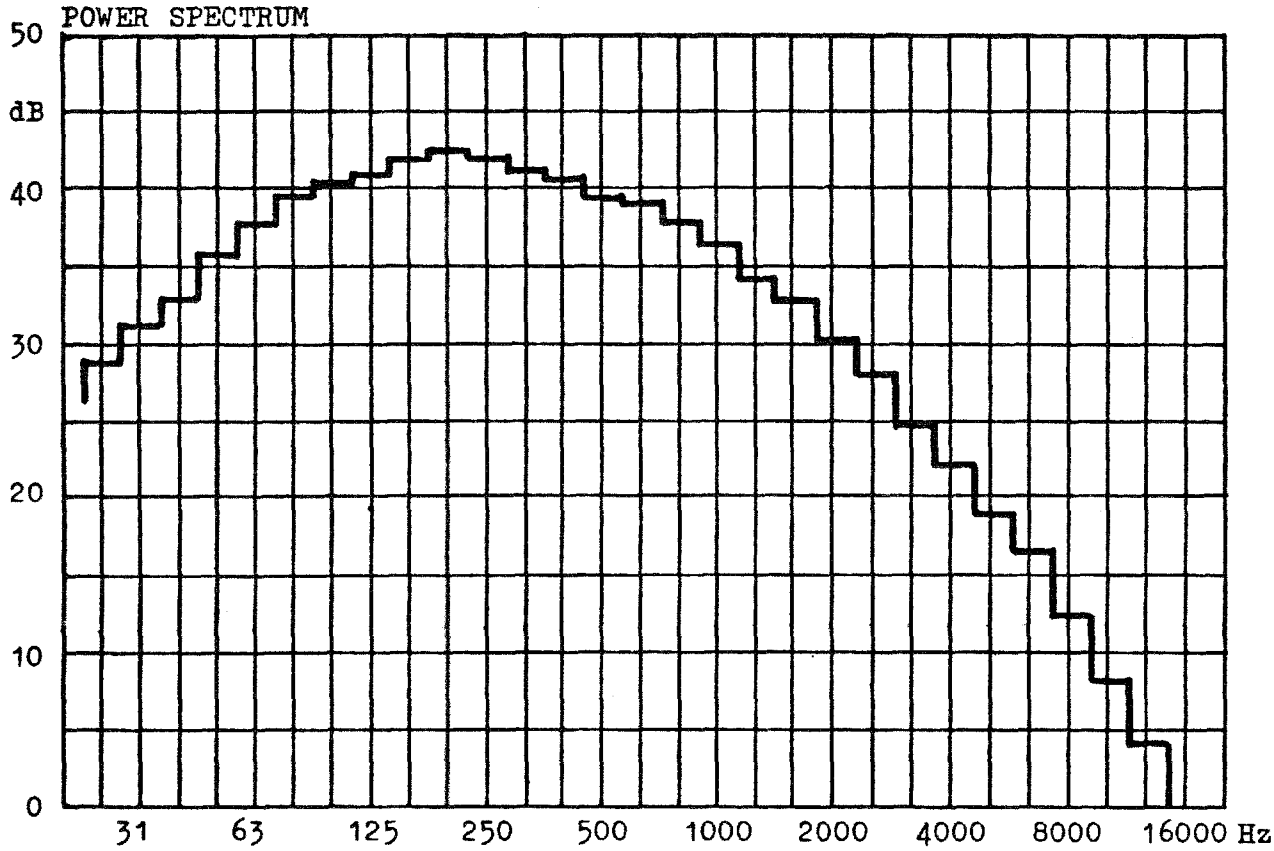


Fig. 5 Noise test signal for accelerated life test of loudspeakers according IEC



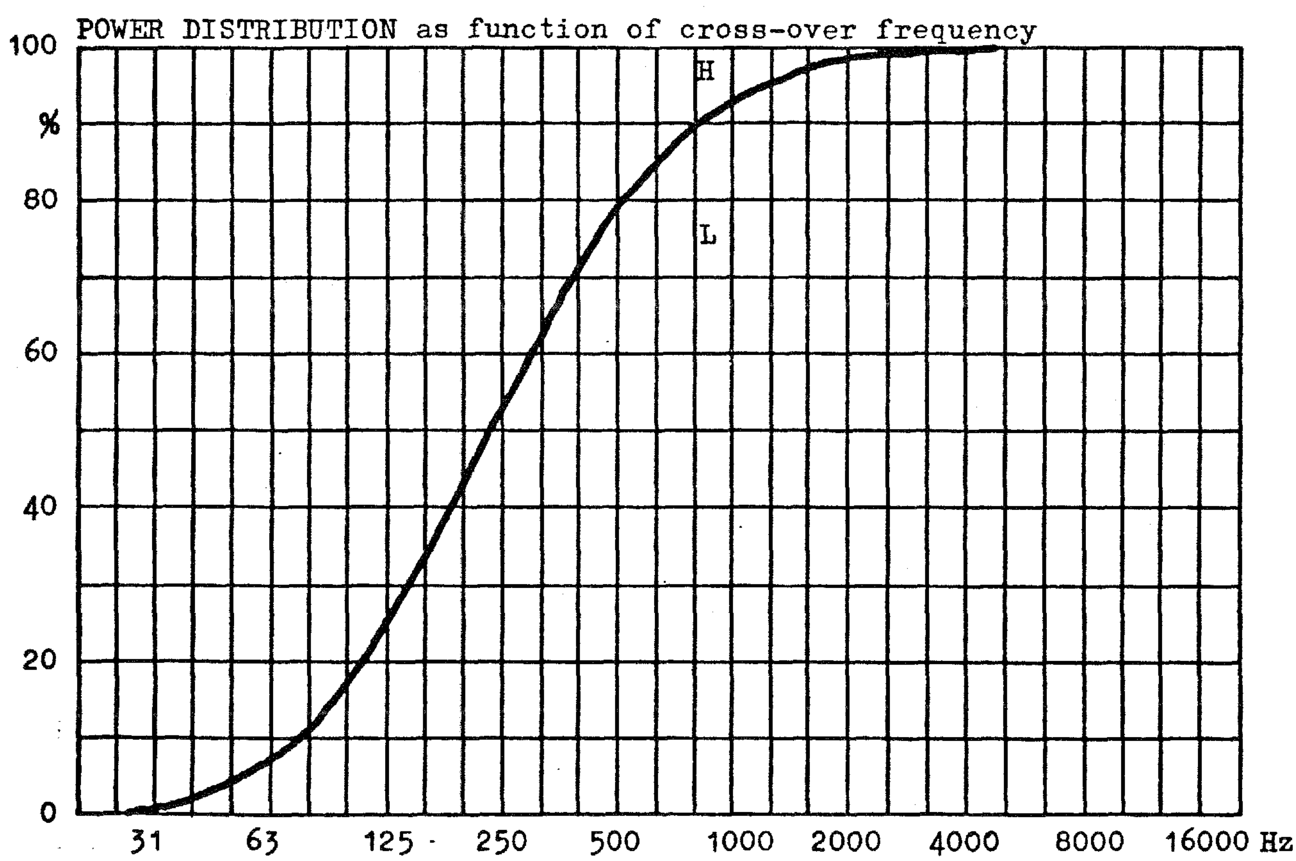
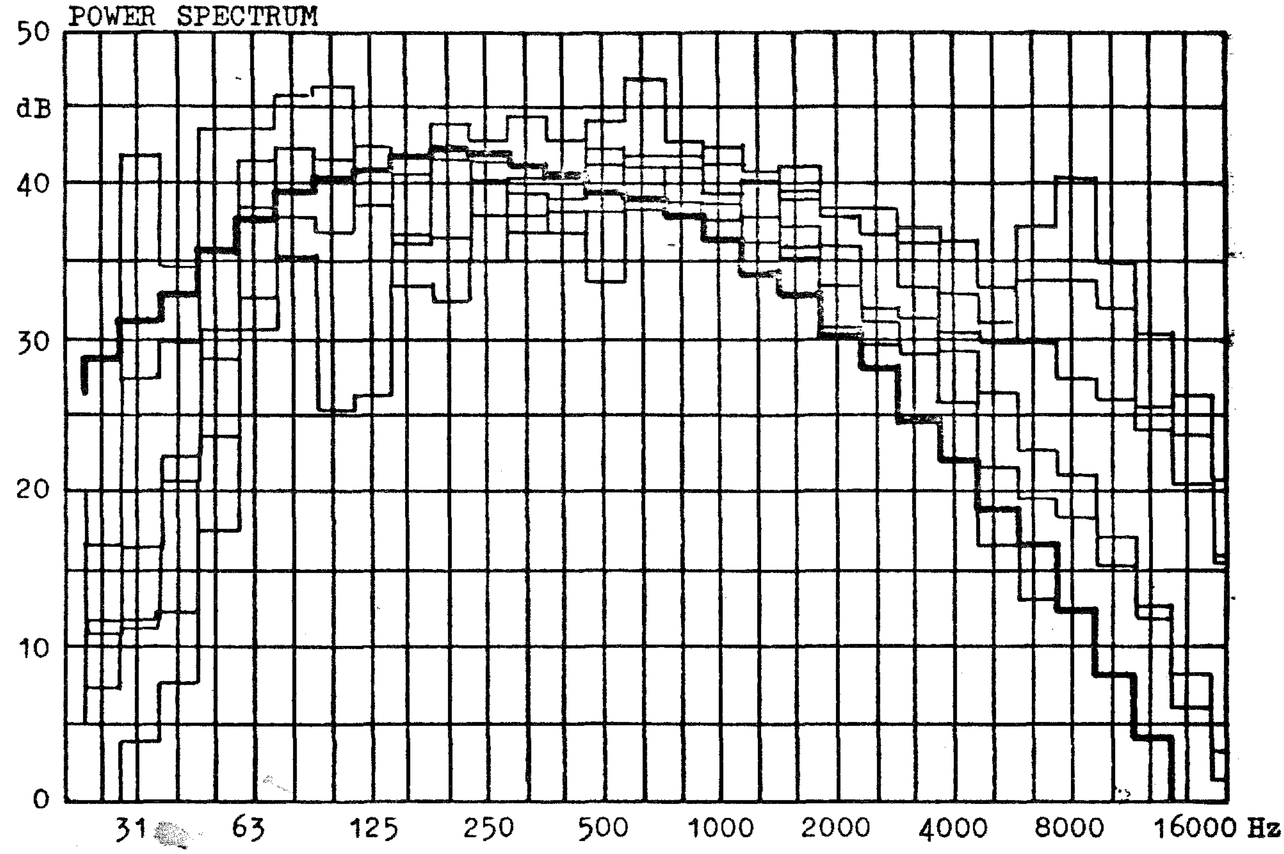


Fig. 6 Comparison between the noise test signal (———) and 6 quite different musicfragments (——)



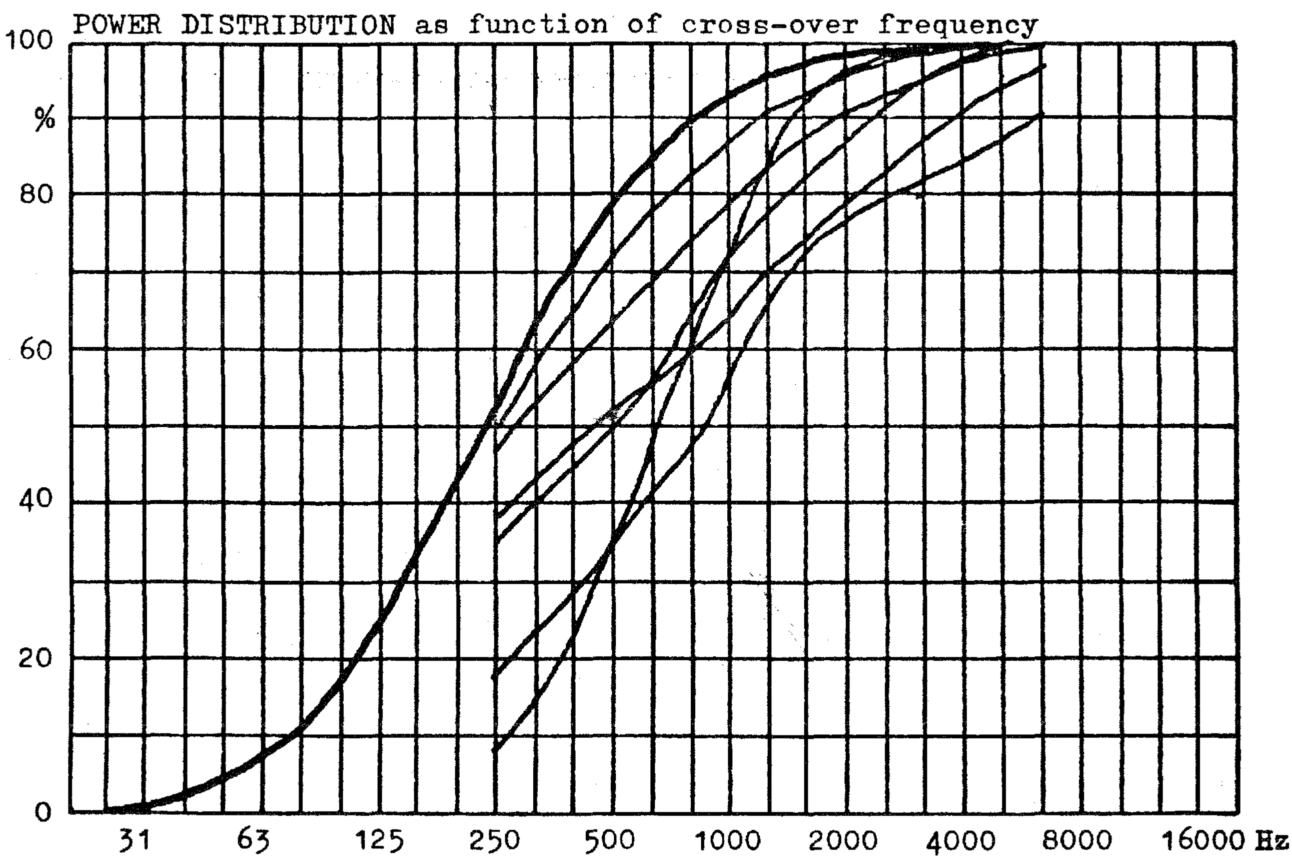


Fig. 7 drawn : new proposed test signal (IEC)
dashed: existing test signal (IEC)
dotted: test signal proposed by NEC to IEC

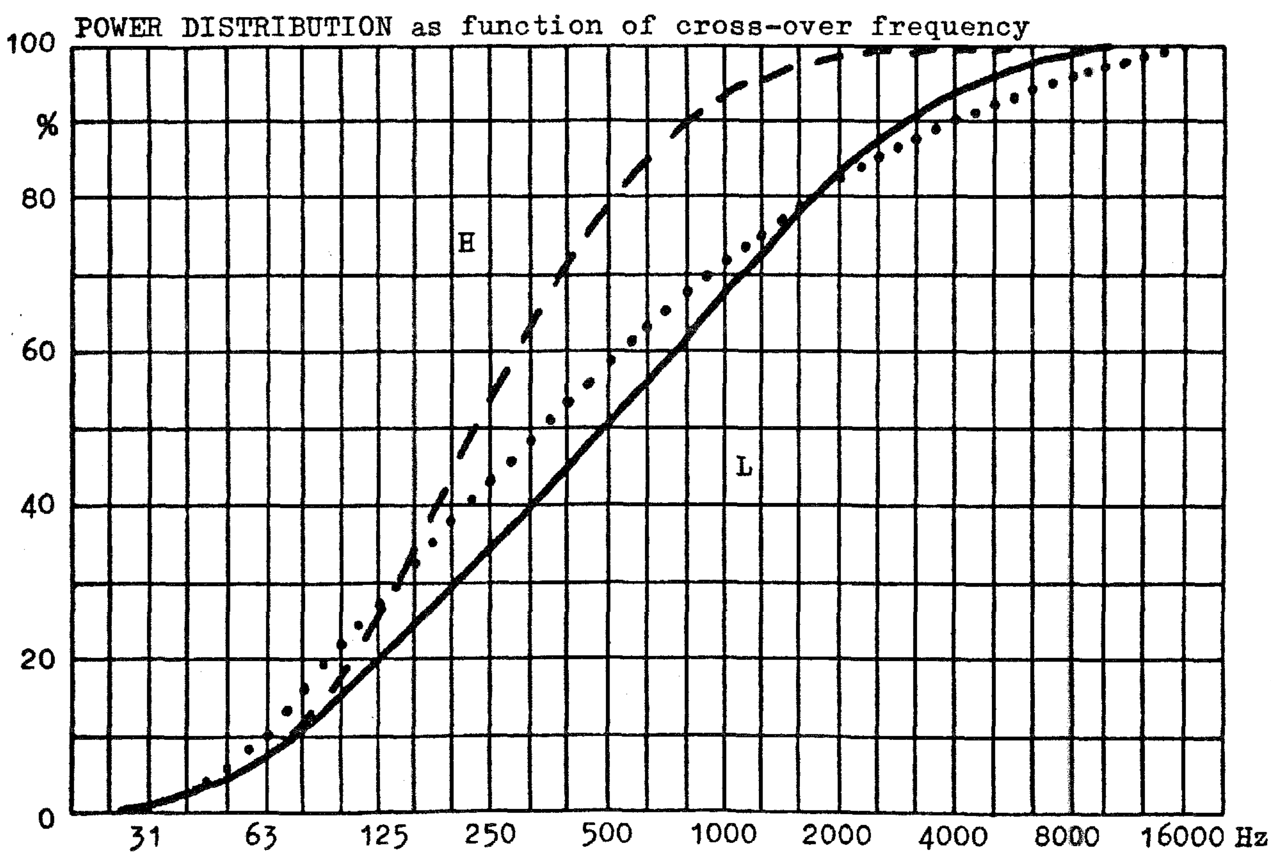


Fig. 8

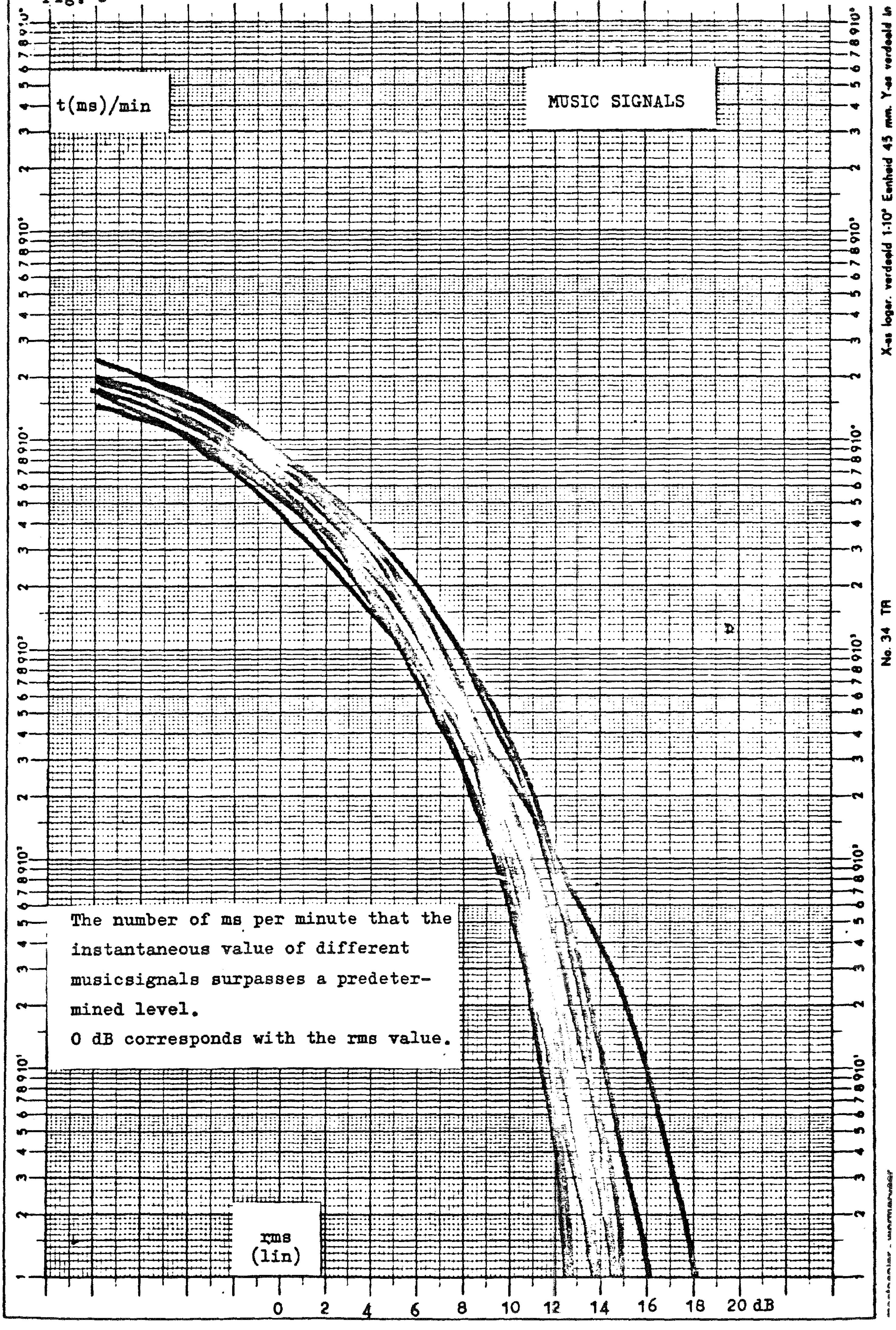

t(ms)/min
MUSIC SIGNALS
The number of ms per minute that the instantaneous value of different musicsignals surpasses a predetermined level.
0 dB corresponds with the rms value.
rms
(lin)
0
2
4
6
8
10
12
14
16
18
20 dB
X-as loger. verdeeld 1:10⁴ Eenheid 45 mm. Y-as verdeeld in
No. 34 TR

Fig. 9

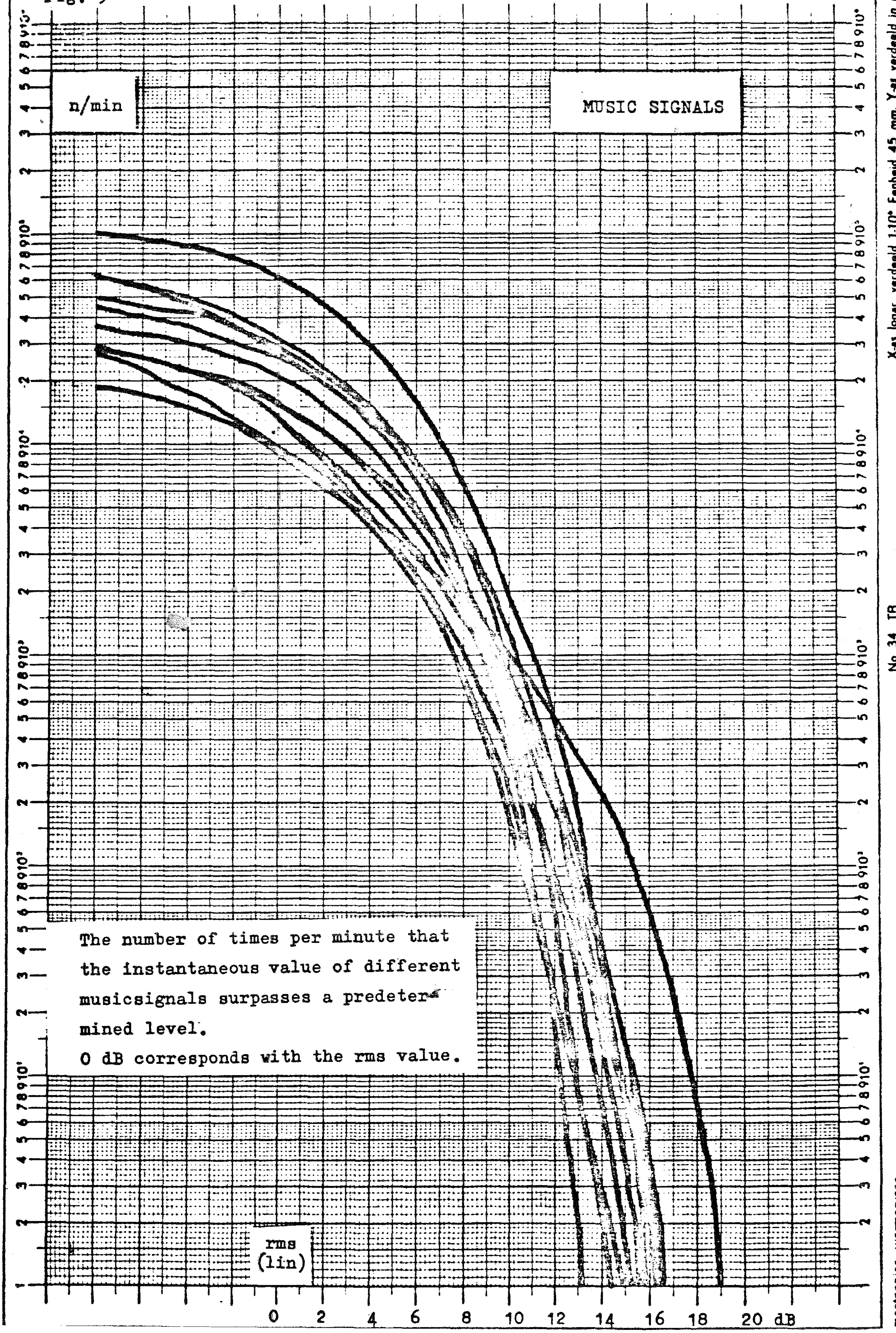
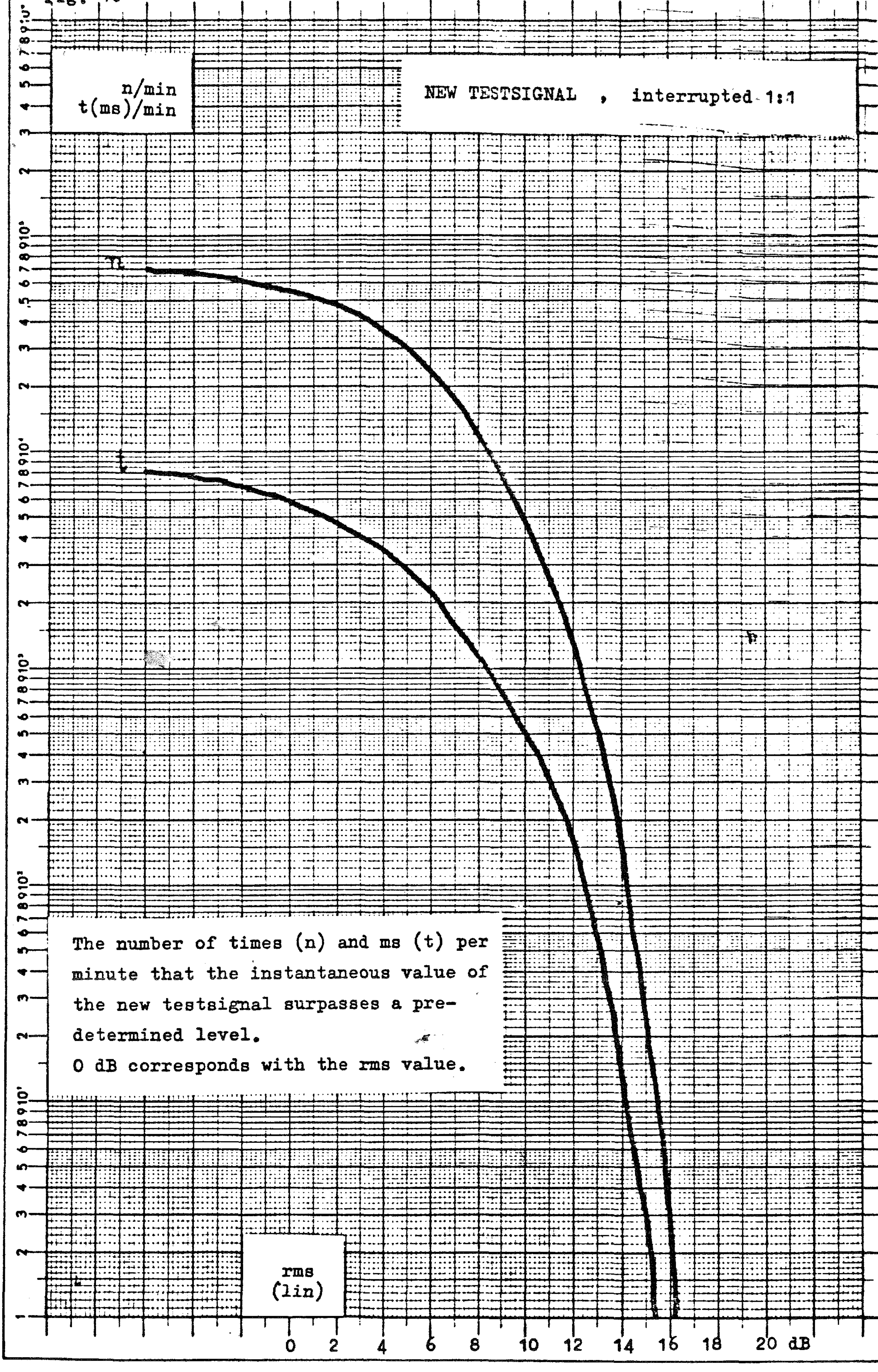

n/min
MUSIC SIGNALS
The number of times per minute that the instantaneous value of different musicsignals surpasses a predetermined level.
0 dB corresponds with the rms value.
rms (lin)
0 2 4 6 8 10 12 14 16 18 20 dB
X-as loger. verdeeld 1:10° Eenheid 45 mm. Y-as verdeeld in m
No. 34 TR
meetpapier - wormerveer

Fig. 10



The number of times (n) and ms (t) per minute that the instantaneous value of the new testsignal surpasses a predetermined level.
0 dB corresponds with the rms value.