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Acoustic safety of Terminal Equipment (TE); An investigation on standards and approval documents

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Speech processing, Transmission and Quality aspects (STQ).

Parts of the present document have been quoted from other standards and national specifications as credited under the References. For text that was not in the English language, unofficial translations have been made. For full text reference you should refer to the relevant organisations as listed in the Reference clause of the present document.

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Introduction

In September 1999, ETSI Collective Letter 1968 pointed out that:

Article 3.1(a) of the R&TTE Directive requires that equipment provide an adequate level of protection so as to ensure the health and safety of users and other persons. Protecting the hearing of persons is one area that is covered by this Article. This raises two questions:

a) Should a Harmonized Standard covering the requirements for protecting health and safety from the phenomenon of acoustic shock be produced?

b) Should ETSI produce a standard specific to telecommunications equipment or leave the matter to CENELEC as a general issue?

Most replies to this Collective Letter supported the idea that an Acoustic Safety standard should be produced in ETSI by TC STQ. There were some caveats referring to the need to ensure that the work was restricted to telecommunications apparatus used for its intended purpose and that any resultant standard was aligned with other standards in the field, working with other Committees as necessary.

At its 7th meeting in Bern, TC STQ decided that as preparation for the work on a candidate harmonized standard on acoustic safety (acoustic shock) for terminal equipment, a collection of current standards and approval documents on the subject should be made and incorporated into a Technical Report.

It was intended that the Report would be considered by TC STQ and that subsequently suggestions would be made on the contents of a candidate harmonized standard.

1 Scope

The present document establishes the results of an investigation into existing standards and approval documents dealing with acoustic safety (including acoustic shock) requirements for telecommunications terminal equipment, together with other relevant background information.

The present document has been produced in order to assist ETSI TC STQ in considering further work to support a possible harmonized standard on acoustic safety pursuant to the requirements of Art. 3.1(a) of Directive 1999/5/EC [11] (the R&TTE Directive).

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.
- A non-specific reference to an ETS shall also be taken to refer to later versions published as an EN with the same number.

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3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

noise induced permanent threshold shift: amount of permanent threshold shift remaining in a population after subtracting the threshold shift that would occur "normally" from causes other than from occupational noise [41]

recruitment: condition where the subjective sensation of loudness is out of proportion to the increase in the physical intensity of the signal [7]

temporary threshold shift: elevation of the hearing threshold following exposure to noise which shows a progressive return to the pre-exposure threshold level and ultimate recovery in less than 10 days [7]

tinnitus: condition where there are noises heard within the head or ear and the only person who can hear the noise is the person themselves

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

CHABA	National Academy of Science Research Council Committee on Hearing Bioacoustics and Biomechanics
DRP	Eardrum Reference Point
ERP	Ear Reference Point
FDA	Food and Drugs Administration (of America)
HATS	Head And Torso Simulator
NIH	National Institute of Health
NIHL	Noise Induced Hearing Loss
NIOSH	National Institute for Occupational Safety and Health
NIPTS	Noise Induced Permanent Threshold Shift
OSHA	American Occupational Safety and Health Administration
PTS	Permanent Threshold Shift
RNID	Royal National Institute for Deaf people
SPL	Sound Pressure Level relative to 20 μPa
TTS	Temporary Threshold Shift
TTS2	Temporary Threshold Shift measured 2 minutes after noise exposure

TUC	Trades Union Congress
UL	Underwriters Laboratory (of America)

4 Acoustic shock

4.1 General

Damage may be caused to hearing either by long-term exposure to high levels of sound or by high levels of acoustic shock.

Acoustic shock is defined by the ITU-T [1] and by ETSI [2] as "any temporary or permanent disturbance of the functioning of the ear, or of the nervous system, which may be caused to the user of a telephone earphone by a sudden sharp rise in the acoustic pressure produced by it". It is noted that "an acoustic shock usually results from the occurrence, in abnormal circumstances, of short-lived high voltages at the terminals of a telephone set".

Acoustic shock has been a known problem in telecommunications apparatus for many years. In the mid 1920s the GEC Hirst Research Centre in England experimented with the use of coherers fitted at feed bridges in exchanges so as to reduce the effect of disturbing clicks. In 1957 Palva [3] reported proven cases of hearing damage to 15 % of telephone operators caused by headphones that were not fitted with shock suppressors, but a later study of telephone operators in Holland reported by Martijn [4] in 1970 was unable to find any risk arising from their work.

A recent report [5] has alleged that 39 % of call centre operators are concerned that their hearing is being damaged as a result of exposure to noise at work.

4.2 Noise induced hearing loss

The American National Institute of Health (NIH) [6] states that sounds of sufficient intensity will damage the ear and result in temporary or permanent hearing loss. The hearing loss may range from mild to profound and may also result in tinnitus. The effect of repeated sound overstimulation is cumulative over a lifetime and is not currently treatable. Hearing impairment has a major impact on one's communication ability and even mild impairment may adversely affect the quality of life.

Two types of injury are recognized: acoustic trauma and Noise Induced Hearing Loss (NIHL). Short-duration sound of sufficient intensity (e.g., a gunshot or explosion) may result in an immediate, severe, and permanent hearing loss, which is termed acoustic trauma. Virtually all of the structures of the ear can be damaged, in particular the organ of Corti, the delicate sensory structure of the auditory portion of the inner ear (cochlea), which may be torn apart.

Moderate exposure may initially cause temporary hearing loss, termed Temporary Threshold Shift (TTS). Structural changes associated with TTS have not been fully established but may include subtle intracellular changes in the sensory cells (hair cells) and swelling of the auditory nerve endings. Other potentially reversible effects include vascular changes, metabolic exhaustion, and chemical changes within the hair cells. There is also evidence of a regional decrease in the stiffness of the stereocilia (the hair bundles at the top of the hair cells), which may recover. This decrease in stereocilia stiffness may lead to a decrease in the coupling of sound energy to the hair cells, which thereby alters hearing sensitivity.

Repeated exposure to sounds that cause TTS may gradually cause permanent NIHL in experimental animals. In this type of injury, cochlear blood flow may be impaired, and a few scattered hair cells are damaged with each exposure. With continued exposure, the number of damaged hair cells increases. Although most structures in the inner ear can be harmed by excessive sound exposure, the sensory cells are the most vulnerable. Damage to the stereocilia is often the first change, specifically, alteration of the rootlet structures that normally anchor the stereocilia into the top of the hair cell. Once destroyed, the sensory cells are not replaced. During the recovery period between some sound exposures, damaged regions of the organ of Corti heal by scar formation. This process is very important because it re-establishes the barrier between the two fluids of the inner ear. If this barrier is not re-established, degeneration of hair cells may continue. Further, once a sufficient number of hair cells are lost, the nerve fibres to that region also degenerate. With degeneration of the cochlear nerve fibres, there is corresponding degeneration within the central nervous system. The extent to which these neural changes contribute to NIHL is not clear.

With moderate periods of exposure to potentially hazardous high-frequency sound, the damage is usually confined to a restricted area in the high-frequency region of the cochlea. With a comparable exposure to low-frequency noise, hair cell damage is not confined to the low-frequency region but may also affect the high-frequency regions. The predominance of damage in different cochlear regions with different frequency exposures reflects factors such as the resonance of the ear canal, the middle-ear transfer characteristics, and the mechanical characteristics of the organ of Corti and basilar membrane.

4.3 Assessment of NIHL

The same NIH statement [6] explains that hearing loss is measured by determining auditory thresholds (sensitivity) at various frequencies (pure-tone audiometry). Pure-tone audiometry is also used in industrial hearing conservation programs to determine whether adequate protection against hazardous sound levels is provided.

The first audiometric sign of NIHL resulting from broadband noise is usually a loss of sensitivity in the higher frequencies from 3 000 to 6 000 Hertz (Hz) resulting in a characteristic audiometric "notch." With additional hearing loss from noise or ageing, the threshold at 8 000 Hz may worsen and eliminate this characteristic audiometric pattern. Thus, the presence or absence of NIHL cannot be established on the basis of audiometric shape, per se. The hearing loss is usually bilateral, but some degree of asymmetry is not unusual, especially with lateralized noise sources such as rifles. After moderate sound exposure, TTS may occur, and, during a period of relative quiet, thresholds will return to normal levels. If the exposure continues on a regular basis, Permanent Threshold Shifts (PTS) will result, increasing in magnitude and extending to lower and higher frequencies. If the exposures continue, NIHL increases more rapidly in the early years. After many years of exposure, NIHL levels off in the high frequencies, but continues to worsen in the low frequencies. Although TTS and PTS are correlated, the relation is not strong enough to use TTS to predict the magnitude of permanent hearing loss.

An important consequence of the sensitivity loss associated with NIHL is difficulty in understanding speech. Whereas a large proportion of the energy in speech is contained within the low-frequency range, much of the information required to differentiate one speech sound from another is contained within the higher frequencies. With significant hearing loss in the high frequencies, important speech information is often inaudible or unusable. Other interfering sounds such as background noise, competing voices, or room reverberation may reduce even further the hearing-impaired listener’s receptive communication ability. The presence of tinnitus may be an additional debilitating condition.

NIHL may interfere with daily life, especially those social activities that occur in noisy settings. Increased effort is required for understanding speech in these situations, which leads to fatigue, anxiety, and stress. Decreased participation in these activities often results, affecting not only hearing-impaired individuals but also friends and family members. Hearing loss is associated with depression in the elderly and maybe related to dementia and cognitive dysfunction. Systematic study of the effects of hearing 1oss on the quality of life have only lately focused specifically on individuals with NIHL; therefore, continued studies of this kind are desirable.

The impairment in hearing ability resulting from NIHL may vary from mild to severe. An individual’s ability to communicate and function in daily life varies with the degree of loss and the individual’s communication needs although these relationships are complex. The magnitude of the effect on communication ability may be estimated by a variety of scales, which are often used in disability determinations. These scales, which vary substantially in the frequencies used, the upper and lower limits of impairment, age correction, and adjustment for asymmetric hearing loss, attempt to predict the degree of communication impairment (understanding of speech) on the basis of pure-tone thresholds. There is no consensus about the validity or utility of the scales, which scale should be used, whether measures of speech understanding should be included, or whether self-assessment ratings should be incorporated into either impairment rating scales or disability determinations.

4.4 What sounds can damage hearing?

The NIH [6] points out that some sounds are so weak physically that they are not heard. Some sounds are audible but do not have any temporary or permanent after-effects. Some sounds are strong enough to produce a temporary hearing loss from which there may appear to be complete recovery. Damaging sounds are those that are sufficiently strong, sufficiently long-lasting, and involve appropriate frequencies so that permanent hearing loss will ensue.

Most of the sounds in the environment that produce such permanent effects occur over a very long time (for example, about 8 hours per workday over a period of 10 or more years). On the other hand, there are some particularly abrupt or explosive sounds that can cause damage even with a single exposure.

The line between these categories of sounds cannot be stated simply because not all persons respond to sound in the same manner. Thus, if a sound of given frequency bandwidth, level, and duration is considered hazardous, it is necessary to specify for what proportion of the population it will be hazardous and, within that proportion, by what criterion of damage (whether anatomical, audiometric, speech understanding) it is hazardous.

The most widely used measure of a sound's strength or amplitude is called "sound level," measured by a sound-level meter in dB. For example, the sound level of speech at typical conversational distances is between 65 and 70 dB. There are weaker sounds, still audible, and of course much stronger sounds. Those above 85 dB are potentially hazardous.

Sounds need also to be specified in terms of frequency or bandwidth. The range of audible frequencies extends from about 20 Hz, below the lowest notes on a piano, to at least 16 000 or 20 000 Hz, well above the highest notes on a piccolo. Most environmental noises include a wide band of frequencies and, by convention, are measured through the "A" filter in the sound-level meter and thus are designated in dB(A) units. It is not clear what effect, if any, sound outside the frequency range covered in dB(A) measurements may have on hearing. At this time, it is not known whether ultrasonic vibration will damage hearing.

To define what sounds can damage hearing, sound level, whether across all frequency bands or taken band by band, is not enough. The duration of exposure, typical for a day and accumulated over many years, is critical. Sound levels associated with particular sources such as snowmobiles, rock music, and chain saws, are often cited, but predicting the likelihood of NIHL from such sources also requires knowledge of typical durations and the number of exposures.

There appears to be reasonable agreement that sound levels below 75 dB(A) will not engender a permanent hearing loss, even at 4 000 Hz. At higher levels, the amount of hearing loss is directly related to sound level for comparable durations.

A World Health Organization publication on noise [7] points out that "acoustic reflex partially protects the ear exposed to high sound levels. The stapedial and tensor tympani muscles contract, limiting movement of the ossicles and so attenuating the general disturbance".

The protection afforded by this reflex is typically 10 dB for frequencies at about 1 kHz but it is ineffective in certain situations because there is a delay of a few milliseconds between sound reaching the ear and activation of the reflex.

4.5 Telephone speech levels

At a distance of 1 metre, French and Steinberg [8] quoted the intensity of speech integrated over the entire spectrum to be 65 dB relative to 10^{-16} watt/cm^2. This figure was measured using a telephone testing crew and is equivalent to a sound pressure of 65 dB SPL. Barnes [9] quotes a nominal speech level of 63,9 dB SPL measured at the ear of the listener in reverberant conditions.

Barnes, in the same paper states that a typical telephone connection with an overall loudness rating of +10 dB, has, for speech, an acoustic loss 19,3 dB less than the 1 metre air path. These results in typical speech levels received at the ear reference point (ERP) of a telephone of a little over 83 dB SPL.

Mellors [10] gives a typical range of overall loudness ratings of 5 to 13 dB for analogue telephones on a modern digital network. This suggests a range of received levels from 80 dB to 88 dB SPL (due to the fact that a connection with an OLR of 13 dB is quieter than one with an OLR of 5 dB).

These figures appear to suggest that use of a telephone for a period of 8 hours would give exposures close to or above the permitted limits, but it should be remembered that the speech levels quoted are for when the speech is active. The proportion of the time during a call that an operator is listening to live speech could be for at most about half of the total call period (for a normal telephone user it would be somewhat less). This would give exposure levels averaged over a call of 77 to 85 dB SPL using a 3 dB relationship for the halving of time exposure.

Recent measurements in operators headsets in call centres with unknown loudness ratings (see annex B) have shown exposures of 75 to 80 dBA averaged over an 8 hour day which leaves some 3 dB to be explained. This difference is probably due to the differences between the flat and "A" weightings.

A document privately received from a major UK network operator states that they work with a receiving loudness rating at the operator position of –1,4 dB although it was said that an allowance of 3 dB was made "because the earpiece is close coupled". This would imply overall loudness ratings of 2,6 to 6,6 dB giving levels at the ear of 83,4 to 87,4 dB SPL.

5 Legislation

5.1 European legislation

5.1.1 The RTTE Directive (1999/5/EC)

This Directive 1999/5/EC [11] establishes a regulatory framework for the placing on the market, free movement and putting into service in the Community of radio equipment and telecommunications terminal equipment.

In Article 3.1(a), "the protection of health and the safety of the user and any other person, including the objectives with respect to safety requirements contained in Directive 73/23/EEC [12] but with no voltage limit applying" is specified as an essential requirement of this Directive applying to all apparatus.

5.1.2 Low voltage Directive (73/23/EEC)

This Directive 73/23/EEC [12] is a "total harmonization" Directive so that the measures it contains replace national rules in the field in question. It applies to all telecommunications terminal equipment through the RTTE Directive. It specifies that equipment "may be placed on the market only if, having been constructed in accordance with good engineering practice in safety matters in force in the Community, it does not endanger the safety of persons, domestic animals or property when properly installed and maintained and used in the applications for which it was made".

It thus covers all safety aspects of this equipment, including protection from hazards of mechanical origin.

5.1.3 Noise at work Directive (86/188/EEC)

This Directive 86/188/EEC [13], which is the third individual Directive within the meaning of Directive 80/1107/EEC [14], has as its aim the protection of workers against risks to their hearing and, in so far as this Directive expressly so provides, to their health and safety, including the prevention of such risks arising or likely to arise from exposure to noise at work.

The Directive requires in Article 4.1 that "where the daily exposure of a worker to noise is likely to exceed 85 dB(A) or the maximum value of the unweighted instantaneous sound pressure is likely to be greater than 200 Pa (140 dB rel 20 μPa), appropriate measures shall be taken".

It goes on to describe such measures, which require workers to be informed of the potential risk, the measures being taken, the obligation to comply with protective measures and the wearing of personal ear protectors.

They are required also to have access to the results of noise assessments.

Article 2 of the Directive defines the daily personal noise exposure as:

$$L_{EP,d} = L_{AEq,Te} + 10\log_{10}\frac{T_e}{T_o}$$

where: $$L_{AEq,Te} = 10\log_{10}\left\{\frac{1}{To}\int_0^{T_e}\left[\frac{p_a(t)}{p_0}\right]^2 dt\right\}$$

T_e = daily duration of a worker's personal exposure to noise,

T_o = 8 hr = 28 800 s,

p_o = 20 μPa

p_A = "A"-weighted instantaneous sound pressure in pascals to which is exposed, in air at atmospheric pressure, a person who might or who might not move from one place to another while at work; it is determined from measurements made at the position occupied by the person's ears during work, preferably in the person's absence, using a technique which minimizes the effect on the sound field.

If the microphone has to be located very close to the person's body, appropriate adjustments should be made to determine an equivalent sound pressure.

Article 5 of the Directive requires that where the daily personal noise exposure exceeds 90 dB(A), "personal ear protectors must be used", and that where the exposure exceeds 85 dB(A), "personal ear protectors must be made available to workers".

5.1.4 The Machinery Directive (98/37/EC)

For the purposes of this Directive 98/37/EC [15], machinery means "an assembly of linked parts or components, at least one of which moves, with the appropriate actuators, control and power circuits, etc., joined together for a specific application".

This would make the Directive applicable to telecommunications terminals, which contain moving parts, such as facsimile machines. Machinery whose only power source is directly applied manual effort are excluded from the scope.

Items covered by this Directive are required to meet the essential health and safety requirements set out in annex 1 which includes in 1.5.8 the requirement that "The machinery must be so designed and constructed that risks resulting from the emission of airborne noise are reduced to the lowest level taking account of technical progress and the availability of means of reducing noise, in particular at source".

5.1.5 Draft Physical agents Directive

In 1994, The European Commission proposed in a draft Physical Agents Directive [16] that 75 dB(A) should be a threshold level for noise exposure at which workers should be informed on risks.

It also proposed that at 80 dB(A) or a peak pressure of 112 Pa (equivalent to 135 dBPa), workers should have a right to hearing surveillance and a supply of personal protective equipment, and that at 85 dB(A) training would be required, noise assessments made, a programme of control measures instituted and that workers should be informed of exposure assessments.

It further required that at 90 dB(A) or a peak pressure of 200 Pa (equivalent to 140 dBPa), "ear protectors must be used".

This Directive was intended to be a Directive with separate annexes dealing with various hazards such as Noise, Vibration, Non-ionising radiation etc. Work on it has been in abeyance for a number of years.

There was an initiative in January 1999 to bring out a new Physical Agents Directive dealing only with vibration.

5.2 American legislation

5.2.1 Walsh-Healey Act of 1969

The American National Institute for Occupational Safety and Health (NIOSH), in its paper entitled "Occupational noise and hearing conservation, selected issues" [17] has set out a critical history of the current United States legislation on noise mandated by the Walsh-Healey Act. It states that:

"In 1965 the National Academy of Sciences-National Research Council, Committee on Hearing, Bioacoustics, and Biomechanics (CHABA) issued criteria for assessing allowable exposures to continuous, fluctuating, and intermittent noise [18]. The CHABA criteria was an attempt to predict the hazard from nearly every conceivable noise exposure pattern, based on TTS experimentation. In the development of its criteria, CHABA used the following postulates:

1) TTS2 (Temporary Threshold Shift measured 2 minutes after noise exposure) is a consistent measure of the effects of a single day’s exposure to noise.

2) All noise exposures that produce a given TTS2 will be equally hazardous (the "equal temporary effect" theory).

3) Permanent Threshold Shift (PTS) produced after many years of habitual noise exposures, 8 hours per day, is about the same as the TTS2 produced in normal ears by an 8-hour exposure to the same noise.

The CHABA postulates were not validated, and also because TTS proved not to be a good predictor of permanent hearing damage, criteria based on TTS patterns could not be relied upon for predicting the long-term adverse effects of noise exposure. TTS2 is not a consistent measure of the effects of a single day’s exposure to noise, and the PTS after many years may be quite different from the TTS2 produced at the end of an 8-hour day. Research has failed to show a significant correlation between TTS and PTS [19], and the relationships among TTS, PTS, and cochlear damage are equally unpredictable.

CHABA’S assumption of the equal temporary effect theory is also questionable in that some of the CHABA-permitted intermittent exposures can produce delayed recovery patterns even though the magnitude of the TTS was within "acceptable" limits and chronic incomplete recovery will hasten the advent of PTS. The CHABA criteria also assume regularly spaced noise bursts, interspersed with periods that are sufficiently quiet to permit the necessary amount of recovery from TTS Both of these assumptions fail to characterize noise exposures in the manufacturing industries.

Botsford [20] published a simplified set of criteria based on the CHABA criteria, having observed that the CHABA method had proved too complicated for general use. The Botsford method [20] assumes that interruptions will be of "equal length and spacing so that a number of identical exposure cycles are distributed uniformly throughout the day". These interruptions would occur during coffee breaks, trips to the washroom, lunch, and periods when machines are temporarily shut down.

During the same period, there was another parallel, but related, development that led to the 5 dB exchange rate. Simplifying the criteria developed by Glorig [21] and adopted by the International Organization for Standardization (ISO) in 1961, the Intersociety Committee in 1970 published its criteria that consisted of a table showing permissible exposure levels (starting at 90 dBA) as a function of duration and the number of occurrences per day. The exchange rates varied considerably depending on noise level and frequency of occurrence. For continuous noise with duration less than 8 hours, the Committee recommended maximum exposure levels based on a 5 dB exchange rate.

In 1968, the Department of Labor proposed a noise standard under the authority of the Walsh-Healey Public Contracts Act [33 Fed. Reg. 14,258 (1968)]. The proposal contained a permissible exposure limit of 85 dBA for continuous noise. Exposure to non-continuous noise was to be assessed over a weekly period according to a large table of exposure indices. The exchange rate varied according to level and duration; a rate of 2 to 3 dB was used for long-duration noises of moderate level, and 6 to 7 dB for short-duration, high-level bursts. This standard was promulgated early in 1969 [34 Fed. Reg. 790 (1969a)], but was withdrawn after a short period.

Later in that same year the Walsh-Healey noise standard that is in effect today was issued [34 Fed. Reg. 7,948 (1969b)]. In this version, any special criteria for non-continuous noise had disappeared and the 5 dB exchange rate became official. Thus, the 5 dB exchange rate appears to have been the outgrowth of the many simplifying processes that preceded it".

The 5 dB rule is implemented in the Walsh Healey Act and subsequent Occupational Health and Safety (OSHA) regulations [22] for the purpose of requiring preventive efforts for noise-exposed workers.

OSHA regulations call for the noise measurement to be made with an A-weighted meter having a slow response. An 8-hour permissible exposure is 90 dB(A) with a halving of exposure period for each 5 dB increase in noise level up to an upper limit of 115 dB(A) for periods of 1/4 hour or less. The exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

A hearing conservation programme is required to be administered whenever the time weighted average exposure exceeds 85 dB(A).

5.2.2 National Institute for Occupational Safety and Health

Arising from a requirements of the Occupational Safety and Health Act of 1970, the US department of Health and Human Services in 1998 published a National Institute for Occupational Safety and Health (NIOSH) document [23] revising earlier recommendations for criteria for a recommended standard on occupational exposure to noise.

This document supports 85 dB(A) as an 8-hour time-weighted limit firmly stating that exposures at or above this level are hazardous. It gives 140 dB(A) as the ceiling limit for continuous, varying, intermittent or impulsive noise. It also recommends a 3 dB exchange rate for the calculation of time weighted average exposure rather than the 5 dB exchange rate still used by OSHA.

It points out that with a 40 year lifetime exposure using the 85 dB(A) limit, the excess risk of developing NIHL is 8 % - considerably lower than the 25 % excess risk at the 90 dB(A) permissible exposure limit currently enforced by OSHA. It also states that the 3 dB exchange rate is more firmly supported by scientific evidence.

Although not yet embodied in US law, this is a clear indication that American thinking on noise exposure is currently falling into line with that of Europe.

5.2.3 Federal Communications Commission

Part 68 of the Rules of the Federal Communications Commission requires that since the 1st January 2000, all telephones, including cordless telephones, manufactured in the United States (other than for export) or imported for use in the United States, "must be hearing compatible" by having a volume control feature consistent with the technical standards in 47 CFR subclause 68.317.

Subclause 68.317 requires that the telephone is equipped with a volume control that provides between 12 dB and 18 dB of gain. "The 12 dB of gain minimum must be achieved without significant clipping of the input signal". The telephone is also required to comply with the upper and lower limits of receive loudness rating defined in subclause 4.1.2 of ANSI/EIA-470-A-1987 when the volume control is set to its normal unamplified level.

Equivalent requirements apply to digital telephones.

The 18 dB of gain may be exceeded provided that the amplified receive capability automatically resets to nominal gain when the telephone goes on-hook.

6 Standardization

6.1 International Standardization

6.1.1 Activities in the ITU

The original CCITT recommendation dealing with acoustic shock was CCITT Recommendation K.7 [24] (adopted in Geneva 1964). This recommended that when a voltage surge occurred on a telephone line that caused the protective device to operate, the amplitude of the sound pressure caused by the diaphragm of the receiver should not exceed 120 dB rel. $2x10^{-4}$ µbar (20 µPa) at 1 000 Hz. Figures were also set for the attenuation caused by the protective device with various a.c. input signals. Measurements were made using instruments indicating rms values.

Work in Study Group 12 under Question. 20 originally started at the beginning of the 1977-1980 period of the then CCITT. At the end of that period two contributions had been received from France and one from Brazil. France input transient voltages into some samples of telephones and measuring using an IEC Publication 179 [25] sound level meter achieved output sound pressure levels in the artificial ear of 120 to 125 dB(A) (rel. 20 µPa, A-weighted) in the most sensitive telephone. Brazil noted outputs of about 140 dB Sound Pressure Level rel. 20 µPa (dB SPL) for an unprotected telephone and below 115 dB SPL unweighted when the telephone was fitted with an acoustic shock suppressor.

It was felt that the available information was not sufficient to allow a detailed revision of CCITT Recommendation K.7 [24] but a Supplement 6 [26] was added to the Yellow Book (Geneva 1981) on the attenuation of the electro-acoustic efficiency of telephone sets in view of protection against acoustic shocks. An IEC Publication 318 [27] ear was to be used for the measurement. The question was continued into the 1981-1984 period.

At the beginning of this period it proposed to concentrate on measurement methods and the maximum unweighted impulse sound pressure level was suggested to be 120 dB. A Swedish input suggested that measurements should be made with equipment having a faster response. The use of an oscilloscope was proposed so as to see the true peak, and a limit of 125 dB was proposed for this peak. It was also suggested that the risk to hearing damage from exposure to transient surges arose from the peak value of the sound pressure in the ear.

The only contribution in this session came from France and showed that in sets protected with silicon rectifiers, instantaneous maxima of 133 dB SPL were achieved with two types of telephone and 140 dB SPL with a third. A fourth telephone using a linear microphone and semiconductor circuitry produced peak levels of less than 50 dB SPL. France suggested that in view of these results, a limit of 135 dB SPL would be appropriate and that 115 dB could be recommended for operator sets.

In spite of the lack of input it was decided to produce a "partial" recommendation, which became CCITT Recommendation P.36 [28] at the Malaga-Torremolinos Assembly in October 1984 and was subsequently published in the Red Book. This recommended peak acoustic pressures of 140 dB with 135 dB recommended in the long term and using an artificial ear conforming to ITU-T Recommendation P.51 [29] (corresponding to the IEC Publication 318 [27] ear) was to be used for the measurement (This reference was clearly incorrect and should have referred to ITU-T Recommendation P.57 [30]). The recommendation also provided for checking with steady state sine waves to ensure that the acoustic shock protection did not distort normal speech signals. The electrical surge test circuit was that specified in figure 1 of CCITT Recommendation K.17 [31]. At the same time, CCITT Recommendation K.7 [24] was revised [32] to refer out to CCITT Recommendation P.36 [28] for its performance requirements.

Question 20 continued into the 1985-1998 session and it was intended to differentiate between hazardous and annoying shocks, but once again there was little formal input. A Spanish contribution gave data for measurements on operators' headsets under normal use. Although these headsets were not fitted with shock protection, no impulses were found that exceeded 135 dB SPL but the 120 dB SPL threshold was exceeded by three impulses a minute.

As there were no other contributions, the rapporteur suggested limits for hazardous noise and annoyance based upon proposals from the Underwriters Laboratories (UL) in the United States. These limits were supported by a rationale which referred to the regulations ISO Publication 1999 [33] of the American Occupational Safety and Health Administration (OSHA) which permits a 5 dB increase per halving of exposure but sets an absolute upper limit of 115 dB SPL (A). The peak figure was derived from damage risk criteria postulated by the National Academy of Science Research Council Committee on Hearing Bioacoustics and Biomechanics (generally referred to as CHABA). Changes were based on the work of Kryter [18] modified by that of Botsford [20].

The daily exposure time was assumed to be 2 seconds (based on one cadence of the American ringing signal) and the damage risk criterion was set at 15 dB below that set by law in the workplace following the example of Cohen AJ et al [34]. A correction of 8 dB was made for exposure time derived somewhat oddly from some "Guidelines for Noise Exposure Control" [35] produced by the American Industrial Hygiene Association. A correction of –5 dB was made for the narrow band spectrum of the noise (derived from Kryter [36]) and of +5 dB for the difference between random noise and that from an earphone (based on the work of Kuhn and Guernsey [37]).

The normal absolute US limit of 115 dB(A) was raised to 132 dB (for the 2 second exposure), then corrected by –15 dB for damage risk, by +8 dB for exposure time, by –5 dB for frequency spectrum and by another +5 dB for sound field. So for handsets the final figure derived was:

$$132\ dB(A) - 15\ dB + 8\ dB - 5\ dB + 5\ dB = 125\ dB(A)$$

This limit was included as the limit for continuous 1 kHz tones in a revision of CCITT Recommendation P.36 [28] that also recommended maximum instantaneous values of 140 dB SPL (as for the OSHA limit) with an advised long-term reduction to 135 dB.

These changes were incorporated in the version of CITT Recommendation P.36 [28] as approved at Melbourne in 1988 and the Question was closed.

There was no relevant Question in the 1989-1992 session but a new Question 26/12 was started in May 1996 near the end of the 1993-1996 period. It arose from a draft proposal made in 1991 for the third edition of IEC Publication 950 [38]. The work was continued in the 1997-2000 period as Question 5/12 – Efficiency of devices for preventing the occurrence of excessive acoustic pressure by telephone receivers.

There were no formal inputs to the work although a German input on artificial ears was relevant. Nevertheless a new ITU-T Recommendation P.360 [39] was drawn up using same limits for handsets as in CITT Recommendation P.36 [28] (140 dB SPL peak and 125 dB SPL (A) for longer duration disturbances). However ITU-T Recommendation P.360 [39] derives these limits by means of a totally different justification that was put forward during the generation of draft IEC Publication 950 [38].

It then uses a damage risk correction of 10 dB, exposure correction of 7 dB, a spectrum correction of 4 dB and a sound field correction of 5 dB. This gives the figure:

$$127\ \text{dB(A)} - 10\ \text{dB} + 7\ \text{dB} - 4\ \text{dB} + 5\ \text{dB} = 125\ \text{dB(A)}$$

ITU-T Recommendation P.360 [39] uses either an artificial ear conforming to ITU-T Recommendation P.57 [30] or a head and torso simulator (HATS) conforming to ITU-T Recommendation P.58 [40]. It further states that "it has been decided that the acoustic level measured by the artificial ear shall never be corrected. It means that for the Type 1 artificial ear the acoustic pressure level shall be measured at the ear reference point, and for all other types of artificial ears the acoustic pressure level shall be measured at the drum reference point. Due to recent contributions, it appears that it is not appropriate to weight the level measured by type 2 and 3.x artificial ears by a "mean" ERP/DRP correction factor".

6.1.2 Other International bodies

6.1.2.1 IEC 950

A proposal for a new work item on the control of acoustic levels was proposed by IEC/TC74 WG 7 in July 1991. The first draft amendment was based on rather poor rewording of CCITT Recommendation P.36 [28] and at voting in early 1993 received a number of negative comments, mainly from European countries.

A fresh draft was produced in 1994, which based the proposed limit of 125 dB SPL on the American legislation quoted in the work leading to CCITT Recommendation P.36 [28] and giving detailed references to the sources of all of the correction factors.

A later version of the draft amendment put out for comment in February 1996 derived the longer duration disturbance limits from the 8 hour limit of 85 dB SPL (A) that is used in Council Directive 86/188/EEC [13] and, calculating on the basis of 3 dB per halving of exposure, derived a starting point for a two second exposure figure of 127 dB SPL. The same limits were proposed but with a different set of correction factors.

No information was given for the source of these new correction factors but it was stated that:

1) Work place data assumes a 10-year exposure period. For non-occupational exposure there should be no damage risk that requires 75 dB(A).

2) For random exposures, the sound field that is 7 dB higher gives the same result.

3) Work place data is for broadband noise. When the energy is concentrated at one frequency it needs to be 4 dB lower for the same risk.

4) Work place data is for free field. The ear amplifies sound by about 5 dB at the ERP.

Owing to adverse comment received at the comment stage this amendment was withdrawn before going to its vote.

6.1.2.2 ISO 1999 (1990)

ISO Publication 1999 [33] sets out procedures for the determination of occupational noise exposure and provides a large collection of formulae for the estimation of noise-induced hearing impairment. It sets out to provide a means of estimating the likelihood of an exposed worker suffering hearing impairment at various ages after a number of years exposure to various levels of noise. The standard uses the concept of Noise Induced Permanent Threshold Shift (NIPTS) in its calculations.

NIPTS is the amount of permanent threshold shift remaining in a population after subtracting the threshold shift that would occur "normally" from causes other than from occupational noise [41]. This concept is sometimes called "excess risk". The problem with using this standard is that it does not lay down fixed criteria for the frequencies at which hearing impairment is assessed nor give guidance on the levels of impairment that cause handicap. Thus different users of the standard can obtain significantly differing results depending in the criteria chosen.

6.2 European Standardization

6.2.1 Activities in CENELEC

The work of CENELEC paralleled the IEC work on the unsuccessful amendment to IEC Publication 950 [38].

Since then a proposal has been made by the UK that CENELEC should commence work on "Acoustic power limitation for the safe use of telecommunications receiving transducers intended for application to the human ear". A three-part document was suggested but it was considered that further research would be needed to complete parts dealing with handset and headset receivers not suitable for sealed coupling to the ear.

6.2.2 Activities in ETSI

The 19 ETSI documents, which make reference to acoustic shock, are listed in clause A.1. The listing also gives extracts indicating the requirements.

Early documents (e.g. ETSI ETS 300 085 [60] on ISDN handset terminals) specified limits of 24 dBPa rms (equivalent to 118 dB rel 20 μPa) measured at the Ear Reference Point (ERP) for continuous signals.

For analogue telephones, testing was performed using a generator delivering a pure tone signal with an e.m.f of 24 dBV (ETSI I-ETS 300 480 [61]).

For ISDN telephones the digitally encoded signal representing the maximum possible signal at the digital interface was used (ETSI I-ETS 300 245-2 [62]).

A figure of 36 dBPa (equivalent to 130 dB rel 20 μPa) at the Ear Reference Point (ERP) was set as the limit for peak signals. In general, no tests were described.

Exceptionally, ETSI I-ETS 300 281 [63] (for 7 kHz telephony) uses a continuous drive signal of +9 dBm0 and quotes the peak limit as 40 dBPa at the Eardrum Reference Point (DRP). ETSI I-ETS 300 131 [64] (for cordless telephones in the frequency band 864,1 MHz to 868,1 MHz) uses a continuous drive signal of +3,14 dBm0 (Tmax) at the uniform PCM interface.

Later standards (after 1994) specified no requirements but pointed out that the prevention of acoustic shock is a safety requirement arising from the Low Voltage Directive (73/23/EEC [12]). It stated that in the absence of any relevant safety standard, a supplier's self-declaration could be based on recommendations (usually given in an advisory annex), which were essentially identical with the previously specified requirements.

ETSI I-ETS 300 131 [64] contains requirements for audible incoming call indication on the cordless portable part (CPP). The sound pressure at the ERP is not permitted to exceed 24 dBPa, initially should not exceed 0 dBPa and should rise in increments no greater than 6 dB, at a rate not greater than 6 dB/s, to a maximum within not less than 6 s.

Where the audible indication is generated other than through the earpiece, the sound pressure at the commencement of such indication is not permitted to exceed 50 dB A-weighted at 1 m free field in any direction. It is noted that the initial level should rise in increments no greater than 6 dB, at a rate not greater than 6 dB/s, to a maximum within not less than 6 s.

ETSI EN 300 001 [65] (for analogue access) contains national requirements for the Czech Republic and for Spain.

6.3 National specifications

6.3.1 European telephone specifications - summary

Clause A.2 gives details of the acoustic shock requirements set out in approval requirements for telephone apparatus from many European Countries.

Of the 11 countries for which specifications are available, four (Belgium, Denmark, Finland and the Netherlands) set a limit of 120 dB SPL for sinusoidal signals. Switzerland now sets a limit of 118 dB SPL as does the UK. France has a limit of 125 dB SPL (although 114 dB SPL is under consideration) and Germany 123,5 dB SPL.

Sweden only sets a peak limit of 120 dB SPL and Spain similarly only sets an instantaneous limit of 126 dB SPL.

Austria has a requirement for a maximum increase in output of 14 dB when the input signal changes by 20 dB from -10 dBm to +10 dBm.

The British standard for cordless telephones contains specific complex requirements for tone callers provided on the portable part. It requires that the sound pressure through the earpiece shall not exceed 24 dBPa (118 dB SPL).

If the sound is generated on the portable part but not through the earpiece, the sound level at the commencement of any calling sequence is required not to exceed 50 dB(A) measured at a distance of 1 m. The rate of increase of the level shall be less than 6 dB/s.

6.3.2 American telephone specifications - summary

Clause A.3 gives acoustic shock requirements taken from American specifications.

EIA-470-A (dated 1987) applies a surge to the telephone line and requires that the peak acoustic pressure in the artificial ear shall not exceed 130 dB SPL (36 dBPa).

EIA-470-B [101] (dated 1995) retained the same peak limit but added a requirement for continuous signals that the sound pressure should not exceed 125 dB(A) with a 4 V input swept from 180 Hz to 10 kHz.

TIA/EIA-IS-810 [108] for digital telephones is still in draft. The test for continuous signals is a swept square wave of maximum amplitude but the requirements are currently described as under study. Short duration pulse testing uses a complex arrangement of bursts of switched cycles lasting up to 500 ms.

UL 1950 [66], which is called up as a legal requirement in many parts of America, sets limits of 125 dB(A) for supra-aural handsets, 121 dB(A) for insert type earphones and 118 dB(A) for supra-aural headphones. If the sound source is away from the earpiece the same limits in the earpiece still apply.

Sound in the earpiece is also tested whilst on-hook using a 20 Hz ringing supply.

The peak pressure measured with a peak hold meter is limited to 136 dB SPL.

The current draft of UL 60950 [102] , which covers all IT and business equipment sets the same limits as UL 1950 [66].

6.3.3 Other countries - summary

Of the three other specifications available, one asks for click suppression to prevent "damage to the ear", a second asks for conformance "to the relevant CCITT Recommendations" and the third requires the level through the earpiece not to exceed 24 dBPa when the incoming call indication is provided on the handset.

6.3.4 European noise exposure standards

Hassel and Zaveri [42] in 1979 quoted the brief summary of some limits for occupational noise exposure in national standards that are reproduced in table 1.

Table 1: National Standards on Occupational Noise Exposure limits

EEC member state	Steady noise level (dB(A))	Time exposure (h)	Halving rate	Overriding limit	Impulse peak SPL (dB)	Impulses (no./day)
Germany	90	8	-	-	-	-
France	90	40	-	-	-	-
Belgium	90	40	5	110	140	100
Luxembourg	-					
Netherlands	-					
UK	90	8	3	135*	150	-
Irish Rep.	90	-	-	-	-	-
Italy	90	8	5	115	140	-
Denmark	90	40	3	115	-	-
Others						
Sweden	85	40	3	115	-	-
Norway	-					
USA (Fed)	90	8	5	115	140	100
Canada (Fed)	90	8	5	115	140	-
Australia	90	8	3	115	-	-

* The UK overriding limit 135 dB SPL on "fast" response

6.4 Other relevant standards

6.4.1 BS 5330

This standard describes a method of test for estimating the risk of hearing handicap due to noise exposure. When it was published in 1976 it differed substantially from the then current version of ISO Publication 1999 [33]. It still differs substantially from the 1990 version of that standard in that it deems handicap to occur if the arithmetic average of the hearing threshold levels, of the two ears combined, at 1 kHz, 2 kHz and 3 kHz is equal to or greater than 30 dB.

This single rule leads to a great simplification of the derivation of the results.

The document provides useful information on the effects of the exposure to noise for that longer period than the normal working life that would occur with normal telephone usage. It also gives data on the various levels of risk of suffering impairment at any particular age.

6.4.2 UK Defence specifications

The UK Defence Standards give useful advice on limits for noise exposure for military personnel. It is acknowledged that the UK Health and Safety at Work Act also applies to service personnel and so the limits recommended are similar to civilian limits. Military standards provide some of the few sources of information on transient noise exposure.

Interim Defence Standard 00-25 (Part 5)/1 [43] sets an 8 hour Leq limit of 85 dB(A) that should not be exceeded during any 24 hour period. It recommends, however, that as far as possible, the sound level at the ear should not exceed 85 dB(A).

It is noted that measurement of impulse noise presents special problems.

Defence Standard 00-27 [44] sets acceptable limits for human exposure to impulse noise, the limits being derived from an American CHABA report rather than current industrial noise standards. The peak pressure is defined as the maximum instantaneous departure, positive or negative, from the ambient pressure. The maximum limit is related to the duration, defined as the time for which the envelope containing the pressure fluctuations exceeds one tenth of the peak pressure.

The maximum acceptable limit passes through the point (5 ms, 159 dB) and falls 2 dB as the duration is doubled.

The preferred limit passes through the point (100 ms, 140 dB) and falls 2 dB as the duration is doubled. No method of measurement is specified but reference is made to the use of a dummy head with a plot of the pressure fluctuations.

The limits are for military personnel and are based on an exposure of 100 impulses per period of 24 hours.

Reference is also made to BS 5330 [45] for lower pressure exposures.

6.5 Other relevant publications

6.5.1 Indecent exposure

In the United Kingdom, the Royal National Institute for Deaf People (RNID) and the Trades Union Congress (TUC) have jointly published a report on noise at work [5]. This report, entitled "Indecent exposure" claims that "call centre workers are being exposed to loud, sometimes painful, noise levels leaving them with dulled hearing, tinnitus, and the risk of long term hearing damage with 39 % saying they were concerned that their hearing was being damaged as a result of exposure to noise at work".

The report also claimed that "call centre employers do not appear to be responding to the concerns of their workforce".

6.5.2 Hearing aid limits

Particularly in view of the use of amplified handsets to assist the hard of hearing, it is necessary to consider whether different limits should be applied for those users. Wide variations of susceptibility to hearing loss are recognized [6] but it is generally assumed that, due to the normal mechanism of hearing loss, the same limits should be applied.

Radley [46] points out that hearing is not ordinarily considered to be sufficiently impaired to require assistance until the loss of sensitivity for speech is of the order of 30 dB. Unfortunately there is seldom, if ever, any corresponding increase in the level at which the speech sounds produce a sensation of speech or discomfort and thus there is a physiological limit to the maximum acoustic power that a hearing aid should deliver. He proposed that a deaf aid should be linear up to an output of 200 dynes/cm^2. This figure of 200 dynes/cm^2 was used as the output limit for an amplified telephone handset intended for use by hearing impaired people, made for the British Post Office by Ericssons [47] in 1960.

It has been suggested that some types of conductive hearing loss could reduce the susceptibility to damage but the effect would be small. Nevertheless users of hearing aids often receive sound pressure levels that would normally be considered dangerous.

It should however be remembered that hearing aids are fitted by qualified audiologists, and special considerations apply. In the UK the Department of Health and Social Security has given information on some hearing aids which discloses that what are considered low powered aids have maximum outputs of 125 dB SPL and higher powered aids produce maximum levels of 138 dB SPL.

Advice with a very high powered aid giving outputs up to 149 dB SPL states that due to the possibility of damage to residual hearing it may be fitted only on the specific recommendation of a consultant otologist. This advice appears to be given concerning any aid capable of producing levels of about 140 dB.

Hearing aid users are nevertheless concerned and in response to a recent letter to the RNID asking whether "using a hearing aid would make my hearing worse?". The reply was given that:

"There was no evidence of hearing aids doing any damage at all, except in very rare cases where the output from the hearing aid had been set much too high.

Hearing aids that have been selected and adjusted by an audiologist to suit your hearing, and which give you comfortable levels of sound, will not damage your hearing." (Quoted from One in Seven magazine [48] Feb/Mar 2000).

7 Further considerations

Before beginning discussion on where to go next, there are a number of factors that have to be taken into account.

7.1 Origins of limits

Although the published information suggests that the presently used limits are based upon detailed considerations of noise exposure, a study of the unpublished contributions that led up to the recommendations reveal that in fact this is not so. They were originally derived from figures that were being achieved at the time that the limits were originally set with the components then available (selenium rectifiers and moving iron earphones). They were agreed as numbers that operators and manufacturers were "not uncomfortable with".

The original impulse response limits were 120 dB SPL and it was said that measurements showed that this could be met "without difficulty". Further measurements made in SG 12 showed one operator reporting SPL measurements of 120 to 125 dB(A) on protected earphones and another 115 dB SPL. 140 dB SPL was measured on an unprotected telephone. The limit was then set to 140 dB SPL with 135 dB recommended as a long-term target.

Proposals were later made to restore the limit to the original 120 dB SPL, and this was effectively achieved by changing the test to measure the true peak instead of using the figure derived from a peak sound level meter.

The source of the 125 dB continuous limit is not so clearly recorded in ITU-T documentation. In a letter to manufacturers and importers of cordless phones dated July 29th 1985 the US Food and Drugs Administration reported damage to users of cordless telephones, which used the earphone as the tone caller. These devices were producing levels of 145 dB SPL A-weighted and using data from Price [49], it was estimated that 50 % of users exposed to this level would suffer some hearing loss.

Price [49] had suggested that there is a critical sound pressure level (CL) at which the equal energy/damage relationship breaks down and where damage occurs irrespective of the period of exposure. He concluded that for the average ear, CL is 145 dB SPL. This conclusion was supported by results in tests on exposure of cats to airbag noises [50].

Using the Price hypothesis, which was acknowledged to be controversial [49], the FDA suggested that the 50 % of damaged users would be reduced to 0,5 % if the levels were reduced to 125 dB SPL. Some uncertainties were noted, particularly the effect of the difference between free field and artificial ear measurements, but it was recommended that no significant risk would exist with a limit of 120 dB and that a case could be made that 125 dB would cause no significant damage.

Private correspondence from a large US manufacturer noted that they adopted the 125 dB limit before UL did. They had an internal debate between 120 and 125 dB but on the grounds that they had several million receivers in the field with a 122 dB limit and without evidence of injury to persons, they supported the 125 dB figure.

The Food and Drugs Administration (FDA) in a letter to UL (June 1991) challenged a proposal to eliminate the 125 dB limit from UL 1459 [67] and pointed out that their original 120-125 dB proposals were not intended to protect against long-term repetitive exposure. They pointed to the OSHA absolute limit of 115 dB(A). They also reported that they "had received a number of complaints from "Hot Line" workers who commonly received harassing phone calls involving loud screams and noises".

The justification in the ITU-T of figure of 125 dB for continuous signals was generated in 1987, well after the limit of 125 dB was first used in the US and was constructed on a totally different basis to that used by the FDA. The relationship of the ITU-T Recommendation P.360 [39] limits to noise exposure regulations using somewhat controversial correction factors was similarly generated long after the limits were actually adopted.

It should be noted that although the limits were originally claimed to be particularly appropriate to occasional tone caller operation they are now applied generally for any signals from the receiver.

7.2 Free field/eardrum correction

One point of uncertainty noted by the FDA was the allowance for the difference between free field and artificial ear measurements. They noted that it was suggested that some ears amplified the free field levels by as much as 8 dB so that the artificial ear measurement was said to be artificially high and that 8 dB should be subtracted from the result.

Shaw [51] reported data on the transformation of sound pressure level from the free field to the eardrum showing it to be highly variable, directional and frequency dependent with excursions ranging from +20 dB to –17 dB dependent on the frequency and direction of the source.

This work was supported by that of Kuhn and Guernsey [37] who measured transformations to the external ear, measuring at the centre of the concha. They also gave data for transformation from the concha to the eardrum.

ITU-T Recommendation P.58 [40], the ITU-T Recommendation for a head and torso simulator, quotes nominal data for the frequency response from free field to its type 3.3 artificial ear for frontally incident sounds. It also gives similar data for the diffuse field response.

Thus data exists for two potential corrections. One from free field to the ear reference point (ERP), and a second from the ERP to the eardrum (DRP). Which, if either or both, should be applied to measurements made using an artificial ear, in order to relate them to noise exposure is a matter for some debate.

The exposure to noise at work Directive clearly states in Article 2 that the instantaneous sound pressure to which the worker is exposed should be "determined from measurements made at the position occupied by the person's ears during work, preferably in the person's absence, using a technique which minimizes the effect on the sound field". It further states that "if the microphone has to be located very close to the person's body, appropriate adjustments should be made to determine an equivalent undisturbed sound pressure".

It can reasonably argued that the Directive intends that any effect of the body on the field is a natural part of the exposure and so no correction should be made for sound generated at the ear (as it is in a telephone). Others disagree with this view and would deduct a free field/ERP (or diffuse field) correction from the noise in the ear. This can give differences of up to approximately 7 dB dependent on the frequency.

There is also debate as to whether the DRP/ERP correction is valid and proposals have been made to eliminate these corrections from both ITU-T Recommendations P.57 [30] and P.58 [40]. This could create frequency dependent differences of up to about 10 dB in the results.

7.3 Risk factors

When considering limits to be set, statistical risk of the occurrence of damage is a major factor. It may reasonably be considered that the permitted exposure of members of the public should be less than that of employees who receive some financial compensation for the risk to which they are exposed in the normal course of their work.

7.4 Exposure lifetime

If a limit were to be set based upon noise at work considerations, some correction would need to be made for the exposure lifetime, as the period of telephone usage is likely to be greater than the 30 or 40 years exposure expected at work. Such a correction could be derived from BS 5330 [45] or ISO Publication 1999 [33].

7.5 Exposure period

If a limit were to be set based upon noise at work considerations, some correction would need to be made for the daily exposure period, with different exposure periods being assigned to differing usages or exposures. The exposure of call centre operators would clearly be different from domestic users. The exposure to speech would differ from that to tone calling.

7.6 Frequency content

Based on over 200 octave spectra of various noisy environments in industry, Hardy [52] stated that on average, the spectra of industrial noises are almost flat with frequency. However the deviations from that average are great. This is the type of exposure for which the noise at work regulations were designed.

Some argue that corrections should be made for specific type of narrow band signals likely to be met when using the telephone.

7.7 Volume controls

If a limit were to be set based upon noise at work considerations, the likely use of any fitted volume control would need to be considered. The information given in subclause 4.5 would suggest that there is little margin left for the use of a volume control to increase the level of the received signal.

An RLR of -19 dB has been proposed for use with mobile telephones. This would imply an overall loudness rating of -11 to –6 dB and would suggest speech levels of 96 to 101 dB SPL and could theoretically require the usage to be limited to 40 minutes per day at the higher level!

The recent imposition of a mandatory requirement in the US, for telephones to be fitted with volume controls giving between 9 and 18 dB increase in level, if these theoretical speech levels are correct, would lead to sound exposures of up to 103 dB SPL, reducing the permitted daily usage to some 24 minutes.

7.8 Impulsive shocks

Except for the work of Price [49] and [50] on the critical level, the few documents that deal with impulsive sounds [53], [54], [55] and [56], refer mostly to gunfire at rates of 100 rounds/day. There is little to be found on limits for occasional shocks as would occur in telephone usage.

In a document on levels of environmental noise requisite to protect public health and welfare [57], it was stated that impulsive noises, which are novel, unheralded, or unexpectedly loud, could startle people and animals. In some circumstances (e.g., when a person is handling delicate or dangerous objects or materials), startle can be hazardous. Because startle and alerting responses depend very largely upon individual circumstances and psychological factors unrelated to the intensity of the sound, it is difficult to make any generalization about acceptable values of SPL in this connection. A high degree of behavioural habituation, even to intense impulse noises such as gunfire, is normally seen in animals and humans when the exposure is repeated, provided that the character of the stimulus is not changed.

Bürck [58] advises (at the end of a paper on annoyance and damage) that: "When the harmfulness of noise is spoken of in the medical sense, it should be borne in mind that this refers not only to the impairment of hearing discussed in the foregoing sections and which may be described as direct physiological organic injuries, but also indirect injuries to health by way of the vegetative or sympathetic nervous system caused by exposure to noise below the limit for the impairment of hearing.

Such noise may likewise eventually lead to organic injuries, although this will depend largely on the psychological condition and mentality of the individual affected".

7.9 Tone callers

Although the present continuous test limits arose from exposure to tone callers, especially when the earphone was used as the tone caller, few standards give applicable tests. This is especially important when the tone caller is on the handset of a portable telephone.

All of the current tests specified are with the earphone sealed to the ear, a totally artificial situation that helps to prevent the sound reaching the microphone in the artificial ear.

In the period 1986-87 rough tests were made in the laboratories of GPT and STC of sounds received in the ear from earphones used as tone callers and handset mounted tone callers when the handset is moved away from the ear. It seems that a gap of about 5mm between the earcap and the artificial ear would give a realistic representation of what may occur in practice, and would allow external sound from a caller elsewhere on the handset to enter the ear as it would in a real ear.

8 Conclusion

The present document provides a collection of extracts from current standards, approval documents and other relevant background information on the subject of acoustic shock and the protection of the user from injury arising from the acoustic output of telecommunications terminal equipment.

It is intended as an input to discussion within ETSI STQ. It does not draw conclusions, nor provide suggestions for any future actions in the subject field.

Annex A (informative): Acoustic shock references in terminal specifications

A.1 ETSI Documents

A.1.1 Technical Reports

A.1.1.1 TR 101 182

Analogue Terminals and Access (ATA);

Definitions, abbreviations and symbols (Aug. 1998)

3.1 General definitions

acoustic shock: any temporary or permanent disturbance of the functioning of the ear, or of the nervous system, which may be caused to the user of a telephone earphone by a sudden sharp rise in the acoustic pressure produced by it [ITU-T Recommendation P.10 [1]].

NOTE: An acoustic shock usually results from the occurrence, in abnormal circumstances, of short-lived high voltages at the terminals of a telephone set.

A.1.2 I-ETSs

A.1.2.1 I-ETS 300 131

Radio Equipment and Systems (RES);

Common air interface specification to be used for the interworking between cordless telephone apparatus in the frequency band 864,1 MHz to 868,1 MHz, including public access services (Nov. 1994)

8.15.1 Maximum intended sound pressure level

With a digitally encoded signal representing the maximum possible signal at the digital interface, the sound pressure level at the ERP shall not exceed +24 dBPa (rms unweighted).

Compliance shall be checked by the test of subclause 11.21.

8.15.2 Maximum possible sound pressure level

The sound output from the receiver shall be limited by the power output capability of the receiver drive amplifier to give a peak sound pressure at the ERP not greater than 36 dBPa under any continuous or transient conditions.

Compliance shall be by supplier's declaration.

8.16 Audible incoming call indication

8.16.1 Provided on CPP: sound pressure level

If audible incoming call indication is provided anywhere on the CPP, the sound pressure level at the ERP shall not exceed 24 dBPa.

NOTE: The initial sound pressure in subclause 8.16.1 should not exceed 0 dBPa and should rise in increments no greater than 6 dB, at a rate not greater than 6 dB/s, to a maximum within not less than 6 s.

8.16.2 Generated other than through the earpiece: maximum sound pressure level

If audible incoming call indication on the CPP is generated other than through the earpiece, the sound pressure at the commencement of such indication shall not exceed 50 dB A-weighted at 1 m free field in any direction, and shall also comply with subclause 8.16.1.

NOTE: The initial level in subclause 8.16.2 should rise in increments no greater than 6 dB, at a rate not greater than 6 dB/s, to a maximum within not less than 6 s.

11.21 Acoustic shock (subclause 8.15)

A digital signal generator is connected to point B of the reference CFP as shown in figure 22, and the level adjusted to produce a level of +3,14 dBm0 (Tmax) at the uniform PCM interface.

Measurements are made at one-third octave intervals as given by the R10 series of preferred numbers in ISO Publication 3 [59] for frequencies from 200 Hz to 4 kHz inclusive. At each frequency, the sound pressure level in the artificial ear is measured.

A.1.2.2 I-ETS 300 176

Digital Enhanced Cordless Telecommunications (DECT);

Approval test specification (Oct 1992)

15.29 Acoustic shock

See subclause 7.8 of ETSI ETS 300 175-8 [68].

15.29.1 Continuous signal

The handset is mounted in the LRGP and the earpiece is sealed to the knife-edge of the artificial ear.

A digital signal generator is connected at the digital interface. It is set to deliver the digitally encoded equivalent of a square wave, with a peak code equal to the maximum code which can be sent over the digital interface at frequencies in third-octave intervals as given by the R.10 series of preferred numbers in ISO Publication 3 [59] for frequencies from 200 Hz to 4 kHz. For each frequency, the sound pressure in the artificial ear shall be measured.

15.29.2 Peak signal

Compliance shall be by manufacturer's declaration, until a test method has been specified.

A.1.2.3 I-ETS 300 245-2

Integrated Services Digital Network (ISDN); Technical characteristics of telephony terminals;

Part 2: PCM A-law handset telephony 2nd Edition (Feb 1996)

Annex B (informative): Acoustic shock requirements

The prevention of acoustic shock is a safety requirement arising from the Low Voltage Directive (73/23/EEC). In the absence of any relevant safety standard a supplier’s self-declaration may be based on the following recommendations.

The limits advised are based on sound pressure levels measured in an ITU-T Recommendation P.57 [30], type 1 artificial ear. For other types of artificial ears different sound pressure levels may be required.

B.1 Continuous signal

With a digitally encoded signal representing the maximum possible signal at the digital interface, the sound pressure level in the artificial ear should not exceed 24 dBPa (RMS).

Compliance should be checked by the following test:

a) the handset is mounted in the LRGP and the earpiece is sealed to the knife-edge of the artificial ear.

b) a digital signal generator is connected at the digital interface. It is set to deliver the digitally encoded equivalent of a square-wave, with a peak code equal to the maximum code which can be sent over the digital interface at frequencies in third-octave intervals as given by the R.10 series of preferred numbers in ISO Publication 3 [59] for frequencies from 200 Hz to 4 kHz. For each frequency, the sound pressure in the artificial ear should be measured. [Identical to ETSI ETS 300 085 [60] & TBR 8 [75]].

B.2 Peak signal

The receiving equipment should limit the peak sound pressure in the artificial ear to less than 36 dBPa. Conformance test methods are for further study. Until such methods exist, compliance should be checked by the suppliers' declaration of conformance. [Identical to TBR 8 [75]].

A.1.2.4 I-ETS 300 245-5

Integrated Services Digital Network (ISDN); Technical characteristics for telephony terminals;

Part 5: Wideband (7 kHz) handset telephony (Dec 1995)

5.4.9 Acoustic shock

NOTE: This subclause needs to be updated when an appropriate IEC Publication is available.

5.4.9.1 Continuous Signal

With an input sinusoidal signal of 9 dBm0, at any frequency between 100 Hz and 8 kHz, the sound pressure level at the ERP shall not exceed 24 dBPa (rms).

Conformance shall be checked by the tests described in annex A, subclause A.2.8.1.

5.4.9.2 Peak signal

The receiving equipment shall limit the peak sound pressure at the Eardrum Reference Point (DRP) to less than 40 dBPa.

Conformance test methods are for further study. Until such methods exist, compliance shall be checked by the supplier's declaration of conformance.

A.2.8 Acoustic shock

A.2.8.1 Continuous signal

The handset is mounted in the LRGP and the earpiece is coupled to the artificial ear. A signal generator is connected at the input port of the reference codec, delivering a sinusoidal signal with a level of 9 dBm0 and at frequencies in one-third octave intervals as given by the R.10 series of preferred numbers in ISO Publication 3 [59] in the range from 100 Hz to 8 kHz.

The output sound pressure level shall be referred to the ERP by the correction coefficients given in ITU-T Recommendation P.57 [30].

A.1.2.5 I-ETS 300 245-8

Integrated Services Digital Network (ISDN); Technical characteristics of telephony terminals;

Part 8: Speech transmission characteristics when using Low-Delay Code-Excited Linear Prediction (LD-CELP) coding at 16 kbit/s (Jan 1996)

5.2.3 Acoustic shock

The prevention of acoustic shock is a safety requirement arising from the Low Voltage Directive (73/23/EEC). In the absence of any relevant safety standard, advice can be found in annex B to I-ETS 300 245-2 [62].

A.1.2.6 I-ETS 300 281

Integrated Services Digital Network (ISDN); Telephony 7 kHz teleservice;

Terminal requirements necessary for end-to-end compatibility (May 1994)

6.4.9 Acoustic shock

NOTE: This subclause needs to be updated when an appropriate IEC Publication is available.

6.4.9.1 Continuous Signal

With an input sinusoidal signal of 9 dBm0, at any frequency between 100 Hz and 8 kHz, the sound pressure level at the ERP shall not exceed 24 dBPa (rms).

Conformance shall be checked by the tests described in annex A, subclause A.2.8.1 of this I-ETS.

6.4.9.2 Peak signal

The receiving equipment shall limit the peak sound pressure at the Eardrum Reference Point (DRP) to less than 4 dBPa.

Conformance test methods are for further study. Until such methods exist, compliance shall be checked by the supplier's declaration of conformance.

A.2.8 Acoustic shock

A.2.8.1 Continuous signal

The handset is mounted in the LRGP and the earpiece is coupled to the artificial ear. A signal generator is connected at the input port of the reference codec, delivering a sinusoidal signal with a level of 9 dBm0 and at frequencies in one-third octave intervals as given by the R.10 series of preferred numbers in ISO Publication 3 [59] in the range from 100 Hz to 8 kHz.

The output sound pressure level is referred to the ERP by the correction coefficients given in ITU-T Recommendation P.57 [30].

A.1.2.7 I-ETS 300 302-1

Integrated Services Digital Network (ISDN); Videotelephony teleservice;

Part 1: Electroacoustic characteristics for 3,1 kHz bandwidth handset terminals (Nov 1996)

5.10 Acoustic shock

The prevention of acoustic shock is a safety requirement arising from the (LVD) (73/23/EEC). In the absence of any relevant safety standard, advice can be found in annex B of I-ETS 300 245-2 [62].

A.1.2.8 I-ETS 300 480

Public Switched Telephone Network (PSTN); Testing specification for analogue handset telephony (Jan 1996)

Annex B (informative): Acoustic shock

B.1 Continuous signal

A frequency generator with a non-reactive source impedance of 600 Ω is connected between terminals A and B shown in figure 1.

Measurements are made at the values of feeding resistance, R_f, specified in the relevant terminal standard.

The frequency generator is set to deliver pure tone signals at an e.m.f. of 24 dBV rms at 1/3 octave intervals at the preferred frequencies given by the R10 series of preferred numbers in ISO Publication 3 [59] for frequencies from 200 Hz to 1 kHz.

For each band the sound pressure in the artificial ear is measured.

A.1.3 ETSs

A.1.3.1 ETS 300 082

Integrated Services Digital Network (ISDN); 3,1 kHz telephony teleservice;

End-to-end compatibility (Jan 1992)

6.2.9 Acoustic shock

6.2.9.1 Continuous signal

With a digitally encoded signal representing the maximum possible signal at the digital interface, the sound pressure level in the artificial ear shall not exceed 24 dBPa (rms).

Compliance shall be checked by the test described in annex A, subclause A.2.9.1.

6.2.9.2 Peak signal

The receiving equipment shall limit the peak sound pressure in the artificial ear to less than 36 dBPa.

Conformance test methods are for further study. Until such methods exist, compliance shall be checked by suppliers' declaration of conformance.

A.2.9 Acoustic shock

A.2.9.1 Continuous signal

The handset is mounted in the LRGP and the earpiece is sealed to the knife-edge of the artificial ear.

A digital signal generator is connected at the digital interface. It is set to deliver the digitally encoded equivalent of a square wave with a peak code equal to the maximum code which can be sent over the digital interface at frequencies in third-octave intervals as given by the R.10 series of preferred numbers in ISO Publication 3 [59] for frequencies from 200 Hz to 4 kHz. For each frequency, the sound pressure in the artificial ear shall be measured.

A.1.3.2 ETS 300 085

Integrated Services Digital Network (ISDN); 3,1 kHz telephony teleservice;

Attachment requirements for handset terminals (Candidate NET 33) (Dec 1990)

6.2.9 Acoustic shock

6.2.9.1 Continuous signal

With a digitally encoded signal representing the maximum possible signal at the digital interface, the sound pressure level in the artificial ear shall not exceed 24 dBPa (rms).

Compliance shall be checked by the test described in annex A, subclause A.2.9.1.

6.2.9.2 Peak signal

The receiving equipment shall limit the peak sound pressure in the artificial ear to less than 36 dBPa.

Conformance test methods are for further study. Until such methods exist, compliance shall be checked by suppliers' declaration of conformance.

A.2.9 Acoustic shock

A.2.9.1 Continuous signal

The handset is mounted in the LRGP and the earpiece is sealed to the knife-edge of the artificial ear.

A digital signal generator is connected at the digital interface. It is set to deliver the digitally encoded equivalent of a square-wave, with a peak code equal to the maximum code which can be sent over the digital interface at frequencies in third-octave intervals as given by the R.10 series of preferred numbers in ISO Publication 3 [59] for frequencies from 200 Hz to 4 kHz. For each frequency, the sound pressure in the artificial ear shall be measured.

A.A.4.6 Acoustic shock

[* The requirement to acoustic shock peak signals shall be verified by a supplier's declaration of conformance. The testing laboratory shall examine the declaration, and it shall be included in the test report as an annex. *]

A.1.3.3 ETS 300 488

Terminal Equipment (TE); Telephony for hearing impaired people;

Characteristics of telephone sets that provide additional receiving amplification for the benefit of the hearing impaired (Jan 1996)

6.6 Acoustic shock

The prevention of acoustic shock is a requirement arising from the Low Voltage Directive (73/23/EEC). In the absence of any relevant safety standard advice can be found in annex B of l-ETS 300 245-2 [62] and for analogue sets in annex A of I-ETS 300 677 [81] .

A.1.4 ESs

A.1.4.1 ES 200 677

Public Switched Telephone Network (PSTN); Requirements for handset telephony (March 1998)

Annex B (informative):

Acoustic shock

B.1 General

The prevention of acoustic shock is a safety requirement outside the scope of the present document and arising from the Low Voltage Directive (73/23/EEC [12]). In the absence of any relevant safety standard, a supplier's self-declaration may be based on the following recommendations.

The limits advised are based on sound pressure levels measured in an ITU-T Recommendation P.57 [30] type 1 artificial ear. For other types of artificial ear different sound pressure levels may be required.

B.1.1 Continuous signal

The sound pressure level in the artificial ear should not exceed 24 dBPa (rms).

Compliance should be checked by the test described in clause B.1 of I-ETS 300 480 [61].

B.1.2 Peak signal

The receiving equipment should limit the peak sound pressure level in the artificial ear to less than 36 dBPa.

Conformance test methods are for further study. Until such methods exist, compliance should be checked by the suppliers' declaration of conformance.

A.1.5 ENs

A.1.5.1 EN 300 001

Attachments to Public Switched Telephone Network (PSTN); General technical requirements for equipment connected to an analogue subscriber interface in the PSTN; (Oct 1998)

Chapter 2: DC characteristics

2.6 (CH) 1 Following overload tests apply with the presently described feeding conditions:

1) The requirement for the overload susceptibility shall be met according to subclause 3.2 (DC mixed with 25 Hz AC instead of pure DC) on TE with and without ringing detection.

2) The acoustic shock for TE with transducers to be applied to the human ear (e.g. handset receiver) shall not exceed the limits mentioned in TBR 8 [75] , annex C. This test is to be conducted with R_f = 2 300 and a 19 dB VEMF (open circuit voltage).

3) The Tests defined under ITU-T Recommendation K.21 [69], table 1, Test 1, Criterion A.

Chapter 10: Additional unclassified requirements

10.4 (E) 4 Protection against acoustic shocks

PROVISION 1: This requirement shall be applied only for TEs with some acoustic transducers intended to be used for the purpose of listening and capable of being placed near the ear.

With TE in the loop condition, the output acoustic pressure from any acoustic transducer like the above indicated shall be controlled in such a manner that the maximum peak value of its instantaneous acoustic pressure level shall not be in any moment greater than 126 dB relative to a sound pressure level of 20 µPa, tested with an impulse as stipulated in the test method in subclause A.10.4 (E) 4, applied between the line terminals.

PROVISION 2: This requirement shall also be applied for self-generated acoustic impulses produced when the TE changes from loop condition to quiescent condition, and from quiescent condition to loop condition, as well as when the TE starts, performs, or finishes a dialling sequence (reference is made to the requirements under clause 5, subclauses 5.3 and 5.4 and to the associated Spanish sections (E) in order to understand the performances of that sequence), tested when no AC signals are applied between the line terminals.

PROVISION 3: No manufacturing tolerance is allowed which would permit this pressure level to be exceeded by any TE.

Compliance shall be checked by the tests outlined in subclause A.10.4 (E) 4.

A.10.4 (E) 4 Protection against acoustic shocks

The TEUT is connected as shown in figure A.10.4 (E) 4, with switch (S 1) in position 1.

The DC voltage source (V f) takes the value of 48 V, and a resistor (R f) takes the value of 1 100 Ω.

The diodes (D 1) and (D 2) have a peak reverse breakdown voltage of more than 3 kV.

The DC voltage source (V 1) takes the value of 1 500 V and the resistor (R 1) takes the value of 1 000 Ω.

The capacitor (C 1 takes the value of 20 µF, and a capacitor (C 2) takes the value of 200 nF. The resistors (R 2), (R 3), and (R 4) take the values of respectively 50 W, 15 W, and 25 W.

The earpiece of the TEUT shall be acoustically terminated by couplers or artificial ear assemblies according with:

a) the IEC Publication 126, for measurements on insert earphones; or

b) the IEC Publication 318, for measurements on supra-aural earphones.

Other earpieces, if provided, shall be adequately terminated to avoid the testing results to become disturbed.

The TEUT is caused to generate its absolute maximum output acoustic signal according with the user's manual.

Switch (S 1) is changed to its position 2, and the instantaneous acoustic pressure shall be measured by a sound level meter according with the IEC Publication 651 (1979), or according with the IEC Publication 179 (1965), in peak detection mode with the A-weighted scale.

When the provision 2 in subclause 10.4 (E) 4 is applied, switch (S 1) shall be in position 1.

The test procedures shall be carried out at least three times and the result with the maximum value shall be chosen.

PROVISION: This test shall be carried out before certain other tests (see subclause 10.1 (E) 1).

A.1.5.2 EN 300 175-1

Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI);

Part 1: Overview (June 1999)

4.8 Part 8: Speech coding and transmission

The speech coding and transmission specifies the requirements for DECT equipment, which includes all the necessary functions to provide real-time two-way speech conversation. It defines the speech encoding algorithm and the detailed speech performance characteristics such as sensitivity, frequency response, sidetone, terminal coupling loss, distortion, variation of gain with input level, out of band signals, noise, **acoustic shock**, delay and network echo control.

A.1.5.3 EN 300 175-8

Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI);

Part 8: Speech Coding and Transmission (June 1999)

7.8 Acoustic shock

7.8.1 Continuous signal

With a digitally encoded signal representing the maximum possible signal level at the digital interface, the sound pressure level at the ERP shall not exceed 24 dBPa (rms unweighted).

7.8.2 Peak signal

The receiving equipment shall limit the peak sound pressure at the ERP to less than 36 dBPa under any continuous or transient condition.

A.1.5.4 EN 300 176-2 V1.3.2

Digital Enhanced Cordless Telecommunications (DECT); Approval test specification;

Part 2: Speech (June 1999)

7.26 Acoustic shock

The essential requirements and test for acoustic shock are not within the scope of the present document. They are covered by the Low Voltage Directive (73/23/EEC [12]).

For information see annex D.

Annex D (informative):

Acoustic shock requirements

The prevention of acoustic shock is a safety requirement arising from the Low Voltage Directive (73/23/EEC [12]). In the absence of any relevant safety standard, a supplier's self-declaration may be based on the following recommendations. The limits advised are based on sound pressure levels measured at ITU-T Recommendation P.57 [30], Type 1 artificial ear. For other types of artificial ears different sound pressure levels may be required.

D.1 Continuous signal

With a digitally encoded signal representing the maximum possible signal at the digital interface, the sound pressure level in the artificial ear should not exceed 24 dBPa (rms). Compliance shall be checked by the following test:

a) the PP is mounted in the LRGP and the earpiece is sealed to the knife-edge of the artificial ear;

b) a digital signal generator is connected at the digital interface. It is set to deliver the digitally encoded equivalent of a square-wave, with a peak code equal to the maximum code which can be sent over the digital line interface at frequencies in third-octave intervals as given by the R.10 series of preferred numbers in ISO Publication 3

[59] for frequencies from 200 Hz to 4 kHz. For each frequency, the sound pressure level in the artificial ear should be measured.

D.2 Peak signal

The receiving equipment should limit the peak sound pressure in the artificial ear to less than 36 dBPa. Conformance test methods are for further study. Until such methods exist, compliance should be checked by the supplier's declaration of conformance.

A.1.6 TBRs

A.1.6.1 TBR 8

Integrated Services Digital Network (ISDN); Telephony 3,1 kHz teleservice;

Attachment requirements for handset terminals (Sept 1994)

8.2.9 Acoustic shock

Reference: I-ETS 300 245-2 [62], subclause 5.2.9.

The prevention of acoustic shock is a safety requirement arising from the Low Voltage Directive (73/23/EEC [12]). In the absence of any relevant safety standard, advice can be found in annex C.

Annex C (informative): Acoustic shock requirements

The prevention of acoustic shock is a safety requirement arising from the Low Voltage Directive (73/23/EEC [12]). In the absence of any relevant safety standard, a supplier's self-declaration may be based on the following recommendations.

The limits advised are based on sound pressure levels measured in an ITU-T Recommendation P.57 [30], type 1 artificial ear. For other types of artificial ears different sound pressure levels may be required.

C.1 Continuous signal

With a digitally encoded signal representing the maximum possible signal at the digital interface, the sound pressure level in the artificial ear should not exceed 24 dBPa (rms).

Compliance shall be checked by the following test:

[Identical to that specified in subclause 2.9.1 of ETS 300 085 [60]].

C.2 Peak signal

The receiving equipment should limit the peak sound pressure in the artificial ear to less than 36 dBPa. Conformance test methods are for further study. Until such methods exist, compliance should be checked by the suppliers' declaration of conformance.

A.1.6.2 TBR 10

Digital Enhanced Cordless Telecommunications (DECT); General terminal attachment requirements;

Telephony applications (Third edition July 1999)

7.26 Acoustic shock

The essential requirements and test for acoustic shock are not within the scope of the present document.

They are covered by 73/23/EEC [12] (the Low Voltage Directive).

Annex D (informative): Acoustic shock requirements

The prevention of acoustic shock is a safety requirement arising from the Low Voltage Directive (73/23/EEC [12]). In the absence of any relevant safety standard, a supplier's self-declaration may be based on the following recommendations. The limits advised are based on sound pressure levels measured at ITU-T Recommendation P.57 [30], Type 1 artificial ear. For other types of artificial ears different sound pressure levels may be required.

D.1 Continuous signal

With a digitally encoded signal representing the maximum possible signal at the digital interface, the sound pressure level in the artificial ear should not exceed 24 dBPa (rms). Compliance shall be checked by the following test:

a) the PP is mounted in the LRGP and the earpiece is sealed to the knife-edge of the artificial ear;

b) a digital signal generator is connected at the digital interface. It is set to deliver the digitally encoded equivalent of a square-wave, with a peak code equal to the maximum code which can be sent over the digital line interface at frequencies in third-octave intervals as given by the R.10 series of preferred numbers in ISO Publication 3 [59] for frequencies from 200 Hz to 4 kHz. For each frequency, the sound pressure level in the artificial ear should be measured.

D.2 Peak signal

The receiving equipment should limit the peak sound pressure in the artificial ear to less than 36 dBPa. Conformance test methods are for further study. Until such methods exist, compliance should be checked by the supplier's declaration of conformance.

A.2 European National specifications

A.2.1 Austria

A.2.1.1 FTV 462

Technical Regulation for Analogue Telephone Sets (draft 1996) [Official 83/189 translation]

2.6 Hearing protection limiting

2.6.1 Definition

Hearing protection limiting is the ratio of the acoustic pressures in two different voltage levels conducted to the telecommunication subscriber line.

2.6.2 Measurement method

The acoustic pressure generated by an electrical voltage of 800 Hz at levels of –10 dBm and +10 dBm respectively is to be measured, using the measurement equipment stated in ITU-T Recommendations P.64 [70] and P.65 [71].

2.6.3 Limit Value

The ratio between the acoustic pressures may not exceed 14 dB.

A.2.2 Belgium

A.2.2.1 RN/SP 208

Postes Téléphoniques analogiques connectés au Réseau Téléphonique Public Commute [STF translation]

5 Protection against overvoltages

a) The telephone shall be effectively protected against the divers overvoltages, which can momentarily exist on the line connecting the user (voltage created by a megger when testing for a line fault, lightning,..).

The device shall be so connected that during its functioning the amplitude of the pressure produced by the diaphragm of the receiver cannot exceed about 120 dB above 20 μPa at 1 000 Hz.

A.2.3 Denmark

A.2.3.1 Tekniske Bestemmler TB 93 004 Rev.B

Telefonapparater (Aug 1993) [STF translation]

2.7.3 Maximum Sound Pressure

When receiving with an IEC Publication 318 [72] artificial ear, the maximum sound pressure may never exceed 120 dB SPL.

The measurement method is shown in figure M.2.7.1.

The sound pressure is measured with loop currents of 16 mA and Imax at frequencies of 300, 100 and 3 150 Hz. At each frequency the generator voltage shall be increased up to 5 V and it shall be checked if the maximum sound pressure is exceeded.

A.2.4 Finland

A.2.4.1 TPL 02 rev.1

Requirements for type approval. Requirements for Telephone [Finnish translation]

6.5 Voltage suppressor for the receiver

The sound pressure produced in the receiver of the telephone shall be limited so that it does not exceed 120 dB when referred to 20 μPa and measured by the CCITT's artificial ear with measuring arrangements described in figure 6, when the E.M.F of the generator is less than 31 V.

A.2.5 France

A.2.5.1 CNET ST/PAA/TPA/AGH/949 (1985)

Spécification des postes téléphoniques (Sept 1985) [STF translation]

3.2.4 Limitation of acoustic level

In the reception conditions of figure 5 with and without artificial line, the level of acoustic pressure measured at the earpiece of the handset of a telephone instrument shall be less than 125 dB ref. 2×10^{-5} Pa (114 dB ref 2×10^{-5} Pa under consideration).

A.2.5.2 CNET ST/PAA/TPA/AGH/0949 (1991)

Specification for telephone sets (December 1991) [Official 83/189 translation]

4.4 Sound pressure level limiting

4.4.1 Handset telephone

Under the reception conditions shown in figure 5, with and without artificial line (l), the sound pressure level measured at the earpiece of a telephone handset must be less than 31 dBPa (20 dBPa under consideration):

- in the 100 Hz – 10 kHz band, for any level below +20 dBm at the line port;
- at 50 Hz, for any level below 80 V at the line port, with the duration of the test limited to one second and impedance z (representing the ringing signal generator) less than 20 Ω;
- with transient overloads, simulated random surges that may occur on a line in the speech phase. The measurement conditions are illustrated in figure 12. The sound pressure measurement device has an integrating

circuit that complies with IEC Publication 651 for measuring isolated impulsive noise with an integrating constant close to 35 ms.

4.4.2 Headsets

In the case of headsets with earpieces that are placed over the ear, the measurement method is the same as that used for a handset telephone.

The sound pressure level must not exceed 20 dBPa on the IEC Publication 318 [72] artificial ear.

In the case of headsets with stud earpieces, the IEC Publication 711 [73] ear simulator must be used.

A.2.6 Germany

A.2.6.1 BAPT 222 ZV 80

Approval Specification for Terminal Equipment of the Mobile Telephone Service for Direct Connection to Analogue Dial-up Connections (except Emergency Call and Direct Inward Dialling Connections) of Deutsche Telekom AG's Telephone Network/ISDN (April 1996) [Official 83/189 translation]

3.2 Limiting

2.9.1 Click absorption

The sound level emitted by the receiver capsule (p_{max}) shall be ≤ 29,5 dBPa (A). If a volume control is used, this value applies for all positions of the volume control.

Measurement circuit: appendix A, subclause A.10.

A.2.6.2 BAPT 223 ZV 24

Acceptance Specification for Terminals used in the 3,1 kHz Telephone Service for Direct Connection to Analogue Switched Connections (with the exception of Emergency Call and Direct Inward Dialling Connections) on the Telephone Network/ISDN operated by Deutsche Telekom AG. (Feb 1995) [Official 83/189 translation]

4.11 Hearing protection

The sound level emitted by the earpiece must be $p_{max} \leq$ 29,5 dBPa (A). If a volume control unit is used, the value applies to all the volume control settings.

Measurement connection: subclause A.11.

A.2.7 Sweden

A.2.7.1 Diavox telephone set (1978)

Acoustic shock [Swedish translation]

When the telephone set is fed with an e.m.f., as specified below with a frequency of 1 000 Hz and from a generator of 600 Ω impedance the following applies:

- Emf Requirement.
- 50V The sound pressure level shall be below 120 dB rel to 2 x 10^{-5} Pa measured with an artificial ear according to CCITT Green Book Vol. V.
- < 0,775 V < 0,5 dB attenuation.

(Ref CCITT White Book Vol. IX, Rec K7 (Geneva 1964)).

A.2.7.2 8211-A 124

Technical requirements for connection of telephone sets to the public switched telephone network (Dec 1989) [Swedish translation]

7.1.6 Level limitation

For sending, the voltage across the apparatus for any sound pressure level at the microphone shall be less than 3 V (peak value).

For receiving the sound pressure level at the telephone receiver shall not exceed 130 dB (peak value) independently of the signal level at the input to the apparatus. It is however desirable that the sound pressure level does not exceed 120 dB (peak value). Tests are carried out with an artificial ear in compliance with subclause 7.1.3 with test voltages of 9 - 50 V (rms).

A.2.7.3 Svensk Standard SS 63 63 41

Telecommunications equipment - Subscriber equipment - Technical requirements for analogue handset telephony (August 1995) [Swedish translation]

4.4 Acoustic shock

NOTE: The prevention of acoustic shock is a safety requirement arising from the Low Voltage Directive (73/23/EEC [12]). In the absence of any relevant safety standard, a supplier's declaration may be based on the following recommendations:

The sound pressure level at the ERP should not exceed 26 dBPa (peak value) independent of the signal level at the input of the telephone set and the output voltage for any sound pressure level at the microphone should be less than 3 V (peak value). The requirements should apply to all positions of any user accessible volume control.

The measurement should be made with an artificial ear according to subclause 4.1 with signals applied in the interval 0 to 34 dBV.

A.2.8 Switzerland

A.2.8.1 PTT 840.50/1

Subscriber installation. Requirement document. Minimum requirements for subscriber apparatus for connection to a Subscriber line/Extension line of the public telephone network (June 1986) [STF translation]

2.5 Hearing Protection

The receiver of the telephone apparatus shall not provide any peak level of noise, which is harmful to hearing. The protection mechanism shall start to operate with a tone signal at the line interface of 1 V_{eff}. When making measurements with large signals, the effect of the protection needs to be taken into account.

Requirement:

The acoustic signal shall not exceed 120 dB(A).

A.2.8.2 SR.784.103.12/2.1/1

Technical requirements for Speech Terminals, which can be connected, to an analogue telecommunications network (May 1992) [STF translation]

4.3.1 Hearing protection

The level of noise provided at the receiver shall not exceed 120 dB(A).

The receiver of the telephone apparatus shall not provide harmful acoustic peak levels, which can damage the hearing.

The protection mechanism shall start to operate with a tone signal of 1 V_{eff} (DC to 10 kHz) at the input connection. When making measurements with large signals, the effect of the protection needs to be taken into account.

A.2.8.3 SR.784.103.12/2.2 Issue 1 (E1)

Technical requirements for Subscriber Equipment: PSTN Access (June 1995) [Swiss translation]

2.5.3 Acoustic shock

Requirement: The maximum acoustic level presented by the receiving transducers when applied to the human ear (e.g. handset receiver) shall not exceed the limits mentioned in TBR 8 [75] , annex C.

Test: The test method as per TBR 8 [75] , annex C, is used. The test is conducted with the test configuration "sli" as per clause B.3. During the transmission phase the TA is supplied with the test signal as per clause B.1, of 19 dBV_{EMF} (receive direction).

A.2.9 The Netherlands

A.2.9.1 T 11-05E

Conformity specification for terminal equipment intended for connection to the Public Switched Telephone Network in the Netherlands (Aug 1988) [Official 83/189 translation]

7.3 Auditory protection

The acoustic signal level at the artificial ear shall be lower than 26 dBPa for sinusoidal signals with a frequency between 300 and 3 400 Hz. Transient voltage peaks may deliver a maximum sound pressure of 29 dBPa at the artificial ear. Auditory protection shall be measured as indicated in figures 6 and 7. These measurements shall be performed at the nominal DC feed conditions described in T 11-00E, clause 8.

A.2.10 The United Kingdom

A.2.10.1 Specification POR 1281.4

Telephones in the special range (1975)

3.3.3 Protection of the user from excessive sound levels

The sound pressure produced by the telephone receiver in an approved artificial ear, or the free field sound pressure produced by the acoustic device (or other transducer) at a distance of 0,25 m from the telephone, shall not exceed +120 dB relative to 20 $\mu N/m^2$ when tested under the conditions detailed in appendix 1, subclause 2.2.

2 Electro-acoustical tests-

2.2 Test conditions used when determining the maximum sound levels emitted by the receiver and the acoustic device

2.2.1 Test conditions used when determining the maximum sound level emitted by the receiver

Various subjective experiments conducted to determine the loudness of noise at a given sound pressure level but having variable duration have shown that bursts of noise of less than 200 ms duration are assessed as quieter than continuous noise. An estimate of the amount by which the sound pressure level of a short burst of noise has to be increased to obtain the same subjective loudness as a continuous noise is shown in figure 5 for noise bursts of between 100 µs and 200 ms duration. In order to check that bursts of electrical noise of duration equal to or less than 35 ms do not cause the receiver to produce sound levels greater than +120 dB relative to 20 µN/m2 when determined subjectively, a continuous sinusoidal tone at a frequency of 1 kHz is applied to the telephone under the following conditions:

2.2.1.1 The telephone is plugged into one of the jacks shown in figures 1 and 2 (Type A and B Telephone) or figure 3 (Type C and D Telephone).

2.2.1.2 A Local Telephone Circuit (LTC) is connected to jack points 2 and 3, the LTC consisting of an artificial 0,5 mm copper cable equivalent to any length between 0 and 6 km, a 200 + 200 ohm non-ballast capacitor bridge with a 50 volt d.c. supply of both polarity, and an oscillator having an out put impedance of 600 Ω.

2.2.1.3 The oscillator is set to give an e.m.f. of +30 dB relative to 1 volt rms at a frequency of 1 kHz.

2.2.1.4 The sound pressure developed by the receiver in an approved artificial ear (see POR 1281.3) must be less than +125 dB relative to 20 @l/m2 whatever the setting of the artificial cable, or polarity of the feeding bridge.

2.2.2 Test conditions used when determining the maximum sound level emitted by the acoustic device.

2.2.2.1 Free standing table telephones are placed at the centre of a smooth hard horizontal surface of minimum dimensions 1 m x 1 m. Wall mounted telephones are mounted in the way intended in use at the centre of a smooth hard vertical surface of minimum dimensions 1 m x 1 m.

2.2.2.2 The telephone in the ‘on hook’ state is plugged into one of the jacks shown in figures 1, 2 (Type A Telephone) or figure 3 (Type C Telephone).

2.2.2.3 The continuous ringing supply detailed in POR 1281.2, appendix 1, subclause 1.1.1 is connected to jack points 2 and 3.

2.2.2.4 The sound pressure developed at a distance of 0,25 m from the telephone is measured and must not exceed +120 dB relative to 20 µN/m2.

A.2.10.2 Specification S1490

Development specification for a new electronic telephone (1982)

2.9.2 Acoustic Shock Protection. The maximum acoustic signal level generated by the receiver shall be insufficient to cause damage to a human ear and its associated nervous control system. The test for this requirement is given in the Transmission Section (subclause 6.14) of this specification, but is reproduced here for the sake of completeness.

(6.14) With a pure tone of 1 kHz having a level of +24 dBV from a 600 ohm source, applied to the telephone as defined in appendix 1 (subclause A.1.8) the sound pressure in the artificial ear shall not exceed +24 dBPa (unweighted).

6.14 Acoustic Shock Protection

With **a** pure tone of 1 kHz having a level of +24 dBV from a 600 ohm source applied to the telephone as defined in appendix 1 (subclause A.1.8) the sound pressure in the artificial ear shall not exceed +24 dBPa (unweighted).

9.3.6 When switching from transmission to signalling and vice versa and during signalling no objectionable clicks shall be produced from the earphone (level < 90 dB rel 2 x 10^{-5} Pa during pulsing, <120 dB rel 2 x 10^{-5} Pa on transition to and from the signalling mode) for method of measurement see appendix 3.

A.1.8 Acoustic Shock Protection Measurement

The signal level shall be set up as described in subclause A.1.3 except that the level shall be +24 dBV.

APPENDIX 3: ‘Click’ Measurement

In order to measure the level of clicks produced by the earphone during signalling, register recall etc, the following equipment shall be used.

Bruel and Kjaer Type UA0318 artificial ear coupler fitted with Type 4134 microphone. Bruel and Kjaer Measuring amplifier Type 2606 or 2607. The earphone shall be sealed to the artificial ear and the measuring amplifier settings shall be:

- Filter and weighting buttons - all out;
- Meter function - Peak Hold (2606) or Max Peak (2607).

The peak level of the click can then be measured.

The peak mode is used as it has a 10 µS time constant as opposed to a 35 ms rise time in the Impulse Hold mode, and thus gives a more accurate indication of potential hearing damage.

A.2.10.3 BS 6317 (1982)

Specification for simple telephones for connection to public switched telephone networks run by certain public telecommunication operators

13.9 Acoustic shock

13.9.1 The sound pressure in the artificial ear shall be not greater than +24 dBPa (unweighted, rms).

Compliance is determined by the tests described in clause B.12.

13.9.2 Where the receiver is used as the transducer for a tone caller with the receiver close to the user's ear and with the apparatus off-line (ringing state), it shall not be possible to induce acoustic shock, that is, to fail to meet the requirement of subclause 13.9.1, without either the use of a tool on the apparatus m the assistance of another person.

Compliance is determined *by* inspection and, in addition, where it is possible to set the apparatus to the off-line ringing state without either the use of a tool or the assistance of another person when the receiver is close to the user's ear, compliance is determined by the tests described in clause **B.12**, with the ringing derived from the circuit described in clause **B.15**.

B.12 Acoustic shock tests

B.12.1 Electrical stimulus

The apparatus is connected to the circuit shown in figure 16.

A signal generator with a non-reactive source impedance of 600 Ω is connected to terminals A and B in figure 16.

A current of 40 mA is applied.

The generator is set to deliver sinusoidal signals at an e.m.f. of 24 dBV rms at frequencies from 200 Hz to 10 kHz in l/3 octave intervals as specified in BS 3593, 1963.

For each frequency, the sound pressure in the artificial ear is measured.

B.12.2 Acoustic stimulus

The apparatus is connected to the circuit shown in figure17.

A low impedance source with an e.m.f. of 60 V is connected to terminals C and D in figure 17.

Sinusoidal signals are applied to the mouth reference point at a sound pressure level of 20 dBPa at frequencies from 1 kHz to 4 kHz in 1/3 octave intervals as specified in BS 3593, 1963.

For resistance loads of 25 Ω and 1 MΩ applied across terminals A and B in figure 17, and for each frequency, the sound pressure in the artificial car is measured.

B.15 Test for restriction of ringing signals in the receiver

The apparatus is connected to the circuit shown in figure 18 with a line length of 0 km, For an apparatus marked with a REN of 4, S1 is left open; for apparatus marked with a REN other than 4, S1 is closed. The earcap of the apparatus is sealed to the knife-edge of the artificial ear. The sound pressure in the artificial ear is measured.

A.2.10.4 BS 6833: Part 2 (1982)

Apparatus using cordless attachments (excluding cellular apparatus) for connection to analogue interfaces of public switched telephone networks: Part. 2: Specification for cordless telephone apparatus using radio links

8.3 Acoustic shock

NOTE: These acoustic shock limits should be applied to all audible function indications that are produced by transducers within the CPP.

8.3.1 Maximum sound pressure level at earpiece

If audible incoming call indication is provided anywhere on the CPP, the sound pressure level through the earpiece shall not exceed 24 dBPa.

Compliance shall be checked by inspection but if, when the receiver is close to the user's ear, it is possible to set the apparatus to the off-line audited incoming call indication state without either the use of a tool or the assistance of another person, compliance shall be checked, in addition, by the test described in clause B.9 with the audible incoming call indication derived from the circuit described in clause B.12.

NOTE: It is recommended that the initial sound pressure level should not exceed 0 dBPa and that the subsequent graduation of level should comply with subclause 8.3.3.

8.3.2 Maximum initial sound pressure level

If audible incoming call indication is provided on the CPP and is generated other than through the earpiece, the sound pressure level at the commencement of any sequence of such indication shall not exceed 50 dB(A) measured, under free-field conditions, at a distance of 1 m. Any subsequent increase in the sound pressure level shall comply with 8.3.3 subject to the constraint in subclause 8.3.1.

Compliance shall be checked by inspection and by the tests described in clause B.15 and figure 18.

8.3.3 Graduation from initial indication level

8.3.3.1 Repetitive cycles of audible indication

If the audible indication is cadenced in repetitive cycles (each of which includes periods during which the audible output falls below the maximum permitted initial level, e.g. to simulate PSTN ringing tones) the sound pressure level shall be permitted to increase in accordance with the following criteria:

(a) For repetitive cycles with periods greater than 2 s and duty cycles greater than 20 %, the maximum level attained during any one cycle shall not exceed the maximum level attained during the previous cycle by more than 10 dB.

(b) For repetitive cycles with periods greater than 2 s and duty cycles less than or equal to 20 %, the maximum level attained during any one cycle shall not exceed the maximum level attained during the previous cycle by more than 6 dB.

(c) For repetitive cycles with periods less than or equal to 2 s, the average rate of increase shall not exceed 6 dB/s.

8.3.3.2 Non-repetitive audible indication

During a non-repetitive indication sequence, the sound pressure level shall be permitted to increase but the total increase in any 1 s shall not exceed 6 dB.

8.3.3.3 Termination of audible indication sequence

If the audible output is above the maximum initial sound pressure level, an existing audible indication sequence shall be terminated and the requirements for maximum initial sound pressure level shall be re-applied when:

- the sound pressure level falls below the initially permitted level for a continuous period of greater than 8 s; or
- the CPP enters, is in, or is released from an operational state in which it could be required to be used subsequently with the earpiece closely coupled to the user's ear.

8.4.2 Acoustic shock

The indication shall comply with subclause 8.3.

NOTE: It is recommended that for audible incoming call indication during intercommunication the maximum level in subclause 8.3.1 be 0 dBPa.

8.4.3 Audibility

If audible incoming call indication is provided through the earpiece then it shall not be below 74 dB(A).

Compliance shall be checked by the tests described in clause B.12.

If audible incoming call indication is provided elsewhere on the CPP then the SPL shall not be below 30 dB(A) at 1 m free field in any direction. Compliance shall be checked by the tests described in clause B.15 and figure 18.

B.9 Acoustic shock tests

B.9.1 Electrical stimulus

The apparatus is connected to the circuit shown in figure 16.

A signal generator with a non-reactive source impedance of 600 Ω is connected to terminals A and B in figure 18.

A current of 40 mA is applied.

The generator is set to deliver sinusoidal signals at an e.m.f. of 24 dBV rms at frequencies from 200 Hz to 10 kHz in one-third octave intervals as specified in BS 9593, 1963.

For each frequency, the sound pressure in the artificial ear is measured.

B.9.2 Acoustic Stimulus

The apparatus is connected to the circuit shown in figure 17.

A low impedance source with an e.m.f, of 50 V is connected to terminals C and Din figure 17.

Sinusoidal signals are applied to the mouth reference point at a sound pressure level of 20 dBPa at frequencies from 1 kHz to 4 kHz in one-third octave intervals as specified in BS 3599, 1963.

For resistance loads of 25 Ω and 1 MΩ applied across terminals A and Bin figure 17, and for each frequency, the sound pressure in the artificial ear is measured.

B.12 Test for restriction of audible incoming call indication in the receiver

The apparatus is connected to the circuit shown in figure l8 with a line length of 0 km. The earcap of the apparatus is sealed to the knife-edge of the artificial ear. The sound pressure in the artificial ear is measured.

B.15 Test for the determination of audible incoming call indication at 1 m

B.15.1 Positioning of handset

Place the handset on a horizontal table surface as shown in figure 21. It will be seen that there are a mutually orthogonal set of axes *xx*, *yy* and *zz*:

(a) Axis *xx* is horizontal and along the long axis of the handset.

(b) Axis *yy* is perpendicular to the table surface, passing through the intersection of *xx*, *zz*.

For each of the handset axes identified, mount the handset with an axis vertical, taking care that the mounting does not obstruct the egress of sound from the tone caller transducer.

With the ringing signal applied to the line terminals of the cordless telephone, using the circuit shown in figure 18, and when the tone caller has achieved its maximum level, rotate the handset about each of the axes in turn and measure the maximum A-weighted sound pressure level at 1 m horizontally from the rotational axis of the handset. Note the positions at which the maximum sound pressure level is achieved during rotation about each axis.

By reference to the positions of maximum output determined during rotation around each axis, and by subsequent simultaneous rotation about all thee axes, position the handset to produce the maximum sound pressure level along the axis between the handset and the measuring microphone.

B.15.2 Measurement of sound level graduation

Cease application of the ringing current to the line interface and switch the CTA from the off-line to the on-line condition and then from the on-line to the off-line condition. Re-apply the ringing current with a cadence of 0,4 s on, 0,2 s off, 0,4 s cm, 2 s off and measure, as a function of time, the A-weighted sound pressure level at a distance of 1 m by means of a chart recorder or storage oscilloscope connected to a suitable output signal port of the measuring amplifier or detector of the sound level measuring equipment.

Determine the rate of increase by the application of graphical techniques to the measured variation of sound pressure level with time.

B.15.3 Tests with other ringing current cadences

Repeat the test described in subclause B.15.2 with the following modulation patterns applied to the ringing current:

(a) a cadence of 1 s on, 2 s off;

(b) no modulation (i.e. continuous a.c. ringing current).

B.15.4 Tests to measure time of audible output interruption required to cause re-initiation of level graduation

Repeat the teat of subclause **B.15.2** but with the ringing current cadence interrupted at 40 s intervals for a period that is Increased in 1 s increments from 3 s until audible output from the handset tone caller ceases for a period of at least 8 s.

On subsequent m-application of the cadenced ringing current, measure the initial sound pressure level and the subsequent increase in level as described in subclause **B.15.2**.

A.3 American specifications

A.3.1 EIA-470-A

Telephone Instruments with Loop Signalling (July 1987)

4.1.6 Peak Acoustic Pressure

4.1.6.1 Definition

The peak acoustic pressure is the maximum sound pressure from a telephone receiver impressed on an artificial ear, due to a short high-amplitude electrical pulse applied to the tip and ring terminals of the telephone.

4.1.6.2 Method of Measurement

The peak acoustic pressure shall be determined by applying between the tip and ring terminals a voltage surge (one of each polarity) of 800 V peak, having a 10 µs maximum rise time to crest and a 560 µs minimum decay time to half crest, measuring the peak acoustic pressure developed in the artificial ear. The test configuration shown in figure 3C of IEEE Standard 269-1983 may be used.

The received acoustic pressure shall be measured in accordance with subclause 4.1.2, except that the sound pressure within the artificial ear shall be measured with a sound level meter having an unweighted "peak hold" mode setting.

NOTE: Standardized ANSI and IEC impulse sound level meters have specified time constants built in to them. If the tests are performed using the "impulse hold" mode of these standardized instruments, the wrong results will be obtained.

4.1.6.3 Standard

The peak acoustic pressure measured in the artificial ear shall not exceed 130 dB SPL (36 dBPa). This requirement is to minimize annoyance to the user.

The specified level is higher than desirable. Several subjective studies have shown that customer annoyance when experiencing loud clicks is directly related to the peak level of the clicks.

Thus, it is extremely important to set the peak pressure as low as possible, but not so low as to interfere with the peaks of normal speech signals.

Safety standards for peak and steady state acoustic pressure are currently under development in UL 1459 [67].

A.3.2 TIA/EIA-470-B

Telecommunications Telephone Terminal Equipment (1995)

Extracts from a draft No T510.95.

In the Scope, clause 1 it is stated:

1.3.2 User Safety

This standard does not include requirements for user safety. The applicable Standards for user safety of telecommunications terminal equipment can be found in the *Canadian Electrical Code, Parts I* and *II*, and UL Standard 1459, *Standard for Telephone Equipment*.

4.2.2.6 Receive Acoustic Limiting

4.2.2.6.1 Peak Acoustic Pressure

4.2.2.6.1.1 Requirement

The peak acoustic pressure measured in the artificial ear shall not exceed 130 dB SPL (36 dBPa). This requirement is to minimize annoyance to the user. This is not a safety requirement.

NOTE: The specified level is higher than desirable. Several subjective studies have shown that customer annoyance when experiencing loud clicks is directly related to the peak level of the clicks. Thus, it is extremely important to set the peak pressure level as low as possible, but not so low as to interfere with the peaks of normal speech signals.

4.2.2.6.1.2 Method of Measurement

The peak acoustic pressure shall be determined as follows:

(a) If the telephone set has adjustable receive gain, it shall be set to provide the maximum output level.

(b) A voltage surge (one of each polarity) of 1 000 V peak having a 10 μs maximum rise time to crest and a 1 000 μs minimum decay time to half crest shall be applied between the telecommunication network connection points of a voice telephone terminal. The test configuration shown in figure 11 shall be used.

(c) Calibrate the artificial ear with the oscilloscope to establish a relationship between acoustic pressure and deflection. Set the power supply voltage to 48 V dc and adjust R1 and R2 to give a current of 20 mA dc. With switch S2 in position 2, operate the surge generator and record the oscilloscope peak deflection. With switch S2 in position 3, operate the surge generator and record the oscilloscope peak deflection.

4.2.2.6.2 Continuous Sound Pressure Level

4.2.2.6.2.1 Requirement

In the off-hook mode, rms acoustic pressure shall not exceed 125 dB(A).

4.2.2.6.2.2 Method of Measurement

The following steps shall be taken:

(a) Set up the test equipment as shown in figure 12. Set the sound level amplifier to provide "A" weighting and "slow" response. With the telephone set off-hook, adjust resistors R3 and R4 to give a loop current of 30 mA. Set the frequency generator to give an output of 4.0 V rms into an open circuit at a frequency of 1 000 Hz.

(b) If the telephone set has adjustable receive gain, it shall be set to provide the maximum output level.

Sweep the generator frequency from 180 Hz to 10 kHz at a rate not greater than 1 octave/s. Record the maximum acoustic output reading during the frequency sweep.

A.3.3 TIA/EIA-IS-810

Telecommunications Terminal Equipment. Transmission requirements for Narrowband Voice over IP and Voice over PCM Digital Wireline Telephones

5.8 Long Duration Acoustic Pressure

5.8.1 General

The long duration acoustic pressure is the maximum, long duration sound pressure disturbance, greater than 500 ms, emitted from a telephone receiver, caused by the maximum excursions of the receive digital signal.

Additional consideration should be given to the acoustic pressure caused by tones, other audio signals or long duration, high amplitude electrical signals applied to power, network, or auxiliary leads of the digital telephone.

5.8.2 Measurement Method

The steady-state A-weighted sound pressure level shall be measured using the digital terminals test procedure in ITU-T Recommendation P.360 [39], with the following modifications.

Apply a digital square wave to the receive input, switched between the maximum positive and the maximum negative values, defined in ITU-T Recommendation G.711. The switching rate shall range from 1 Hz to 4 000 Hz over a sweep time of not less than 30 seconds. The measurement shall be made with an rms detector set to 1-second effective averaging time (rms Slow).

Telephone sets with adjustable receive levels shall be adjusted to the maximum setting.

5.8.3 Requirements

The requirements are currently under study.

5.9 Short Duration Acoustic Pressure

5.9.1 General

The short duration acoustic pressure is the maximum short duration, sound pressure impulse, less than 500 ms, from a telephone receiver, caused by the maximum excursions of the receive digital signal.

Additional consideration should be given to the peak acoustic pressure caused by tones or short duration, high amplitude electrical pulses applied to power, network, or auxiliary leads of the digital telephone.

5.9.2 Measurement Method

The peak acoustic pressure level shall be measured using the digital terminals test procedure in ITU-T Recommendation P.360 [39], with the following modifications instead of applying electrical impulses to the send and receive pairs. The short duration acoustic pressure shall be determined by applying digital codes to the receive input. The codes shall be switched between the maximum positive and the maximum negative values, defined in ITU-T Recommendation G.711. The switching rate shall range from 2 Hz to 4 000 Hz. The duration of the ON codes shall be a number of complete cycles approximating but not exceeding 500 ms. The ON codes must be followed by a quiet interval of at least 500 ms before repeating the codes, as shown in figure 9.

Telephone sets with adjustable receive levels shall be adjusted to the maximum setting.

5.9.3 Requirements

The requirements are currently under study.

A.3.4 UL 1459

Telephone Equipment, Third Edition September 21 1995

66 Acoustic Pressure Test

66.1 General

66.1.1 In any operating state, during reasonable operation of the unit, the maximum acoustic pressure emanating from a receiver earpiece of a telephone or similar device shall not exceed 125 dB(A) (relative to 20 micro-Pascals) for supra-aural (on-ear) handsets, 121 dB(A) for insert type (in ear) earphones, or 118 dB(A) for supra-aural headphones. The unit shall be tested in accordance with subclauses 66.1.2 – 66.3.4. Handsets, earphones, and headphones should be tested with the equipment they are intended to be used with, or equivalent equipment. Typical signals that should be considered are alerting and paging signals (on-hook operating state), DTMF-tone (Dual Tone Multi Frequency tone) and other signals generated within the device, and network signals that can cause high acoustic pressure output (off-hook operating state).

66.1.2 The maximum acoustic pressure at the earpiece is still limited to the values in subclause 66.1.1 if the source of acoustic pressure is separated from the receiver earpiece.

66.2 Off-hook testing

66.2.1 While in an off-hook operating state, the unit shall be tested using any signals that can be generated within the device and also with the simulated network signals specified in subclause 66.2.2. For equipment intended to be used with specialized PBX or Key systems and the like, signals that can be generated by the system should also be considered.

66.2.2 An audio signal, generated from an audio oscillator with 600 Ω source impedance, is to be superimposed on a DC current of 20 mA and applied between the tip and ring terminals of the telephone. With an audio signal voltage of about 1/2 volt open circuit, the oscillator is to be swept from 100 to 10 000 Hz at a rate not exceeding 1/3 octave per second (about a 30 second sweep) to determine the maximum acoustic pressure at the test voltage. The audio signal voltage is then adjusted to give the maximum acoustic pressure, but not greater that 12 V open circuit, at the frequency where the 1/2 volt open-circuit sweep obtained the maximum measured acoustic pressure. For equipment not intended to be directly connected to the telecommunication network, such as equipment used with specialized PBX or Key systems and the like, the simulated network signals shall be applied between the tip and ring terminals of the system. Where the maximum output signal characteristics of a system are known, different simulated signals may be used to test the unit for maximum acoustic pressure.

66.3 On-hook testing

66.3.1 While in an on-hook operating-state, the unit shall be tested using any signals that can be generated by the device (i.e. paging and the like) and also with the telephone ringing. For units intended to be directly connected to the telecommunication network, or similar systems, ringing shall be simulated using the signal specified in subclause 66.3.2. For equipment intended to be used with specialized PBX and Key systems and the like, ringing signals generated by the system shall be used.

66.3.2 A signal generator with 400 Ω source impedance is to be set to 90-105 V open circuit, at a test frequency of 20 Hz sinusoidal. This frequency is acceptable for most equipment, but some telephones intended primarily for party line service may require a different frequency setting. The AC signal is to be superimposed on a DC voltage of 48 V and applied between the tip and ring terminals of the telephone. Testing is to be conducted for 30 seconds.

66.3.3 Response for handsets and headsets is to be measured using an IEC coupler for supra-aural earphones as indicated in the Method for Coupler Calibration of Earphones, ANSI S3.7-1973 (R 1986), with a type M microphone as indicated in Specifications for Laboratory Standard Microphones, ANSI S1, 12-1967 (R 1986). Normal headband pressure shall be used for headsets. An acoustic seal is to be made between the telephone and the measuring device, or the best possible seal that can be obtained. Acoustic holes that fall outside the knife-edge of the coupler are also to be sealed. The sound pressure within the coupler is measured with a sound level meter set to use an A-weighted slow response.

66.3.4 Response for insert type earphones is to be measured with an in-ear coupler as indicated in the American National Standard for Occluded Ear Simulator, ANSI S3.25, extended by an ear canal simulator consisting of a cylinder 8 mm long and 7.5 mm in diameter. The tip of the earphone is inserted until tangent with plane X - X' shown in figure 1 of ANSI S3.25, The sound pressure within the coupler is measured with a sound level meter set to use an A-weighted slow response.

67 Peak Acoustic Pressure Test

67.1 The peak acoustic pressure emanating from the receiver earpiece shall not exceed 140 dB (relative to 20 micro-Pascals) with the unit in any operating state, or with a voltage surge of 800 V peak open circuit (either polarity), having a 10 microsecond rise time to crest and a minimum decay time to half crest of 560 microseconds, and a minimum current of 10 A peak (short circuit), and applied between the tip and ring terminals of the unit. For equipment not intended to be directly connected to the telecommunication network, such as equipment used with specialized PBX or Key systems and the like, the voltage surge is to be applied between the tip and ring terminals of the system. Response is to be measured using the appropriate coupler as specified in subclauses 66.3.3 and 66.3.4. The sound pressure within the coupler is measured with a sound level meter set to use an unweighted "peak hold" response. "Peak hold" is defined as an acoustic response having a duration less than 50 microseconds.

A.3.5 CSA/UL 60950

Safety of Information Technology equipment, including Electrical Business equipment (Draft June 1999)

6.5 Acoustic tests

The compliance tests described in this subclause require simulation of the TELECOMMUNICATION NETWORK to perform the following functions:

- generation of test signals that produce acoustic output at the telephone receiver;
- generation of ringing signals that activate the alerting device of the telephone; and
- provision of d.c. power superimposed on the above signals.

Examples of simulators are given that are representative of many analogue TELECOMMUNICATION NETWORKS. *The simulator may consist of discrete components or proprietary equipment, with appropriate analogue or digital interfaces for two or four wires.*

6.5.1 Acoustic pressure limiting

These requirements apply to equipment intended to be connected directly or indirectly to a TELECOMMUNICATION NETWORK containing an earphone, which is held against or in the ear.

The effect on human hearing of impulsive noise or of disturbances, which are less than 0,5 s duration is evaluated under subclause 6.4.3.2. The effect of longer disturbances, such as those which might be produced during tone-type dialling, is evaluated under subclause 6.4.3.3.

For equipment not intended to be connected to a PSTN (such as connected behind a PABX or connected to a digital TELECOMMUNICATION NETWORK), it is permitted to apply a test voltage to the equipment under test that simulates the effect of the PABX interface or the digital TELECOMMUNICATION NETWORK interface between the equipment under test and the PSTN.

These tests are suitable only for closed-type supra aural and supra-concha earphones, which are physically compatible with the IEC Publication 60318 coupler.

NOTE 1: Measurement methods for handsets or headsets not covered by this requirement are under consideration by the ITU-T (formerly CCITT) in CCITT Draft Recommendation P.57 [30]. Terminology for earphones is as defined in ITU-T Recommendation P.57 [30].

NOTE 2: These requirements are based on CCITT Recommendation P.36 [28], which assumes a 2 s exposure for long duration disturbances and no more than one incident per day. Authorities may deem it appropriate to use lower limits for specific cases, for instance for the headsets used by operators.

NOTE 3: A PABX or digital TELECOMMUNICATION NETWORK termination may block network voltages, in which case no test voltage is applied. However, signals that can be generated by the system should be considered.

6.5.2 Short duration impulses

The peak acoustic pressure measured at the earpiece of the telephone handset or headset shall be limited to reduce the risk of permanent hearing damage due to short duration impulses (≤ 0,5 s) that may occur under normal operation.

Compliance is checked by the following tests. The handset or headset is placed under normal operating conditions in position for the exchange of calls (such as talking state with the handset raised), and fixed to an artificial ear conforming to the requirements of IEC Publication 60318. The earpiece is sealed to the knife-edge of the artificial ear. Holes in the earpiece, which partially fall outside the knife-edge of the artificial ear, are sealed. Response for insert type earphones is to be measured with an in-ear coupler as indicated in the American National Standard for Occluded Ear Simulator, ANSI S3.25, extended by an ear canal simulator consisting of a cylinder 8 mm long and 7,5 mm in diameter. The tip of the earphone is inserted until tangent with plane X-X' shown in figure 1 of ANSI S3.25. The artificial ear is electrically connected to a precision sound level meter conforming with IEC Publication 60651, with an unweighted peak-hold response and capable of measuring impulses having a duration less than 50 µs.

The equipment under test is connected to a network simulator and impulse generator as shown in figure 6D, by closing switches A and B. An equivalent network simulator may be used.

One positive and one negative polarity impulse is applied to the equipment under test with U_c = 1 kV. For analogue equipment, the impulses are applied to the receive circuit. For digital equipment, the impulses are applied to both the transmit and receive circuits. In addition, the equipment is checked for self-generated acoustic impulses such as those produced by operation of the hook switch or by dialling.

During the above tests, the peak acoustic pressure level measured in the artificial ear or coupler shall not exceed 136 dB (relative to 20 µPa).

6.5.3 Long duration disturbances

The maximum steady-state A-weighted sound pressure measured at the earpiece of the telephone handset or headset shall be limited to reduce the risk of permanent hearing damage due to long duration disturbances (> 0,5 s) that may occur under normal operation.

NOTE 1: Typical signals considered are alerting (ringing) signals during the on-hook operating condition; and tone-type dialling, network signals and other similar signals generated within the device, which can cause excessive acoustic output during the off-hook operating condition.

Compliance is checked by the following tests. The handset or headset is placed under normal operating conditions in position for the exchange of calls (such as talking state or ringing state with the handset raised) and fixed to an artificial ear conforming to the requirements of IEC Publication 60318. The earpiece is sealed to the knife-edge of the artificial ear.

Holes in the earpiece, which partially fall outside the knife-edge of the artificial ear, are sealed. Response for insert type earphones is to be measured with an in-ear coupler as indicated in the American National Standard for Occluded Ear Simulator, ANSI S3.25, extended by an ear canal simulator consisting of a cylinder 8 mm long and 7,5 mm in diameter. The tip of the earphone is inserted until tangent with plane X-X' shown in figure 1 of ANSI S3.25. The artificial ear is electrically connected to a precision sound level meter conforming to IEC Publication 60651, with A-weighted slow response.

An off-hook signal source as described below is applied to the receive circuit of the equipment under test. The amplitude and frequency is adjusted to produce the maximum acoustic output from the earpiece.

An on-hook signal source as described below is applied to the receive circuit of the equipment under test that contains an alerting device in the handset. The ringing frequency is adjusted to produce the maximum acoustic output from the earpiece.

NOTE 2: Ringers that port their output through holes in a handset can produce excessive acoustic output.

Measurement techniques for this case are under study.

Off-hook signal source

The equipment under test is connected to a network simulator and test tone generator as shown in figure 6D, by closing switches A and D. An equivalent network simulator may be used.

The analogue signal generator in the simulator circuit produces a sine-wave signal. For the equipment under test with a digital interface, a digital sequence representing minimum to maximum transition square wave at frequencies between 300 Hz and 5 000 Hz may be used.

On-hook signal source

The equipment under test is connected to a network simulator and ringing generator as shown in figure 6D, by closing switches A and C. An equivalent network simulator may be used. A signal generator in the simulator circuit produces a sine-wave signal. For equipment under test with a digital interface, a digital sequence, which will activate the alerting device at its maximum acoustic output, may be used.

In addition, the equipment is checked for self-generated acoustic disturbances, such as tone dialling signals fed back to the receiver and paging signals sent to a cordless handset.

During the above tests, the maximum steady-state A-weighted sound pressure coming from the earphones shall not exceed 125 dBA for handsets, 118 dB(A) for headsets, and 121 dB(A) for insert earphones.

A.4 Specifications from other Countries

A.4.1 Hong Kong

Technical Guide Number 2 Hong Kong Telephone Company (Feb 1984) [109].

Appendix 2 Supplementary requirements for cordless telephones

5 If audible incoming call indication is provided anywhere on the handportable unit, the sound pressure through the earpiece shall not exceed 24 dBPa.

A.4.2 Papua New Guinea

Tender PTC-508 [103] (Nov 1990).

4.1.8 Click suppression

The instrument shall be fitted with Click Suppression to prevent the feedback of signalling transients to the earpiece, which could cause damage to the user.

A.4.3 Nepal

Nepal Telecommunication Corporation - Technical Specification of Telephone Instruments (March 1988) [110].

5.5 A click suppressor shall be provided as part of the receiver circuit to prevent acoustic shock to the user. The properties of the click suppressor shall conform to the relevant CCITT Recommendations.

Annex B (informative): Informal input on acoustic shock from UK Health and Safety Executive (HSE)

Notes on a conversation with a specialist inspector (26/11/99)

The HSE is currently working on the exposure of call centre operators to noise. The work arises from a Royal National Institute for the Deaf (RNID) input to Parliament suggesting that there is a problem. Call centre operators currently 1,5 % of population!

They are using a Kemar manikin connected in parallel with call centre operator to measure length, duration, levels and no of calls to work out 8 hr daily exposure.

Current levels found to be 75-80 dB so no real problem.

RNID's own call centre had difficulty with operators increasing volume on quiet calls and then leaving at the same level for loud calls. They have now arranged for gain to drop back to normal after each call.

The HSE think Kemar accurate and repeatable. He noted that Plantronics put 118 dB limiters into their headsets.

Further conversation 8/2/00.

No report available yet. Only done three investigations so far. Doing one a month – hoping to do 10. So far no problems - figures in upper 70 s. No reports of transient shocks in spite of direct questioning.

RNID wrote report called "indecent exposure" which started HSE work. Original HSE initial survey on all aspects of call centres, put noise well down list of problems below stress, and using VDUs. Two sites using Plantronics headsets with built-in limiters, one with GM Netcom headsets.

Bibliography

The following material, though not specifically referenced in the body of the present document (or not publicly available), gives supporting information.

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History

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