Non-destructive testing – Characterization and verification of ultrasonic examination equipment

Part 1: Instruments

English version of DIN EN 12668-1

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ICS 19.100

Zerstörungsfreie Prüfung – Charakterisierung und Verifizierung der Ultraschall-Prüfausrüstung – Teil 1: Prüfgeräte

European Standard EN 12668-1 : 2000 has the status of a DIN Standard.

A comma is used as the decimal marker.

National foreword

This standard has been prepared by CEN/TC 138 ‘Non destructive testing’.

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English version

Non-destructive testing – Characterization and verification of ultrasonic examination equipment

Part 1: Instruments

Essais non destructifs – Caractérisation et vérification de l'appareillage de contrôle par ultrasons – Partie 1: Appareils

Zerstörungsfreie Prüfung – Charakterisierung und Verifizierung der Ultraschall-Prüfausrüstung – Teil 1: Prüfgeräte

This European Standard was approved by CEN on 2000-04-13.

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CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

Ref. No. EN 12668-1 : 2000 E

Contents

Foreword

This European Standard has been prepared by Technical Committee CEN/TC 138 "Non-destructive testing", the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by November 2000, and conflicting national standards shall be withdrawn at the latest by November 2000.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

This standard consists of the following parts :

EN 12668-1, Non-destructive testing - Characterization and verification of ultrasonic examination equipment - Part 1 : Instruments

EN 12668-2, Non-destructive testing - Characterization and verification of ultrasonic examination equipment - Part 2 : Probes

EN 12668-3, Non-destructive testing - Characterization and verification of ultrasonic examination equipment - Part 3 : Combined equipment

1 Scope

This standard specifies methods and acceptance criteria for assessing the electrical performance of analogue and digital ultrasonic instruments for pulse operation using A-scan display, employed for manual ultrasonic non-destructive examination with single or twin transducer probes operating within the centre frequency range 0,5 MHz to 15 MHz. Ultrasonic instruments for continuous waves are not included in this standard. This standard may partly be applicable to ultrasonic instruments in automatic systems but then other tests can be needed to ensure satisfactory performance.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 1330-4:2000, *Non-destructive testing - Terminology - Part 4 : Terms used in ultrasonic testing.*

EN 12668-3:2000, *Non-destructive testing - Characterization and verification of ultrasonic examination equipment – Part 3 : Combined equipment.*

EN ISO 9001, *Quality systems - Model for quality assurance in design/development, production, installation and servicing (ISO 9001:1994).*

EN ISO 9002, *Quality systems - Model for quality assurance in production, installation and servicing (ISO 9002:1994).*

3 Definitions

For the purposes of this standard the definitions given in EN 1330-4:2000 apply, together with the following definitions.

3.1
amplifier frequency response
variation of the gain of an amplifier versus frequency

NOTE Usually specified by a plot of gain (normalized to the peak gain value) versus frequency.

3.2
amplifier bandwidth
width of the frequency spectrum between the high and low cut-off frequencies. This standard uses as limits the points at which the gain is 3 dB below the peak value

3.3
cross-talk damping during transmission
defines the amount of energy transfer from the transmitter output to the receiver input during the transmission pulse, with the ultrasonic instrument set for twin probe working (separate transmitter and receiver)

3.4
calibrated dB-switch
device controlling the overall gain of the ultrasonic instrument calibrated in decibels

3.5
dead time after transmitter pulse
time interval following the start of the transmitter pulse during which the amplifier is unable to respond to incoming signals, when using the pulse echo method, because of saturation by the transmitter pulse

3.6
digitisation sampling error
error introduced into the displayed amplitude of an input signal by the periodic nature of measurements taken by an analog to digital converter

3.7
dynamic range
ratio of the amplitude of the largest signal to the smallest signal which a ultrasonic instrument can display. The smallest signal may be limited by noise in the system, the largest by the saturation of the amplifier or by the maximum attenuation which can be introduced to bring a large signal onto the screen

3.8
equivalent input noise
a measure of the electronic noise level observed on the ultrasonic instrument screen, and defined by the input signal level, measured at the receiver input terminals, that would give the same level on the screen if the amplifier itself were noiseless

3.9
external attenuator
a standard attenuator calibrated to a traceable source used to test the ultrasonic instrument

3.10
fall time of proportional output
the time it takes the proportional gate output to fall from 90 % to 10 % of it's peak value

3.11
frequency response of proportional gate output
measure of how the amplitude of the proportional gate output varies with input signal frequency

3.12
hold time of switched outputs
the time for which the switched output from a monitor gate will remain above 50 % of it maximum output following a signal in the monitor gate which is above the threshold

3.13
hold time of proportional output
the time for which the proportional output is above 90 % of it's peak output following a signal in the monitor gate

3.14
linearity of proportional output
measure of how close the voltage output from the proportional gate is to being directly proportional to the input signal amplitude

3.15
linearity of time base
measure of how close the horizontal graticule reading on the ultrasonic instrument screen is to being directly proportional to the time of flight of an echo

3.16
linearity of vertical display
measure of how close the vertical graticule reading of a signal on the ultrasonic instrument screen is to being directly proportional to the input signal amplitude

3.17
mid gain position
ultrasonic instrument gain setting which is half way between the maximum and minimum gains, measured in decibels, e.g. for an ultrasonic instrument with a maximum gain of 100 dB and a minimum gain of 0 dB, the mid gain position would be 50 dB

3.18
monitor gate
a section of the time-base on the A-scan display in which the amplitude is compared to a threshold and/or converted to an analog output

3.19
monitor threshold
the minimum signal amplitude that will operate the monitor gate output

3.20
noise of proportional output
measure of the noise on the proportional output

3.21
proportional output
output from the ultrasonic instrument which gives a d.c. voltage nominally proportional to the amplitude of the largest received signal within a monitor gate

3.22
pulse duration
time interval during which the modulus of the amplitude of a pulse is 10 % or more of it's peak amplitude

3.23
pulse repetition frequency
frequency at which the transmission pulse is triggered

3.24
pulse rise time
time taken for the amplitude of the leading edge of a pulse to rise from 10 % to 90 % of its peak value

3.25
pulse reverberation
a secondary maximum in the transmitter pulse waveform after the intended output

3.26
receiver input impedance
characterisation of the internal impedance of the receiver as a parallel resistance and capacitance

3.27
response time of digital ultrasonic instruments
the time over which a signal has to be detected by a digital ultrasonic instrument before it is displayed at 90 % of it's peak amplitude

3.28
rise time of proportional output
the time interval that it takes the proportional gate output to rise from 10 % to 90 % of it's peak value

3.29
temporal resolution
the minimum time interval over which two pulses are resolved by a drop in amplitude of 6 dB

3.30
time-dependent gain (TDG)
time dependent or swept gain function fitted to some ultrasonic instruments to correct for the distance related reduction in reflected amplitude

3.31
short pulse
unrectified pulse which has fewer than 1,5 cycles in the time interval over which the pulse amplitude exceeds half its maximum peak amplitude

3.32
suppression
preferential rejection of signals near the baseline of the screen, deliberately introduced to remove grass and noise or to steepen the trailing edges of larger echoes

3.33
switching hysteresis
the difference in amplitude between the signal which turns on and turns off a monitor gate

4 Symbols

Table 1 - Symbols

Symbol	Unit	Meaning
A_o, A_n	dB	Attenuator settings used during tests
C_{max}	pF	Parallel capacity of receiver at maximum gain
C_{min}	pF	Parallel capacity of receiver at minimum gain
D_S	dB	Cross-talk damping during transmission
Δf_g	Hz	Frequency bandwidth measured at proportional gate output
f_{go}	Hz	Centre frequency measured at proportional gate output
f_{gu}	Hz	Upper frequency limit at - 3 dB, measured at proportional gate output
f_{gl}	Hz	Lower frequency limit at - 3 dB, measured at proportional gate output
f_{gmax}	Hz	Frequency with the maximum amplitude in the frequency spectrum measured at proportional gate output
f_o	Hz	Centre frequency
f_u	Hz	Upper frequency limit at - 3 dB
f_l	Hz	Lower frequency limit at - 3 dB
f_{max}	Hz	Frequency with the maximum amplitude in the frequency spectrum
Δf	Hz	Frequency bandwidth
I_{max}	A	Amplitude of the maximum current that can be driven by the proportional gate output
N		Number of measurements taken

"continued"

Table 1 - Symbols *(concluded)*

Symbol	Unit	Meaning
n_{in}	$V/\sqrt{Hz}$	Noise per root bandwidth for receiver input
R_l	Ω	Termination resistor
R_{max}	Ω	Input resistance of receiver at maximum gain
R_{min}	Ω	Input resistance of receiver at minimum gain
S	dB	Attenuator setting
ΔT	s	Time increment
t_d	s	Pulse duration
T_{final}	s	Time to the end of distance amplitude curve
T_o	s	Time to the start of distance amplitude curve
t_r	s	Transmitter pulse rise time from an amplitude of 10 % to 90 % of peak amplitude.
t_{A1}, t_{A2}	s	Temporal resolution
V_E	V	Input voltage at the receiver
V_{ein}	V	Receiver input equivalent noise
V_{in}	V	Input voltage
V_l	V	Proportional gate output voltage with load resistor
V_{max}	V	Maximum input voltage of the receiver
V_{min}	V	Minimum input voltage of the receiver
V_o	V	Proportional gate output voltage with no load resistor
V_r	V	Voltage amplitude of the ringing after the transmitter pulse
V_{50}	V	Voltage amplitude of the transmitter pulse with a 50 Ω loading of the transmitter
V_{75}	V	Voltage amplitude of the transmitter pulse with a 75 Ω loading of the transmitter
Z_o	Ω	Output impedance of transmitter
Z_A	Ω	Output impedance of proportional output

5 General requirements for compliance

An ultrasonic instrument complies with this standard if it satisfies the following conditions :

a) the ultrasonic instrument shall comply with clause 7 ;

b) either a declaration of conformity, issued by an organisation certified in accordance with EN ISO 9001 or EN ISO 9002 ; or a certificate issued by an organisation accredited according to the EN 45000-series ; or a test report issued by an organisation performing in house calibration ;

c) the ultrasonic instrument is clearly marked to identify the manufacturer, type and series, and carries a unique serial number marked on both the chassis and the case ;

d) there is available a users instruction manual for the particular type and series of the ultrasonic instrument ;

e) there is available a manufacturer's technical specification for the appropriate type and series of ultrasonic instrument which defines the performance criteria in accordance with clause 6.

NOTE This specification can form part of the ultrasonic instrument instruction manual or can be separate from it, but it shall state the type and series of the ultrasonic instrument to which it applies. The manufacturer's technical specification does not in itself constitute the certificate of measured values required in b).

6 Manufacturer's technical specification for ultrasonic instruments

6.1 General

The manufacturer's technical specification for a particular model of ultrasonic instrument shall contain, as a minimum, the information listed in 6.2 to 6.5. Values obtained from the tests described in clause 7 shall be quoted as nominal values, with tolerances given as indicated.

6.2 General attributes

The following shall be detailed :

a) size ;

b) weight (at an operational stage) ;

c) type(s) of power supply ;

d) type(s) of probe sockets ;

e) battery operational time (as new, at maximum power consumption) ;

f) temperature and voltage (mains and/or battery) ranges, in which operation complies with the technical specification. If a warm-up period is necessary, the duration of this shall be stated ;

g) form of indication given when a low battery voltage takes the ultrasonic instrument performance outside of specification ;

h) the percentage change in amplitude and time base position of a nominally constant signal over the battery voltage range during it's normal discharge and recharge cycle ;

i) pulse repetition frequencies (PRFs) (switched positions and/or variable ranges) ;

j) unrectified (i.e. radio frequency, RF) and/or rectified signal output available via socket ;

k) signal monitor outputs provided, i.e., go/no-go and/or proportional and, where applicable, output response time, linearity, maximum current drive capability and stability of proportional output(s). The hysteresis and accuracy of the threshold of any go/no-go gate together with the hold time of any switched output.

6.3 Display

The following shall be detailed :

a) dimensions of display graticule area ;

b) number of major and minor subdivisions in vertical and horizontal directions ;

c) if any form of suppression, not controllable by the operator, is built into the equipment ;

d) time-base velocity and delay ranges, and linearity of time base.

6.4 Transmitter

The following shall be detailed :

a) shape of transmitter pulse (i.e. square wave, uni-directional or bi-directional) and, where applicable, polarity ;

b) at each pulse energy setting and pulse repetition frequency, with the output loaded with a 50 Ω non-reactive resistor :

   1) transmitter pulse voltage (peak-to-peak) ;

   2) pulse rise time ;

   3) pulse duration (for square wave the range over which the pulse duration can be set) ;

   4) effective output impedance (with tolerance) ;

   5) pulse fall time (for square wave only) ;

   6) pulse reverberation amplitude ;

   7) frequency spectrum plot.

6.5 Amplifier and attenuator

The following shall be detailed :

a) characteristics of calibrated attenuator (sometimes called "gain control"), i.e. dB range, step-size, accuracy ;

b) characteristics of any uncalibrated variable gain, i.e. decibel range ;

c) vertical linearity measured with respect to the screen graticule ;

d) centre frequency and bandwidth (between -3 dB points) of each band setting (give tolerances). The effect (if any) of the attenuator setting ;

e) dead time after transmitter pulse, including the effects of pulse energy, damping, attenuator/gain control and frequency band setting ;

f) input equivalent noise (microvolts) at all frequency settings.

g) minimum input voltage for 10 % screen height over all specified frequency ranges.

h) dynamic range of the ultrasonic instrument over all the specified frequency ranges ;

i) equivalent input impedance of the ultrasonic instrument over all the specified frequency ranges ;

j) details of any distance amplitude correction (DAC) function including the dynamic range, the maximum correction slope (in decibels per microsecond), the form of the correction and the influence of any DAC controls.

For instruments with logarithmic amplifiers, see annex A.

6.6 Digital ultrasonic instruments

In addition to the information given above in 6.1 to 6.4 details should be supplied on the principles of :

a) the analog to digital conversion ;

b) the number of pixels used to display the A-scan ;

c) the data output and storage facilities ;

d) the printer output ;

e) the calibration storage facilities ;

f) the display and recall facilities ;

g) the automatic calibration ;

h) the type of display and its response time.

Where applicable, these details should also include sampling rates used, effect of pulse repetition frequency or display range on the sampling rate and response time. In addition, the principles of any algorithm used to process data for display should be described and the version of any software installed shall be quoted.

7 Performance requirements for ultrasonic instruments

To meet the performance requirements of this standard an ultrasonic instrument shall be verified using the two groups of tests described below :

Group 1 : tests to be performed by the manufacturer (or his agent) on a representative sample of the ultrasonic instruments produced. A high level of electronic measuring equipment is required for these tests ;

Group 2 : tests to be performed on every ultrasonic instrument :

1) by the manufacturer, or his agent, prior to the supply of the ultrasonic instrument (zero point test) ;

2) by the manufacturer, the owner, or a laboratory, at twelve months intervals to verify the performance of the ultrasonic instrument during its lifetime ;

3) following the repair of the ultrasonic instrument.

Only basic electronic measurement equipment is required for the tests in group 2.

By agreement between the parties involved these tests may be supplemented with additional tests from group 1.

A third group of tests for the complete system (ultrasonic instrument and probe combined) are given in EN 12668-3:2000. During their lifetime these are performed at regular intervals on site. Table 2 summarises the tests performed on ultrasonic instruments.

For ultrasonic instruments marketed before the introduction of this standard, continuing fitness for purpose shall be demonstrated by performing the group 2 (periodic) tests every twelve months.

Following repair, all parameters which may have been influenced by the repair shall be checked using the appropriate group 1 or group 2 tests.

Manufacturer's tests are group 1 tests together with group 2 tests.

Zero point periodic tests and repair tests are group 2 tests.

Table 2 - List of tests for ultrasonic instruments

Title of test	Part 1 : Ultrasonic instruments		Part 3 : Combined equipment
	Manufacturer's tests	Periodic and repair tests	
	Subclause	Subclause	Subclause
Physical state and external aspects	9.2	9.2	3.4.2
Stability			
Stability against temperature	8.2		
Stability after warm up time	9.3.2	9.3.2	
Display jitter	9.3.3	9.3.3	
Stability against voltage variation	9.3.4	9.3.4	
Transmitter pulse			
Pulse repetition frequency	8.3.2		
Effective output impedance	8.3.3		
Transmitter pulse frequency spectrum	8.3.4		
Transmitter voltage, rise time, reverberation and duration	9.4.2	9.4.2	
Receiver			
Cross talk damping from transmitter to receiver during transmission	8.4.2		
Dead time after transmitter pulse	8.4.3		
Dynamic range	8.4.4		
Receiver input impedance	8.4.5		
Distance amplitude correction	8.4.6		
Temporal resolution	8.4.7		
Amplifier frequency response	9.5.2	9.5.2	
Equivalent input noise	9.5.3	9.5.3	
Sensitivity and signal to noise ratio			3.4.3
Accuracy of calibrated attenuator	9.5.4	9.5.4	3.2.2

"continued"

Table 2 - List of tests for ultrasonic instruments *(concluded)*

Title of test	Part 1 : Ultrasonic instruments		Part 3 : Combined equipment
	Manufacturer's tests	Periodic and repair tests	
	Subclause	Subclause	Subclause
Linearity of vertical display	9.5.5	9.5.5	3.2.2
Linearity of equipment gain			3.2.2
Linearity of timebase	9.6	9.6	3.2.1
Monitor gate			
Response threshold and switching hysteresis with a fixed monitor threshold	8.5.2		
Switching hysteresis with adjustable monitor threshold	8.5.3		
Hold time of switched output	8.5.4		
Proportional output			
Impedance of proportional gate output	8.6.1		
Linearity of proportional gate output	8.6.2		
Frequency response of proportional gate output	8.6.3		
Noise on proportional gate output	8.6.4		
Influence of the measurement signal position within the gate	8.6.5		
Effect of pulse shape on the proportional gate output	8.6.6		
Rise, fall and hold time of proportional gate output	8.6.7		
Additional tests for digital ultrasonic instruments			
Linearity of time-base for digital ultrasonic instruments	8.7.2	8.7.2	3.2.1
Digitisation sampling error	8.7.3		
Response time of Digital ultrasonic instruments	8.7.4		

8 Group 1 tests

8.1 Equipment required for Group 1 tests

The items of equipment essential to perform group 1 tests on ultrasonic instruments are as follows :

a) either :

1) oscilloscope with a minimum bandwidth of 100 MHz and a spectrum analyser with a 40 MHz bandwidth at least, or

2) digital oscilloscope with a minimum bandwidth of 100 MHz and the capability to calculate Fast Fourier Transforms ;

b) 50 Ω and 75 Ω ± 1 % non-reactive resistors ;

c) standard 50 Ω attenuator with 1 dB steps and a total range of 100 dB. The attenuator shall have a cumulative error of less than 0,3 dB in any 10 dB span for signals with a frequency up to 15 MHz ;

d) either :

1) an arbitrary waveform generator, or

2) two pulsed signal generators, with external triggers or gates, capable of producing two gated bursts of sinusoidal radio frequency signals. The amplitudes of the two signals shall be independently variable by up to 20 dB ;

NOTE If two pulsed signal generators are used then suitable matching circuits will have to be used to combine the output of the two generators into one test signal.

e) a protection circuit. An example is shown in figure 1 ;

f) digital counter timer capable of generating an overflow pulse after 1000 trigger pulses and measuring the interval between two pulses with an accuracy of 0,01 % ;

g) impedance analyser ;

h) environmental test chamber.

All the tests in Group 1, except for the test of stability against temperature (8.2), use electronic means of generating the required signals. The characteristics of the equipment employed and its stability shall be adequate for the purpose of the tests.

NOTE Before connecting the oscilloscope and/or spectrum analyser to the transmitter of the ultrasonic instrument, as required for some of the tests in this standard, check that it will not be damaged by the high transmitter voltage.

8.2 Stability against temperature

8.2.1 Procedure

Generate two echoes on the ultrasonic instrument screen using e.g. a zero degree compression wave probe with a centre frequency between 2 MHz to 6 MHz and a test block. The amplitude of the first echo shall be adjusted to 80 % of full screen height, and the time-base adjusted so that the signals are at 20 % and 80 % of screen width. During the test the temperature of the probe and test block shall not vary by more than 2°C and the necessary precautions taken to avoid variations in coupling.

The ultrasonic instrument is placed into a climatic chamber and subjected to varying ambient temperatures. The echo heights and positions are to be read off and recorded at a maximum of 10°C intervals over the temperature range specified by the manufacturer.

8.2.2 Acceptance criterion

The amplitude and range of the reference echo shall not change by more than ± 5 % and ± 1 % respectively for each 10 °C change in temperature.

8.3 Transmitter pulse parameters

8.3.1 General

This clause contains tests for pulse repetition frequency, output impedance and frequency spectrum. Test methods and acceptance criteria for transmitter pulse shape and amplitude are given in 9.4.

8.3.2 Pulse repetition frequency

8.3.2.1 Procedure

Switch the ultrasonic instrument to double probe working (separate transmitter and receiver) and connect an oscilloscope to the transmitter terminal.

NOTE Check that the oscilloscope input will not be damaged by the high transmitter voltage.

Measure the pulse repetition frequency, using the oscilloscope, at each setting which gives a different pulse repetition frequency. Where more than one combination of controls results in the same pulse repetition frequency (usually the range and pulse repetition frequency) then the pulse repetition frequency only needs to be measured with one of the combinations. For ultrasonic instruments with a continuously adjustable pulse repetition frequency control a setting shall be chosen as given in the manufacturer's technical specification.

8.3.2.2 Acceptance criterion

At each setting the measured value of the pulse repetition frequency shall be within ± 20 % of that given in the technical specification.

8.3.3 Effective output impedance

8.3.3.1 Procedure

Using the methods in 9.4.2, measure the transmitter pulse voltage, V_{50} with the transmitter terminated by a 50 Ω non reactive resistor. Replace the 50 Ω resistor with a 75 Ω resistor and measure, using the oscilloscope, the transmitter pulse voltage V_{75} with the transmitter terminated by a 75 Ω resistor. The measurement shall be made for each pulse energy setting and transmitter pulse frequency, at maximum and minimum pulse repetition frequencies, with both maximum and minimum damping.

For each pulse setting calculate the effective output impedance, Z_o by means of the equation :

$$Z_o = 50 \times 75 \frac{(V_{75} - V_{50})}{(75V_{50} - 50V_{75})} \quad \Omega \tag{1}$$

NOTE Voltages V_{50}, and V_{75} are the values of the maximum excursions of the respective pulses from the baseline.

8.3.3.2 Acceptance criterion

The effective output impedance shall be within ± 20 % of the value in the technical specification and shall be no greater than 50 Ω.

8.3.4 Transmitter pulse frequency spectrum

8.3.4.1 Procedure

Measure the frequency spectrum of the transmitter pulse using either a spectrum analyser or an oscilloscope capable of performing Fast Fourier Transforms. The spectrum shall be plotted for at least the 30 dB limits of the frequency response. The pulse settings and the window parameters shall be recorded. The window shall be twice the pulse duration and centered about the pulse.

8.3.4.2 Acceptance criterion

The frequency spectrum shall be within the tolerances quoted in the technical specification.

8.4 Receiver

8.4.1 General

This clause gives tests to measure the transmitter/receiver crosstalk damping, receiver sensitivity, dead time due to transmitter pulse, dynamic range, input impedance, distance amplitude correction and temporal resolution. The methods and acceptance criteria for amplifier bandwidth, equivalent input noise, accuracy of calibrated attenuator, vertical display linearity are given in 9.5.

8.4.2 Cross-talk damping from transmitter to receiver during transmission

8.4.2.1 Procedure

The pulser and receiver are terminated with 50 Ω and the equipment set for twin probe working (separate transmitter and receiver). The peak to peak voltages at the pulser output V_{50} (measured in 9.4.2) and the receiver input V_E are measured with an oscilloscope as shown in figure 2. The logarithm of the ratio of both voltages is specified as the cross-talk damping during transmission D_s (given in decibels).

$$D_s = 20 \log_{10}\left(\frac{V_{50}}{V_E}\right) \qquad (2)$$

8.4.2.2 Acceptance criterion

The cross talk damping during transmission (D_s) shall be more than 80 dB.

8.4.3 Dead time after transmitter pulse

8.4.3.1 Procedure

Calibrate the ultrasonic instrument screen width from 0 µs to 25 µs at full scale. Then adjust the zero offset so that the leading edge of the transmitter pulse coincides with the zero screen division.

Connect the circuit shown in figure 3, with the ultrasonic instrument in single element working (combined transmitter and receiver).

NOTE The circuit shown in figure 1 is used to protect the function generator from the transmitter spike. Suitable gated pulses of RF for most ultrasonic instruments are 5 µs in duration and 24 µs spacing.

Select each frequency band setting of the ultrasonic instrument in turn and adjust the radio frequency of the input signal to give approximately maximum level signal on screen as shown in figure 4. Adjust the amplitude to half screen height at the maximum range of the screen. In doing this, check by varying the input signal level, that the ultrasonic instrument amplifier is not saturated.

Express the dead time as the time in microseconds from the transmitter pulse's leading edge to the point on the time base where the amplitude is 25 % screen height (i.e. 50 % of its amplitude at the end of the screen).

8.4.3.2 Acceptance criterion

For the worst case frequency band setting, the dead time after the transmitter pulse shall be less than 10 μs.

8.4.4 Dynamic range

8.4.4.1 Procedure

The dynamic range is checked using the test equipment in figure 5 at the centre frequency f_o of each frequency band as measured in 9.5.2. The test signal of ten cycles that shall be generated by this equipment is shown in figure 6. Set the ultrasonic instrument attenuator/gain controls (calibrated and uncalibrated) to minimum gain. Increase the amplitude of the input signal until either saturation occurs or the signal is displayed at 100 % full screen height. Measure (taking due account of the standard attenuator setting) the input voltage amplitude, V_{max}.

Set the ultrasonic instrument gain controls (calibrated and uncalibrated) to maximum gain.

If the noise level at the gain setting is higher than 5 % of the screen height, then decrease the gain until the noise level is 5 % of the screen height.

Adjust the amplitude of the input signal so that it is displayed at 10 % screen height. Measure (taking due account of the standard attenuator setting) the input voltage amplitude, V_{min}.

NOTE If the pulsed generator is unable to provide sufficiently low voltage, then reset the ultrasonic instrument to 20 dB above minimum gain and make the necessary correction to the measurement.

The usable dynamic range is given by :

$$20\log_{10}\left(\frac{V_{max}}{V_{min}}\right) \text{ dB} \qquad (3)$$

except where V_{min} is less than the input equivalent noise V_{ein} when the dynamic range is limited to :

$$20\log_{10}\left(\frac{V_{max}}{V_{ein}}\right) \text{ dB} \qquad (4)$$

8.4.4.2 Acceptance criteria

The usable dynamic range shall be at least 100 dB and the minimum input voltage V_{min} shall be within the tolerance quoted in the manufacturer's technical specification.

8.4.5 Receiver input impedance

8.4.5.1 Procedure

Real and imaginary parts of the receiver input impedance are determined with an impedance analyser with the ultrasonic instrument set for both double (separate transmitter and receiver) and single probe (combined transmitter and receiver) working. The transmitter pulse should be disabled while measuring the input impedance in single probe mode without disconnecting the receiver from the transmitter. These measurements are to be carried out at a signal frequency of 4 MHz, at the minimum (R_{min}, C_{min}) and maximum (R_{max}, C_{max}) gain setting. A damping control, if fitted, should be set to minimum during the test.

In general, the input impedance can be sufficiently established by an input resistance and a parallel capacitance.

8.4.5.2 Acceptance criterion

At 4 MHz the real part of impedance R_{max} at maximum gain shall be greater than or equal to 50 Ω and less than or equal to 1 KΩ. The parallel capacity C_{max} shall be less than or equal to 150 pF. The real components of the input impedance at maximum gain R_{max} and at minimum gain R_{min} shall meet the following condition :

$$\frac{|R_{max} - R_{min}|}{R_{max}} \leq 0{,}1 \qquad (5)$$

and the capacitive components of the input impedance at minimum gain C_{min} and at maximum gain C_{max} shall meet the following condition :

$$\frac{|C_{max} - C_{min}|}{C_{max}} \leq 0{,}15 \qquad (6)$$

8.4.6 Time-dependent gain (TDG)

8.4.6.1 Procedure

The performance of the TDG or DAC correction is verified by comparing the theoretical DAC curve requested by the operator with the actual curve generated by the ultrasonic instrument. The theoretical curve is calculated from the information supplied by the manufacturer on the operation of the DAC controls. This is compared with the actual curve, which is measured by the change in the amplitude of a test pulse, at a number of positions on the horizontal time-base over which the DAC is active. The DAC curve selected for this test shall contain the steepest correction slope possible with the ultrasonic instrument.

With the ultrasonic instrument set for twin probe working (separate transmitter and receiver), connect the test equipment as shown in figure 5. Adjust the gain of the ultrasonic instrument to maximise the dynamic range of the DAC. Throughout this test avoid saturating the pre-amplifier preceding the DAC circuit.

Enable the DAC selected for the test. With the test signal at a position on the horizontal time-base just before the start of the DAC curve, adjust the external standard attenuator so that the amplitude of the test signal is 80 % of screen height, call the standard attenuator setting A_o.

Increase the delay of the test signal to move the test signal along the time-base by ΔT where :

$$\Delta T = \frac{T_{final} - T_0}{N} \qquad (7)$$

and T_0 is the time to the start of the DAC curve, T_{final} is the time to the end of the DAC curve and N is the number of measurements to be taken. N shall be greater than or equal to eleven.

Adjust the standard attenuator to bring the test signal to 80 % of screen height, and record the attenuator setting A_n. Increase the range of the test signal by increasing the time delay a further ΔT and again record the attenuator setting to bring the test signal to 80 % of screen height. Continue increasing the time delay and adjusting the standard attenuator until N measurements have been made.

After the last measurement, test the DAC for saturation by increasing the external calibrated attenuation by 6 dB and ensuring that the signal is between 38 % to 42 % of screen height. If the signal is not within these limits reduce the range by ΔT and repeat the saturation test. The dynamic range of the DAC is measured at the point where saturation no longer occurs.

Plot out the actual DAC curve and the theoretical curve.

Repeat the measurement with the centre frequency for each filter setting and for maximum, medium and minimum DAC gain settings.

8.4.6.2 Acceptance criterion

The difference between the theoretical DAC curve requested by the operator and the actual DAC correction shall not exceed ± 1,5 dB.

8.4.7 Temporal resolution

8.4.7.1 Procedure

The widest band setting of the equipment is selected. Set the equipment in figure 5 to generate two single cycle measurement pulses with centre frequency f_o measured in 9.5.2 for the frequency band chosen. These pulses should follow each other at a distance so that they do not influence each other. The indications are adjusted to 80 % screen height. The equipment should be arranged so that the amplitude of the two pulses can be varied independently over a 20 dB range.

Measure the temporal resolution (t_{A1}) and temporal resolution (t_{A2}) after an interface echo using the methods below :

1) measurement of the temporal resolution t_{A1}

Decrease the distance between the two measurement pulses until the dip between them is 6 dB. In doing this, both pulses shall not change by more than 10 % of screen height. The distance from the start edge of the first measurement pulse, to the start of the second measurement pulse (measured at the pulse generator) is the temporal resolution t_{A1} ;

2) measurement of the temporal resolution after an interface echo t_{A2}

Increase the amplitude of the first measurement pulse by 20 dB, while maintaining the amplitude of the second pulse as 80 % of screen height. Decrease the distance between the two measurement pulses until the dip between both of them is 6 dB (relative to the smaller signal). In doing this, the indication of the smaller measurement pulse shall not change by more than 10 % screen height. The distance from the start of the first measurement pulse to the start of the second measurement pulse (measured at the pulse generator) is the temporal resolution t_{A2}.

8.4.7.2 Acceptance criterion

The measurement shall be within the tolerances quoted in the manufacturer's technical specification.

8.5 Monitor gate

8.5.1 General

This clause describes tests for any monitor gates with switching outputs. Tests for a proportional monitor gate output are given in 8.6.

The monitor output is wired according to the manufacturer's technical specification and a diagram of this circuit should be made. Statistical interference suppression is to be switched off if not specified by the manufacturer.

All the monitor gate tests use the equipment set-up shown in figure 7. In this set-up the trigger for the test signal is derived from a transmitter pulse using a fixed attenuator, a counter timer and a pulse generator. As shown in figure 8 the counter timer enables this set-up to generate a test signal for one transmitter pulse followed by a large number (at least 1000) of transmitter pulses for which no test signal is generated.

8.5.2 Response threshold and switching hysteresis with a fixed monitor threshold

8.5.2.1 Procedure

The trigger of the test signal is adjusted so that each transmitter pulse produces a test signal.

Then the amplitude of the test signal is varied to measure the amplitude at which the gate monitor signal turns on and off.

The difference in the amplitudes to turn the gate on and off is the switching hysteresis and its mean value is the threshold level. Repeat the measurement at different positions of the signal within the gate with centre frequency (f_o) and at the upper and lower 3 dB frequencies (f_u, f_l) as measured in 9.5.2.

8.5.2.2 Acceptance criteria

For monitor gates with fixed thresholds the amplitudes that turn the monitor signal on and off shall be within ± 2 % of screen height of the value in the manufacturer's specification. The switching hysteresis of the threshold shall be less than 2 % of screen height.

8.5.3 Switching hysteresis with adjustable monitor threshold

8.5.3.1 Procedure

For equipment with adjustable monitor thresholds, measurements are to be carried out according to 8.5.2 for threshold values at 20 %, 40 %, 60 % and 80 % screen height. If a scaled adjustment is possible then the scale values are to be recorded with the adjusted threshold values on the display.

8.5.3.2 Acceptance criterion

The hysteresis of the monitor gate threshold shall be less than 2 % of screen height.

8.5.4 Hold time of the switched output

8.5.4.1 Procedure

The amplitude of the trigger signal is adjusted so that the switching output is on. Then the trigger of the measurement signal is changed so that a transmission pulse with trigger signal is followed by approximately one thousand pulses without a trigger signal, as shown in figure 8.

The time interval between end of the test signal and the time when the switched output turns off, measured at it's 50 % level, is the hold time. If outputs are available with different hold times, measurements have to be carried out for all outputs.

8.5.4.2 Acceptance criterion

The hold time of the switching output shall be within ± 20 % of that specified in the manufacturer's technical specification.

8.6 Monitor gates with proportional outputs

8.6.1 Impedance of proportional gate output

8.6.1.1 Procedure

Select the setting at which the gain controls are in the middle of their range, and the widest band setting of the equipment.

Adjust the trigger of the measurement signal so that a measurement signal, with the carrier frequency f_o measured in 9.5.2, is produced with every transmitted pulse.

Set the amplitude of the measurement signal to produce an indication at 80 % of screen height and measure the output voltage V_o. Terminate the proportional gate output with a resistor of value R_l which satisfies the following condition :

$$0{,}75 I_{\max} \leq \left(\frac{V_o}{R_l} \right) \leq 0{,}85 I_{\max} \qquad (8)$$

where I_{max} is the maximum current that can be driven by the proportional gate output. Record the altered output voltage V_l. The (resistive part of the) output impedance is calculated using

$$|Z_A| = \left(\frac{V_o}{V_l} - 1 \right) R_l \qquad (9)$$

8.6.1.2 Acceptance criterion

The measured output impedance shall be within the tolerance quoted in the manufacturer's technical specification.

8.6.2 Linearity of proportional gate output

8.6.2.1 Procedure

Select the setting at which the gain controls are in the middle of their range, and the widest band setting of the equipment, adjust the triggering of the measurement signal so that a measurement signal is generated with each transmitted pulse. Adjust the amplitude of the measurement signal to give an indication at 80 % of screen height, and measure the voltage at the proportional gate output, calling this the reference voltage. The output voltage for full screen height (FSH) is 1,25 times the reference voltage.

The amplitude of the measurement signal is changed in steps according to table 3.

The deviation of the output voltage from the nominal value is recorded.

Table 3 - Expected output voltage for specified attenuator settings

Attenuation (dB)	Nominal Value (% of FSH output voltage)
+ 1	90
0	80
- 2	64
- 4	50
- 6	40
- 8	32
- 10	25
- 12	20
- 14	16
- 16	13
-18	10

8.6.2.2 Acceptance criterion

The measurement shall be within the tolerance quoted in the manufacturer's technical specification.

8.6.3 Frequency response of proportional gate output

8.6.3.1 Procedure

This test measures the response of the proportional output to the frequency of the receiver input signal. The measurement setup in figure 7 is used whereby a measurement signal is generated with every transmitted pulse.

Set the calibrated gain control to the mid position and the non-calibrated control to maximum gain. The frequency f_{gmax} for maximum output is found by varying the carrier frequency of the measurement signal until the FSH voltage is obtained at the analog output. Once f_{gmax} has been found, adjust the amplitude of the measurement signal so that the output voltage is 80 % of the FSH voltage found in 8.6.2. After this, the carrier frequency of the measurement signal is reduced and increased until the output voltage drops by 3 dB.

The values f_{gu}, f_{gl} are measured. Using f_{gu} and f_{gl}, the centre frequency f_{go} is calculated according to :

$$f_{go} = \sqrt{f_{gu} \times f_{gl}} \quad (10)$$

and the frequency bandwidth Δf is calculated according to :

$$\Delta f_g = f_{gu} - f_{gl} \quad (11)$$

8.6.3.2 Acceptance criterion

The measurement shall be within the tolerance quoted in the manufacturer's technical specification.

8.6.4 Noise on proportional gate output

8.6.4.1 Procedure

Terminate the receiver input with 50 Ω. Set all gain controls to the maximum value and use the widest band on the equipment. The output voltage shall not exceed 40 % of the FSH output. Otherwise, the gain is to be reduced so that 40 % of the FSH output voltage is not exceeded. The gain setting is to be recorded.

8.6.4.2 Acceptance criterion

The measurement shall be within the tolerance quoted in the manufacturer's technical specification.

8.6.5 Influence of the measurement signal position within the gate

8.6.5.1 Procedure

Use the setup shown in figure 7 to generate a measurement signal for each transmitter pulse. Select a mid gain position and the widest band setting on the equipment. Adjust the amplitude of the measurement signal, of the centre frequency f_o, to produce an indication at 80 % of screen height. Position the measurement signal in the first fifth, centre and in the last fifth of the gate and measure the voltages of the analog output.

8.6.5.2 Acceptance criterion

The measurement shall be within the tolerance quoted in the manufacturer's technical specification.

8.6.6 Effect of pulse shape on the proportional gate output

8.6.6.1 Procedure

Pulse transfer is characterized by the response of the amplifier to different measurement signals.

Use setup in figure 7 to produce a measurement signal with each transmitter pulse. Select mid gain and the widest band setting on the ultrasonic instrument. Set the carrier frequency of measurement signal to f_o, as measured in 9.5.2 for the selected filter. Adjust the amplitude measurement signal so that the voltage at the output of the proportional gate is 80 % of the FSH output voltage.

Using the test signals given below, note the external attenuator setting required to bring the output voltage to 80 % of the FSH output voltage :

a) a single sine wave with a negative leading edge ;

b) a single sine wave with a positive leading edge ;

c) measurement signal with five periods, similar to figure 6 ;

d) measurement signal with fifteen periods, similar to figure 6.

8.6.6.2 Acceptance criterion

The measurement shall be within the tolerance quoted in the manufacturer's technical specification.

8.6.7 Rise, fall and hold time of proportional gate output

8.6.7.1 Procedure

Using the measurement setup in figure 7, adjust the measurement signal trigger so that each transmitter pulse generates a measurement signal. Also use a mid gain setting and the widest band setting of the equipment and a measurement signal with a carrier frequency f_o, as measured in 9.5.2. Adjust the measurement signal so that 80 % of the FSH output voltage is obtained at the proportional gate output. Change the trigger of the measurement signal so that at the analog output, the minimal output voltage can be observed between two consecutive output signals (e.g. for one transmitter pulse with a measurement signal there follows approximately one thousand transmitter pulses without a measurement signal). The rise time is the time interval in which the output voltage rises from 8 % to 72 % (see Figure 8) of the FSH output voltage (this being equivalent to 10 % and 90 % of the output signal generated by the measurement signal).

The fall time is the time interval in which the output voltage falls from 72 % to 8 % of the FSH output voltage (see Figure 8). The hold time is the time interval in which the output voltage is above 72 % of the FSH output voltage following the end of the test signal (see Figure 8).

8.6.7.2 Acceptance criterion

The measurement shall be within the tolerance quoted in the manufacturer's technical specification.

8.7 Digital ultrasonic instruments

8.7.1 General

With some adaptation the other tests in this standard can be applied to digital ultrasonic instruments. However for a digital ultrasonic instrument these tests are incomplete. Additional parameters, which are not applicable to analog ultrasonic instruments, affect the performance of a digital ultrasonic instrument. These parameters are introduced by the digitisation of the A-scan and the algorithm used to produce the A-scan display. This is a new area for NDT instrumentation and conventions are still developing. However, this clause gives guidance on three tests which may be appropriate for some digital ultrasonic instruments. These tests are not exhaustive and, depending on the design of the digital ultrasonic instrument, further testing may be required to ensure suitability for an application.

8.7.2 Linearity of time-base for digital ultrasonic instruments

8.7.2.1 Procedure

This test compares the time base linearity of the ultrasonic instrument screen with that of a calibrated counter timer.

Connect the equipment as shown in figure 5. Set the pulse generator to produce a single cycle sine wave with a frequency at the centre frequency f_o of an appropriate filter. Set the time base to minimum, maximum and mid-range position in turn. At each setting adjust the trigger delay, the ultrasonic instruments gain/attenuator control and the external calibrated attenuator to obtain a signal which is at least 80 % of screen height at the centre of the time base.

Vary the trigger delay in increments of not more than 5 % of the screen width and record each delay (as measured on the counter/timer) and the corresponding location of the leading edge of the indication on the ultrasonic instrument screen. Plot the location on the ultrasonic instrument screen against the delay measured by the counter/timer. Draw or calculate a best fit curve to the measured values and calculate the error for each measurement.

8.7.2.2 Acceptance criterion

The time base non-linearity shall not exceed ± 0,5 % of the screen width.

8.7.3 Digitisation sampling error

8.7.3.1 Procedure

This test verifies that a signal, having the highest frequency within the ultrasonic instrument bandwidth, is correctly displayed on the screen, and particularly that its amplitude is independent of its range.

The test should be done with each filter, on rectified and RF mode, if available, and with DAC disabled. The test should also be repeated with each setting that influences the digitisation, for example time-base and pulse repetition frequency.

Set the ultrasonic instrument for twin probe working (separate transmitter and receiver) and using the set up shown in figure 5 generate a test pulse synchronised to the transmitter pulse. Set the delay T of the signal to T_o, longer than the receiver dead time. Set the frequency of the waveform generator to the upper 3 dB point, measured in 9.5.2, for the filter with the widest bandwidth which includes the highest frequency. Adjust the waveform generator to produce a single period sinusoid with an amplitude of 80 % of screen height.

Using the variable time delay, increase T by a small increment

$$\Delta T = \frac{1}{10 f_u} \qquad (12)$$

where f_u is the upper 3 dB break point for the filter as measured in 9.5.2.

At each increment of ΔT, measure the amplitude of the signal on the screen. Continue increasing the time delay and measuring the amplitude until 30 measurements have been made (i.e. 3 wavelengths).

8.7.3.2 Acceptance criterion

The signal shall not vary by more than ± 5 % of full screen height from the largest to the smallest amplitude recorded.

8.7.4 Response time of digital ultrasonic instruments

8.7.4.1 Procedure

The displays of most digital ultrasonic instruments have a limited refresh rate, and this may not match the ultrasonic pulse repetition frequency. Hence transient echoes which are only detected for a short period of time may not be displayed on the screen at their full amplitude. The purpose of this test is to measure the time. A transient echo has to be detected before it is displayed, at 90 % of it's full amplitude, on the screen of the digital ultrasonic instrument.

Use the same set up as the previous tests (8.7.3) to produce a single cycle sinusoidal test pulse with a frequency at the higher 3 dB point for the filter as measured in 9.5.2. Adjust the ultrasonic instrument gain to the middle of it's dynamic range and the amplitude of the test pulse to 80 % of screen height. Set the signal generator to produce a single shot pulse, after which the signal generator will require rearming before the next pulse is generated. After arming the test signal, an indication should appear on the ultrasonic instrument screen at 80 % of FHS.

If no echo appears or the amplitude is not between 75 % and 85 % of screen height, set the function generator to multi shot mode and increase the number of shots, by increasing the width of the gate used to enable the signal generator, until the signal is between 76 % and 85 % of screen height.

Measure the response time of the ultrasonic instrument by measuring the time from the start of the transmitter pulse triggering the test signal gate to the start of the transmitter pulse following the end of the test signal gate, as shown in figure 9.

Repeat this test for each setting which influences the response time of the ultrasonic instrument, such as range or pulse repetition frequency setting.

8.7.4.2 Acceptance criterion

The response time shall be within the tolerance quoted by the manufacturer.

9 Group 2 tests

9.1 Equipment required for group 2 tests

The items of equipment essential to assess ultrasonic instruments in accordance with the tests in Group 2 of this standard are as follows :

a) oscilloscope with a minimum bandwidth of 100 MHz ;

b) 50 Ω ± 1 % non-reactive resistor ;

c) standard 50 Ω attenuator with 1 dB steps and a total range of 100 dB. The attenuator shall have a cumulative error of less than 0,3 dB in any 10 dB span for signals with a frequency up to 15 Mhz ;

d) pulsed signal generator with an external trigger or gate capable of producing a gated burst of sinusoidal radio frequency signals of variable amplitude in the range suitable for the equipment being tested ;

e) variable DC power supply suitable to replace any battery used in the ultrasonic instrument ;

f) variable transformer to control mains voltage.

All the tests in the standard, except for those of stability, use electronic means of generating the required signals. The characteristics of the equipment employed and its stability shall be adequate for the purpose of the tests.

9.2 Physical state and external aspects

Visually inspect the outside of the ultrasonic instrument for physical damage which may influence it's current operation or future reliability.

9.3 Stability

9.3.1 General

The following clauses describe tests for measuring the stability of the ultrasonic instrument against time, line and battery voltage.

9.3.2 Stability after warm up time

9.3.2.1 Procedure

Generate an echo on the ultrasonic instrument screen using e.g. a zero degree compression wave probe with a centre frequency between 2 MHz to 6 MHz, and a test block. The amplitude of the first echo shall be adjusted to 80 % of full screen height, and the time-base adjusted so that the signal is at 80 % of screen width with a range equal to, or greater than 50 mm of steel for compression waves. During the test the necessary precautions shall be taken to avoid variations in coupling. If a delay control is fitted, this shall be set to zero delay.

Observe the stability of amplitude and position of this signal on the time base at 10 min intervals over a period of 30 min.

Carry out the test in an environment whose temperature is maintained within ± 5 °C of range specified in the manufacturer's technical specification of the ultrasonic instrument. Ensure that the mains or battery voltage is within the ranges required by the manufacturer's technical specification.

9.3.2.2 Acceptance criteria

During a 30 min period following an allowance for warm-up, in accordance with the manufacturer's technical specification :

a) the signal amplitude shall not vary by more than ± 2 % of full screen height ;

b) the maximum acceptable shift along the time base shall be less than ± 1 % of full screen width.

9.3.3 Display jitter

9.3.3.1 Procedure

Set up a reference signal as described above and observe variations in amplitude and/or range having frequencies greater than approximately 1 Hz. Avoid high gain settings where amplifier noise may prevent measurement.

9.3.3.2 Acceptance criteria

The signal amplitude shall not vary by more than ± 2 % of full screen height.

The position of the signal shall not vary by more than ± 1 % of full screen width.

9.3.4 Stability against voltage variations

9.3.4.1 Procedure

Set up a reference signal as described in 9.3.2, powering the ultrasonic instrument from a regulated supply at the centre of the working range specified for the ultrasonic instrument.

Observe the consistency of amplitude and position on the time base of the reference signal over the ranges defined in the manufacturer's technical specification, for the following :

a) variation of line voltage (adjust by mains transformer) ; and/or

b) variation of battery voltage (using a variable voltage d.c. power supply in place of a standard battery pack).

If an automatic cut-off system or warning device is fitted, decrease the mains and/or battery voltage and note the signal amplitude at which the cut-out system or warning device operates.

9.3.4.2 Acceptance criteria

The amplitude and position of the signal shall be stable within the limits specified in manufacturer's specification.

Operation of automatic cut-off or warning light (if fitted) shall occur before the reference signal amplitude varies by more than ± 2 % of the full screen height or the range changes by more than ± 1 % of the full screen width from the initial setting.

9.4 Transmitter pulse parameters

9.4.1 General

This clause contains tests for transmitter pulse shape and amplitude.

9.4.2 Transmitter voltage, rise time, reverberation and duration

9.4.2.1 Procedure

Switch the ultrasonic instrument to double probe working (separate transmitter and receiver) and connect an oscilloscope to the transmitter terminal.

NOTE Before connecting the oscilloscope it should be checked that the input will not be damaged by the high transmitter voltage.

Set the pulse repetition frequency to maximum and connect a 50 Ω non-reactive resistor across the transmitter output socket. Using the oscilloscope, measure the transmitter pulse voltage, V_{50}. Measure the pulse rise time, duration and amplitude of any reverberation as shown in figure 10.

Repeat the measurements at each pulse energy setting and/or transmitter pulse frequency setting and with maximum and minimum damping.

Repeat the tests with the minimum pulse repetition frequency that gives a clearly defined trace on the oscilloscope screen.

9.4.2.2 Acceptance criteria

At maximum and minimum pulse repetition frequency and on each pulse energy and/or transmitter pulse frequency band :

a) transmitter pulse voltage (loaded, i.e. V_{50}) shall be within ± 10 % of the manufacturer's specification ;

b) pulse rise time t_r shall be less than the maximum value quoted in the manufacturer's technical specification ;

c) pulse duration t_d shall be within ± 10 % of the value quoted in the manufacturer's technical specification ;

d) any pulse reverberation V_r shall be less than 4 % of the peak to peak transmitter pulse voltage.

9.5 Receiver

9.5.1 General

This clause gives tests to measure the amplifier bandwidth, equivalent input noise, and the accuracy of calibrated attenuator. The suppression control, if fitted, shall be switched off during these tests.

9.5.2 Amplifier frequency response

9.5.2.1 Procedure

Using the circuit shown in figure 5 plug the input signal into the receiver terminal of the ultrasonic instrument and switch to double probe operation. Adjust the input signal to the ultrasonic instrument to be ± 1 V peak to peak and adjust the calibrated attenuator to produce a signal at 80 % screen height. Report the gain setting of the receiver.

Select each frequency band setting in turn. Vary the frequency of the input signal over the range 0,1 MHz to 25 MHz and note the frequency (f_{max}) for each band, giving the maximum signal amplitude displayed on the ultrasonic instrument screen, and the height of this level. In doing this, ensure that the amplifier is not overloaded, and also that the input amplitude, as displayed on the oscilloscope, is kept constant. Decrease the calibrated external attenuator by 3 dB to increase the displayed signal height.

In turn, increase and decrease the frequency from f_{max}, in small increments which are less than 5 % of the nominal bandwidth and observe the higher (f_u) and lower (f_l) frequencies (3 dB points) at which the displayed height on the ultrasonic instrument screen returns to its original value. Again make sure that the input signal to the calibrated external attenuator is constant.

9.5.2.2 Acceptance criteria

The centre frequency (f_o) (for each band setting in the case of selectable values) as given by :

$$f_o = \sqrt{f_u \times f_l} \tag{13}$$

shall be within ± 5 % of the value stated in the technical specification or marked on the control. The bandwidth Δf (between - 3 dB points) as given by :

$$\Delta f = f_u - f_l \tag{14}$$

shall be within ± 10 % of the bandwidth specified in the technical specification.

9.5.3 Equivalent input noise

9.5.3.1 Procedure

Select double probe operation and use the circuit shown in figure 5. Carry out the measurements of equivalent input noise as follows for each frequency range, using a signal at the centre frequency, f_o of each band.

Set the ultrasonic instrument to maximum gain on all controls, including the variable gain. Disconnect the input signal and note the noise level on the ultrasonic instrument screen.

Reduce the gain by 40 dB and reconnect the input signal. Adjust the calibrated external attenuator and/or the input signal level until the drifting RF pulses appear at the same level as the previous noise level. Measure the input signal V_{in} in volts peak-to-peak from the oscilloscope, and the attenuation of the calibrated external attenuator (S dB). The equivalent input noise, V_{ein} (in Volts), is

$$V_{ein} = \frac{V_{in}}{10^{\left(\frac{S+40}{20}\right)}} \tag{15}$$

and the noise per root bandwidth is given by :

$$n_{in} = \frac{V_{ein}}{\sqrt{f_u - f_l}} \tag{16}$$

where f_u and f_l are the 3dB points measured in 9.5.2.

9.5.3.2 Acceptance criterion

For each frequency band setting n_{in} shall satisfy the following condition :

$$n_{in} < 80 \times 10^{-9} \quad V / \sqrt{Hz} \tag{17}$$

9.5.4 Accuracy of calibrated attenuator

9.5.4.1 Procedure

Compare the calibrated attenuator of the ultrasonic instrument with a matched external calibrated attenuator using a reference signal as follows.

Continue using the set up in figure 5 and make the comparison at the centre frequency (f_o) measured in 9.5.2 for each filter setting. For instruments with logarithmic amplifiers, see annex A.

Adjust the calibrated attenuator of the ultrasonic instrument to mid position and set the reference signal from the signal generator to show a signal at 80 % of screen height with the external calibrated attenuator set 10 dB higher than the ultrasonic instrument gain.

Check the ultrasonic instrument attenuator control by reducing the attenuation of the ultrasonic instrument in appropriate increments and adjusting the external calibrated attenuator to maintain the signal at constant height. Check the gain in three stages. First check the gain at it's smallest increment over a 1 dB range if possible. Secondly, check the fine gain over it's whole range at its smallest increments, but not less than 1 dB increments. Finally check the coarse gain over it's whole range, at each of it's increments. Note deviations between the two attenuators greater than those specified in the acceptance standard. These indicate errors in the ultrasonic instrument attenuator.

9.5.4.2 Acceptance criteria

The following shall apply at each frequency setting chosen :

a) the cumulative error in the fine gain attenuator(s) shall not exceed ± 1 dB in any successive 20 dB span, or the full range, whichever is the smaller ;

b) the cumulative error in the coarse gain attenuator(s) shall not exceed ± 2 dB in any successive 60 dB span, or the full range, whichever is the smaller.

9.5.5 Linearity of vertical display

9.5.5.1 Procedure

Test the ultrasonic instrument screen linearity by altering the amplitude of a reference input using an external calibrated attenuator and observing the change in the signal height on the ultrasonic instrument screen. Report the gain setting at the beginning of the test.

Check the linearity at prescribed intervals from 0 dB to -26 dB of full screen height.

Repeat the test for centre frequencies (f_o) of each filter as measured in 9.5.2.

Using the same setup shown in figure 5 set the external calibrated attenuator to 2 dB and adjust the input signal and the gain of the ultrasonic instrument so the signal is 80 % of full screen height.

Without changing the gain of the ultrasonic instrument switch the external calibrated attenuator to the values given in the table 4. For each setting measure the amplitude of the signal on the ultrasonic instrument screen.

Table 4 - Acceptance levels for vertical display linearity

External attenuator setting (dB)	Target amplitude on screen (% screen height)	Acceptable amplitude (% screen height)
1	90	88 to 92
2	80	(Reference line)
4	64	62 to 66
6	50	48 to 52
8	40	38 to 42
12	25	23 to 27
14	20	18 to 22
20	10	8 to 12
26	5	3 to 7

9.5.5.2 Acceptance criteria

At each frequency setting, the amplitude measured shall be within the tolerances given in table 4.

9.6 Linearity of time-base

9.6.1 Procedure

This test measures the linearity of the ultrasonic instrument timebase by comparing the graticules with the positions of the eleven regularly spaced bursts of sine waves generated by a pulse generator.

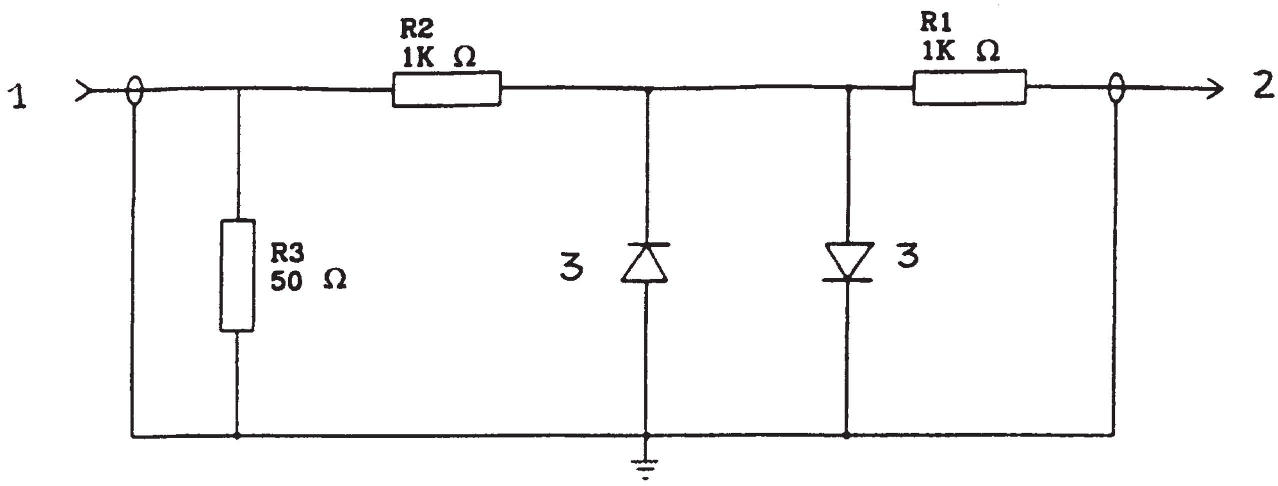
Using the setup shown in figure 5, generate a test signal with eleven regularly spaced bursts of sine waves as shown in figure 11. Select an appropriate frequency band and set the carrier frequency of the test signals to the centre frequency measured in 9.5.2. With the ultrasonic instrument set to mid gain adjust the external calibrated attenuator and the amplitude of the function generator output, until the test pulses, displayed on the ultrasonic instrument, are at 80 % of screen height. Adjust the timing of the pulses so that the leading edge of the third pulse is at 20 % of the horizontal scale, and the leading edge of the ninth pulse is at 80 % of the full horizontal screen width.

Record the deviations of the leading edges of the nine remaining pulses which are outside the tolerances given in the acceptance criteria.

Repeat the measurements for all positions of the stepped horizontal calibration control, with the continuous calibration control in the mid position. Also repeat the measurement for both end positions of any continuous horizontal calibration control, with the stepped calibration control at a mid position.

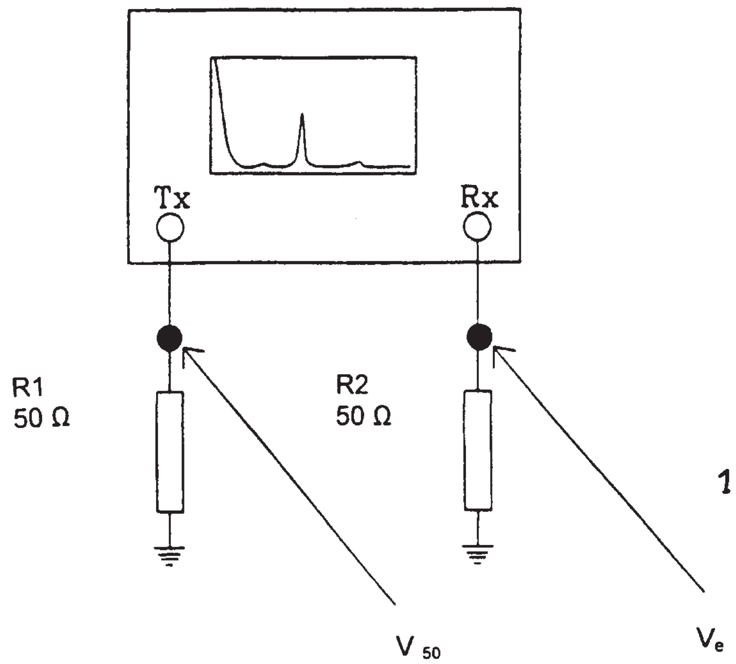
9.6.2 Acceptance criterion

The deviation of the reference signals from the ideal positions shall not be greater than ± 1 % of the full screen width.



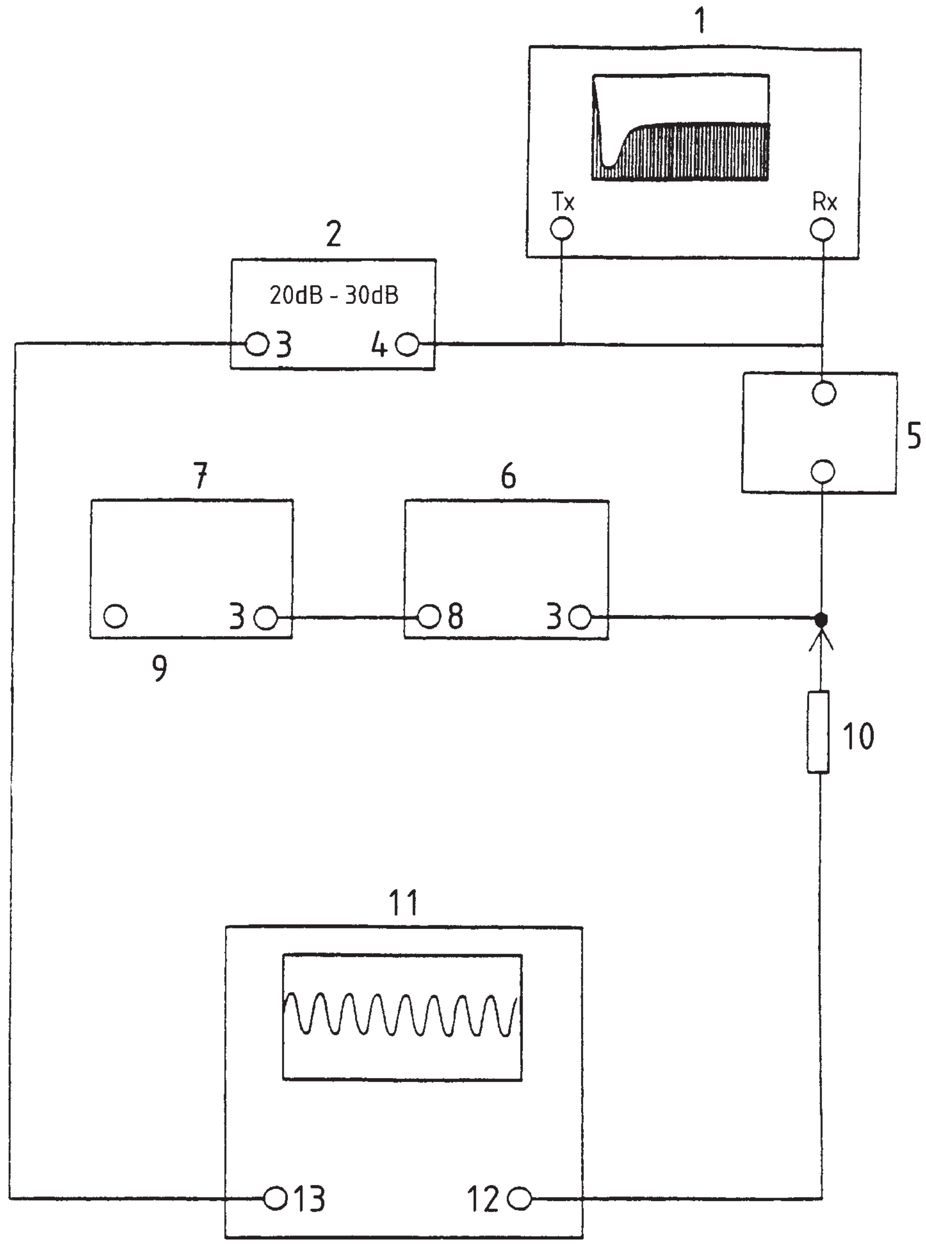
Key
1 Signal generator
2 Flaw detector
3 Silicon switching diode

Figure 1 - Circuit to protect equipment from the transmitter pulse



Key
1 Probes 10pF +/-4 pF

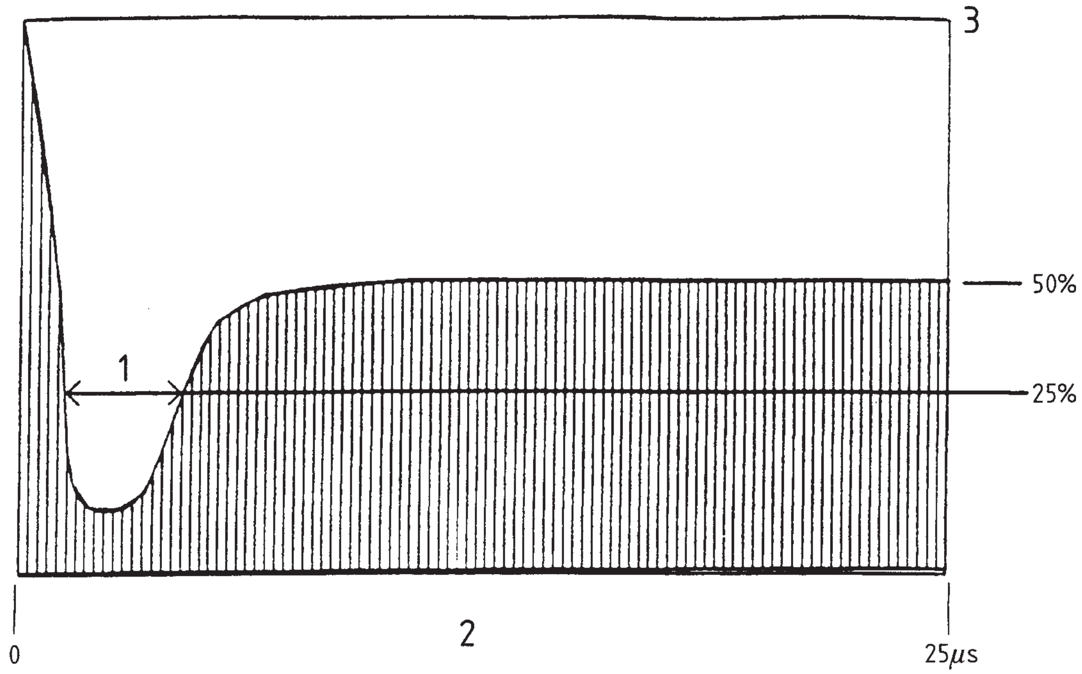
Figure 2 - Equipment set-up used to measure cross-talk damping



Key

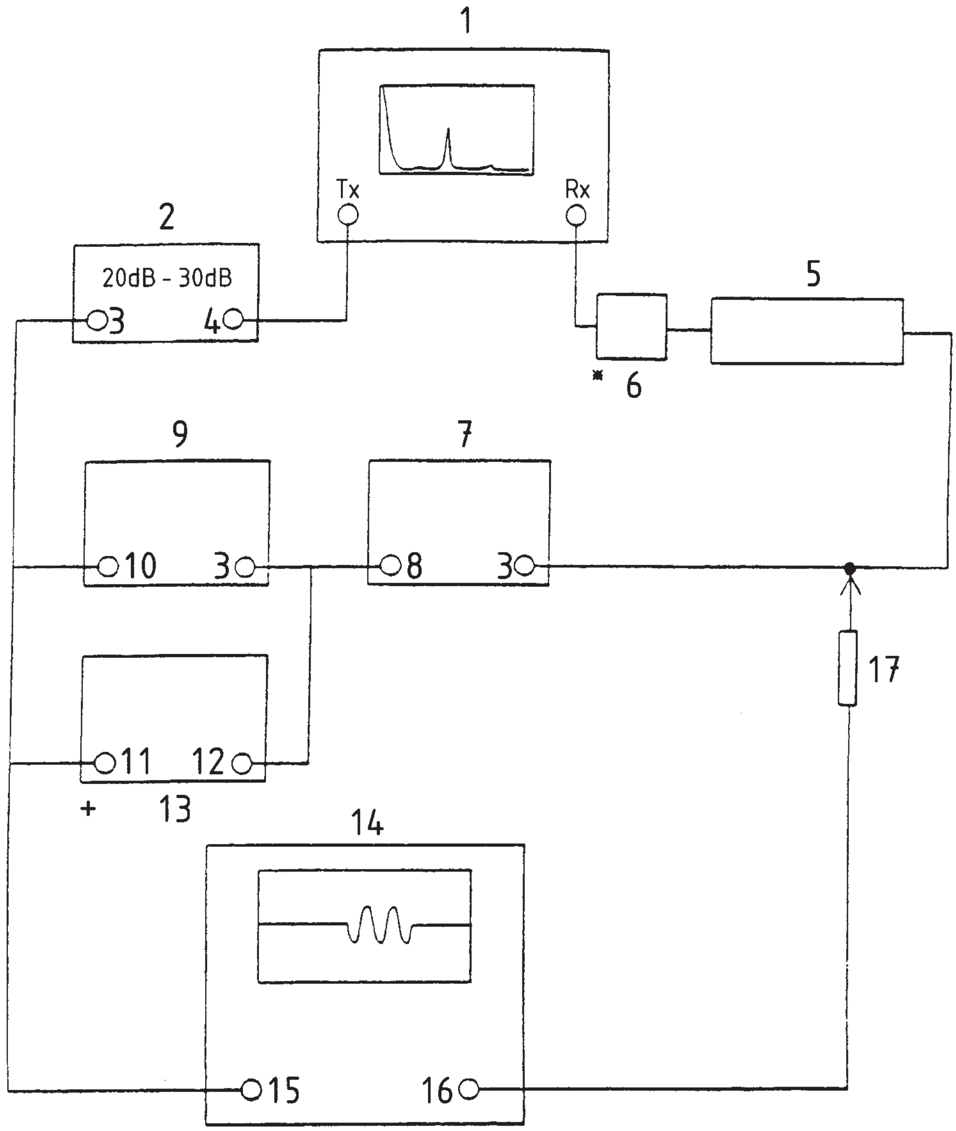
1 Flaw detector
2 Fixed attenuator
3 Out
4 In
5 Protection circuit (see fig.1)
6 Gated RF signal generator
7 Pulse generator
8 Gate
9 Pulse width = 5 µsec
Rate = 10 kHz
10 x 10 Scope Probe (100 MHz)
11 100 MHz Oscilloscope
12 Y Input
13 T.B. Trig

Figure 3 - Equipment set-up used to measure dead time after the transmitter pulse



Key
1 Dead time
2 Non – syncronised rectified sinewave
3 Screen height

Figure 4 - Waveform used to measure dead time after the transmitter pulse as seen on the flaw detector screen during the test



Key

1 Flaw detector
2 Fixed attenuator
3 Out
4 In
5 Variable RF attenuator
6 Termination pad
7 Gated RF signal generator
8 Gate
9 Pulse generator
10 Trig
11 Start
12 Stop
13 Interval timer
14 100 MHz oscilloscope
15 T.B. Trig
16 Y Input
17 x 10 Scope probe (100 MHz)

+ counter timer only required for tests on DACs and digital flaw detectors

* Termination pad only required to match impedance of flaw detector to test instruments

Figure 5 - General purpose set-up for equipment

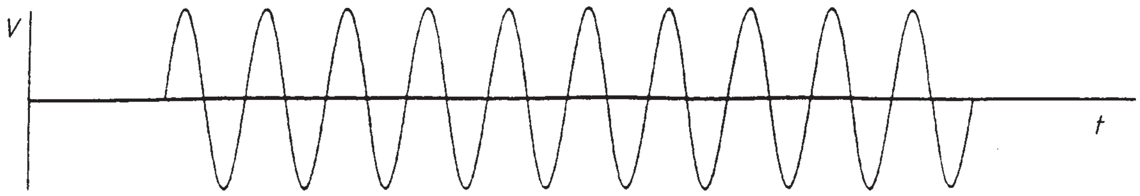
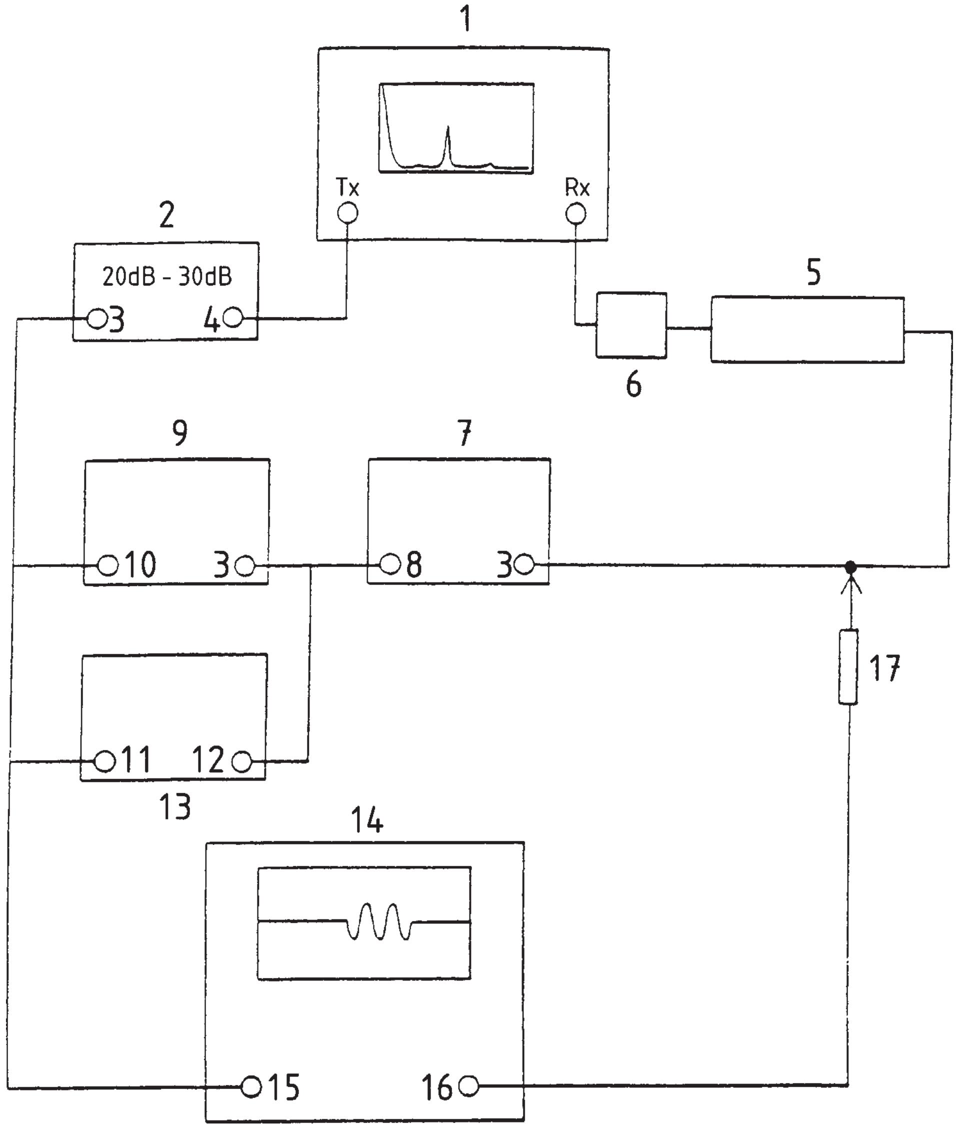


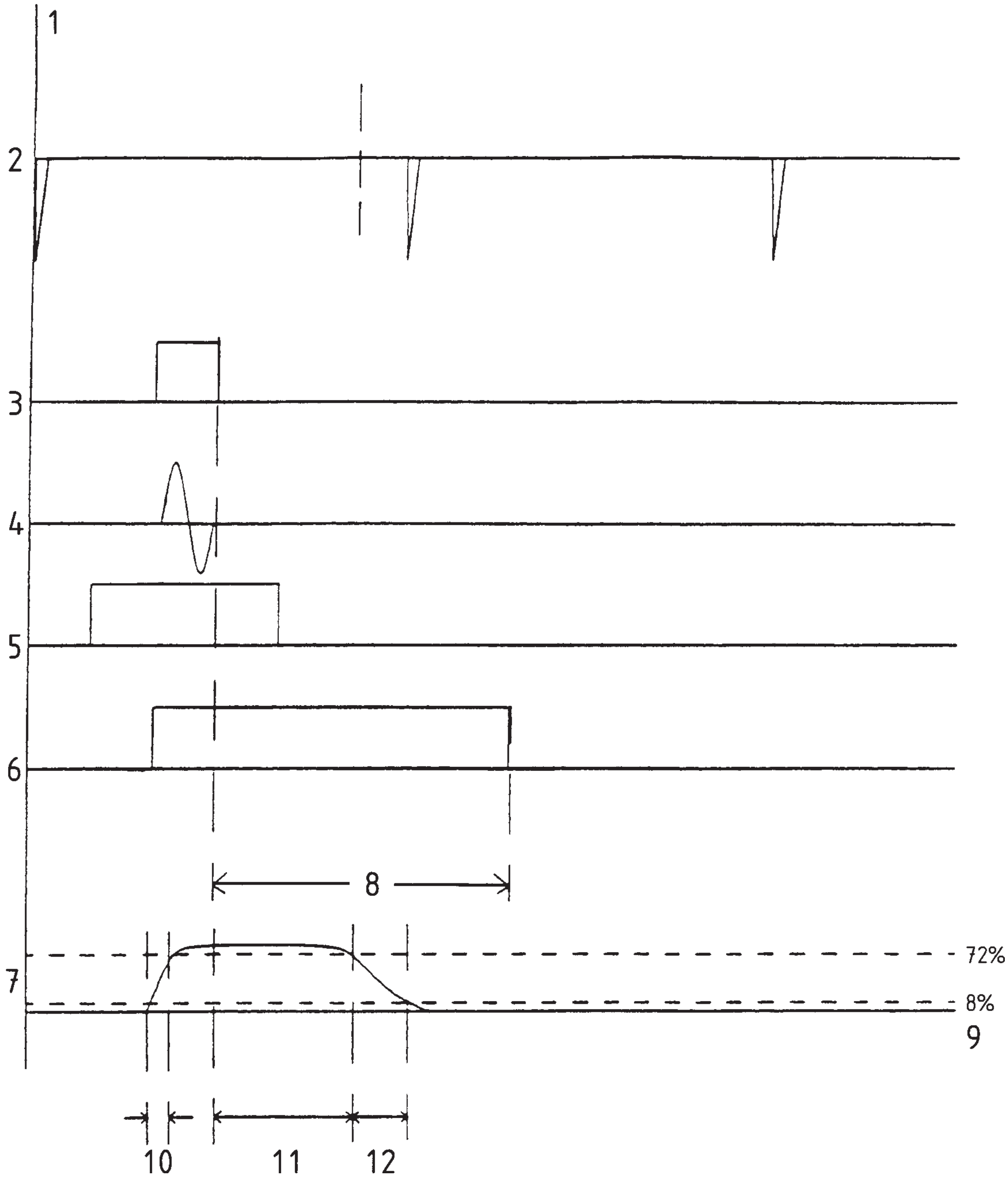
Figure 6 - Test waveform generated by general purpose equipment set-up



Key

1 Flaw detector
2 Fixed attenuator
3 Out
4 In
5 Variable RF attenuator
6 Termination Pad
7 Gated RF signal generator
8 Gate
9 Pulse generator
10 Trig
11 Start
12 Overflow
13 Counter timer
14 100 MHz Oscilloscope
15 T.B. Trig
16 Y input
17 x 10 scope probe (100 MHz)

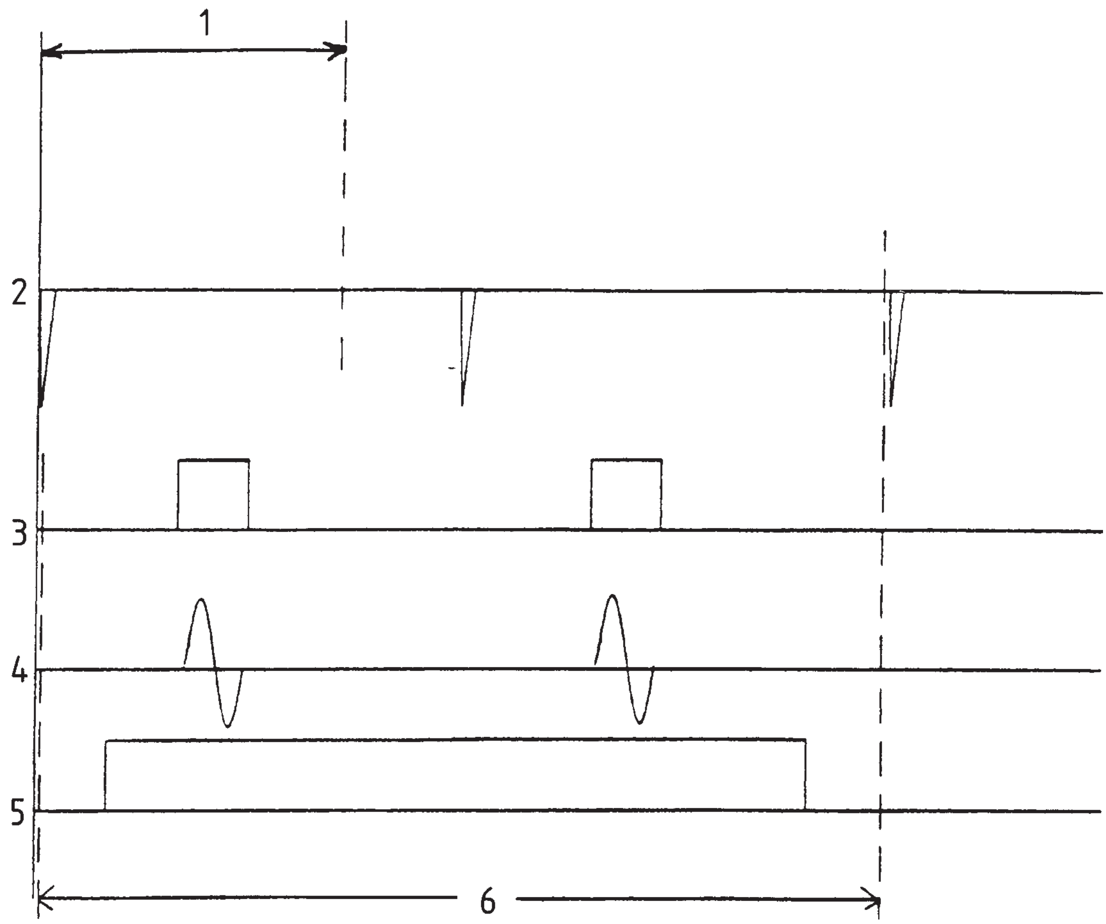
Figure 7 - Set-up of equipment for tests on monitor gate



Key

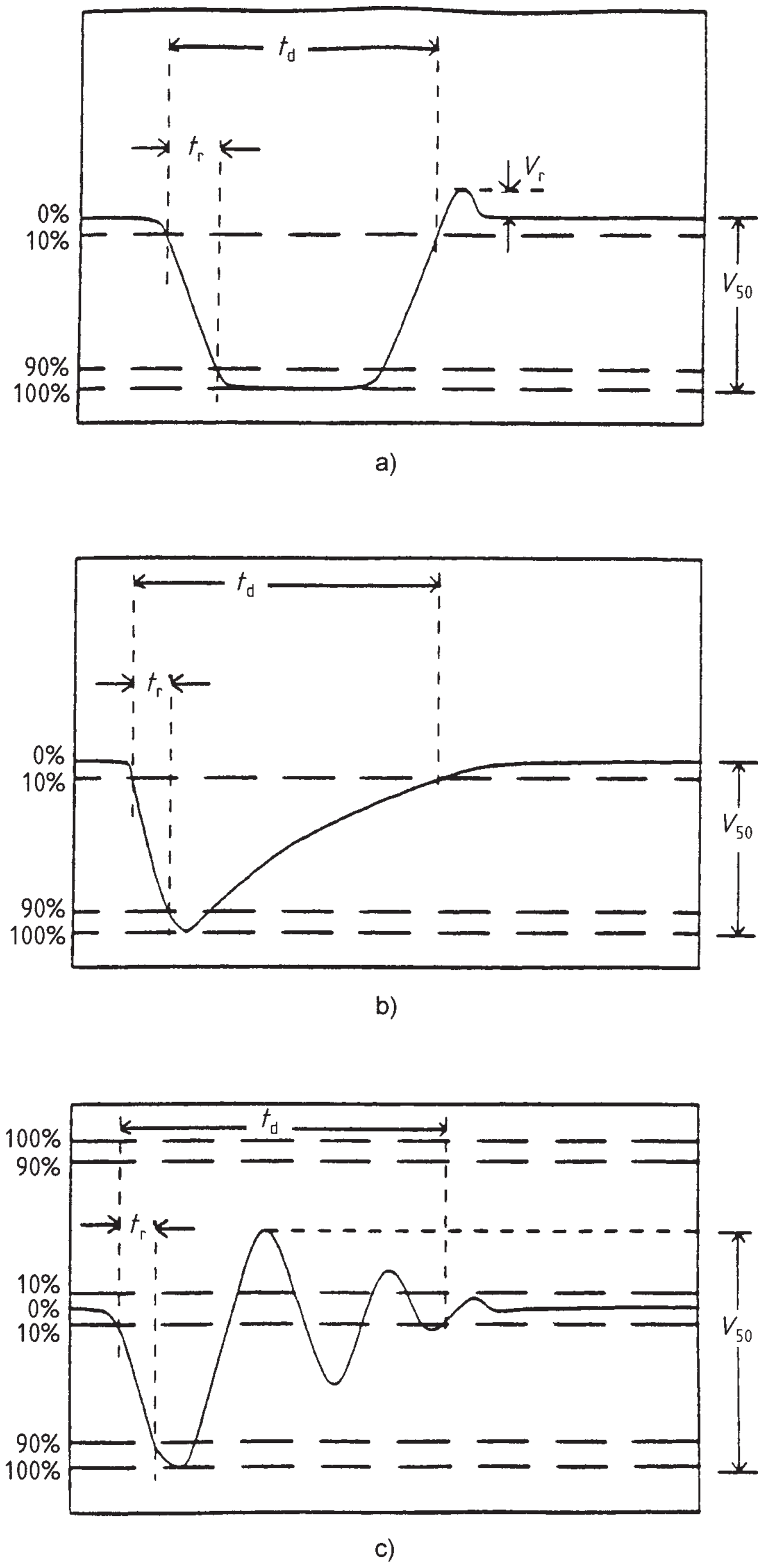
1 Screen width
2 Transmitter pulses
3 Test enabling signal
4 Test signal
5 Monitor gate
6 Switched monitor gate signal
7 Proportional gate output
8 Hold time
9 % of FSH
10 Rise time
11 Hold time
12 Fall time

Figure 8 - Timing diagram of signals used to test the monitor gate



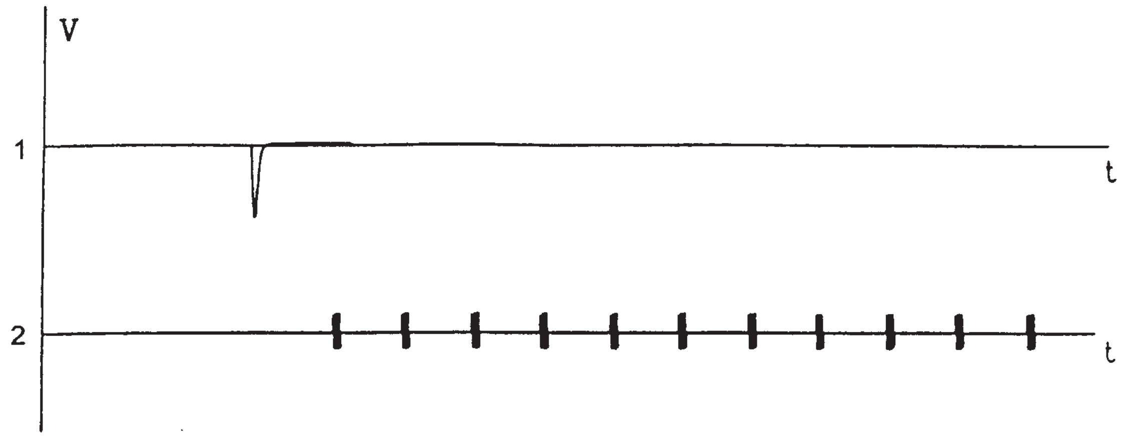
Key
1 Screen width
2 Transmitter pulses
3 Test enabling signals
4 Test signal
5 Test signals gate
6 Response time

Figure 9 - Timing diagram showing how to measure the response time of digital flaw detectors



Key
a) Square
b) Spike
c) Tuned

Figure 10 - Transmitter pulse parameters to be measured



Key
1 Transmitter pulse
2 test signal

Figure 11 - Signals used to test time base linearity

Annex A
(normative)

Special conditions for ultrasonic instruments with logarithmic amplifiers

A.1 Introduction

Certain ultrasonic instruments are designed with a logarithmic amplifier instead of a linear amplifier.

An ultrasonic instrument based upon a logarithmic amplifier can be characterized as follows :

1) the amplitude on the display (and on a monitor output, if any) is linear in a decibel scale rather than in a percentage scale ;

2) gain control is replaced (fully or partly) by range and offset controls for the vertical display scale.

A.2 Basic requirements

A.2.1 Measuring accuracy

In order to meet this standard an ultrasonic instrument with a logarithmic amplifier shall meet the same requirements as regards overall measuring accuracy, i.e. from input to display, as stated in clause 9.5.4, i.e. :

the cumulative measuring error shall not exceed ± 1 dB in any 20 dB span and ± 2 dB in any 60 dB span.

A.2.2 Vertical display "linearity"

Since the vertical display by nature is non-linear the clause 9.5.5 shall be replaced by the following requirement :

vertical display errors shall not exceed ± 1 dB in any 20 dB span and ± 2 dB in any 60 dB span.

A.3 Tests

The test set-up in figure 5 shall be used. Verification of compliance with the above requirements shall be performed by means of tables showing measured decibel outputs versus set decibel inputs.

Bibliography

EN 12223, *Non-destructive testing - Ultrasonic examination - Specification for calibration block No. 1.*

ISO 10012-1, *Quality assurance requirements for measuring equipment - Part 1 : Metrological confirmation system for measuring equipment.*