TrecscaN® 2003

Operation Manual

ANDSCAN®/TRECSCAN® Version No. Beta 2.30 Rev K

TRECSCAN Hardware Version No. QinetiQ Mk III/ Mk IV

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Contents.

1. Instructions for acquiring a TRECSCAN scan

1. Activate ANDSCAN.

2. In the tool bar 'Enable TRECSCAN' (Trecscan menu) within ANDSCAN with the appropriate probe connected.

3. Turn on the transient display if it is not already on. Should see a rising edge followed by a flat top. If just noise then plug the probe in! If there is still just noise then move on to the next step. The check-box in the transient display window should be checked for a transient relative to the 'balance' transient but at present there is no balance so the raw unbalanced transient will be seen.

4. The Configuration dialog box should be open. If not then select TRECSCAN configure from the TRECSCAN menu. If the signal is still not the expected rising edge and flat top, then press the 'Configure Acquisition' button and set the controls for the box you are using. Pre-sets (eg DERA Mk III) can be pressed. The calibration of the output amplitude in Amps per Volt should have been set up. This will affect whether the requested current is provided and can be determined using one of the processes in Appendix C.

5. Adjust drive amplitude and rise-time controls to ensure there is no discontinuity or overshoot in the rising edge (requiring a longer rise-time) and that the transient rises to a maximum, without a sharp corner (caused by saturation of the Hall sensor preamplifier) and stays there. Click Apply after each change to see the effect. TRECSCAN Mk III and onwards should give a warning in the Configure dialog box if the drive is saturated. Table 1 gives starting values for various probes, but the procedure in paragraphs 6 and 7 should be followed:

Probe type	Current (mA)	Rising Edge Time Constant (μs)	Maximum Safe Current (mA)
LF	50	150	82
FMF (320T)	100	80	132
TMF (230T)	100	80	362
MF	100	50	132
SF	50	30	53
TSF	390	50	580
TRSF	400	120	580
NTRSF	400	150	580
VSF	80	40	80
VLF	300*	100	580*

Table 1: Starting values of drive current and rise times for various probes.
***VLF probe is known to suffer from saturation of the Hall sensor preamplifier at around 300 mA and is not usable with currents above this saturation limit.**

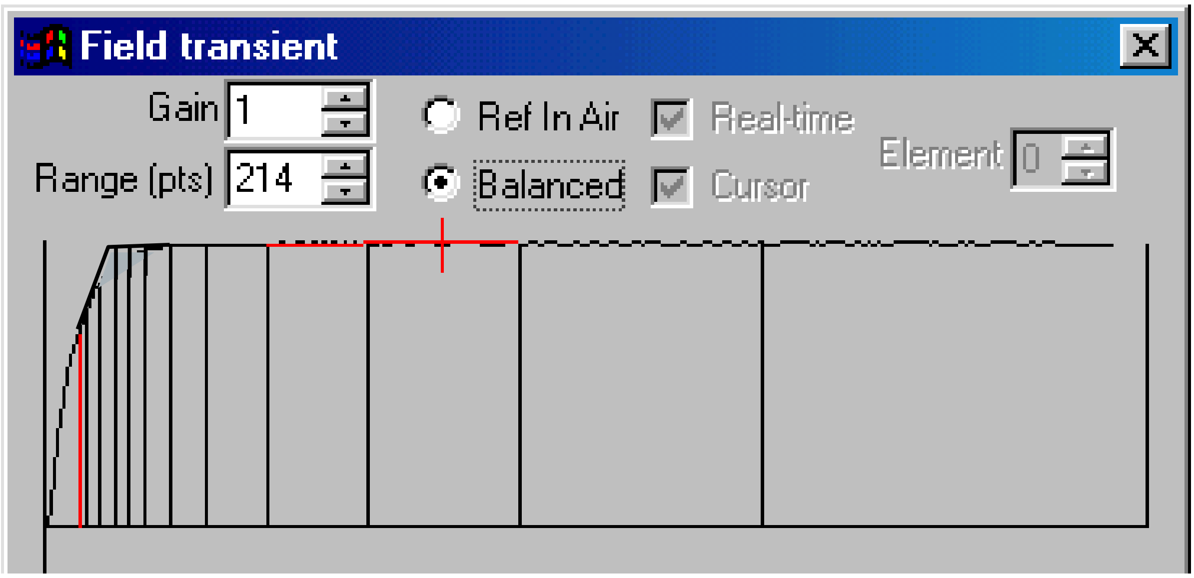
6. The best procedure is to use shorter rise times for thinner materials. Hence an estimate should be made of the thickness of the thinnest material that will be scanned.

A rough guide is to use a maximum time constant (TC) of 10 µs for every 1.0 mm of material of conductivity between 30%IACS and 40%IACS, or 40 µs, whichever is largest. For other materials of other conductivities, use the equation:

$$TC = 1.7t\sqrt{\sigma}$$

where *TC* is the maximum time constant in µs, *t* is the thickness of the material in mm, and σ is the conductivity in %IACS.

7. Having chosen a rise time, with the probe 'in air' find the highest current that causes neither saturation nor a corner in the rising edge (due to saturation of the Hall sensor preamplifier). Higher currents give better sensitivity and the maximum safe current stated in Table 1 already allows an adequate safety factor.



Example of an 'in-air' transient that exhibits the 'corner' indicating saturation of the Hall sensor's preamplifier. Reduce the current if this is observed..

8. Press 'Apply' in the TRECSCAN Configure dialog box.

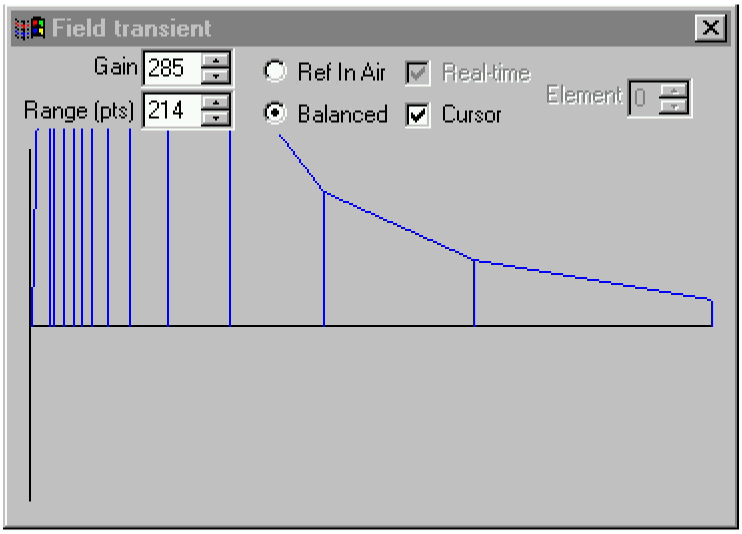
9. Press 'Zero in Air' in the TRECSCAN Toolbar - ensure no metal is near the probe end (e.g. probe holder) whilst measuring the in-air transient.

10. At this stage TRECSCAN should automatically offer to adjust the delay to timeslice 0 (first timeslice, as counting from zero) so that it gives approx. 25% of unbalanced signal height (Figure 1). This is so that the data used in the lift-off compensation algorithm is above the background noise levels. Accept any adjustment and check that the new offset has been applied. If not, close and re-open the TRECSCAN Configure dialog box.

11. With the number of points displayed in the transient window set to the maximum, use the following procedure to check that all signals decay away within the transient display/capture window; otherwise adjust the duration in the TRECSCAN Configure dialogue box and press 'Apply'.

- Switch to the 'specimen' or 'Ref In Air' transient (should be zero when probe is isolated in air and a negative going 'pulse' which decays at longer times when the probe is on a specimen).
- Check that the number of points displayed in the 'transient display' window is set to the maximum.
- Increase the gain in the 'transient display' window to between 100 and 500.
- Verify that the transient with the probe <u>on the thickest part of the specimen</u> is effectively decaying to zero (i.e. below the noise level) before the end of the transient duration (ie before the end of the 'transient display' window when set at the maximum number of points). If the transient signal does not decay to zero, increase the sample duration and repeat steps 5 thru 8 (and re-measure the in-air transient).

<u>NOTE</u>: *Step 9 is checking to see whether the transient signal resulting from placing the probe on the thickest part of the specimen has decayed to zero before the end of the transient 'duration'. The question is how we define that the effect is 'finished'. We are defining it by saying that the transient has to have decayed 'into the noise' i.e. below the noise level.*



Example of a transient that does not decay into the noise before the end of the captured transient duration.

- If the specimen transient is decaying to essentially zero within the first half of the transient duration, the transient duration can be reduced.
- A compromise will generally need to be made for thicker specimens as the longer transient slows the update rate when scanning.
- The software includes an adjustment to partially correct the specimen transient for truncation due to insufficient duration (so the effects of using an insufficient transient duration are not as noticeable as they otherwise would be.)
- Switch back to 'Ref In Air' in the transient display window.

12. Close the Configuration dialog box and follow the instructions to acquire the in-air transient again.

13. Open a New scan using New in the File Menu and choose ‘Use defaults’ button.

14. Press Acquire in ANDSCAN toolbar and Scan around a bit on representative structure.

15. Put a box around that area on the screen and press Scale. This will adjust the colours for each time-slice.

16. Choose Lift-Off Setup from the TRECSCAN toolbar or menu, which is a ‘Wizard’ that takes you through the capturing of ‘Zero-in-air’, ‘Balance’ and ‘Balance-with-lift-off’ transients. (Appendix A contains information on how to do this if the Lift-Off Setup Wizard is unavailable.) This is important, as lift-off compensation will only be effective subsequently if this is performed for each scan.

    - Follow the instructions to acquire ‘Zero-in-air’, ‘Balance’ (on a good area of the specimen) and ‘Balance-with-lift-off’ transient signals. When required to place the probe on a ‘good’ part of the specimen, it Is best to choose a part with a thickness about as large as will be experienced during scanning. Introduce ‘lift-off’ by inserting a few sheets of paper between the specimen and probe.
    - When the Lift-off Compensation Setup window is opened automatically, with Real-time Cumulative Averaging checked, a procedure should be followed to obtain a good lift-off setup.
    - Both curves (black - measured and red - fitted) should be below the zero line (ie negative) and relatively well-behaved. Add enough lift-off to put the black curve at about 20% of the full negative scale. If there is a kink in the black (measured) curve (greater than about 10% of the deviation of the black curve from the zero line) then go back to item 4 above and increase the rise-time as the drive system is nonlinear with the chosen rise-time.
    - The aim is for the red ‘fitted’ curve to follow the black ‘normalised and balanced’ transient signal for different amounts of lift-off.
    - This is achieved by adjusting the ‘Max Measured Points’ to exclude the noise-effected right-hand tail of the transient, and then by pressing ‘Measure Now’.
    - To check that this is satisfactory, uncheck the ‘Cumulative Averaging for Improved Measurements’ check-box. Then manually vary the amount of lift-off and check that the red curve fits the black well. If the red curve does not follow well, then re-check the ‘Cumulative Averaging for Improved Measurements’ check-box and press ‘Measure Now’ again.
    - You will be asked whether to store the lift-off values in the INI file and you should agree to do this.
    - Finally close the Lift-Off Compensation setup dialog box.

17. Consider using ‘Averaging Scan Mode’ if points on the scan are likely to be passed more than once and you want to average the transient with previously-stored transients.

18. Perform the scan, saving at regular intervals in case of crashes. ….

19. Two files are saved, one by ANDSCAN containing the ANDSCAN display and channel bitmaps in ANDSCAN file format, and the other by TRECSCAN containing the 16-bit transient data. Save the first (ANDSCAN) file with a .edd extension and answer Yes

when asked to store the TRECSCAN 16-bit transient data too (this will be stored in a .tre file with the same filename as the .edd file)

20. When the .edd file is opened at a late date, TRECSCAN will search for the .tre file of the same name and ask if you want to open it. Answering No will mean that the transient data will be unavailable.

2. Analysis Instructions for Corrosion detection

You must balance if thickness modes are going to work properly.

1. Open the file and open the 16-bit transient data file too (when asked).
2. Turn on the Transient Display, check the ‘cursor’ check-box, move the mouse and check that the transient is a curve into a rising edge followed by a curve to a flat top.
3. Draw a box over a good region and press ‘Balance In Box’.
4. With the Transient display on, and after balancing, check that the tail-end of the balanced transient goes to zero. If not, then there was something happening at acquisition time. The two possible causes are: static electricity building up between two plastic surfaces (eg a plastic coating on the specimen and a PTFE layer on the probe); or something applying pressure to the Hall device. To avoid these it is best to cut a central hole in any PTFE tape.
5. In ‘Measure’ select the time-slice channels, up to about time-slice 8, plus the total thickness and thickness change (relative to the balance point) channels. You may want Time-to-peak too. Click OK to come out of the Measurements dialog box.
6. Use ‘Scale’ on a box on the scan if you have lost the colours at this stage. This will get the colours right on all the channels. **If Scale does not work for thickness mode, it is probably because you have not balanced!**
7. You will need a spot size of about 4 mm and will need to set the Redraw Mode (Display/Redraw Mode) to Average, and press Redraw, to get a smoothed image. In reality eddy-currents smooth by this amount anyway!
8. Go through the time-slice channels and check there is not too much noise.
9. For deeper time-slices the image will be less noisy with Lift-off compensation ON, but earlier time-slices become noisier.
10. The total thickness and thickness change channels should be investigated with lift-off compensation, and without, as this can sometimes improve noise and sometimes make it worse.
11. The thickness mode channels are calculated using the long-time transient data where there is a lot of noise. In the Measurements dialog box a threshold can be set for thickness modes to prevent the use of the transient when it falls below a certain proportion of the peak balanced transient. The threshold values are in thousandths of full scale transient signal, so 20 corresponds to 2%. A higher threshold gives a less noisy image but less accurate thickness values.
12. Check that you have balanced on a good region and go to thickness change mode. This will show percentage changes in thickness relative to the balance point. Don’t forget this will show structural changes too.
13. If you want to remove structural changes such as edges, you can use the **Edge Subtraction** tool. Press Define Edge and click left on points that define the edge which can include a gentle curve. Click right when finished. The edge subtraction will not take effect until a balance transient has been determined for each distance from the defined edge. Select a balance box, preferably excluding fasteners, structural changes etc, that covers all the distances from the edge that are required. Press Balance in Box and you will be asked whether “Reject points at/near fasteners?”. If you answer Yes then the

software will attempt to identify fasteners (based on lift-off signals) and will ignore these areas. Answer No if there are no fasteners in your selected box. When balanced, the Subtract Edge check box should be checked and the scan should be edge subtracted.

14. To show a Time-to-Peak scan, select this mode in one of the channels in the Measurements dialog box. Then select the Time-to-Peak reject threshold level in the same dialog box. This is in units of 1/10,000ths of the full scale transient signal and sets the reject threshold.

    Note: *If the peak of a balanced transient does not exceed this reject level then the Time-to-Peak scan will display a high value by default.*

15.

16.

3. Analysis Instructions for Crack Detection

4. Defect Sizing

1. This defect sizing method is based on the –6 dB drop method (see Appendix D) commonly used in ultrasonic inspection of flat defects. The principle is that the probe should be directly over the edge of the defect when the signal drops by 6 dB, if the edge is straight.
2. In order to implement the method correctly, it is assumed that the bottom of the ANDSCAN 8-bit amplitude scale is at the 'reference level' – ie the lowest signal. If the signal increases over the defect then this reference level is the level of the good material around the defect. If the signal decreases over the defect then the reference level is that from the centre of the defect.
3. The bottom of the 8-bit ANDSCAN scale can be set to the reference level as follows:
   - Draw a box around the defect.
   - Check Trecscan/Scale Mode is set to 95%
   - Press Scale (button or TRECSCAN menu item).
   - Draw a box over a representative region at the 'reference level'
   - Check Trecscan/Scale Mode is set to 'Mean To Bottom' which will ensure that the next time Scale is pressed it will just shift the reference level to the bottom of the ANDSCAN 8-bit scale.
   - Press Scale (button or TRECSCAN menu item).

   The scale should now have the reference level at the bottom.
4. For –6 dB width or Area measurements a 'Background' level is required from which the –6 dB threshold is determined. This is the greatest of the level in the centre of the defect and the level in the good material around the defect.
5. Draw a box in a region of the 'Background' level and press menu item Analysis/Average Background.
6. Then draw a box around the whole defect plus some of the good region around it and press menu item Analysis/-6dB Area. The area will be reported in the Measurements Box of ANDSCAN.
7. Similarly, having done an 'Average Background' measurement, press –6 dB Width. The following instructions explain how to continue:
8. A window showing the profile along the defined diagonal, is displayed together with the background level, -6dB level and intersection points with the -6dB level. The -6dB width is the distance between the two crossings (vertical lines) and if accepted, by choosing OK, the value measured is displayed in the measurement window. Each –6dB measurement written to the measurement window is numbered so that multiple measurements can be distinguished between.
9. The following instructions explain how to adjust the measurement in the –6 dB width box if necessary.

Best Fit:
This is the default option, the –6dB width estimation being calculated automatically. The number of data points used to fit a line to find the crossing point can be determined by the slide bar on the left hand side of the dialog box. This defaults to 8 but can be varied between 1 and 100, the more points used, the greater the accuracy in general. However the points should all be part of the main slope at the edge and should exclude changes of slope.

Where the defect edge is not a simple slope, however, for example where a stepped slope occurs, the following options may be considered preferable.

Actual Crossing:
Ignores the lines of best fit and just uses the actual points where the 6dB level is crossed.

Manual:
Allows the user to manipulate the crossings (vertical lines) to manually set the width.

Appendix A Manual lift-off compensation Setup (if Lift-Off setup Wizard unavailable)

1. Pause acquisition in ANDSCAN
2. Hold the probe in air
3. Press the Average button and wait a few seconds
4. Press the “Zero in Air” button on the TRECSCAN Toolbar and follow the instructions
5. Toggle the Average button OFF

6. Put the probe onto a representative part of the specimen
7. Press the Average button and wait a few seconds
8. Press the Balance button on the TRECSCAN Toolbar
9. Toggle the Average button OFF

10. Add a few sheets of paper under the probe to give representative lift-off
11. Turn on the Normalised and Balanced Transient display in the TRECSCAN drop down menu.
12. Select the Display check-box on the Normalised and Balanced Transient display, to show the lift-off curve in red
13. The red lift-off curve needs to be fitted the black real-time one as follows:
14. Click Setup button.
15. Set Range (pts) in the Normalised and Balanced Transient display window to 100(?)
16. Select the Use Measured Lift-off' check-box in the Lift off Compensation Settings window.
17. Adjust number of Max Measured Points to exclude noise but have as many points up to the noisy part
18. Press the Average button and wait a few seconds
19. Push Measure Now in the Lift off Compensation Settings window.
20. Toggle the Average button OFF

21. Check the fit by varying the probe lift-off and repeat the Measure Now process if the red lift-off line does not fit tightly to the black real-time transient line.
22. When asked whether to store this in ini. file select OK.

Appendix B Instructions for determining detectability threshold for thinning

1. Load .tre file (Small, Medium and Large probes, scans 1,2,3,4,5,6,7,8,9,12 & 13.)

2. Turn on Lift-off compensation

3. Increase spot size to 5 mm

4. Check that Display/Redraw Mode is on Average

5. Draw a box over thinning region and press Scale button on TRECSCAN toolbar

6. Draw a box on a region with no defects and press Balance button in TRECSCAN toolbar

7. Turn on the Transient Display, increase gain to around 20

8. Go to Time-slice Mode and select a time-slice near the peak of the transient over an area of corrosion.

9. This should show all the defects within the scale but if there are regions of all black or all white then adjust the colour scale to ensure this is not the case. When happy, press Remap to go back to the 16-bit transient data to redraw the raw data bitmaps and the screen image with the best data.

10. Histogram data is needed from the centre of each defect and a reference region near it. This should be copied into Excel using the clipboard. The procedure is as follows:

11. Work down in columns from the top-left defect. Put a small box in the centre of each defect. For the first one in each column COPY the histogram measurements to the clipboard. For the subsequent 4 defects APPEND the Histogram measurements into the clipboard. Then ALT+TAB to Excel spreadsheet and Paste the data in the appropriate column. Repeat for a column of reference data. Then continue until 10 columns are full.

12. Then copy the spreadsheet and start the next scan. One Workbook (file) for each probe, one worksheet for each scan.

13. It may be worth changing the Display/Redraw Mode to Average and repeating this exercise to see whether the detectability is different.

14. Within Excel the standard deviations are used to give the noise level whilst the difference in the mean values gives the signal. The signal-to-noise is plotted as a function of amount of thinning for each defect size and the detectability is the amount of thinning giving a signal-to-noise ratio of 2:1.

Appendix C Instructions for calibrating TRECSCAN output current

1) When using a NI card:

From Desktop run ‘NI Measurement and Automation’, double-click on ‘devices and interfaces’, right-click on the correct card, choose ‘Test panel’.

Tab: Analogue Output

DC voltage = 1V
Output mode = DC Voltage
NB: you must remember to press ‘Update Channel’

Tab: Analogue Input

Channel No. = 0
Input limits = +\- 10
Data mode = strip chart
Y-scale mode = Autoscale

Switch on TRECSCAN box and probe

Record average reading and switch box off immediately.

Shut down ‘NI Measurement and Automation’

Go to 3).

2) When using a DT card:

Run CEXMPL32.EXE

Menu: Configure/Board

Choose correct board

Menu: Configure/Input

Interface Mode: Differential
Clock Source: Internal
Trigger Source: Internal
Range: +/- 10V
Encoding: Offset Binary
Triggered scan: Uncheck

Menu: Configure/Output

Interface Mode: Differential
Clock Source: Internal
Trigger Source: Internal

Range: +/- 10V
Encoding: Offset Binary

Menu: Single Value/ Analogue IO

Input: Channel: 0
Input: Gain: 1.0

Output: Channel: 0
Output: Channel: 1.0

Value: 1.0
Press: PUT.
Press: GET repeatedly until value stabilises.

Record value and switch box off immediately.

Shut down CEXMPL32.EXE

Go to 3).

3) Start ANDSCAN

Go to TRECSCAN, 'Enable data acquisition'.

In 'TRECSAN configuration' go to 'Configure acquisition'.

System ID = Trecscan MkIII
No. of field channels = 1
H Field channel no. = 7
Current drive channel no. = 0
Use D/A waveform generation
Monitor digital I/P warnings
Output Calibration (A/V) = Value obtained from 1) or 2) divided by 10.

OK

Appendix D -6 dB Width and Area.

–6 dB Defect Area Measurements

The -6 dB area is defined as the area over which the ultrasonic reflection amplitude is attenuated by more than 6 dB of the maximum signal reflected from either the defect or the back surface, depending on the type of signal gating in use.

Definition of attenuation in decibels

A 'decibel' is defined as one-tenth of a 'bel', a unit of sound intensity. It is a measure of power ratio, based on logarithms to the base ten, and may be expressed as a gain or loss; it does not express absolute values, but by having a datum of reference we can express absolute values in decibels, up or down from this datum. The fact that they are logarithmic means that they can be added, although the powers they represent are multiples.

A gain of -6 dB corresponds to an amplitude (or acoustic pressure) ratio of 0.501 and a power (or intensity) ratio of 0.251.

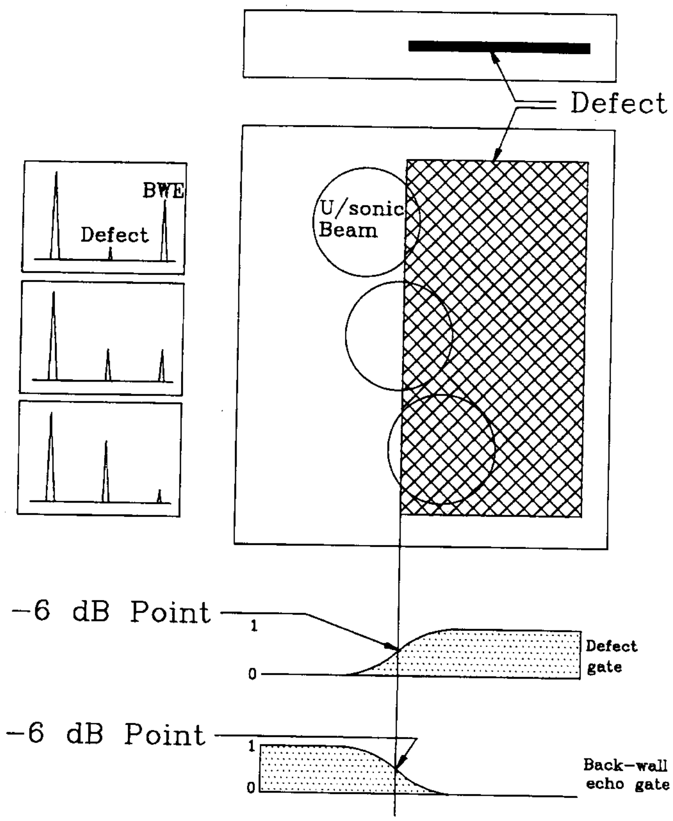


Figure E1. Illustration of how the -6 dB point corresponds to the position of a straight defect edge.

Back-surface signal attenuation
Straight defect edges

When a plane-wave ultrasonic beam crosses a straight edge of a defect, which itself transmits no ultrasound, the amplitude of the ultrasonic echo from the back surface of the material will reduce by a factor of two (ie approximately 6 dB) when the centre of the beam is directly above the edge, if diffraction effects are assumed to be negligible. An accurate positioning of the edge will be possible providing the following conditions are met:

1. The ultrasonic beam is a cylindrically-symmetrical plane wave.
2. The signal reflected from the defect does not appear in the back-surface echo gate.
3. The back-surface signal around the defect is uniform enough to obtain a good background reading.

Thus, the -6 dB point is a good method of determining the defect edge, and the 6 dB area is the best method to assess defect size without a detailed knowledge of the ultrasonic beam profile (28).

Curved defect edges

If the edge of the defect is not straight, then the above statement does not hold. For a convex edge of a defect the -6 dB point will be inside the defect boundary and the area will be underestimated. Thus, the smaller the defect, the more the -6 dB area will underestimate the true area.

A simple theory illustrated in Figure E2 (**Error! Reference source not found.**), modelling the defect and the ultrasonic beam as overlapping discs, has produced the theoretical curve in Figure E3. Also shown are experimental points using two different ultrasonic probes and effective ultrasonic beamwidths. In each case the effective beamwidth is the value which optimised the fit of the experimental data to the theoretical model if the ultrasonic beam were assumed to be a uniform plane wave over a circle, surrounded by zero amplitude. In fact, as measurements were made at one-fifth of the distance to the last-axial-maximum in the transducer field, this is a reasonable approximation.

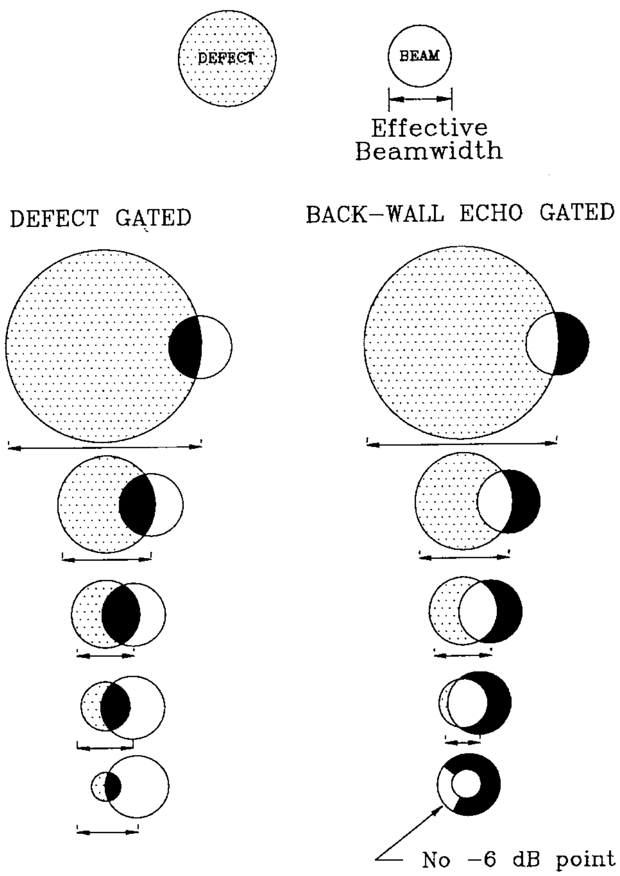


Figure E2. Illustration of how the simple disc theory predicts an over-estimation of -6 dB width and area for defect-gated scans and an under-estimation for back-wall echo-gated or through-transmission scans.

Defect-gated signal attenuation

Straight defect edges

When a plane-wave ultrasonic beam crosses a straight edge of a defect the amplitude of the ultrasonic echo from the defect itself will reduce by a factor of two (ie approximately 6 dB) when the centre of the beam is directly above the edge, if diffraction effects are assumed to be negligable, and providing the following conditions are met:

4. The ultrasonic beam is a cylindrically-symmetrical plane wave.
5. The defect is large enough to reflect the complete ultrasound beam when it is over the centre of the defect.
6. The defect has uniform reflectivity.

The defect is either flat and in a single plane or, if it is spread over several different depths, then a Depth Amplitude Correction (DAC) or Time Corrected Gain (TCG) system must be used to remove the attenuation effects of the propagation medium.

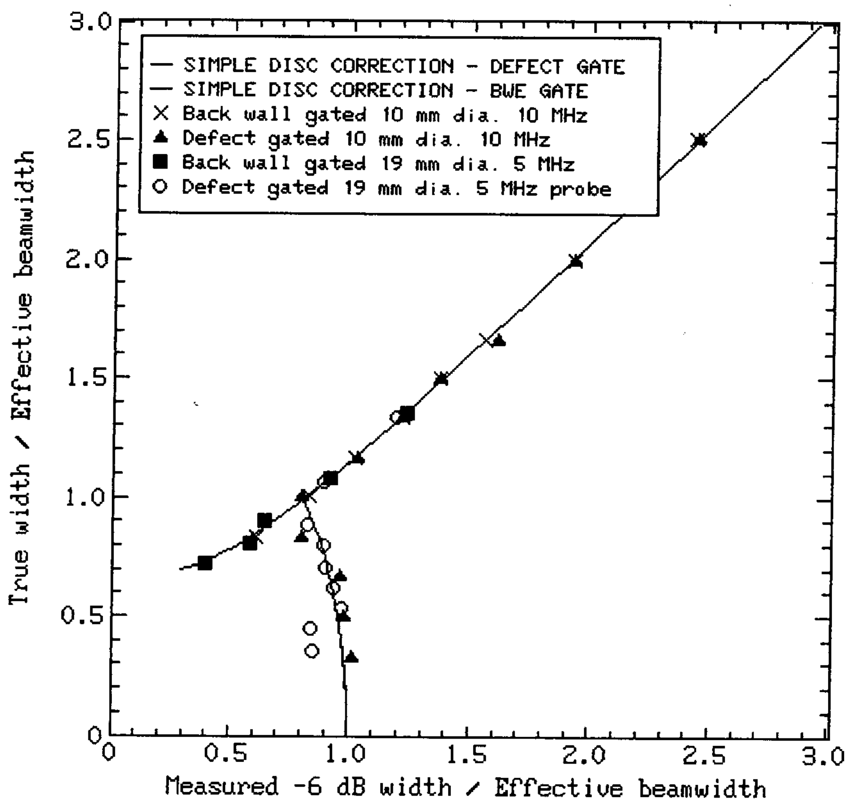


Figure E3. Simple disc theory for -6 dB defect width measurements showing experimental measurements from the plane-wave region of two planar transducers.

Curved defect edges

The same conditions apply as for straight defect edges (see above) but in addition there will be other complications. As for the back-surface signal attenuation, if the edge of the defect is not straight, then the above statement does not hold. For a convex edge of a defect the -6 dB point will be inside the defect boundary and the area will be underestimated. This would cause an underestimate of the true area as the size of defect reduces. However, the maximum signal from a defect which is smaller than the ultrasound beam will be smaller than from a complete reflection of the beam and the size of the ultrasound beam will be measured instead, thus counteracting the above underestimate for small defects. The smallest defect size that can be measured with reasonable confidence is probably twice the ultrasonic beamwidth.