Appendix A

SAFT-UT Images of the Most Significant Flaws

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SAFT-UT Images of the Most Significant Flaws

The SAFT-UT images display the vessel's axes and list the material coordinates rather than the scanner coordinates. The units in the images are given in inches, as determined by the software, and displays in metric units are not available at this time. Metric units are given in the text whenever possible.

Planar Indications in the Near Surface Weldment

Figures A.1a-d show planer indication #1 in the near surface weldment. This plan indication has a through-wall extent of 8 mm based on different depth estimates of 10 to 18 mm. The detections were made in modes 0, 1, and 4. In the mode 4 inspection, the indication had isolated TOF shape at a depth of 18 mm. There was a confirmation in mode 5 at a depth of 15 mm. The wave packet width in mode 4 gives a smaller size of 3 mm. There is good evidence of coin shape in the end view of mode 4 and in the side view of mode 5. The indication is characterized as planar based on the coin shape in modes 4 and 5. The length is 13 mm and was made to LOS in mode 4. The width is 13 mm and was made to LOS in mode 5. The range of aspect radios (length/depth) of this indication is 1.6 to 3. The maximum amplitude-to-noise ratio is 8 (131 to 16). With an X coordinate of 8 mm, the indication is 2 mm from the HAZ. With Z coordinates of 10 to 18 mm, the indication is clearly below the cladding.

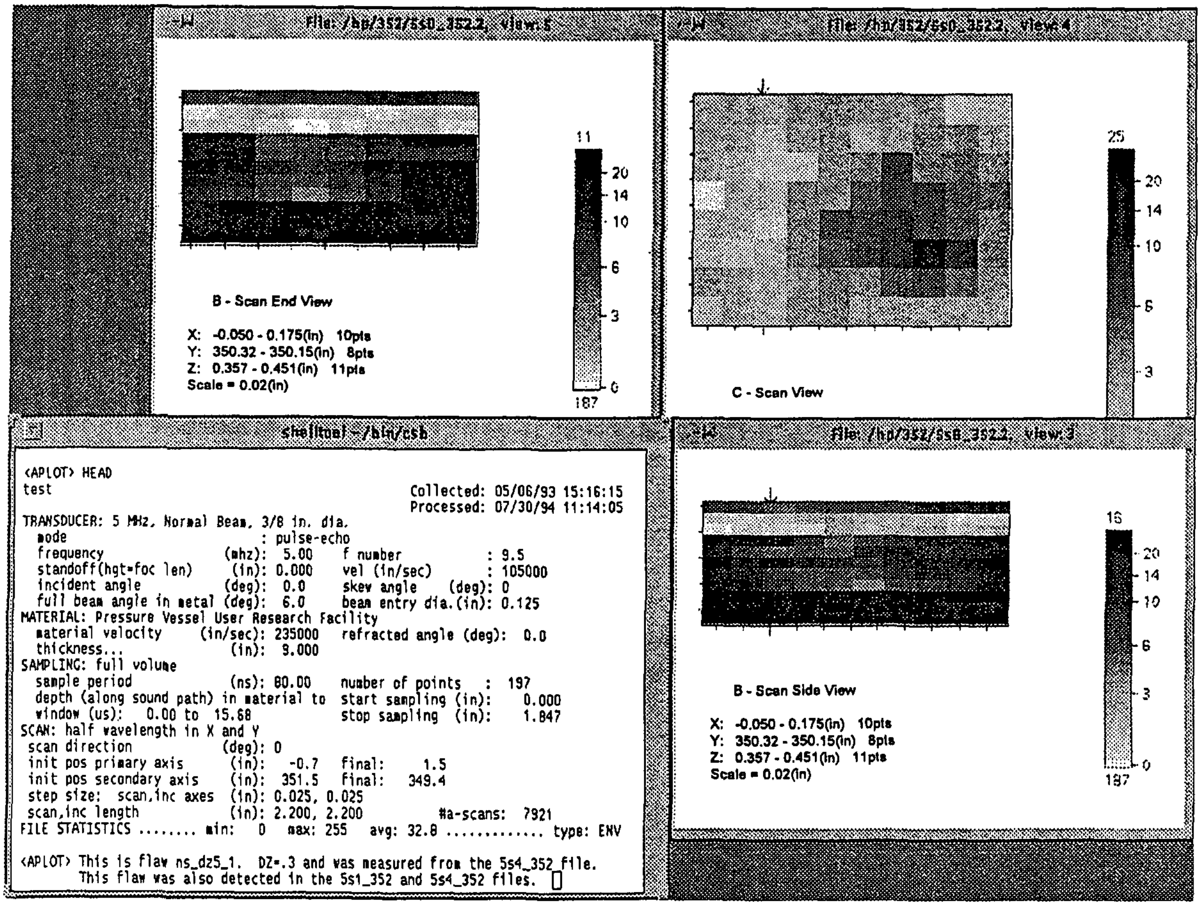


Figure A.1a Planar indication #1 in the near surface weldment: mode 10

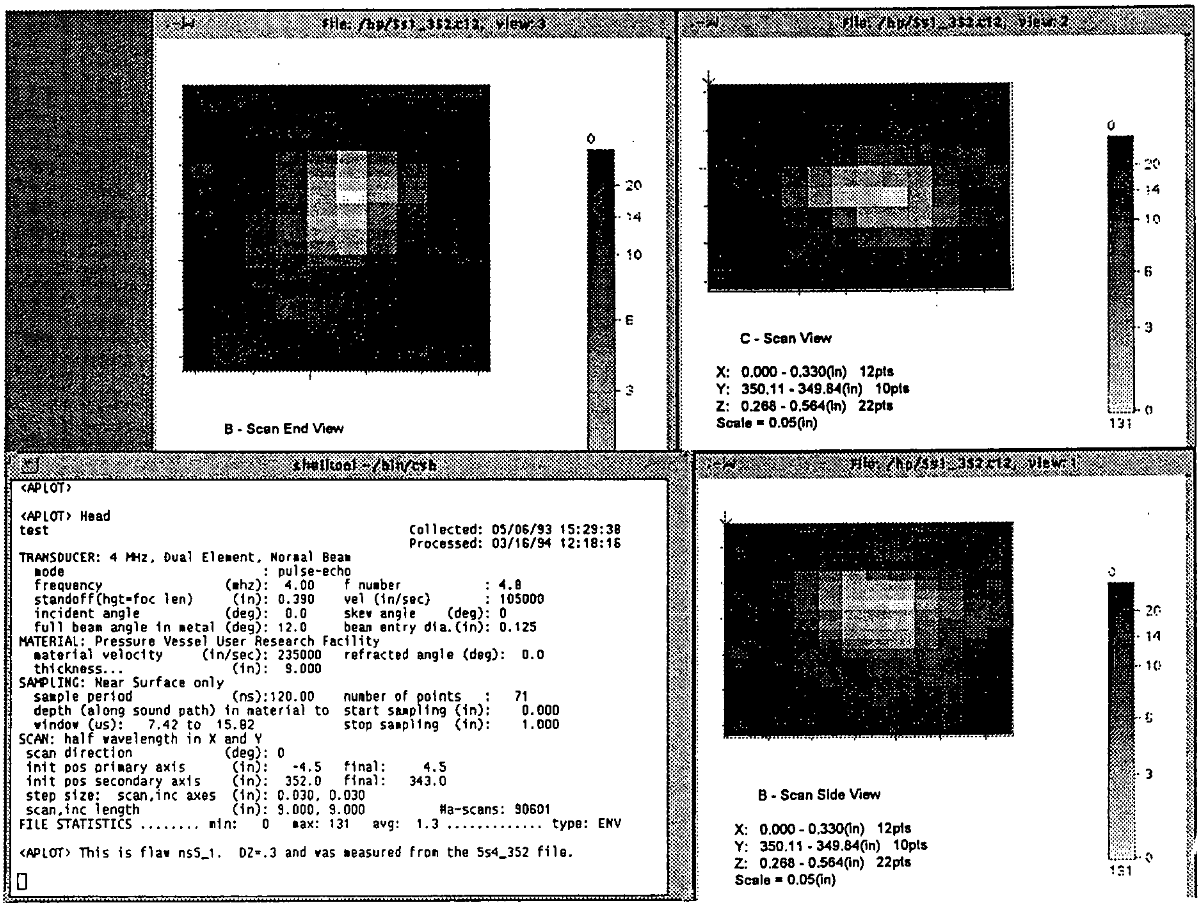


Figure A.1b Planar indication #1 in the near surface weldment: mode 1

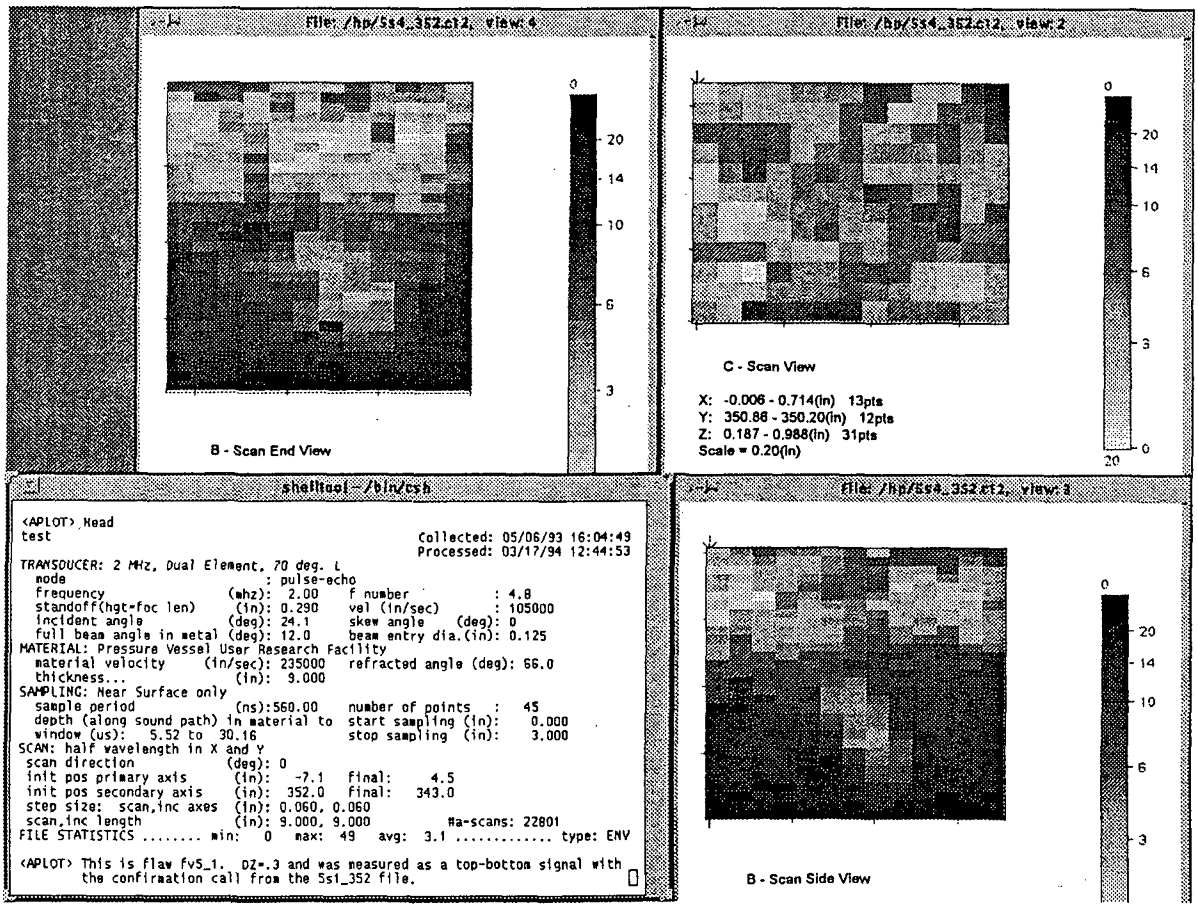


Figure A.1c Planar indication #1 in the near surface weldment: mode 4

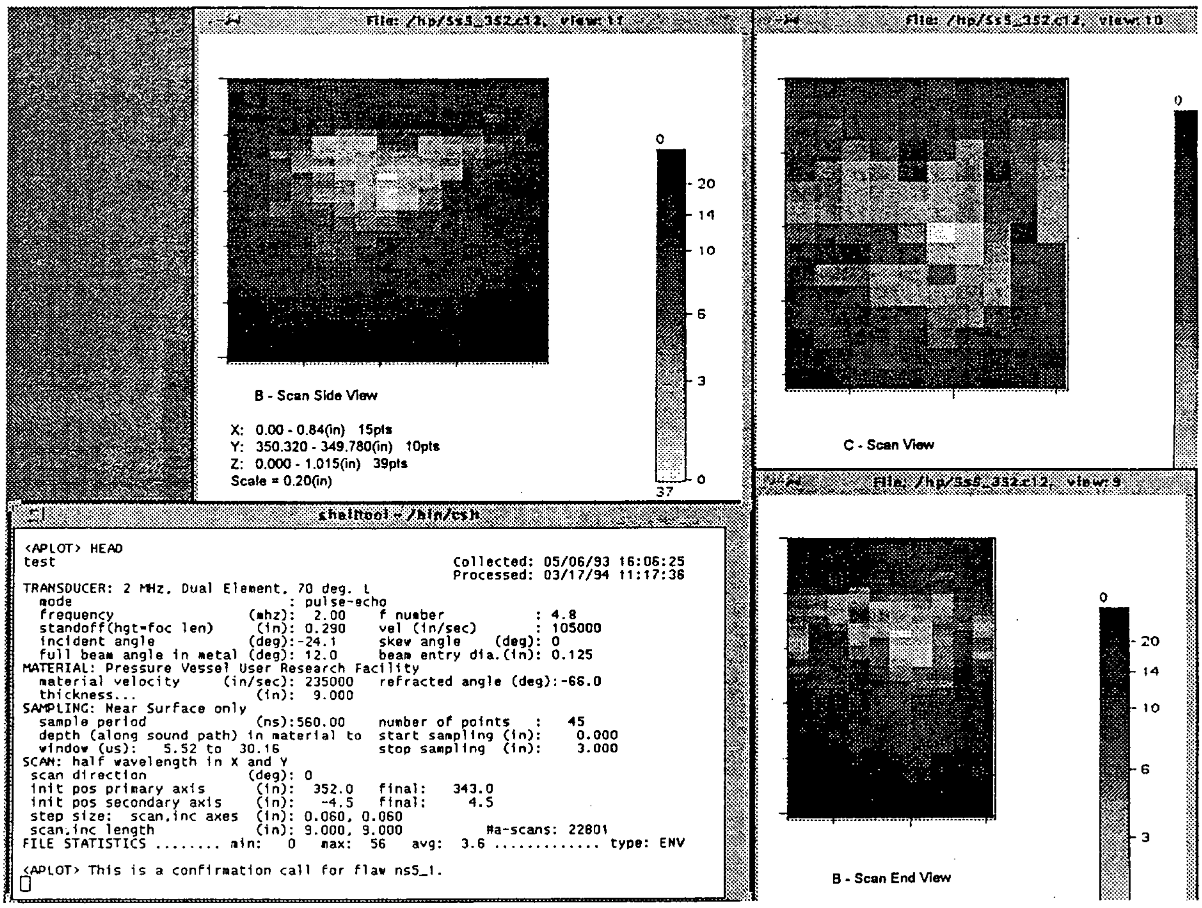


Figure A.1d Planar Indication #1 in the near surface weldment: mode 5

Figures A.2a-b show planar indication #2 in the near surface weldment. This planar indication has a through-wall extent of 6 mm based on different depth estimates of 12 to 18 mm. The detection was made in mode 5 where it had isolated TOF shape at a depth of 18 mm. There was a confirmation in mode 3 at a depth of 12 mm. The wave packet width in mode 5 gives an alternate size of 2.5 mm. The indication is characterized as planar based on lack of normal beam detection. There is no evidence of coin shape in the side view of modes 3 or 5. The width is 7 mm and was made to LOS in mode 5. The range of aspect ratios (width/depth) of this indication is 1 to 3. The maximum amplitude-to-noise ratio is high at 75 to 15. With an X coordinate of 8 mm, the indication is 2 mm from the HAZ. With Z coordinates of 12-18 mm, the indication is clearly below the cladding.

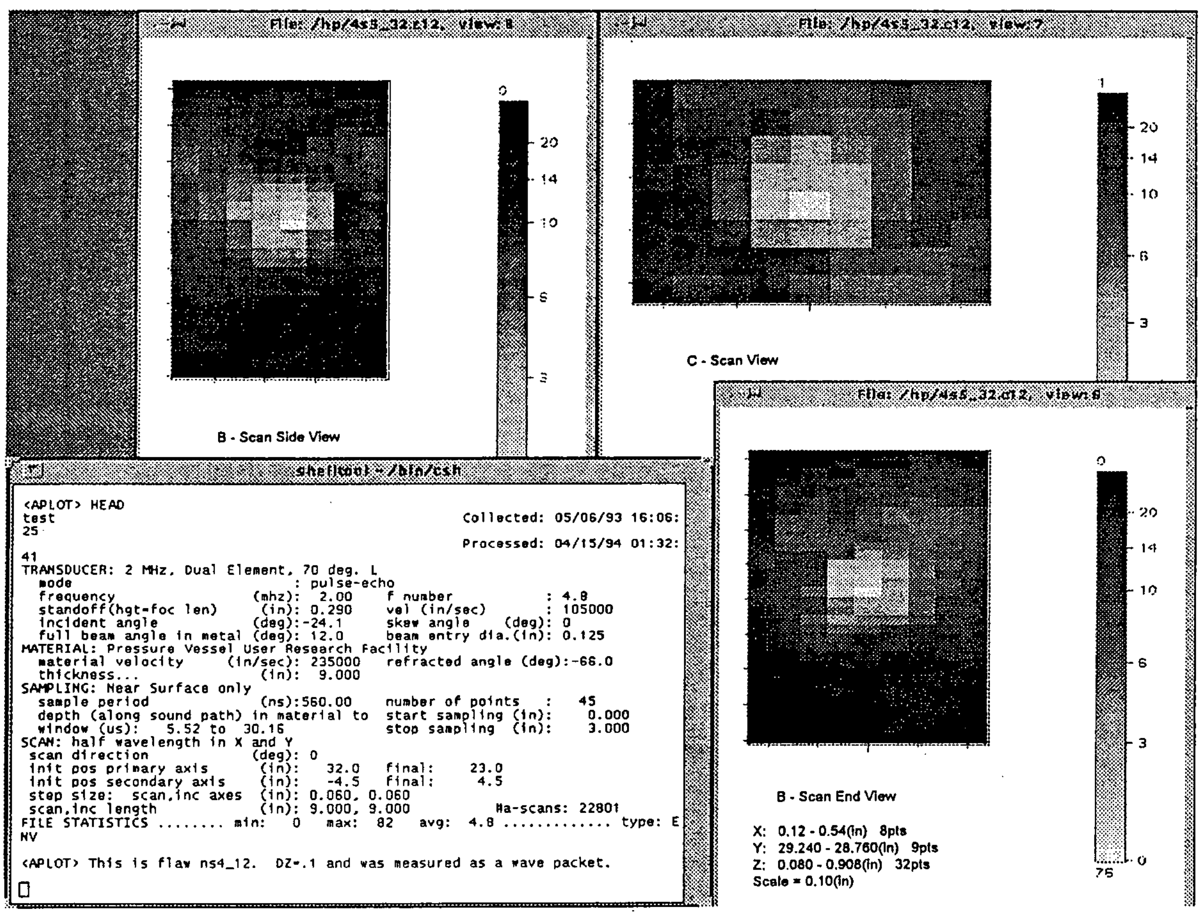


Figure A.2a Planar indication #2 in the near surface weldment: mode 5

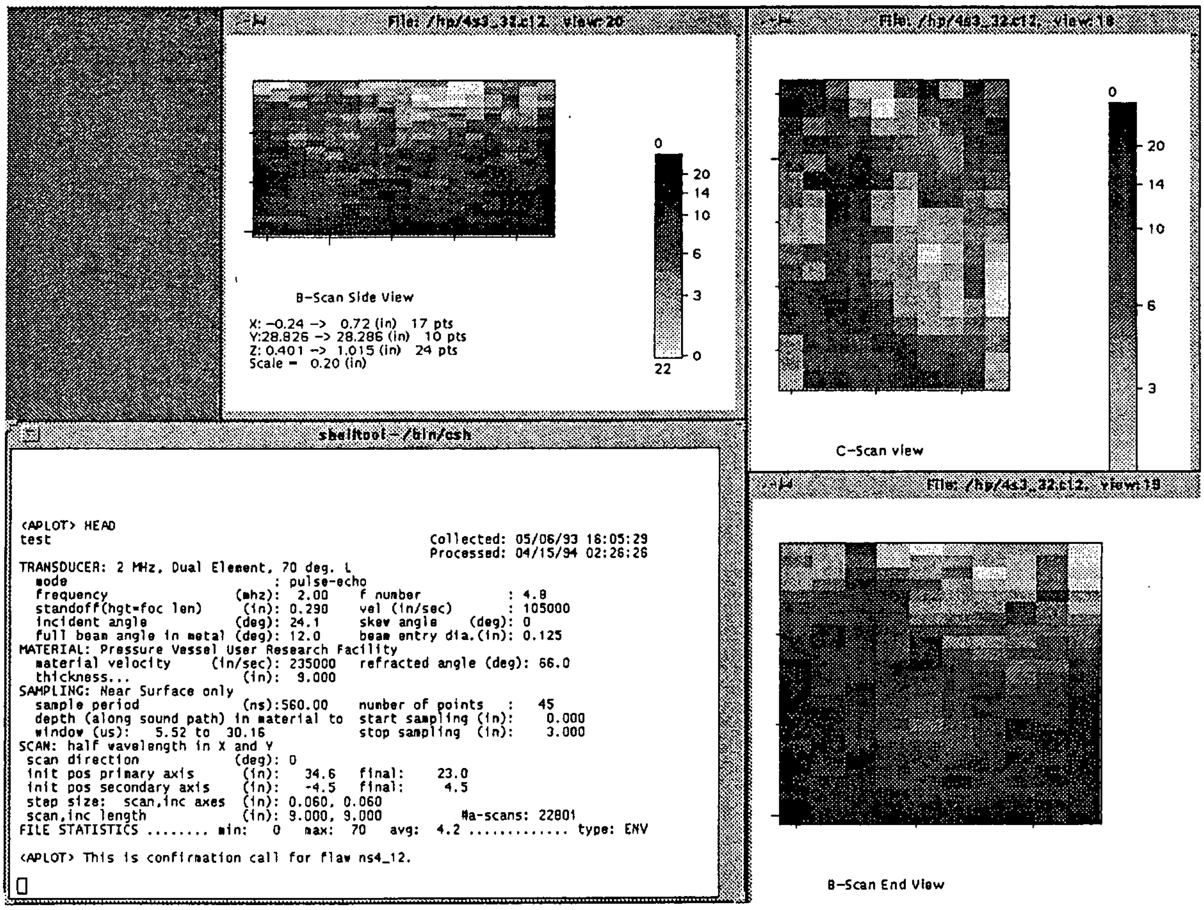


Figure A.2b Planar indication #2 in the near surface weldment: mode 3

Figure A.3 shows planar indication #3 in the near surface weldment. This planar indication has a through-wall extent of 3 mm based on wave packet width. The detection was made in mode 4 where it had isolated TOF shape at a depth of 21 mm. There was no confirmation in other modes and the indication is characterized as planar based on lack of normal beam detection. There is no evidence of coin shape in the end view. The length is 10 mm and was made to LOS in mode 4. The aspect ratio (length/depth) of this indication is 3 implying that it is probably oriented along the weld. The maximum amplitude-to-noise ratio is low at 13 to 6. With an X coordinate of -8 mm, the indication is 2 mm from the HAZ. With a Z coordinate of 21 mm, the indication is clearly below the cladding.

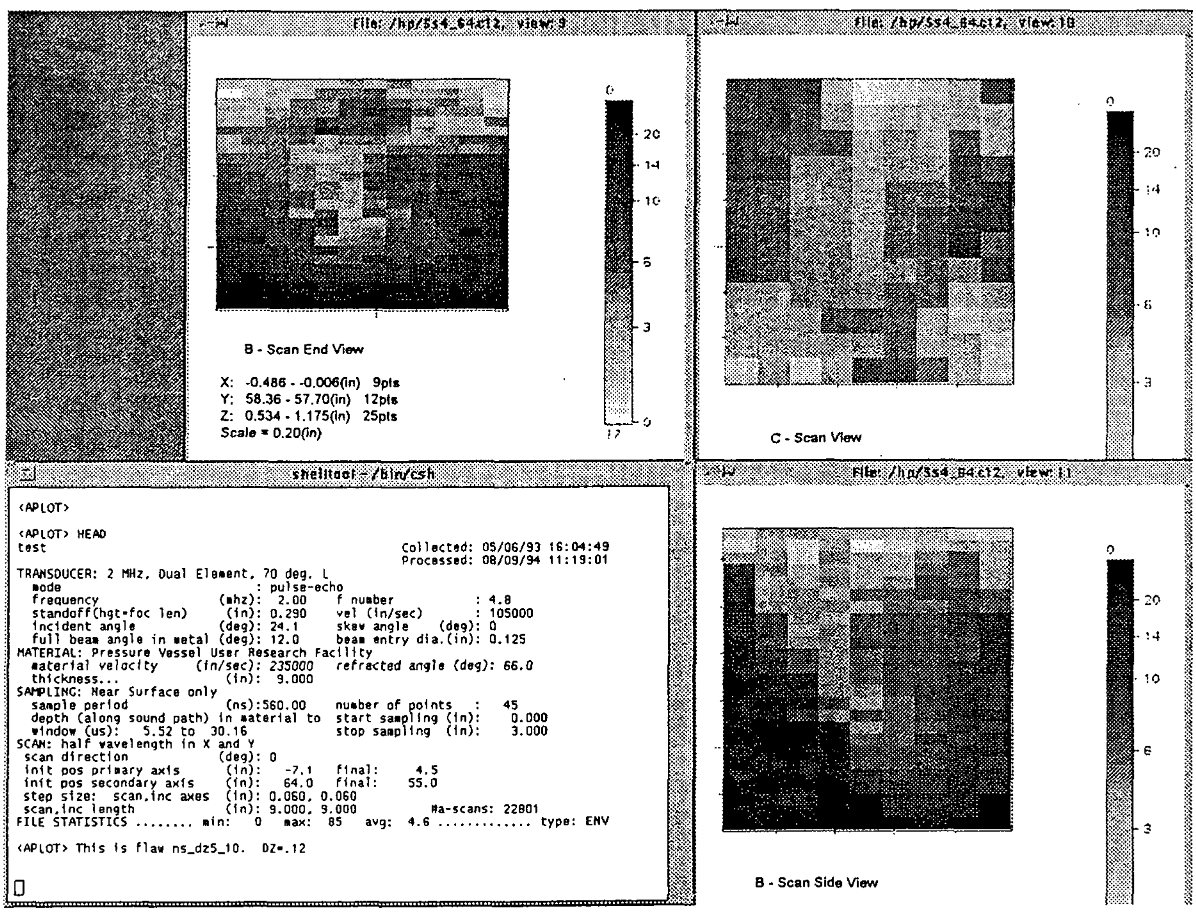


Figure A.3 Planar Indication #3 in the near surface weldment: mode 4

Figures A.4a-b show planar indication #4 in the near surface weldment. This planar indication has a through-wall extent of 3 mm based on different depth estimates of 16 to 19 mm. The detection was made in mode 4 where it had isolated TOF shape at a depth of 16 mm. There was a confirmation in mode 8 at a depth of 19 mm. The wave packet width in mode 4 gives an alternate depth size of 2.3 mm. The indication is characterized as planar based on lack of normal beam detection. There is some evidence of coin shape in the end view of mode 4. The length is 14 mm and was made to LOS in mode 8. The aspect ratio (length/depth) of this indication is 5 giving an orientation along the weld. The maximum amplitude-to-noise ratio is low at 25 to 12. The X coordinates of -4 to -8 mm show that the indication is 2 to 4 mm from the HAZ. The Z coordinates of 16 to 19 mm show that the indication is clearly below the cladding.

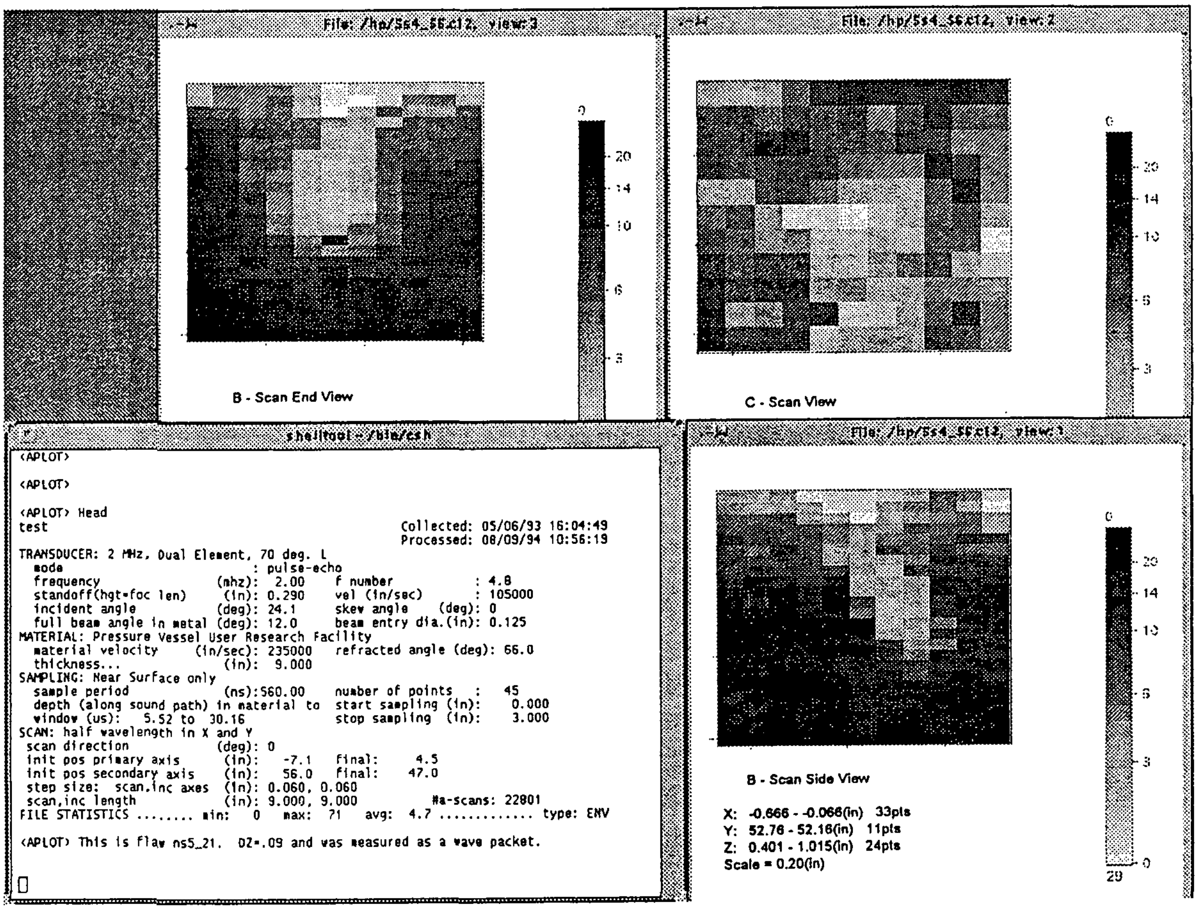


Figure A.4a Planar indication #4 in the near surface weldment: mode 4

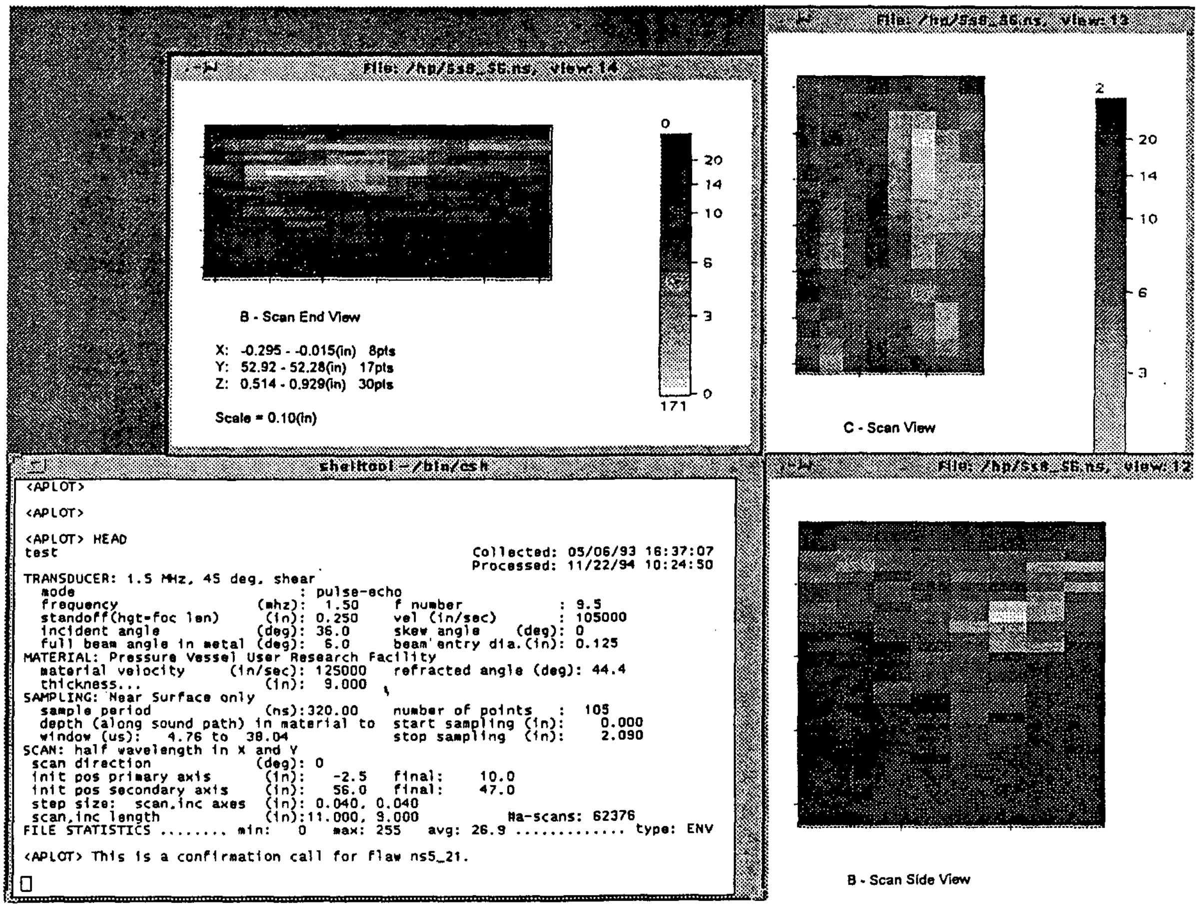


Figure A.4b Planar indication #4 in the near surface weldment: mode 8

Figures A.5a-b show planar indication #5 in the near surface weldment. This planar indication has a through-wall extent of 2.3 mm based on wave packet width. Detections were made in modes 2 and 4 where the indication had isolated TOF shapes at depths of 11 and 12 mm. The indication is characterized as planar based on lack of normal beam detection. There is some evidence of coin shape in the end view of mode 2. The length is 10 mm and was made to LOS in mode 2. The aspect ratio (length/depth) of this indication is 4 giving an orientation along the weld. The maximum amplitude-to-noise ratio is high at 63 to 12. With X coordinates of -6 and -14 mm, the indication is in the weld, possibly in the HAZ. With Z coordinates of 11 and 12 mm, the indication is clearly below the cladding.

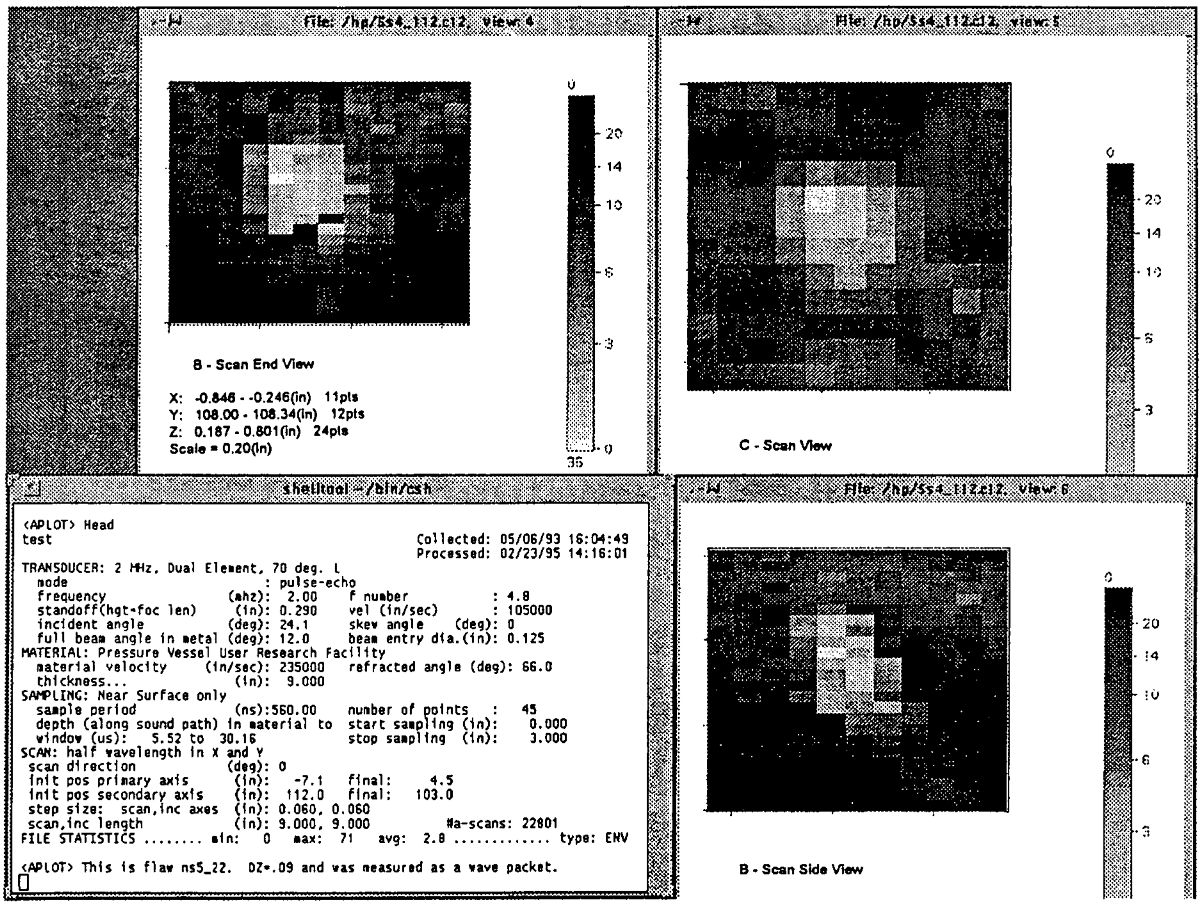


Figure A.5a Planar indication #5 in the near surface weldment: mode 4

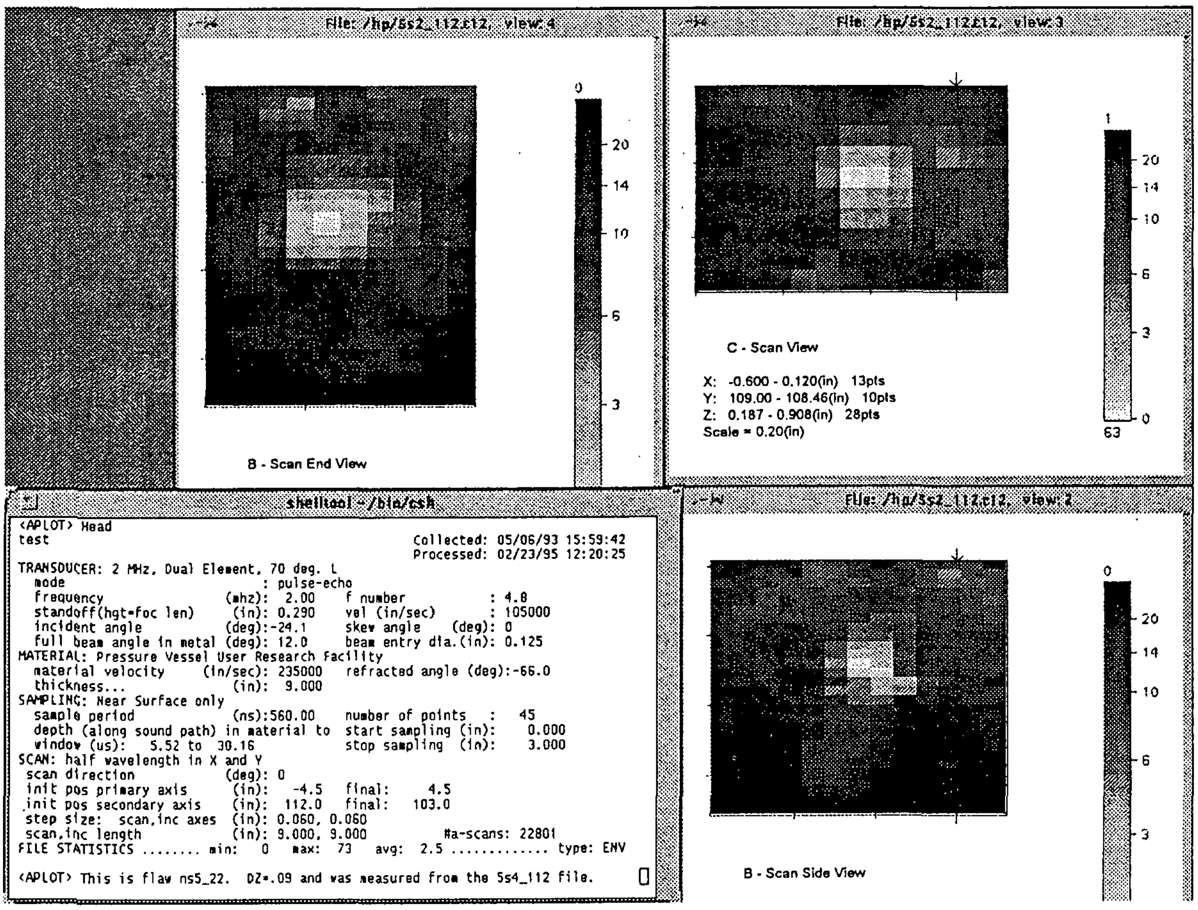


Figure A.5b Planar indication #5 in the near surface weldment: mode 2

Figure A.6 shows planar indication #6 in the near surface weldment. This planar indication has a through-wall extent of 2 mm based on wave packet width. The detection was made in mode 4 where it had isolated TOF shape at a depth of 16 mm. There were no confirmations in other modes. The indication is characterized as planar based on lack of normal beam detection. There is no evidence of coin shape in the end view of mode 4. The length is 9 mm and was made to LOS in mode 4. The aspect ratio (length/depth) of this indication is 4 giving an orientation along the weld. The maximum amplitude-to-noise ratio is of medium range at 18 to 6. With an X coordinate of -3 mm, the indication is clearly in the weld metal. With a Z coordinate of 16 mm, the indication is clearly below the cladding.

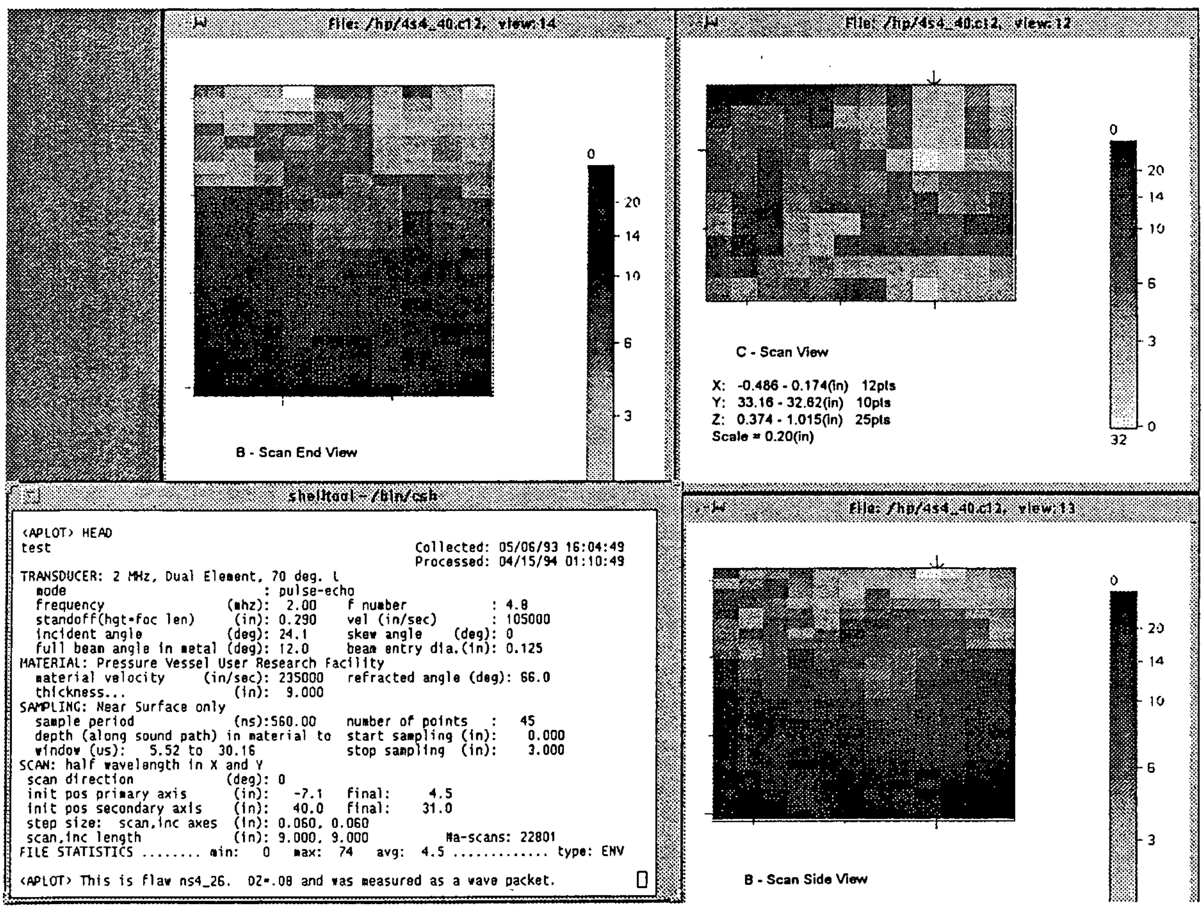


Figure A.6 Planar indication #6 in the near surface weldment: mode 4

Figure A.7 shows planar indication #7 in the near surface weldment. This planar indication has a through-wall extent of 2 mm based on wave packet width. The detection was made in mode 2 where it had isolated TOF shape at a depth of 15 mm. There were no confirmations in other modes. The indication is characterized as planar based on lack of normal beam detection. There is no evidence of coin shape in the end view of mode 2. The length is 11 mm and was made to LOS in mode 2. The aspect ratio (length/depth) of this indication is 5 giving an orientation along the weld. The maximum amplitude-to-noise ratio is high at 52 to 12. With an X coordinate of -6 mm, the indication is clearly in the weld metal. With a Z coordinate of 15 mm, the indication is clearly below the cladding.

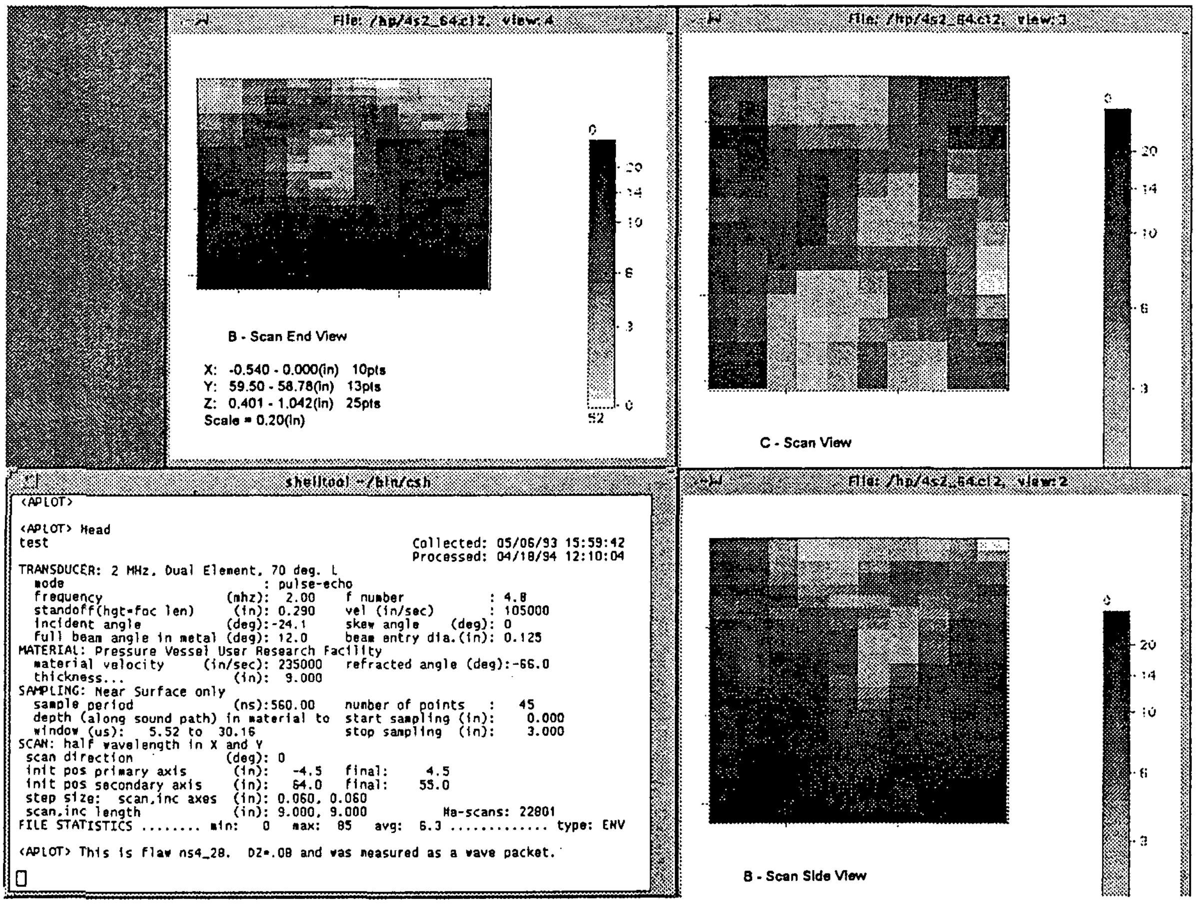


Figure A.7 Planar indication #7 in the near surface weldment: mode 2

Figure A.8 shows planar indication #8 in the near surface weldment. This planar indication has a through-wall extent of 2 mm based on wave packet width. The detection was made in mode 7 where it had isolated TOF shape at a depth of 23 mm. There were no confirmations in other modes. The indication is characterized as planar based on lack of normal beam detection. There is no evidence of coin shape in the side view of mode 7. The width is 10 mm and was made to LOS in mode 7. The aspect ratio (width/depth) of this indication is 5 giving an orientation across the weld. The maximum amplitude-to-noise ratio is of medium range at 69 to 28. With an X coordinate of 11 mm, the indication is in the weld, possibly in the HAZ. With a Z coordinate of 23 mm, the indication is clearly below the cladding.

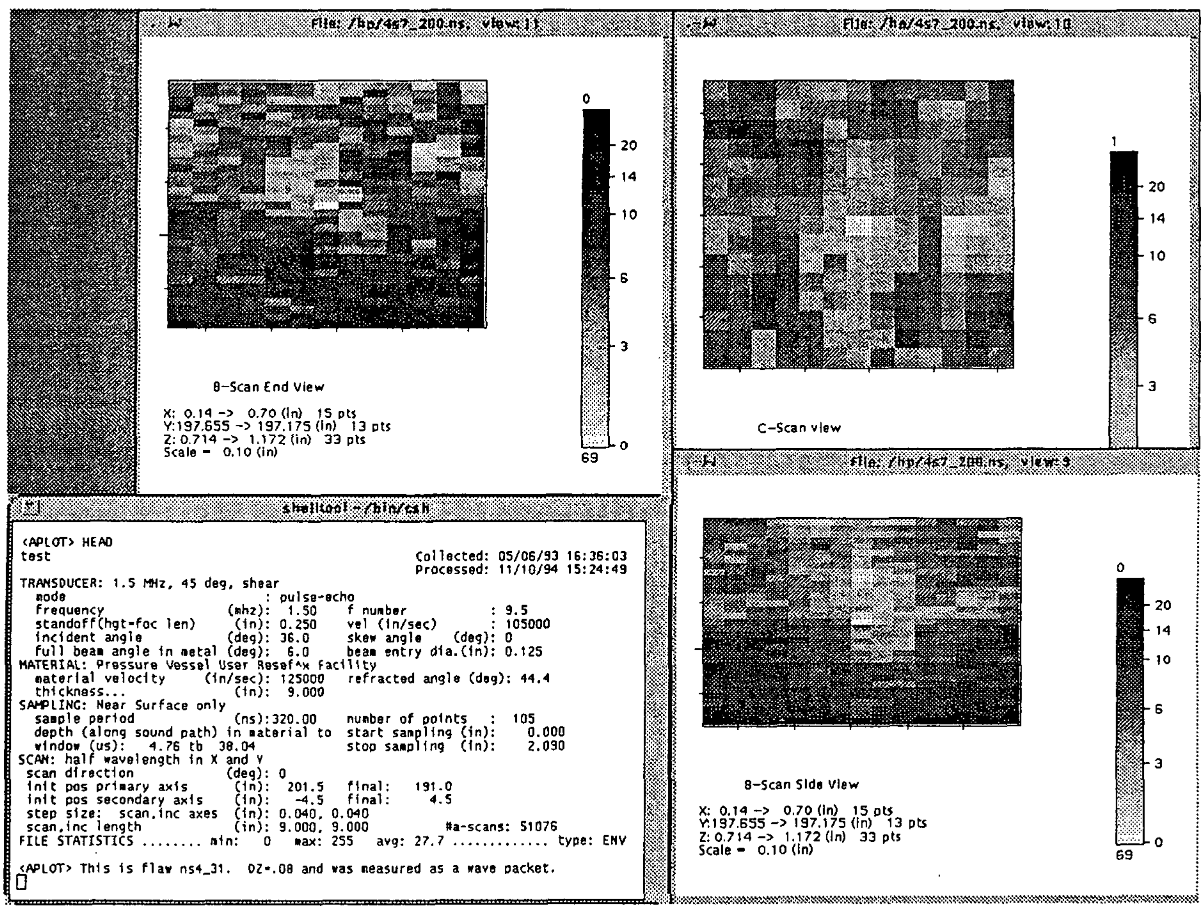


Figure A.8 Planar indication #8 in the near surface weldment: mode 7

Figure A.9 shows planar indication #9 in the near surface weldment. This planar indication has a through-wall extent of 2 mm based on wave packet width. The detection was made in mode 4 where it had isolated TOF shape at a depth of 24 mm. There were no confirmations in other modes. The indication is characterized as planar based on lack of normal beam detection. There is no evidence of coin shape in the end view of mode 4. The length is 11 mm and was made to LOS. The aspect ratio (length/depth) of this indication is 6 giving an orientation along the weld. The maximum amplitude-to-noise ratio is high at 16 to 3. With an X coordinate of 12 mm, the indication is in the weld metal, possibly in the HAZ. With a Z coordinate of 24 mm, the indication is clearly below the cladding.

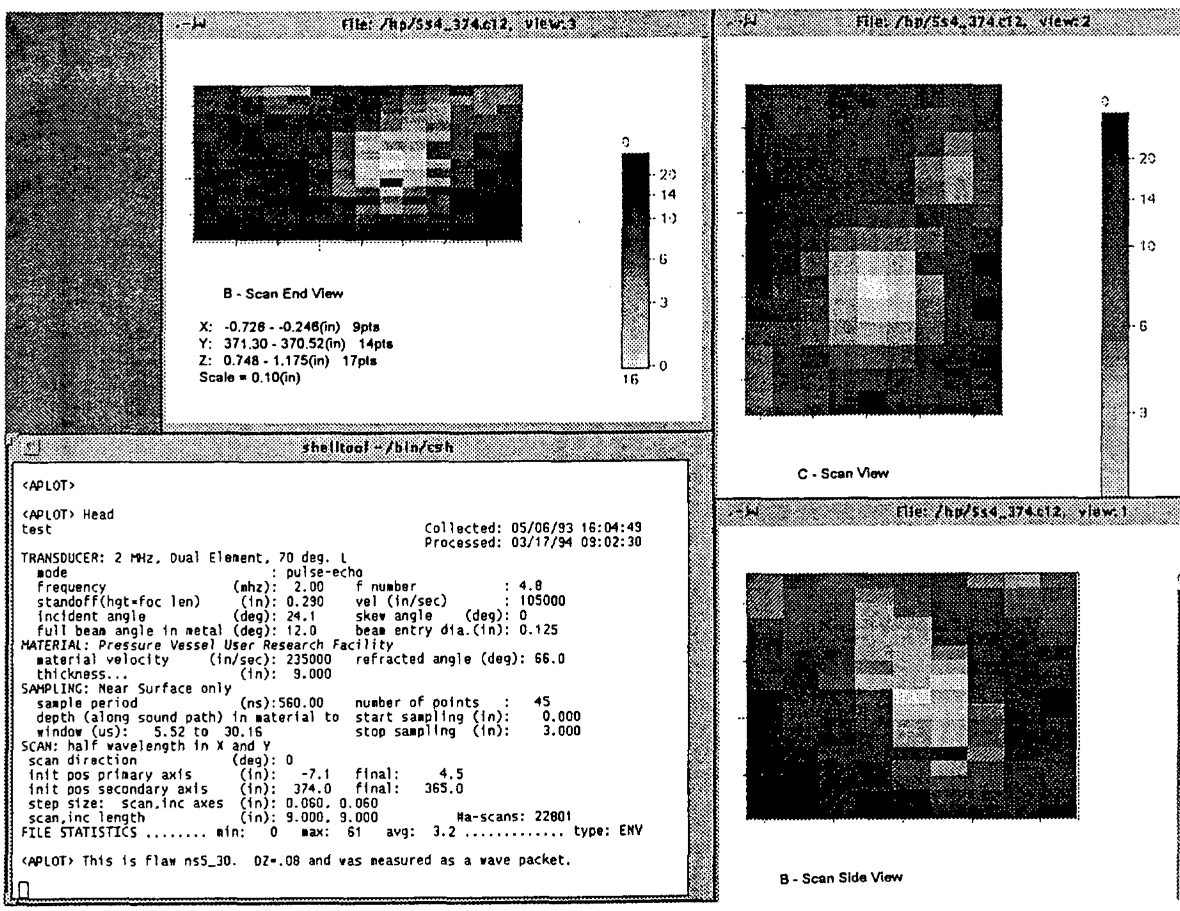


Figure A.9 Planar indication #9 in the near surface weldment: mode 4

Volumetric Indications in the Near Surface Weldment

Figures A.10a-f shows volumetric indication #1 in the near surface weldment. This volumetric indication has a through-wall extent of 6 mm based on different depth estimates of 18 to 24 mm. The detections were made in modes 7 and 8 where they had isolated TOF shape at depths of 20 to 24 mm. There were confirmations in modes 3, 4, 5, and 9 at depths of 18 to 23 mm. The wave packet width in modes 7 and 8 gives an alternate depth size of 2 mm. The indication is characterized as volumetric based on detection in orgothonal modes. There is no evidence of coin shape in the end views. The length is 10 mm and was made to LOS in mode 4. The width is 10 mm and was made to LOS in mode 5. The range of aspect ratios (length/depth) of this indication is 1.7 to 5. The maximum amplitude-to-noise ratio is of medium range at 97 to 30. With an X coordinate of -6 mm, the indication is clearly in the weld metal. With Z coordinates of 18 to 24 mm, the indication is clearly below the cladding.

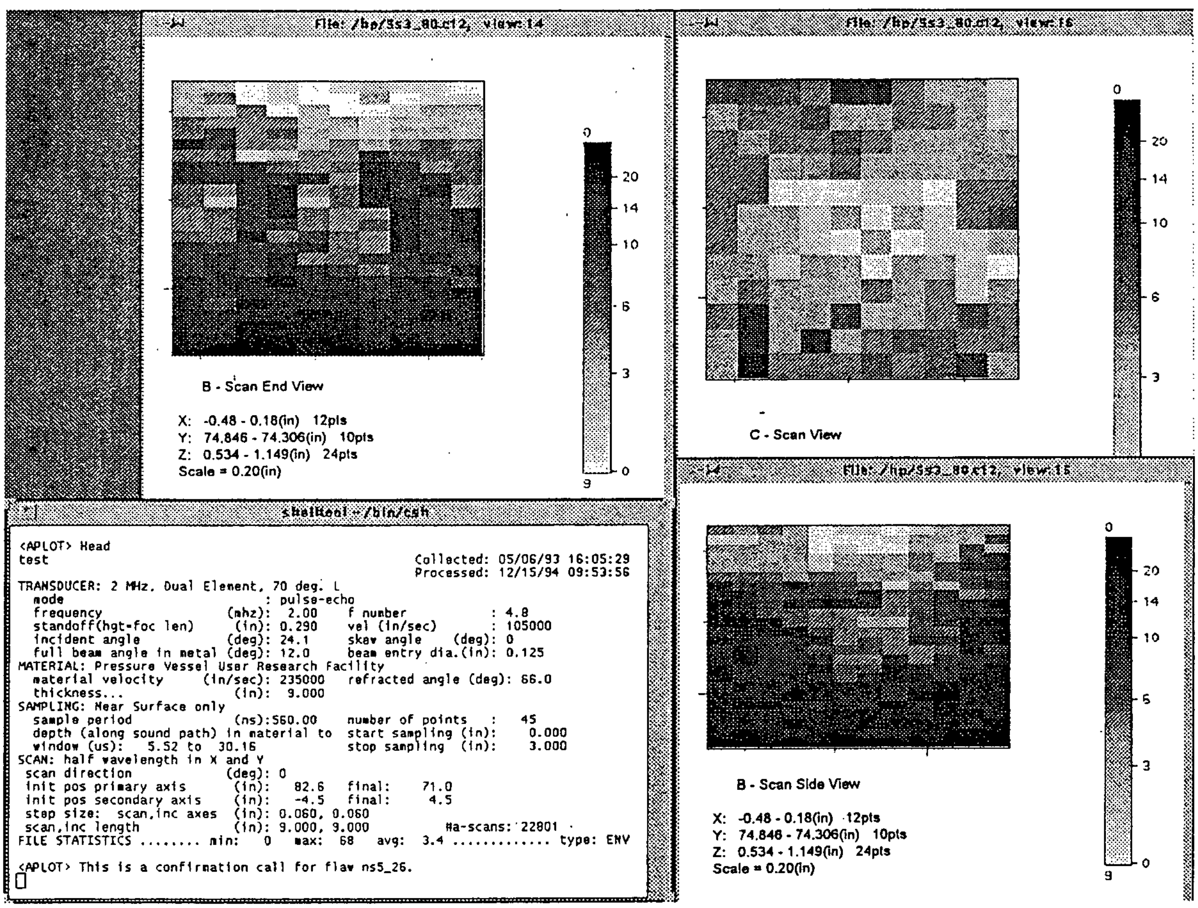


Figure A.10a Volumetric indication #1 in the near surface weldment: mode 3

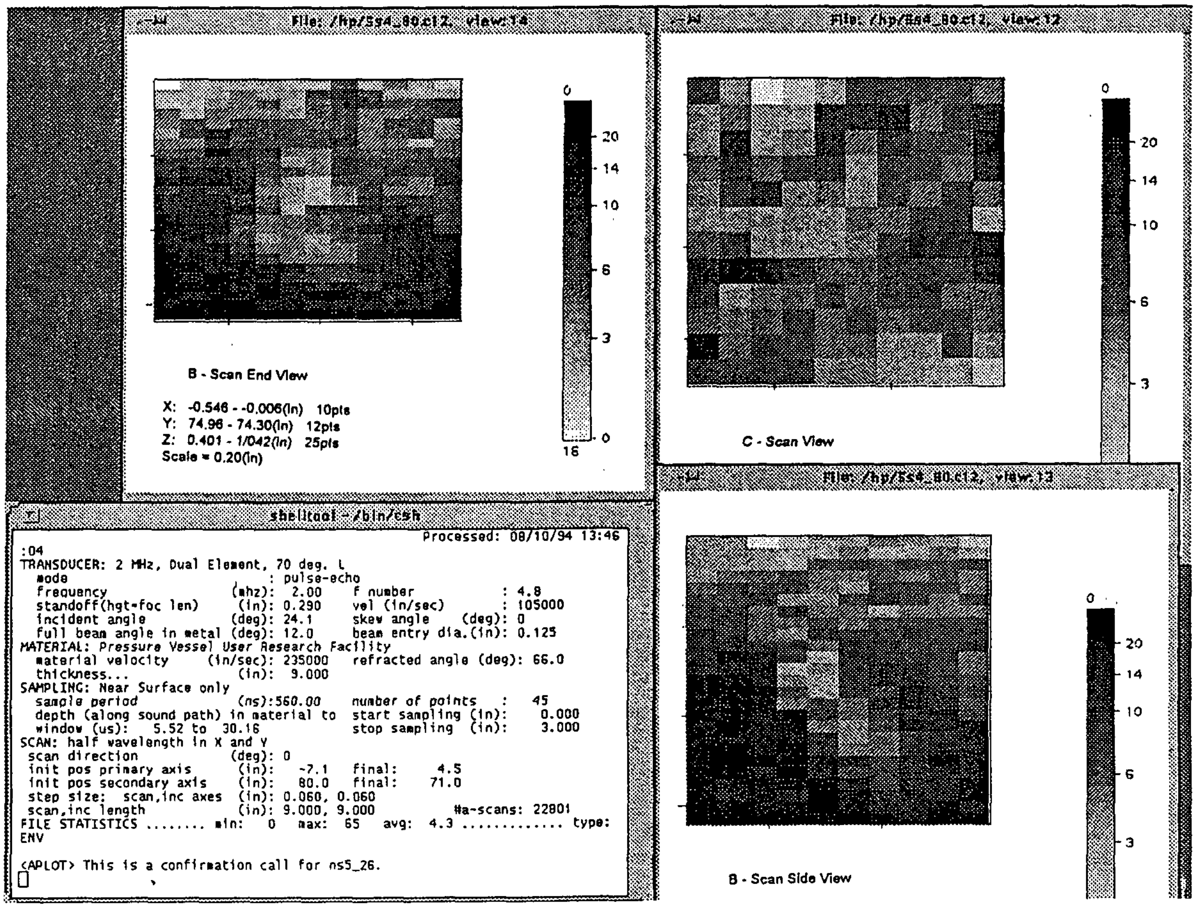


Figure A.10b Volumetric indication #1 in the near surface weldment: mode 4

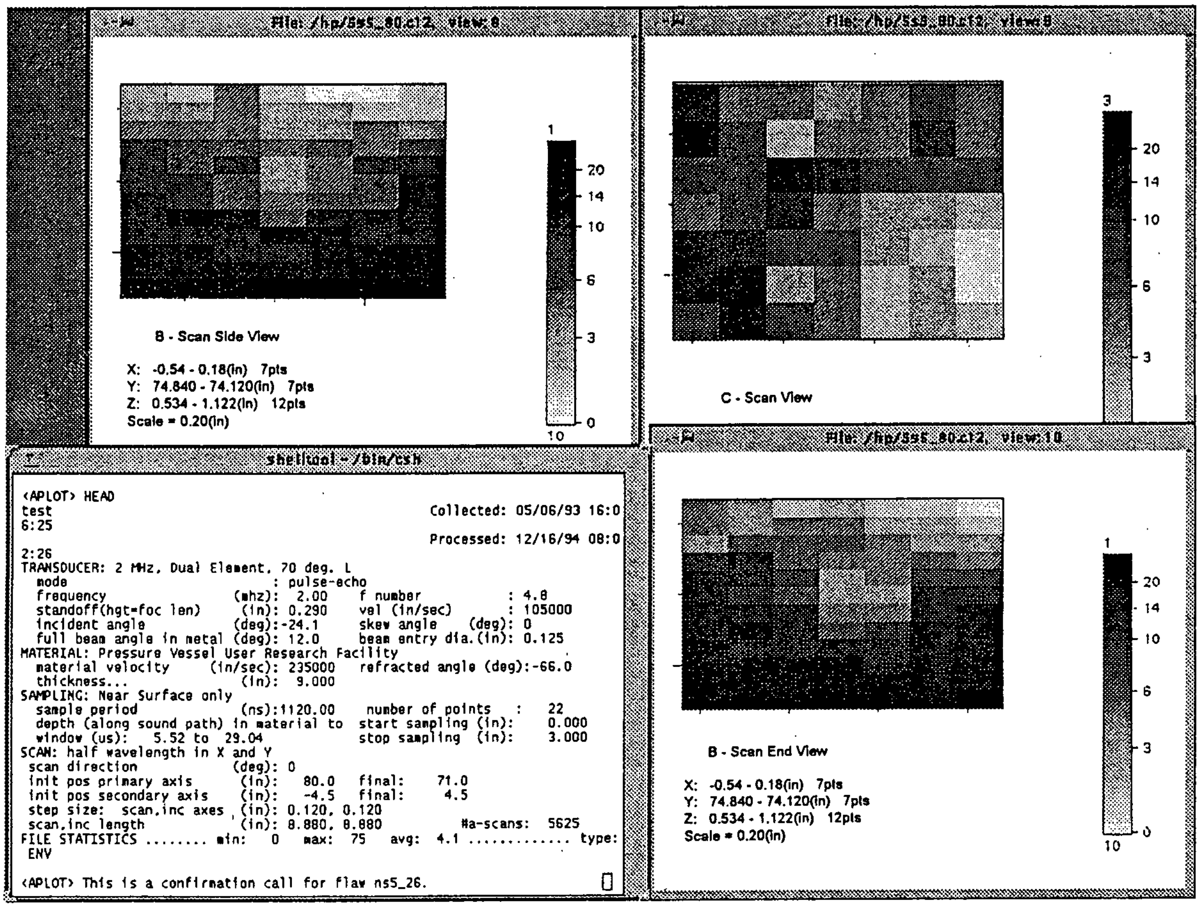


Figure A.10c Volumetric indication #1 in the near surface weldment: mode 5

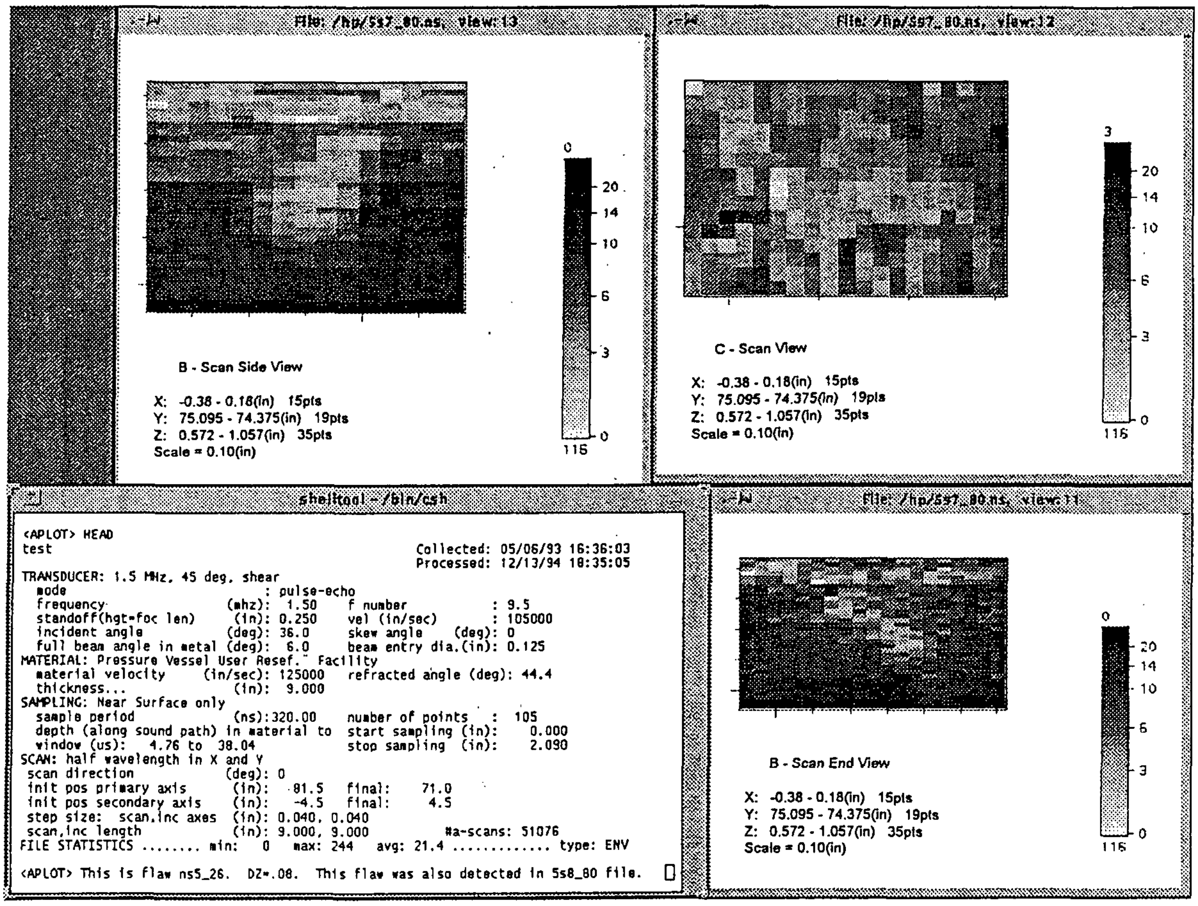


Figure A.10d Volumetric indication #1 in the near surface weldment: mode 7

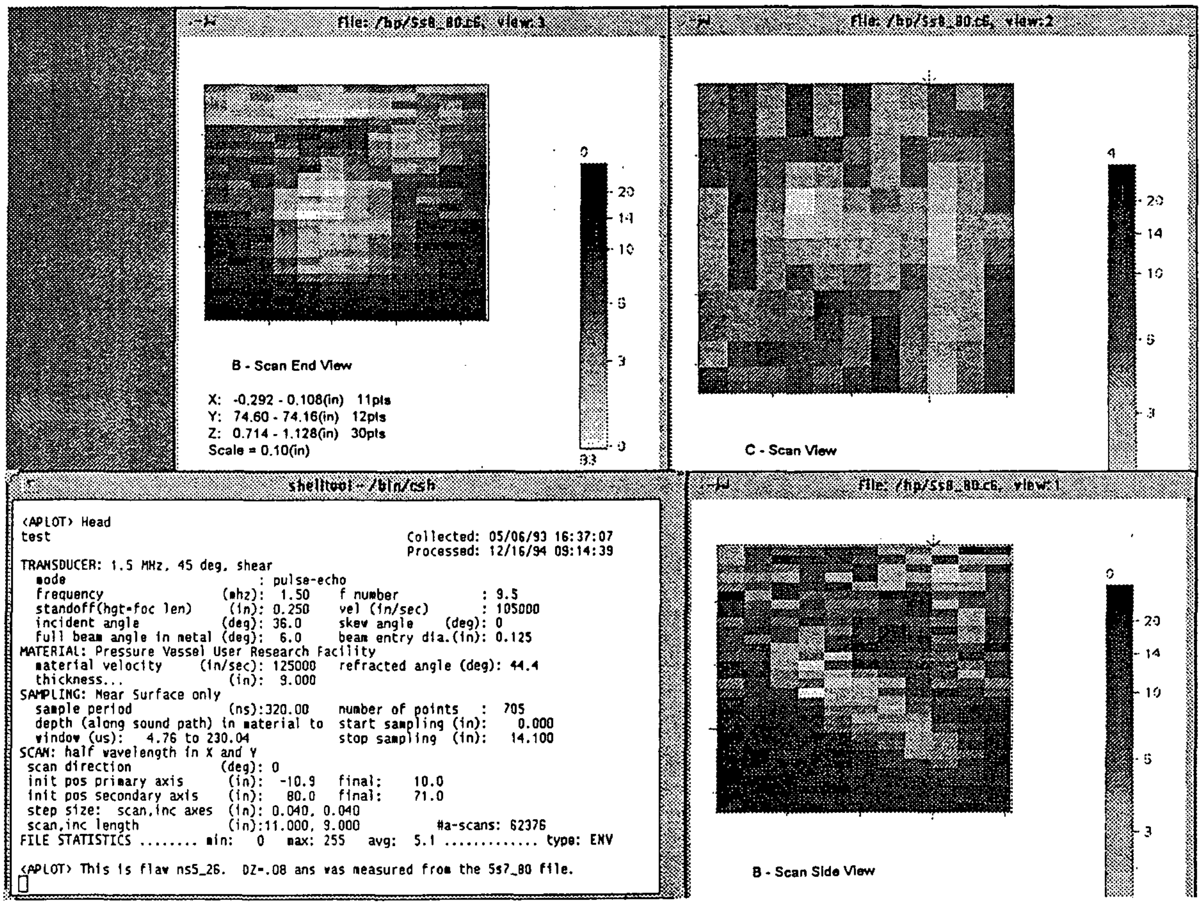


Figure A.10e Volumetric indication #1 in the near surface weldment: mode 8

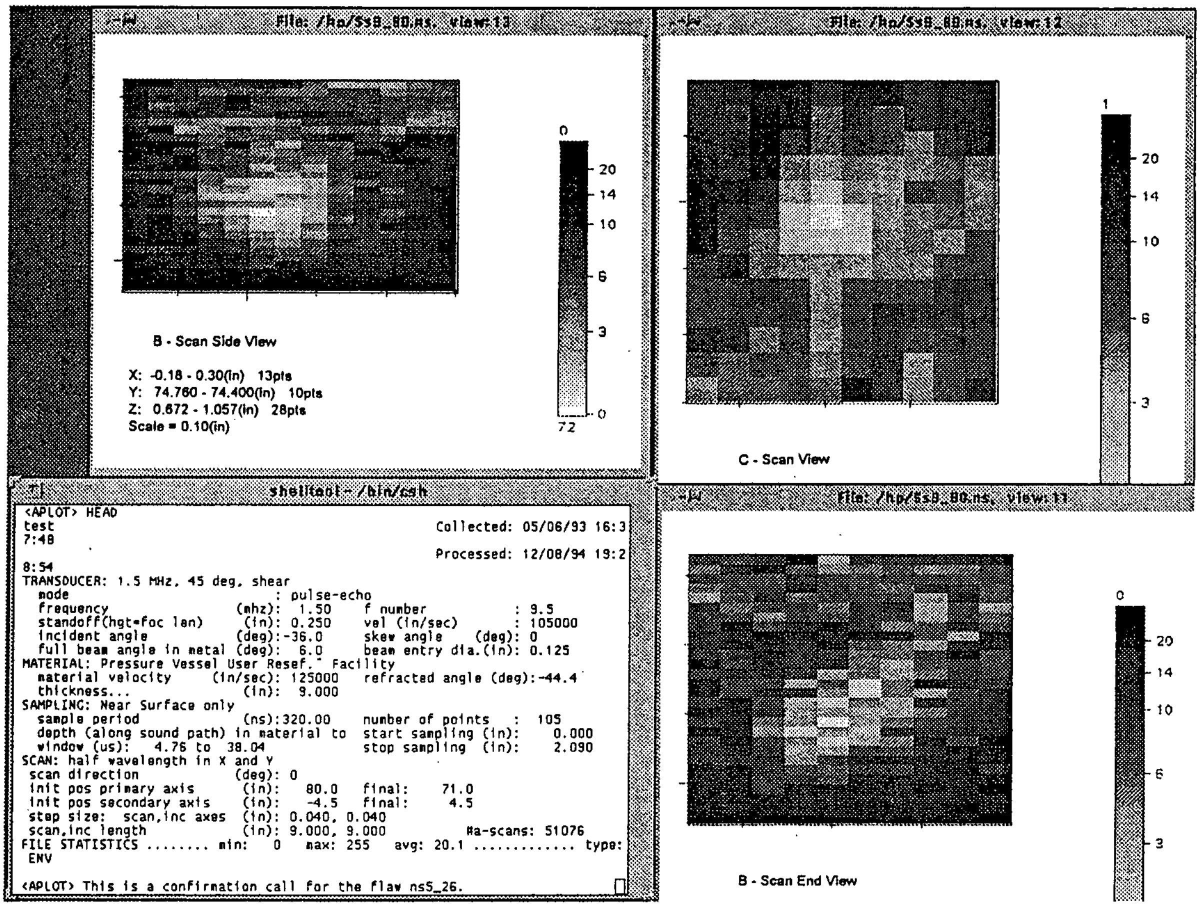


Figure A.10f Volumetric indication #1 in the near surface weldment: mode 9

Figures A.11a-f show volumetric indication #2 in the near surface weldment. This volumetric indication has a through-wall extent of 6 mm based on different depth estimates of 20 to 26 mm. The detection was made in mode 9 where it had isolated TOF shape at a depth of 23 mm. There were confirmations in modes 2, 5, 6, 7, and 8 at depths of 20 to 26 mm. The wave packet width in mode 9 gave an alternate depth size of 3 mm. The indication is characterized as volumetric based on detection in orgothonal modes. There is good evidence of coin shape in the end view of mode 2 but the depth of the indication implies that it is not connected to the cladding. The length is 13 mm and was made to LOS in mode 2. The width is 14 mm and was made to LOS in mode 5. The range of aspect ratios (length/depth) of this indication is of medium range at 117 to 35. With an X coordinate of 9 mm, the indication is in the weld metal and 2 mm from the HAZ. With a Z coordinate of 25 mm the indication is clearly below the cladding.

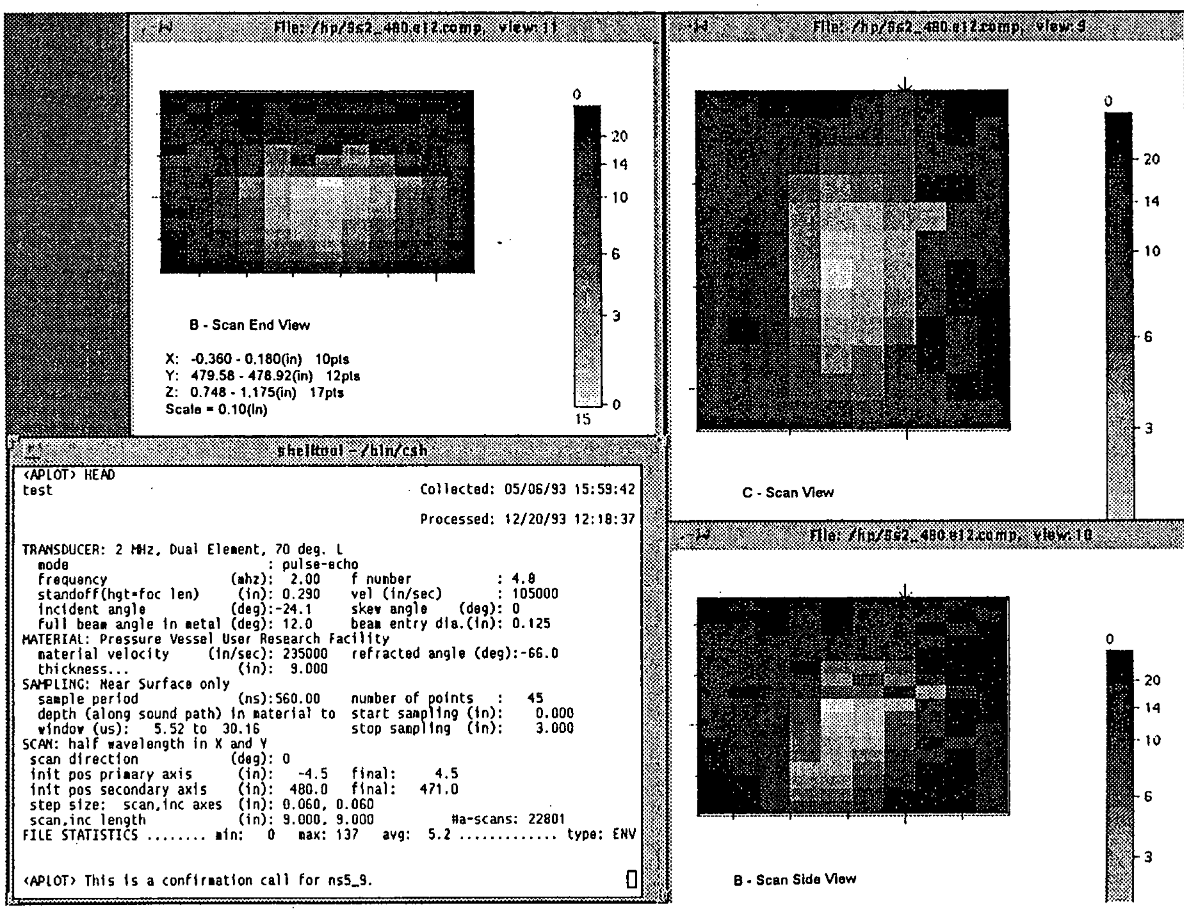


Figure A.11a Volumetric indication #2 in the near surface weldment: mode 2

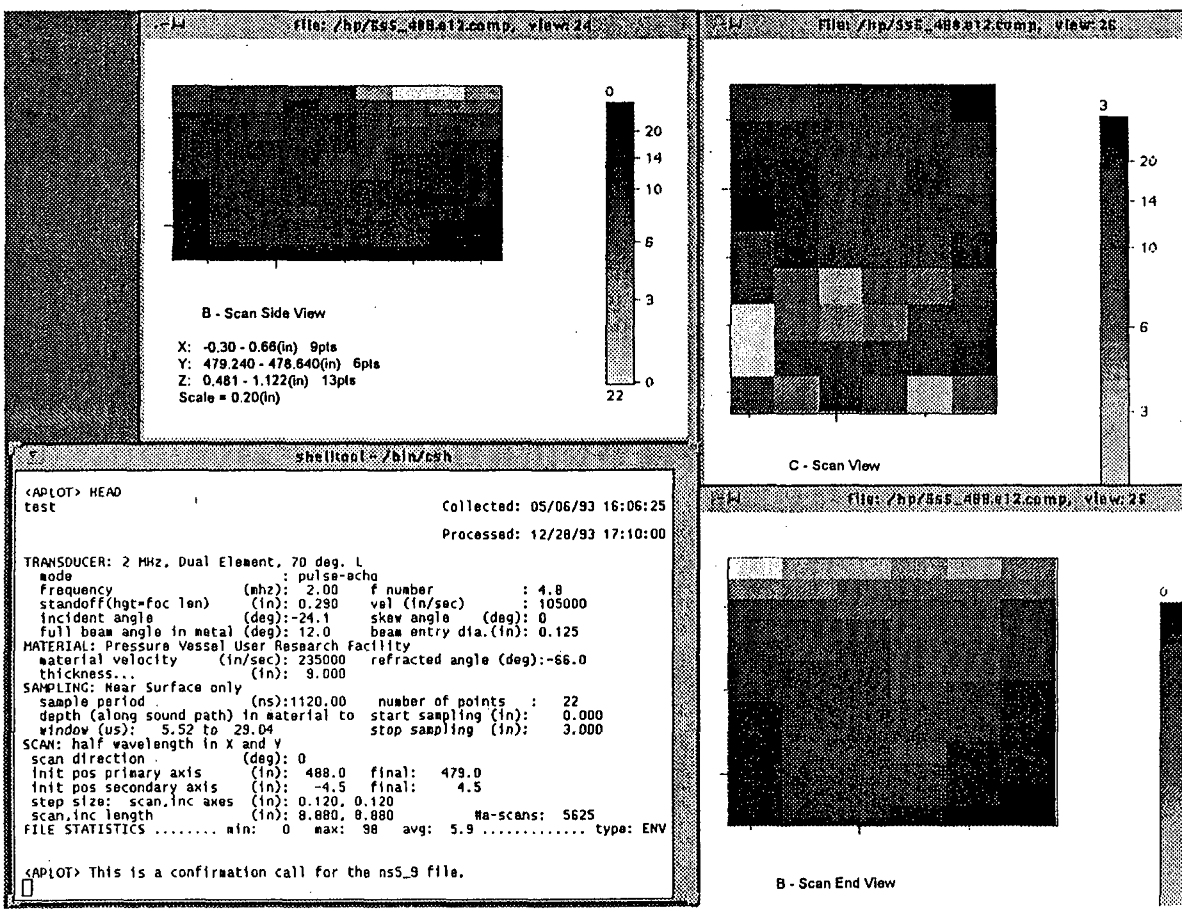


Figure A.11b - Volumetric indication #2 in the near surface weldment: mode 5

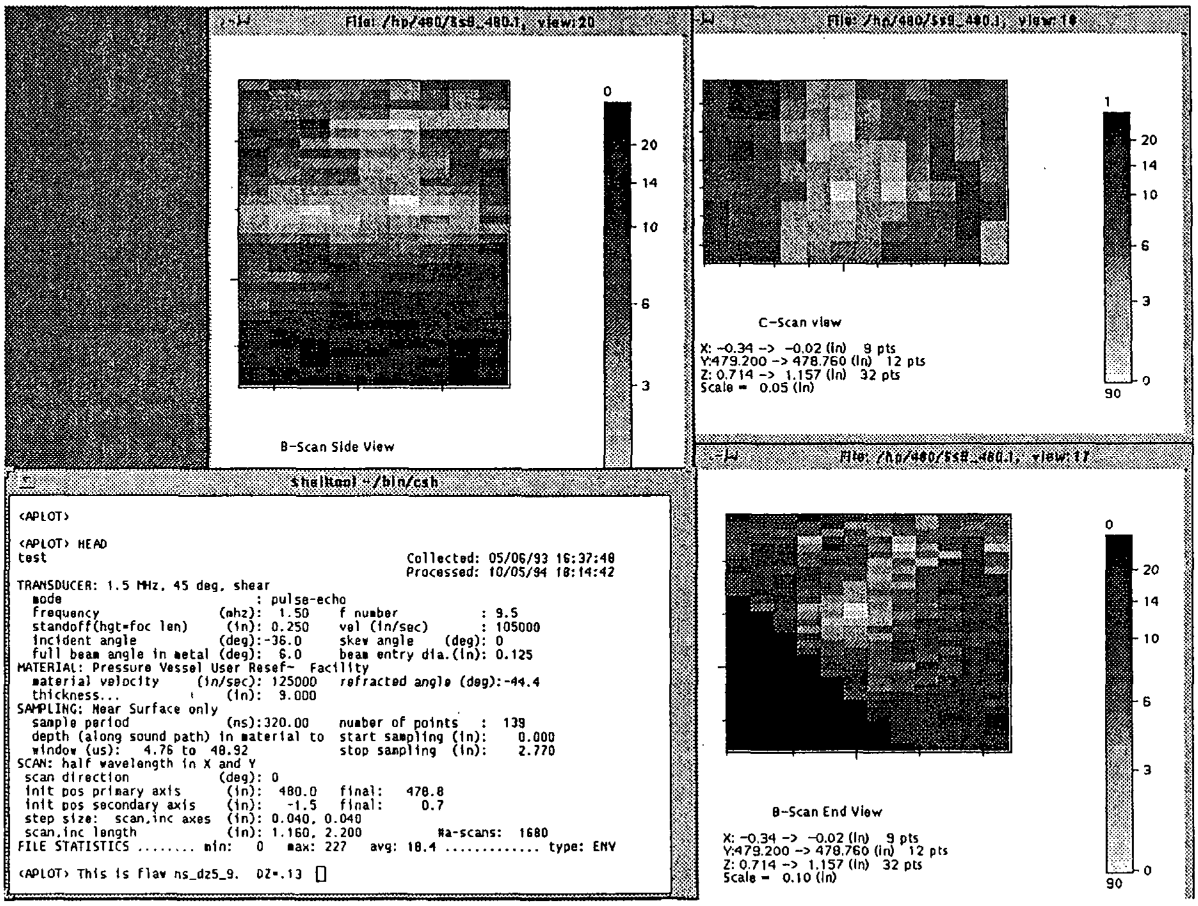


Figure A.11c - Volumetric indication #2 in the near surface weldment: mode 9

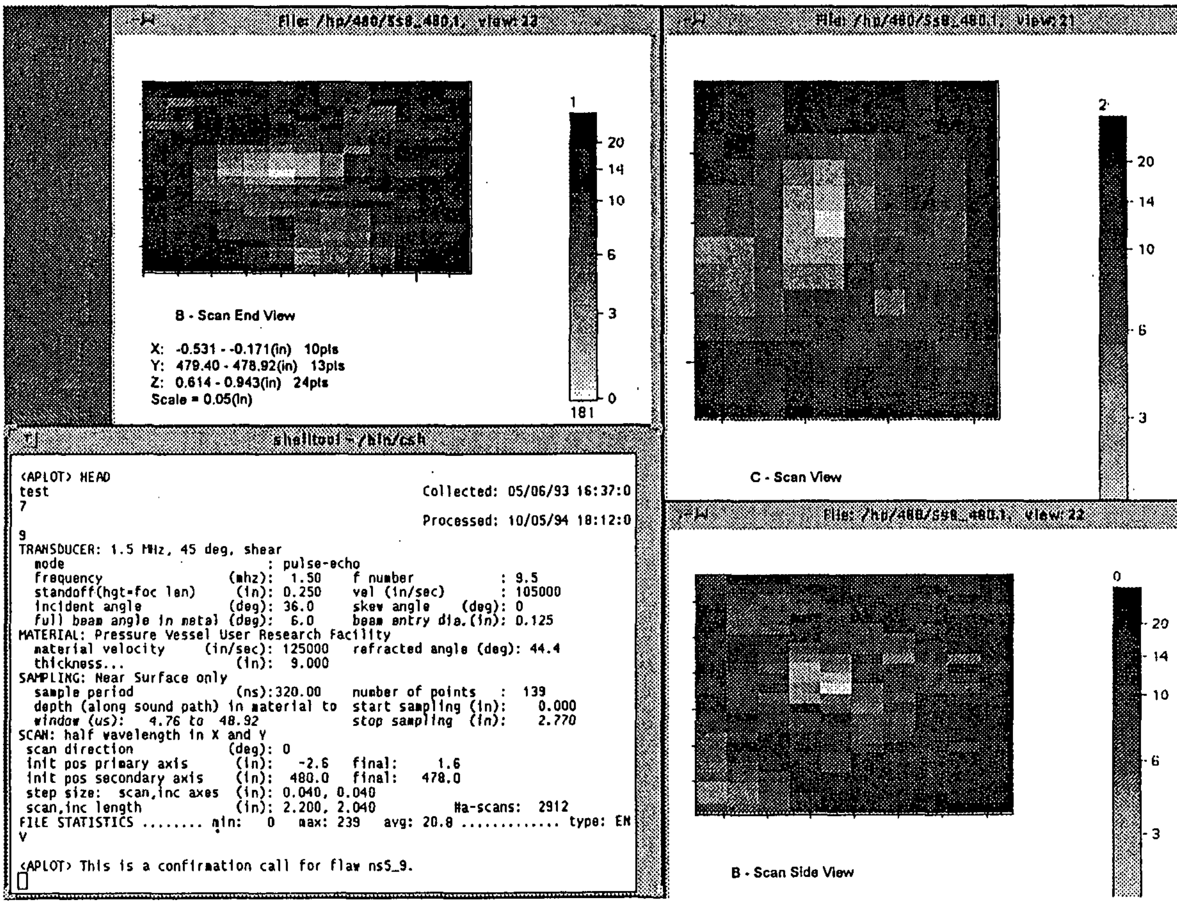


Figure A.11d - Volumetric indication #2 in the near surface weldment: mode 8

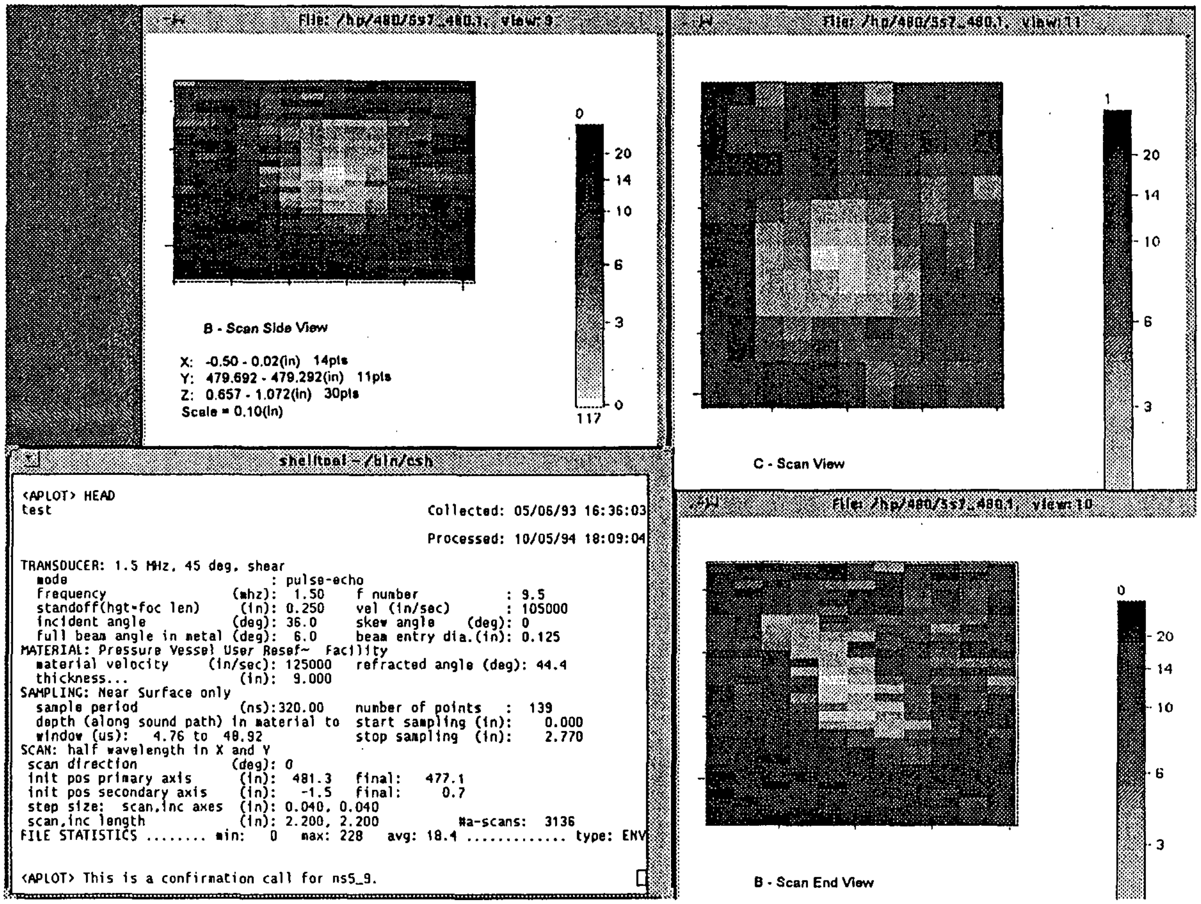


Figure A.11e - Volumetric indication #2 in the near surface weldment: mode 7

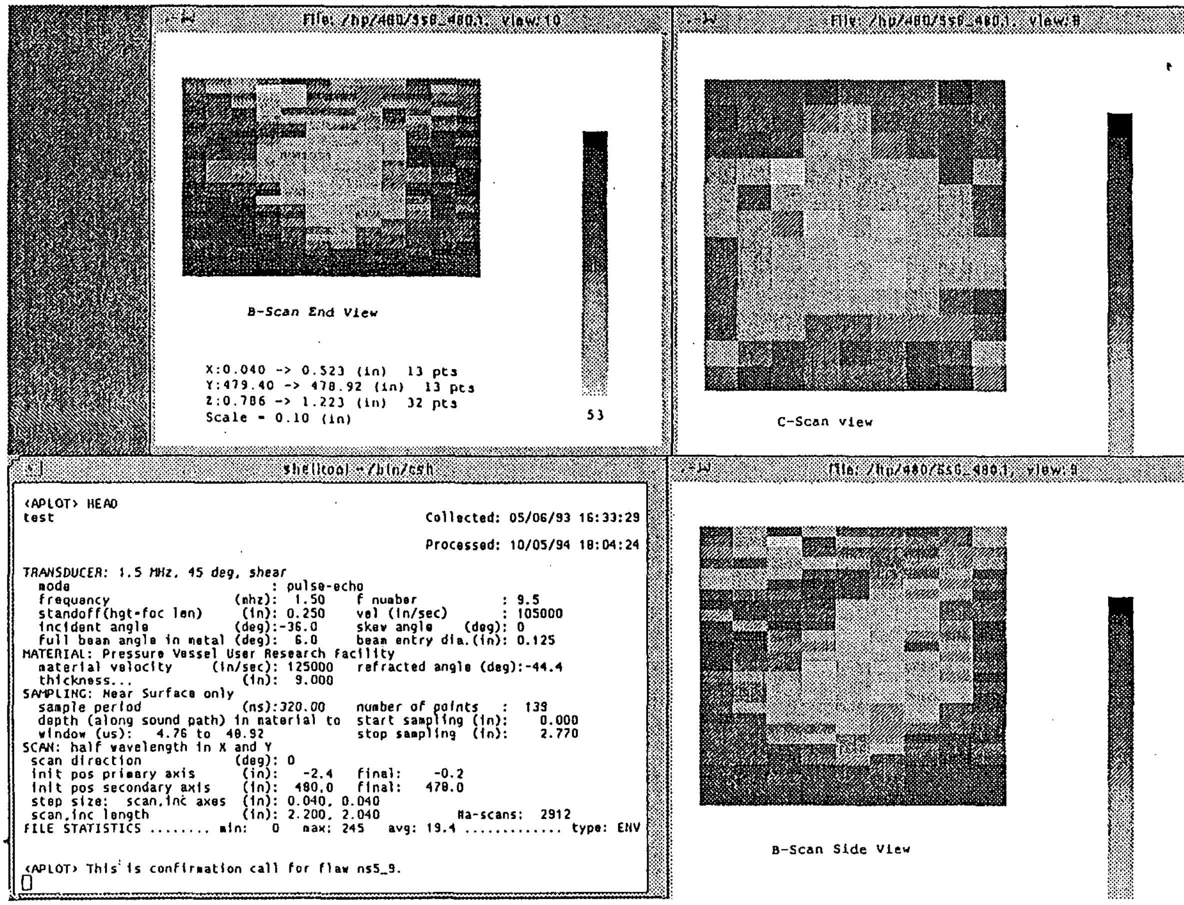


Figure A.11f - Volumetric indication #2 in the near surface weldment: mode 6

Planar Indications in the Near Surface HAZ

Figures A.12a-c show planar indication #1 in the near surface HAZ. This planar indication has a through-wall extent of 3 mm based on wave packet width. Detections were made in modes 2, 3, and 5 where it had isolated TOF shape at depths of 13 to 14 mm. There is good evidence of coin shape in the end view of mode 2. The indication is characterized as planar based on the coin shape in mode 2. The length is 2 mm and was made to LOS in mode 2. The width is 10 mm and was made to LOS in mode 3. The aspect ratio (length/depth) of this indication is 5 giving an orientation along the weld. The maximum amplitude-to-noise ratio is of medium range at 88 to 25. With X coordinates of 11 to 18 mm, the indication is probably in the HAZ. The Z coordinate of 13 to 14 mm shows that the indication is below the cladding by at least 4 to 5 mm.

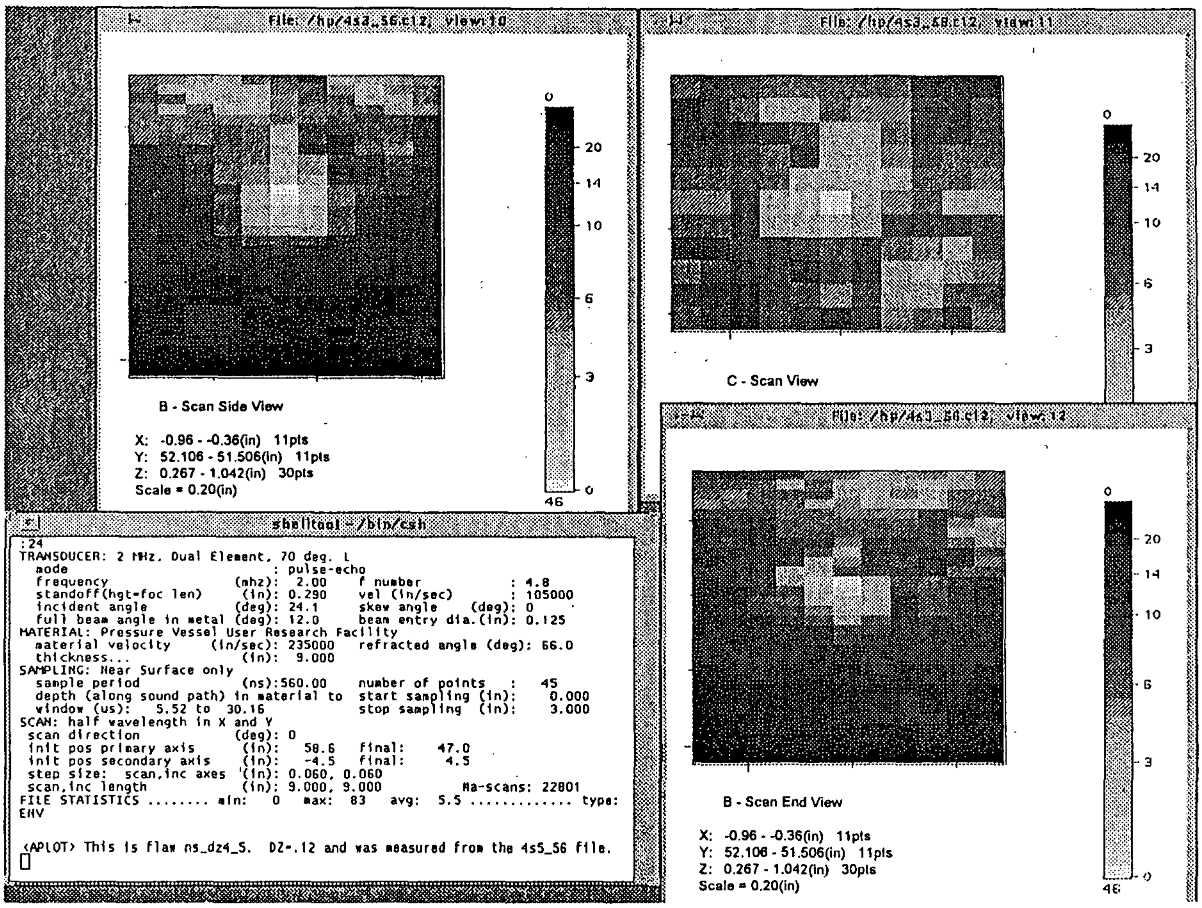


Figure A.12a - Planar indication #1 in the near surface HAZ: mode 3

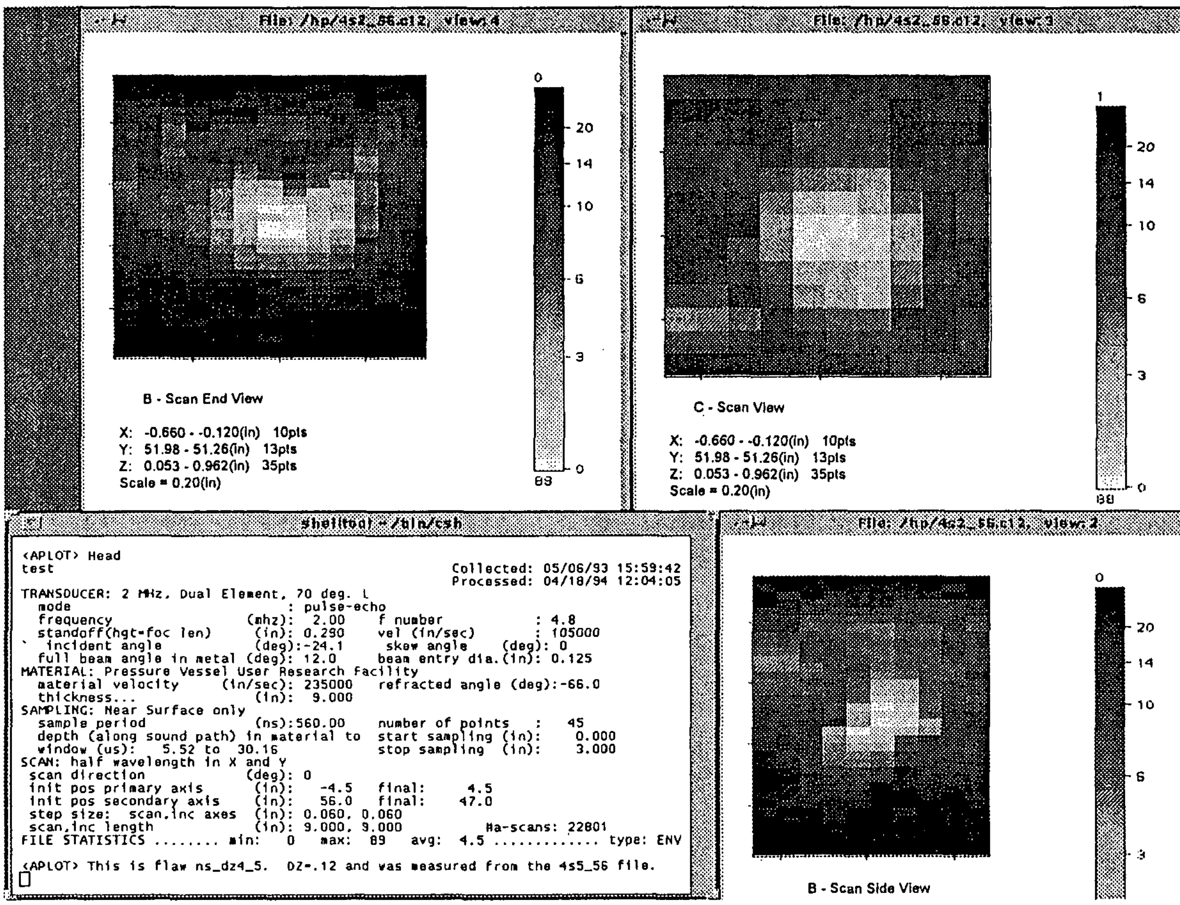


Figure A.12b - Planar indication #1 in the near surface HAZ: mode 2

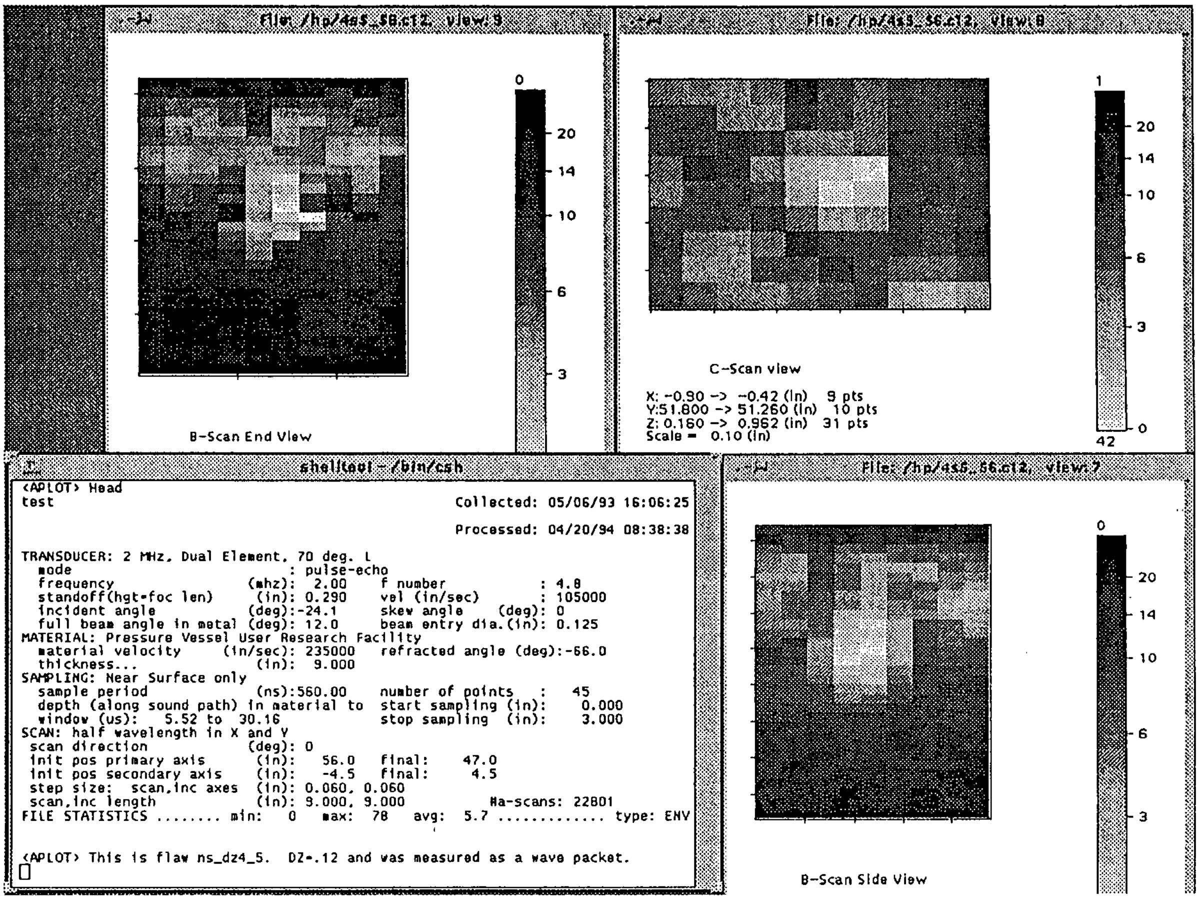


Figure A.12c - Planar indication #1 in the near surface HAZ: mode 5

Volumetric Indications in the Near Surface HAZ

Figures A.13a-b show volumetric indication #1 in the near surface HAZ. This volumetric indication has a through-wall extent of 7 mm based on wave packet width. The detection was made in mode 6 where it had isolated TOF and possibly cloud-like shapes at a depth of 20 mm. There was a confirmation in mode 5 at a depth of 20 mm. The indication is characterized as volumetric based on detection in orgothonal modes. There is no evidence of coin shape in the end views. The length is 7 mm and was made to LOS in mode 6. The width is 13 mm and was made to LOS in mode 5. The range of aspect ratios (width/depth) of this indication is 1.8 to 2.6. The maximum amplitude-to-noise ratio is high at 118 to 25. With X coordinates of 6 to 17 mm, the indication is in the HAZ, possibly in the weld. With a Z coordinate of 20 mm, the indication is clearly below the cladding.

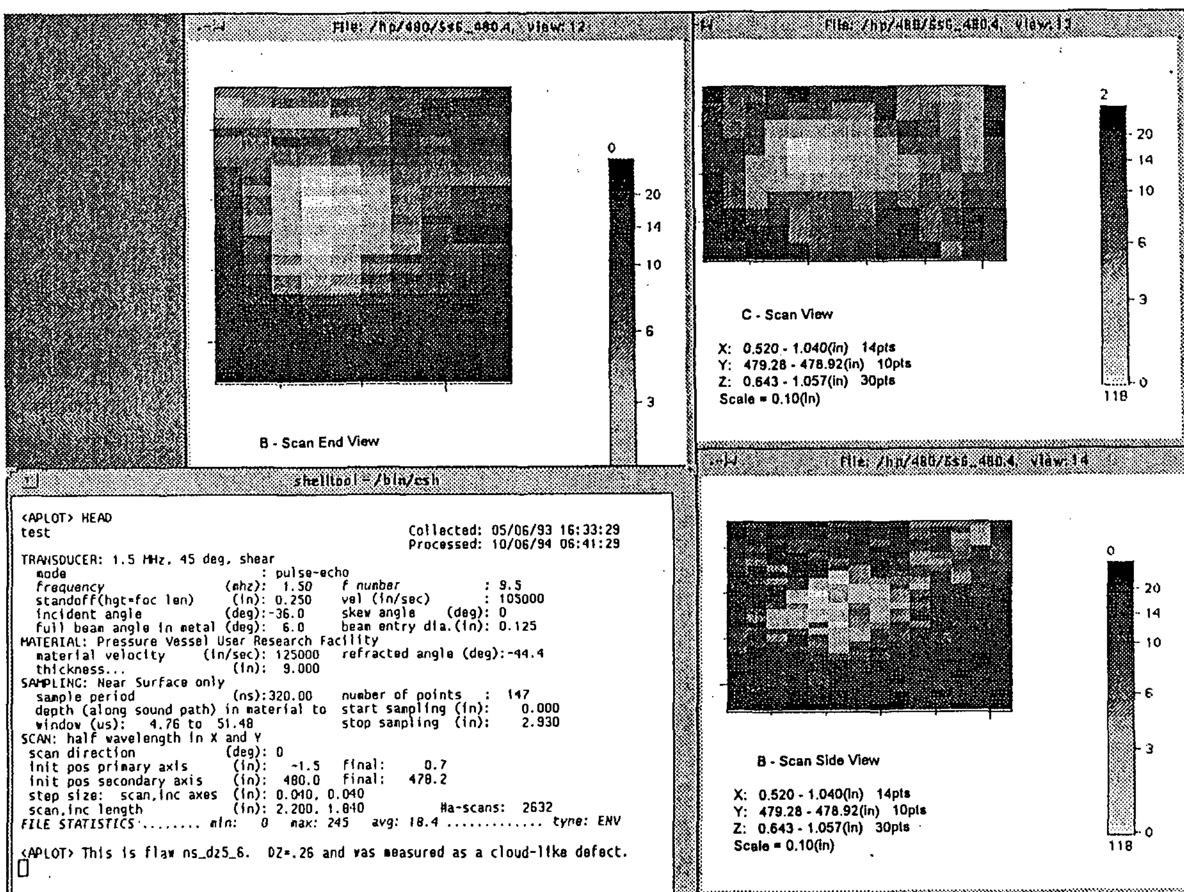


Figure A.13a - Volumetric indication #1 in the near surface HAZ: mode 6

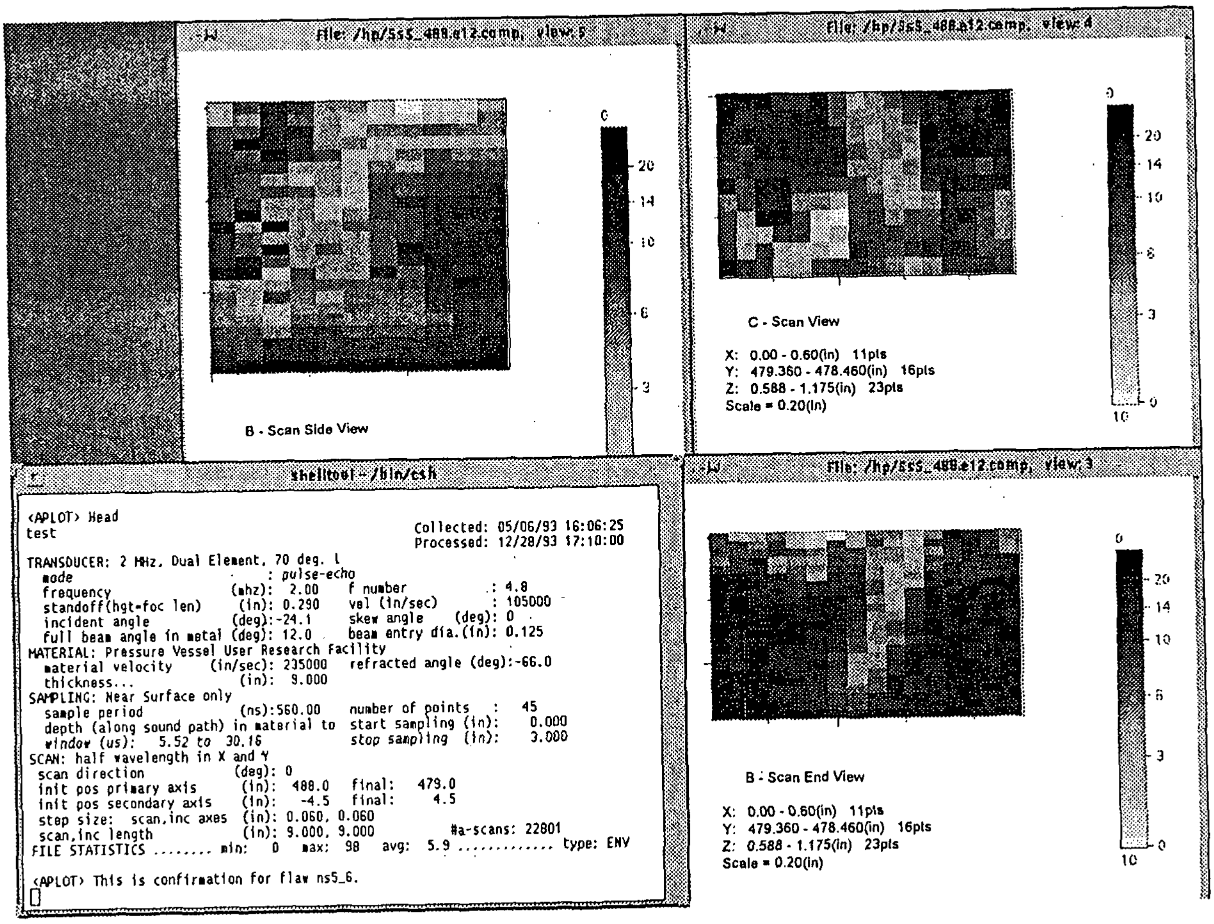


Figure A.13b - Volumetric indication #1 in the near surface HAZ: mode 5

Figures A.14a-b show volumetric indication #2 in the near surface HAZ. This volumetric indication has a through-wall extent of 3 mm based on different depth estimates of 11 to 14 mm. The detection was made in mode 2 where it had isolated TOF shape at a depth of 11 mm. There was a confirmation in mode 1 at a depth of 14 mm. The wave packet width in mode 2 gave an alternate depth size of 2.5 mm. The indication is characterized as volumetric based on normal beam detection. There is no evidence of coin shape in the end views. The length is 13 mm and was made to LOS in mode 2. The width is 8 mm and was made to LOS in mode 1. The range of aspect ratios (length/depth) of this indication is 4 to 6 giving an orientation along the weld. The maximum amplitude-to-noise ratio is of medium range at 71 to 20. With X coordinates of -14 to -25 mm, the indication is in the HAZ, possibly in the base metal. With Z coordinates of 11 to 14 mm, the indication is below the cladding by at least 2 mm.

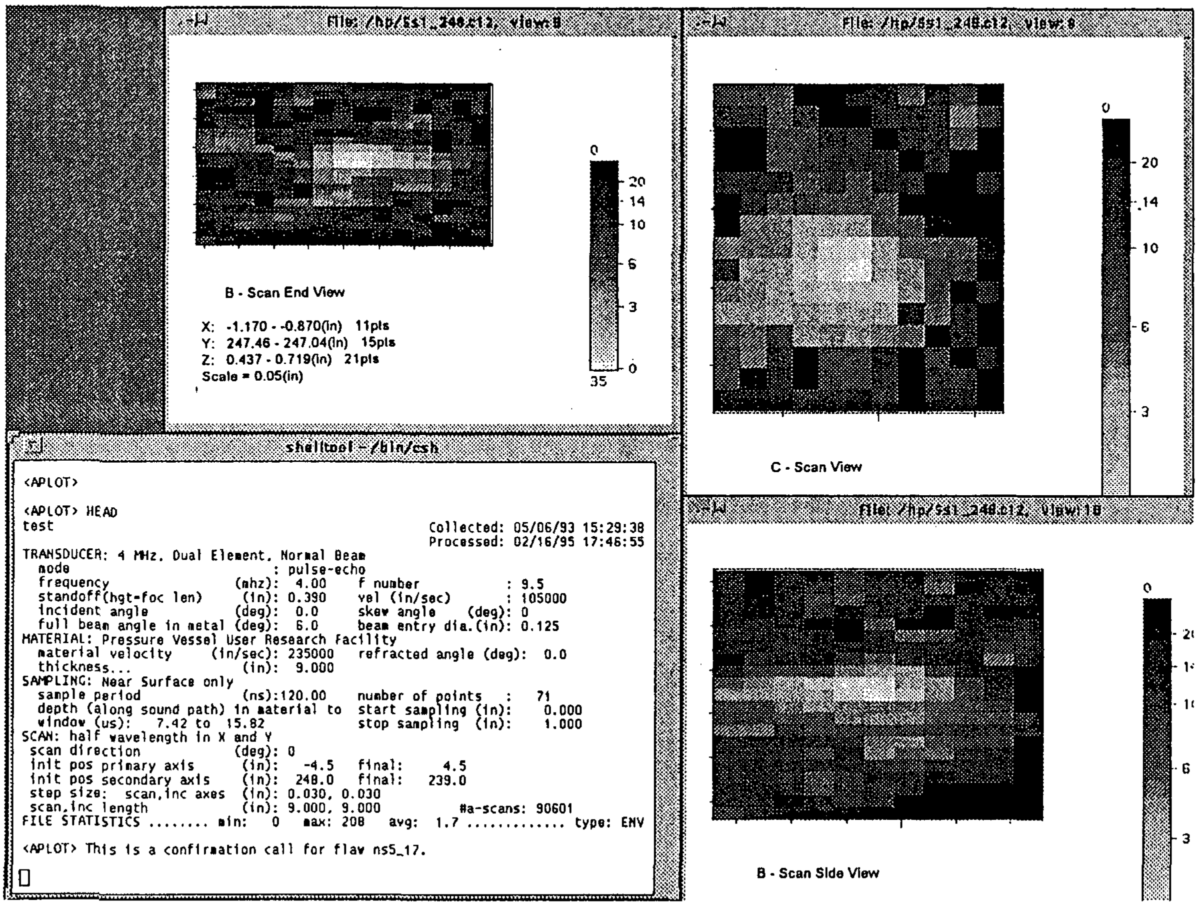


Figure A.14a - Volumetric indication #2 in the near surface HAZ: mode 1

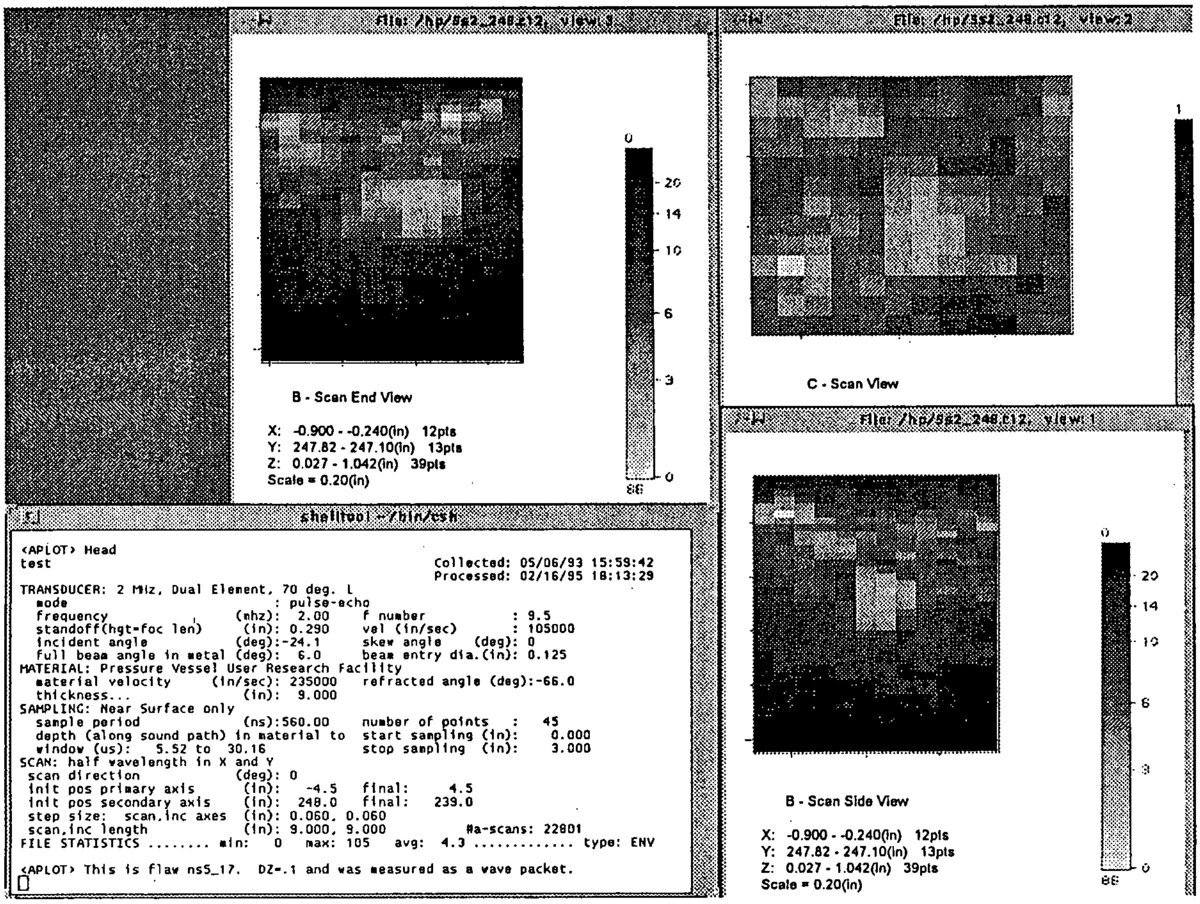


Figure A.14b - Volumetric indication #2 in the near surface HAZ: mode 2

Planar Indications in the Near Surface Base Metal

Figure A.15 shows planar indication #1 in the near surface base metal. This planar indication has a through-wall extent of 8 mm based on LOS in a cloud like shape, possibly 2.5 mm based on wave packet width. The detection was made in mode 8 where it had isolated TOF shape at a depth of 18 mm. There were no confirmations in other modes. The indication is characterized as planar based on lack of normal beam detection. There is no evidence of coin shape in the end view of mode 8. The length is 7 mm and was made to LOS in mode 8. The range of aspect ratios (length/depth) of this indication is 0.7 to 2.8. The maximum amplitude-to-noise ratio is low at 165 to 70. With an X coordinate of 122 mm, the indication is clearly in the base metal. With a Z coordinate of 18 mm, the indication is clearly below the cladding.

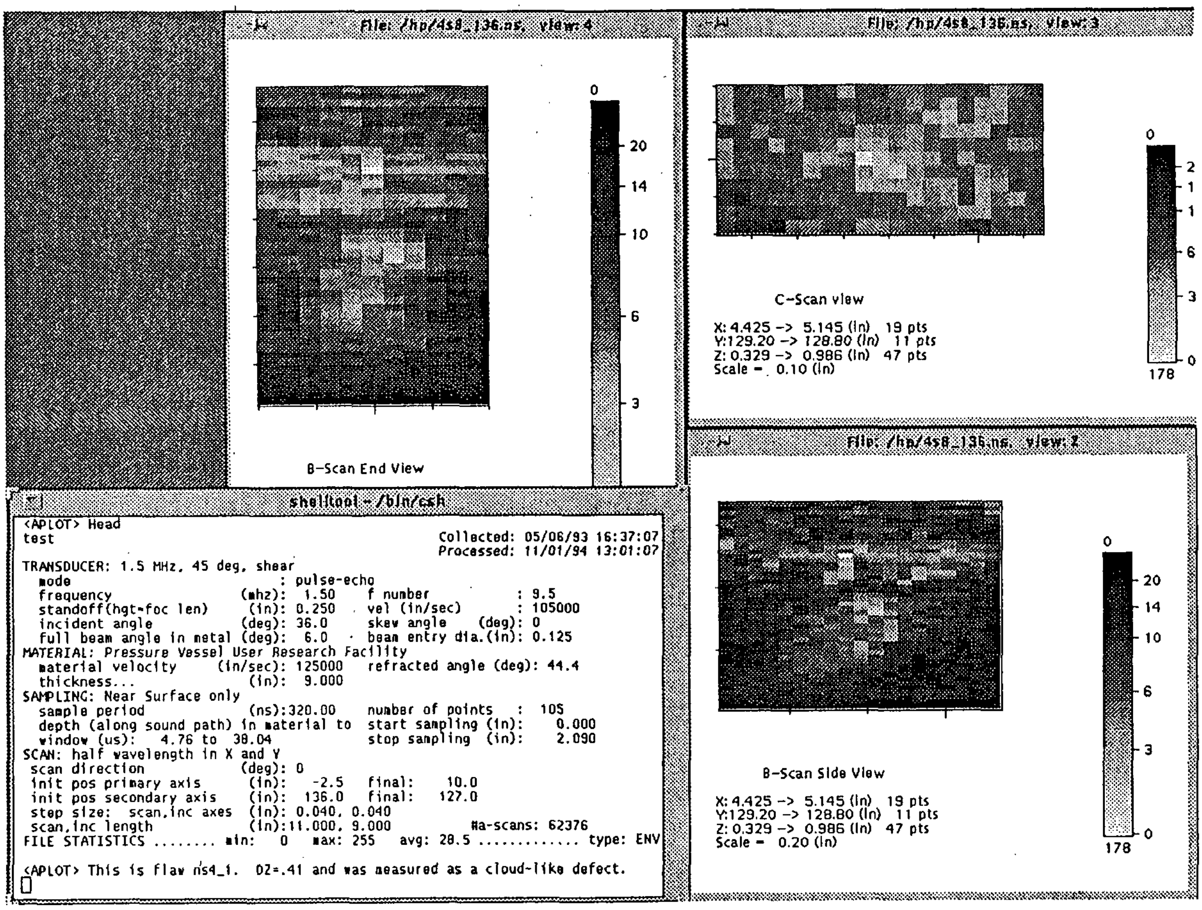


Figure A.15 - Planar indication #1 in the near surface base metal: mode 8

Figure A.16 shows planar indication #2 in the near surface base metal. This planar indication has a through-wall extent of 7.4 mm based on LOS in a cloud like shape, possibly 3.5 mm based on wave packet width. The detection was made in mode 8 where it had isolated TOF shape at a depth of 20 mm. There were no confirmations in other modes. The indication is characterized as planar based on lack of normal beam detection. There is no evidence of coin shape in the end view of mode 8. The length is 13 mm and was made to LOS in mode 8. The range of aspect ratios (length/depth) of this indication is 1.8 to 4. The maximum amplitude-to-noise ratio is high at 190 to 35. With an X coordinate of 112 mm, the indication is clearly in the base metal. With a Z coordinate of 20 mm, the indication is clearly below the cladding.

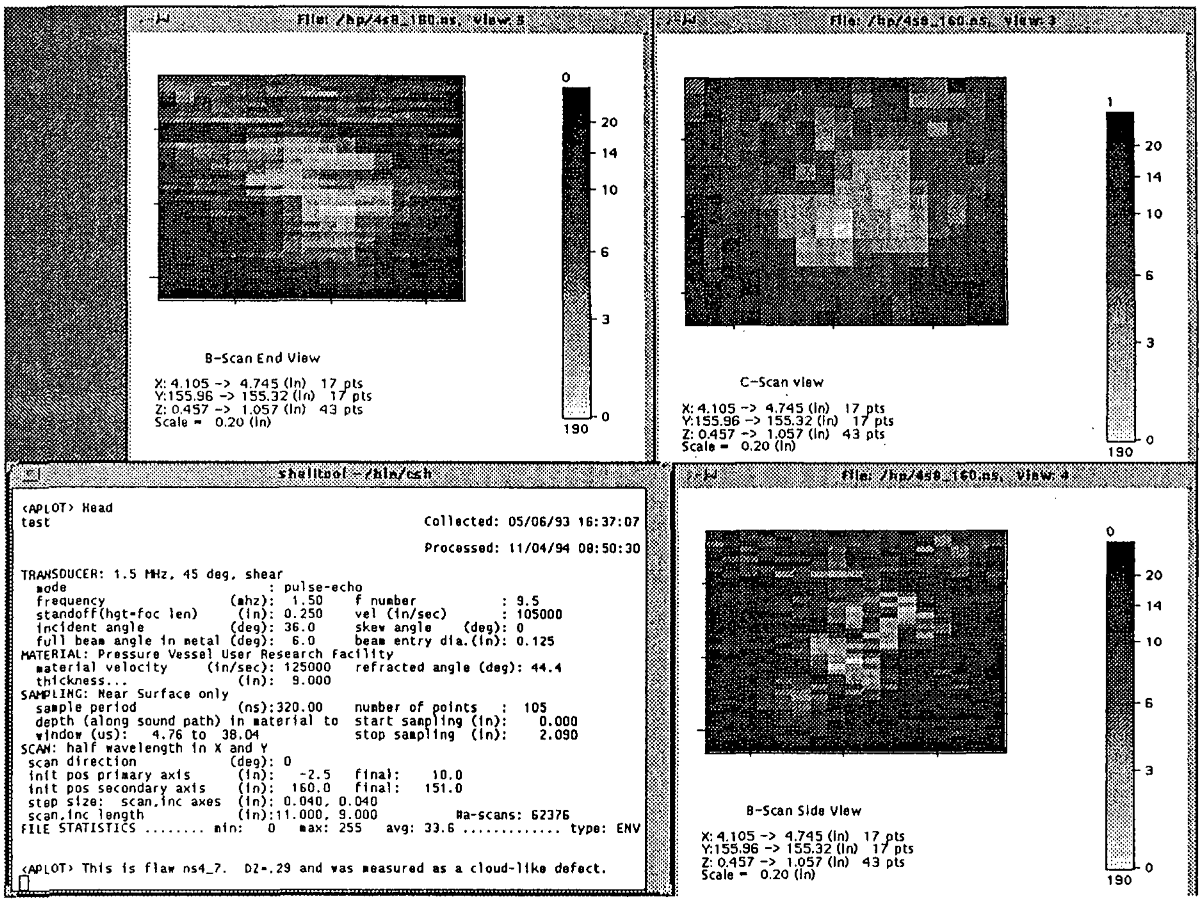


Figure A.16 - Planar indication #2 in the near surface base metal: mode 8

Figure A.17 shows planar indication #3 in the near surface base metal. This planar indication has a through-wall extent of 4 mm based on wave packet width. The detection was made in mode 2 where it had isolated TOF shape at a depth of 15 mm. There were no confirmations in other modes. The indication is characterized as planar based on lack of normal beam detection. There is no evidence of coin shape in the end view of mode 2. The length is 12 mm and was made to LOS in mode 2. The aspect ratio (length/depth) of this indication is 3 giving an orientation along the weld. The maximum amplitude-to-noise ratio is of medium range at 22 to 9. With an X coordinate of 122 mm, the indication is clearly in the base metal. With a Z coordinate of 15 mm, the indication is clearly below the cladding.

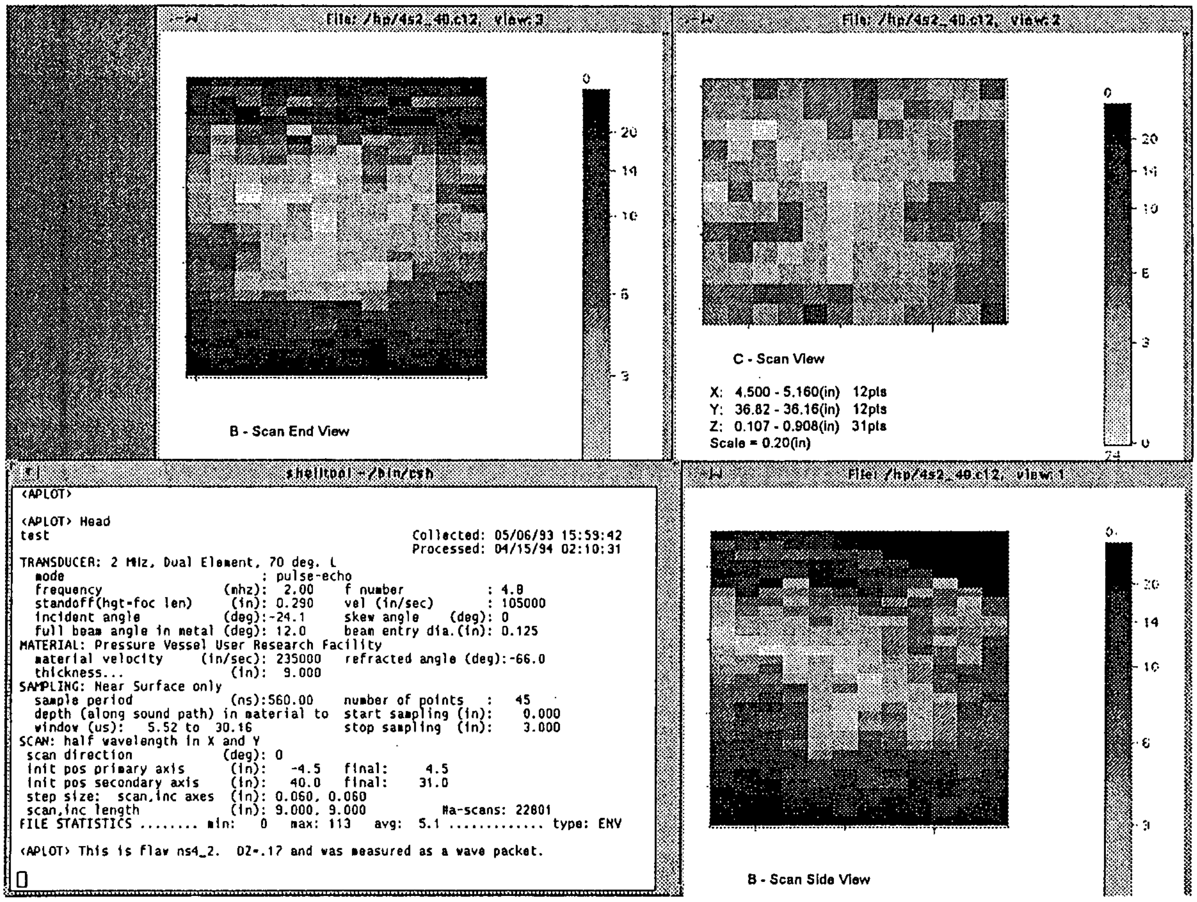


Figure A.17 - Planar indication #3 in the near surface base metal: mode 2

Figure A.18 shows planar indication #4 in the near surface base metal. This planar indication has a through-wall extent of 4 mm based on wave packet width. The detection was made in mode 2 where it had isolated TOF shape at a depth of 11 mm. There were no confirmations in other modes. The indication is characterized as planar based on lack of normal beam detection. There is no evidence of coin shape in the end view of mode 2. The length is 9 mm and was made to LOS in mode 2. The aspect ratio (length/depth) of this indication is 2 which is unusually low compared to the other indications detected in this data set. The maximum amplitude-to-noise ratio is high at 25 to 5. With an X coordinate of -46 mm, the indication is clearly in the base metal. With a Z coordinate of 11 mm, the indication is below the cladding by 2 mm.

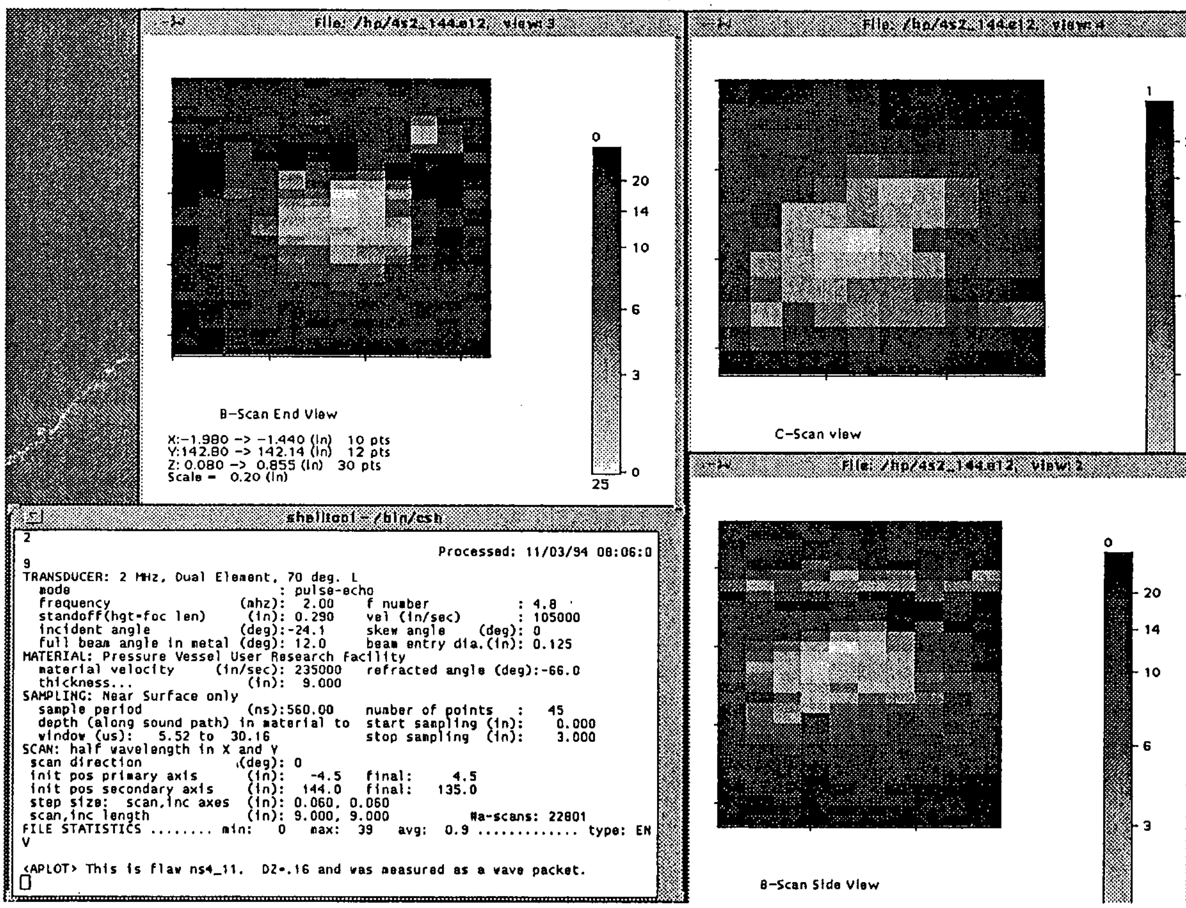


Figure A.18 - Planar indication #4 in the near surface base metal: mode 2

Figure A.19 shows planar indication #5 in the near surface base metal. This planar indication has a through-wall extent of 3.6 mm based on wave packet width. The detection was made in mode 4 where it had isolated TOF shape at a depth of 12 mm. There were no confirmations in other modes. The indication is characterized as planar based on lack of normal beam detection. There is good evidence of coin shape in the end view of modes 4. The length is 15 mm and was made to LOS in mode 4. The aspect ratio (length/depth) of this indication is 4 giving an orientation along the weld. The maximum amplitude-to-noise ratio is low at 19 to 9. With an X coordinate of -49 mm, the indication is clearly in the base metal. With a Z coordinate of 12 mm, the indication is below the cladding by 3 mm.

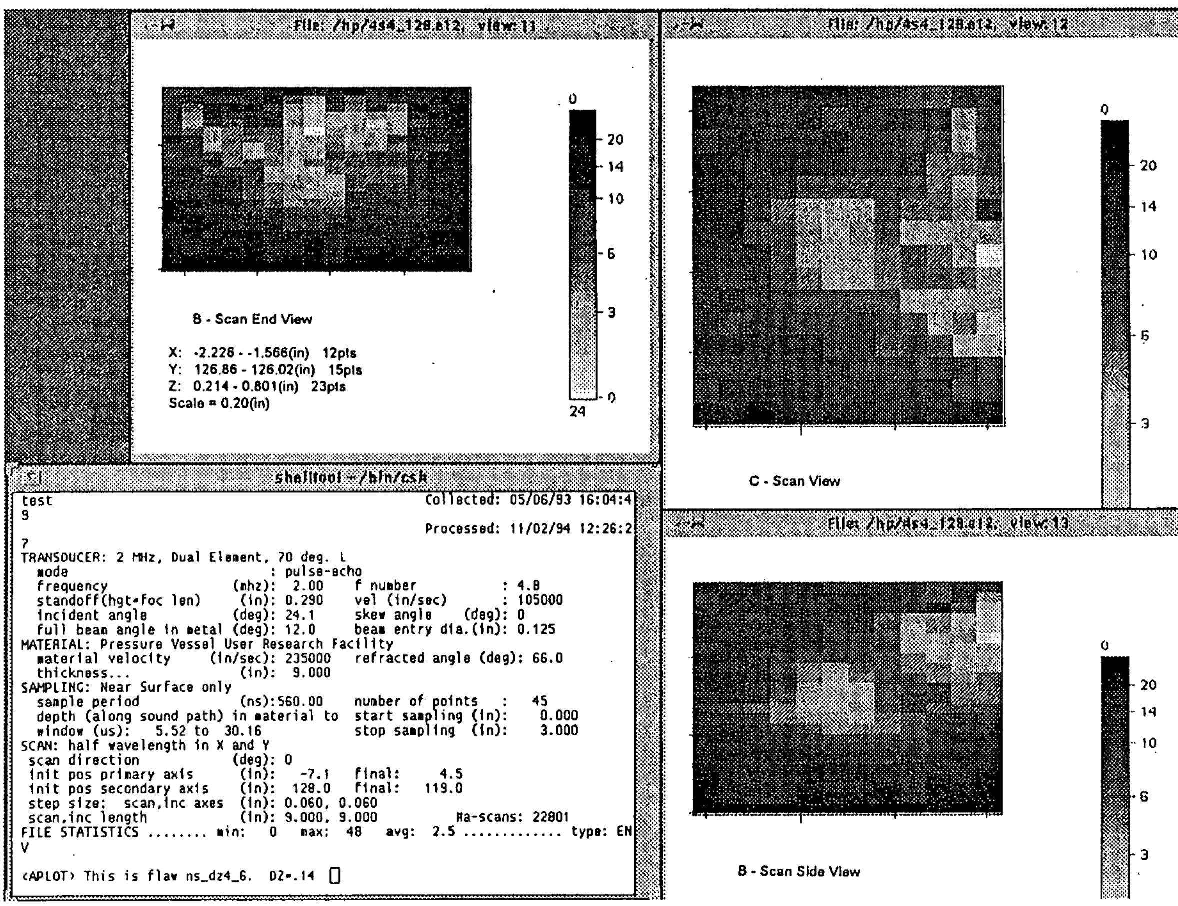


Figure A.19 - Planar indication #5 in the near surface base metal: mode 4

Figures A.20a-c show planar indication #6 in the near surface base metal. This planar indication has a through-wall extent of 3.5 mm based on wave packet width. The detections were made in modes 3 and 5 where it had isolated TOF shape at depths of 13 and 16 mm. The shape quality is good for this indication. There was a confirmation in mode 1 at a depth of 14 mm. The different Z values 13 to 16 mm give an alternate depth size of 3 mm. There is good evidence of coin shape in the end view of mode 3. The indication is characterized as planar based on the coin shape in mode 3. The length is 12 mm and was made to LOS in mode 1. The width is 20 mm and was made to LOS in mode 3. The aspect ratio (width/depth) of this indication is 6 which tends to confirm planar orientation. The maximum amplitude-to-noise ratio is of medium range at 29 to 10. With an X coordinate of -29 mm, the indication is clearly in the base metal. With a Z coordinate of 13 mm, the indication is below the cladding by 4 mm.

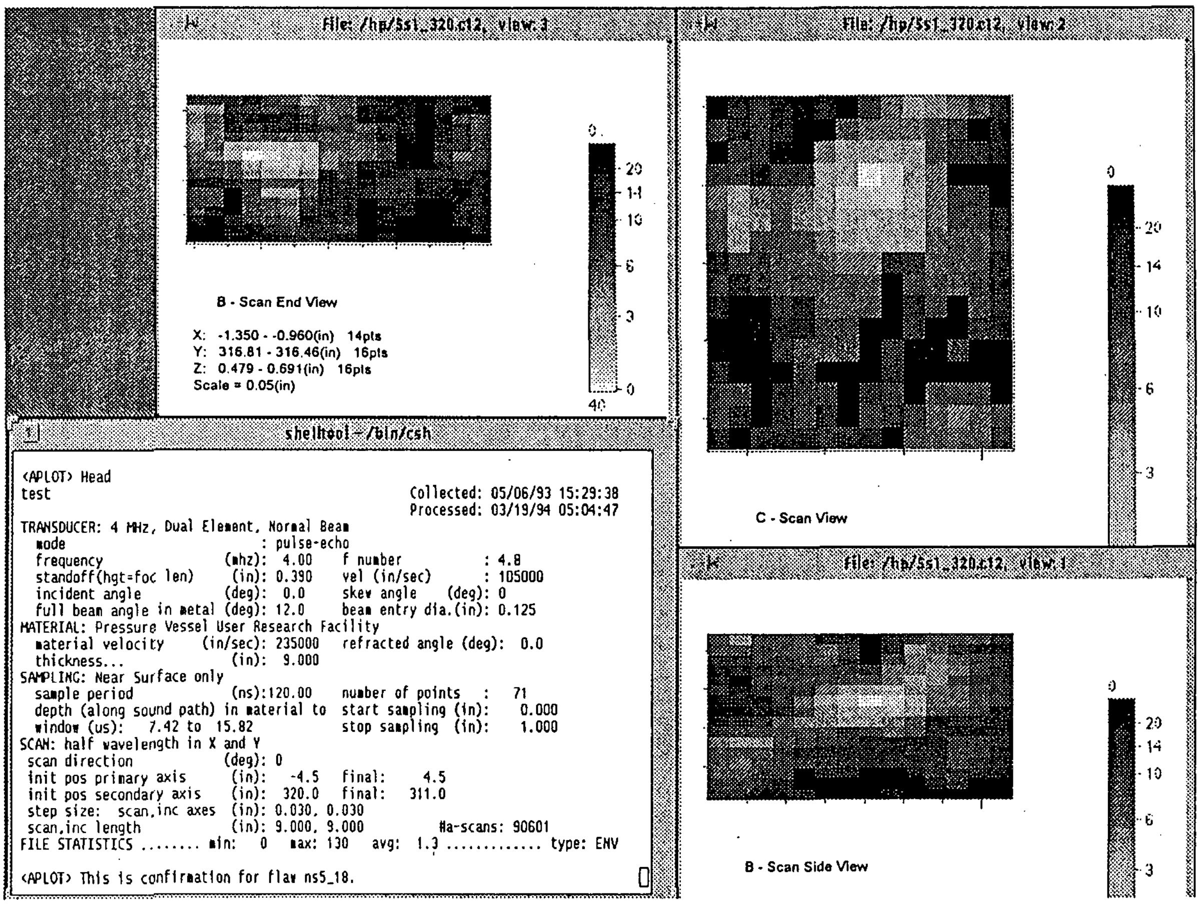


Figure A.20a - Planar indication #6 in the near surface base metal: mode 1

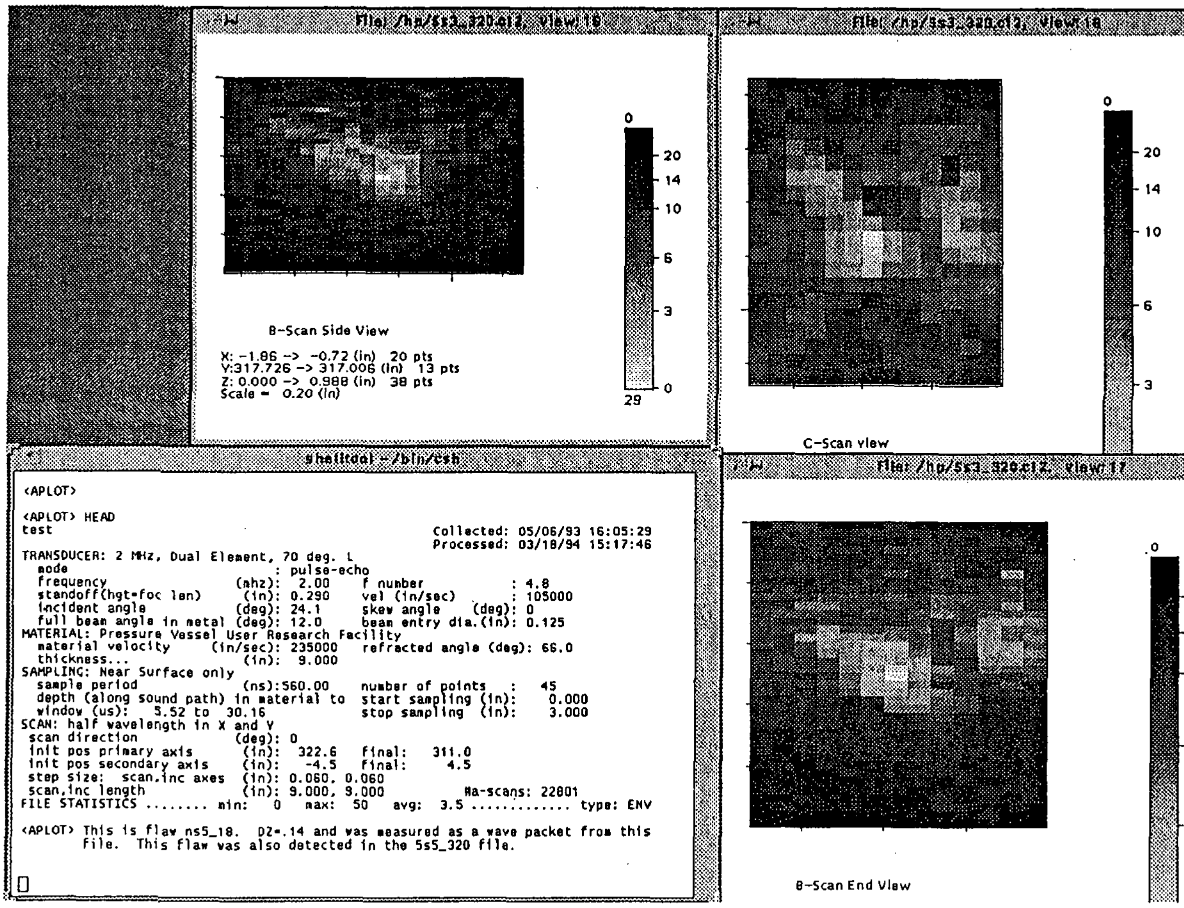


Figure A.20b - Planar indication #6 in the near surface base metal: mode 3

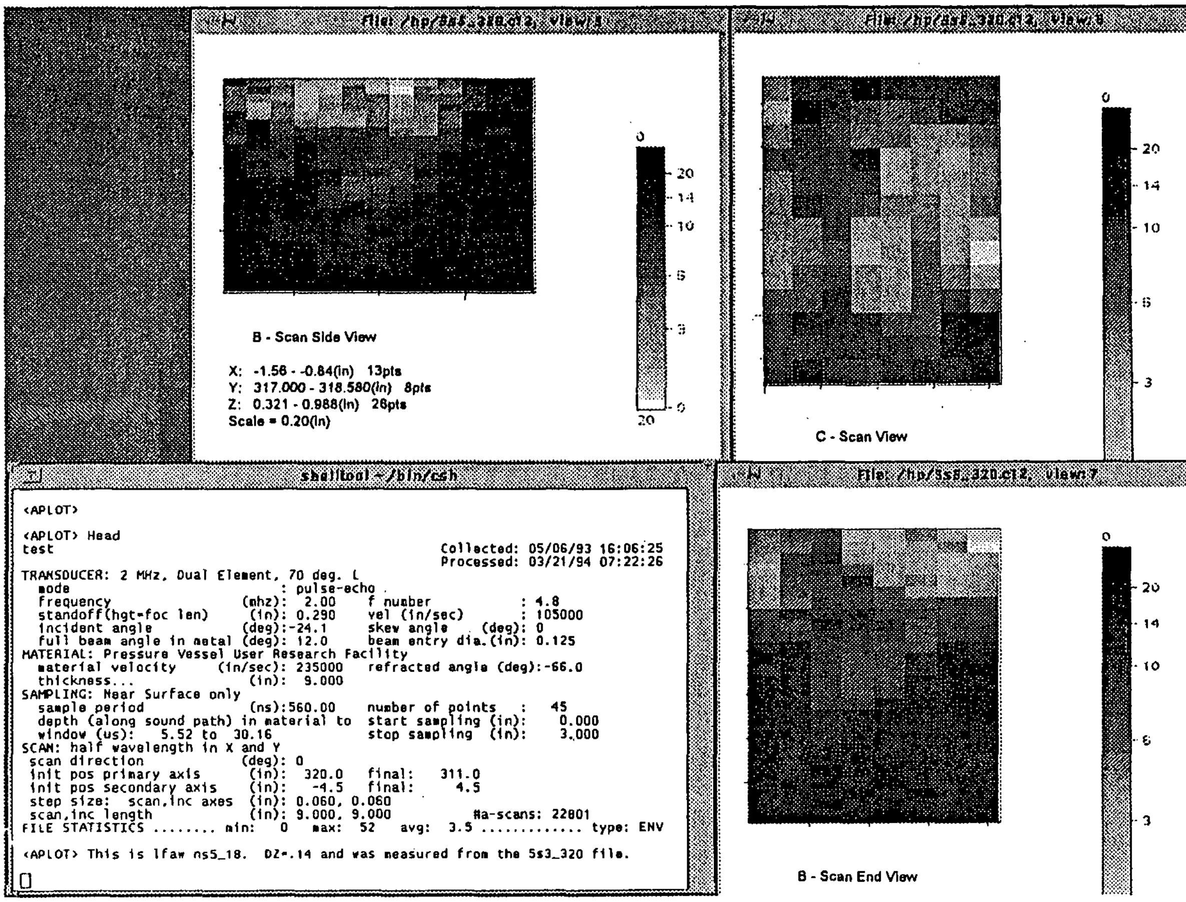


Figure A.20c - Planar indication #6 in the near surface base metal: mode 5

Figure A.21 shows planar indication #7 in the near surface base metal. This planar indication has a through-wall extent of 3 mm based on wave packet width. The detection was made in mode 4 where it had isolated TOF shape at a depth of 13 mm. There were no confirmations in other modes. The indication is characterized as planar based on lack of normal beam detection. There is no evidence of coin shape in the end view of mode 4. The length is 9 mm and was made to LOS in mode 4. The aspect ratio (length/depth) of this indication is 3 giving an orientation along the weld. The maximum amplitude-to-noise ratio is of medium range at 22 to 7. With an X coordinate of 32 mm, the indication is clearly in the base metal. With a Z coordinate of 13 mm, the indication is below the cladding by 4 mm.

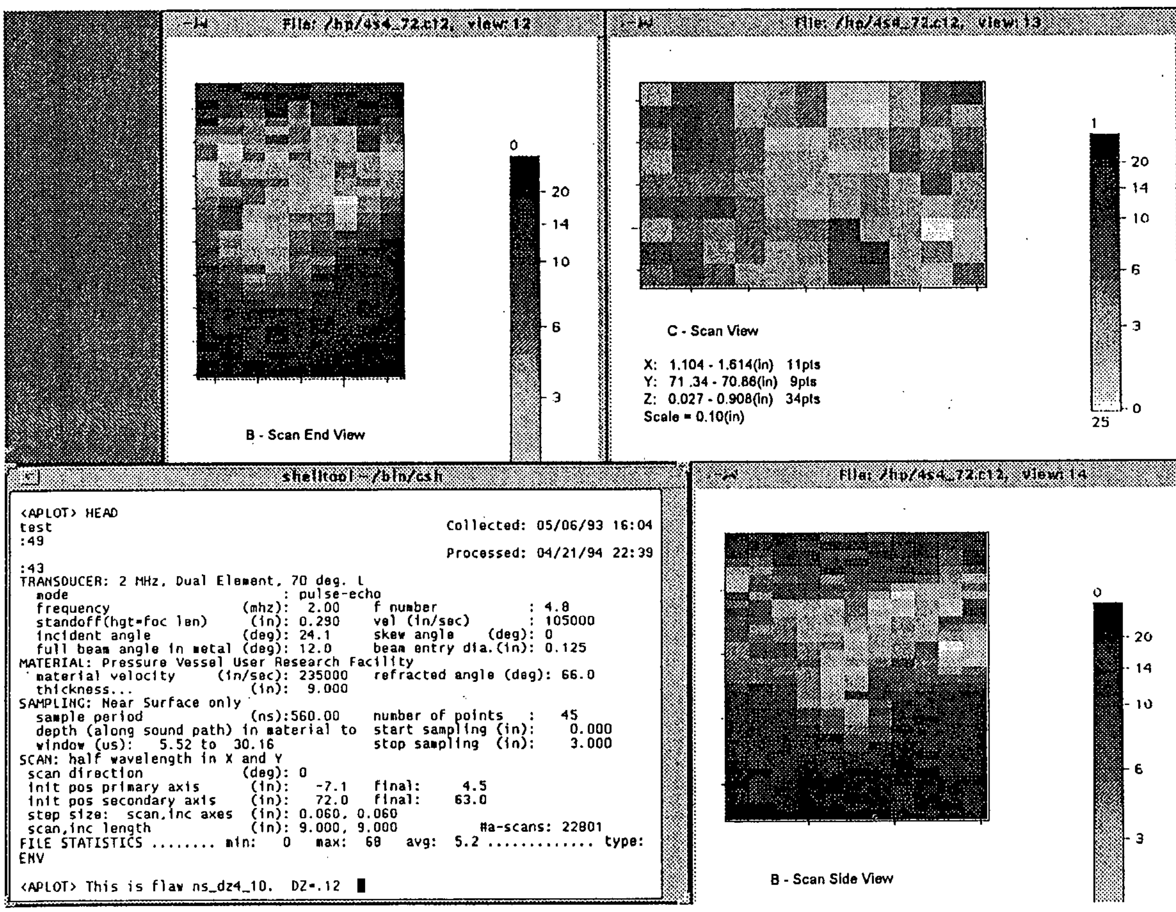


Figure A.21 - Planar indication #7 in the near surface base metal: mode 4

Figure A.22 shows planar indication #8 in the near surface base metal. This planar indication has a through-wall extent of 2.5 mm based on wave packet width. The detection was made in mode 3 where it had isolated TOF shape at a depth of 15 mm. There were no confirmations in other modes. The indication is characterized as planar based on lack of normal beam detection. There is no evidence of coin shape in the side view of mode 3. The width is 11 mm and was made to LOS in mode 3. The aspect ratio (width/depth) of this indication is 4 giving an orientation across the weld. The maximum amplitude-to-noise ratio is low at 14 to 7. With an X coordinate of -100 mm, the indication is clearly in the base metal. With a Z coordinate of 15 mm, the indication is clearly below the cladding.

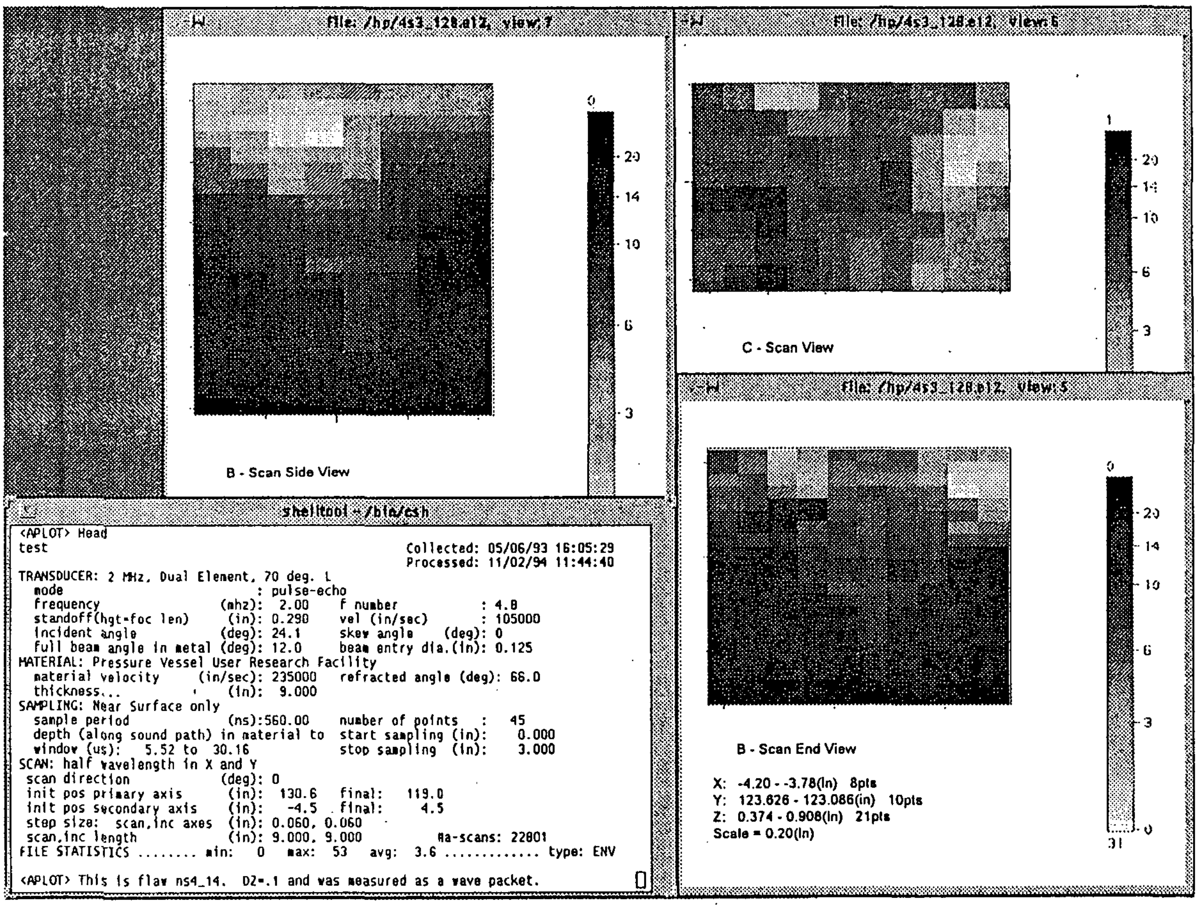


Figure A.22 - Planar indication #8 in the near surface base metal: mode 3

Figure A.23 shows planar indication #9 in the near surface base metal. This planar indication has a through-wall extent of 2.5 mm based on wave packet width. The detection was made in mode 3 where it had isolated TOF shape at a depth of 17 mm. There were no confirmations in other modes. The indication is characterized as planar based on lack of normal beam detection. There is no evidence of coin shape in the side view of mode 3. The width is 7 mm and was made to LOS in mode 3. The aspect ratio (width/depth) of this indication is 2.8 giving an orientation across the weld. The maximum amplitude-to-noise ratio is of medium range at 27 to 7. With an X coordinate of -102 mm, the indication is clearly in the base metal. With a Z coordinate of 17 mm, the indication is clearly below the cladding.

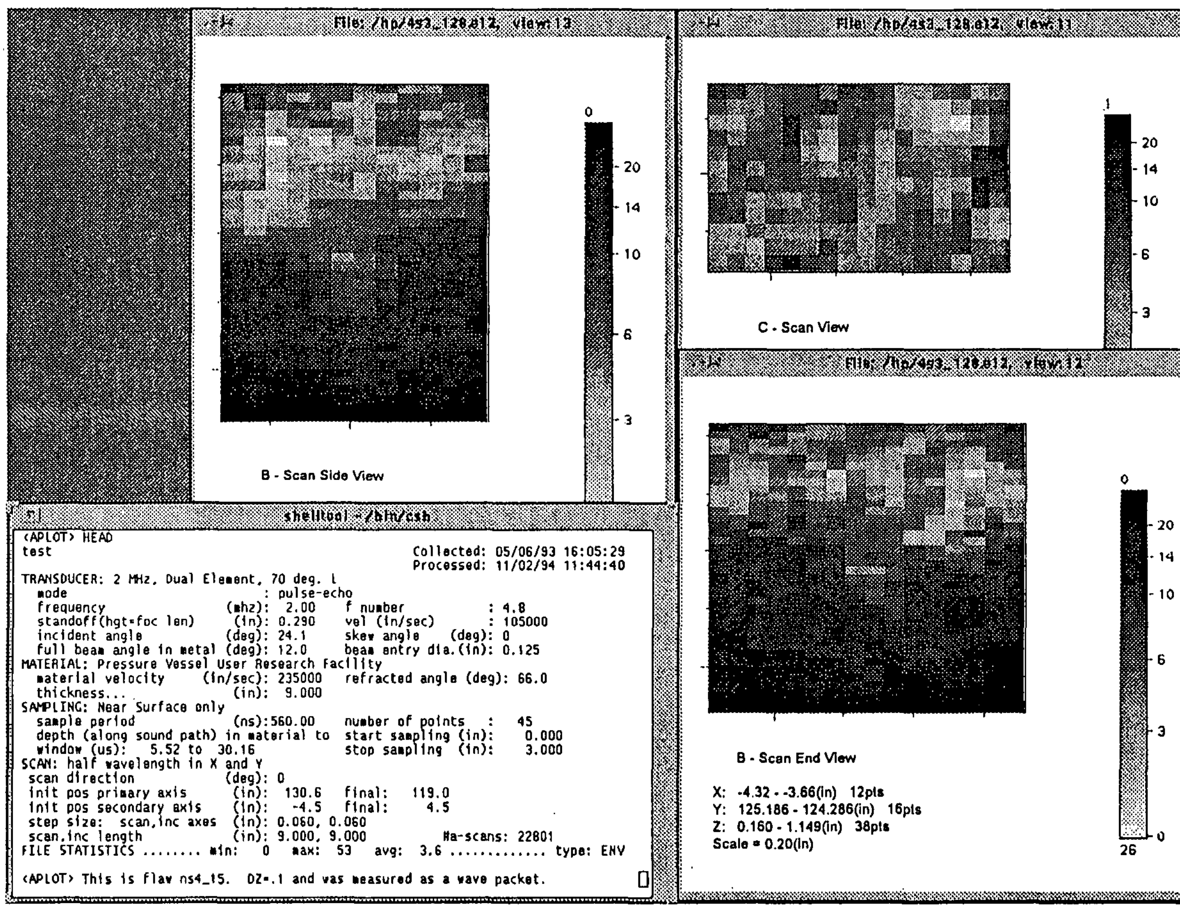


Figure A.23 - Planar indication #9 in the near surface base metal: mode 3

Figure A.24 shows planar indication #10 in the near surface base metal. This planar indication has a through-wall extent of 2.5 mm based on wave packet width. The detection was made in mode 2 where it had isolated TOF shape at a depth of 13 mm. There were no confirmations in other modes. The indication is characterized as planar based on lack of normal beam detection. There is no evidence of coin shape in the end view of modes 2. The length is 7 mm and was made to LOS in mode 2. The aspect ratio (length/depth) of this indication is 2.8 giving an orientation along the weld. The maximum amplitude-to-noise ratio is of medium range at 24 to 10. With an X coordinate of -18 mm, the indication is in the base metal, possibly in the HAZ. With a Z coordinate of 13 mm, the indication is below the cladding by 4 mm.

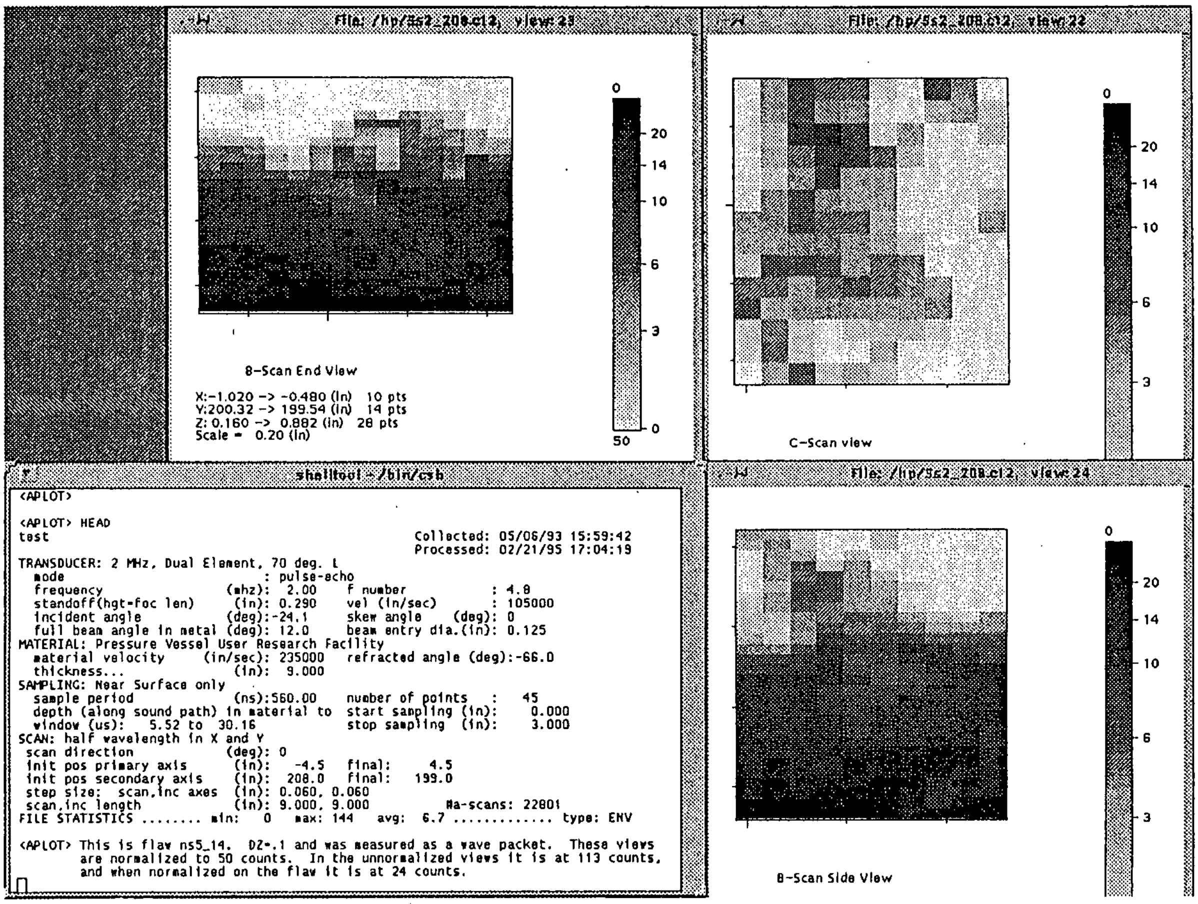


Figure A.24 - Planar indication #10 in the near surface base metal: mode 2

Figure A.25 shows planar indication #11 in the near surface base metal. This planar indication has a through-wall extent of 2.5 mm based on wave packet width. The detection was made in mode 4 where it had isolated TOF shape at a depth of 15 mm. The TOF shape may be artificial do to the limits of the scanning aperture; the shape quality is poor for this indication. There were no confirmations in other modes. The indication is characterized as planar based on lack of normal beam detection. There is no evidence of coin shape in the end view of mode 4. The length is 15 mm and was made to LOS in mode 4. The aspect ratio (length/depth) of this indication is 6 giving an orientation along the weld. The maximum amplitude-to-noise ratio is of medium range at 15 to 6. With an X coordinate of 20 mm, the indication is in the base metal. With a Z coordinate of 15 mm, the indication is clearly below the cladding.

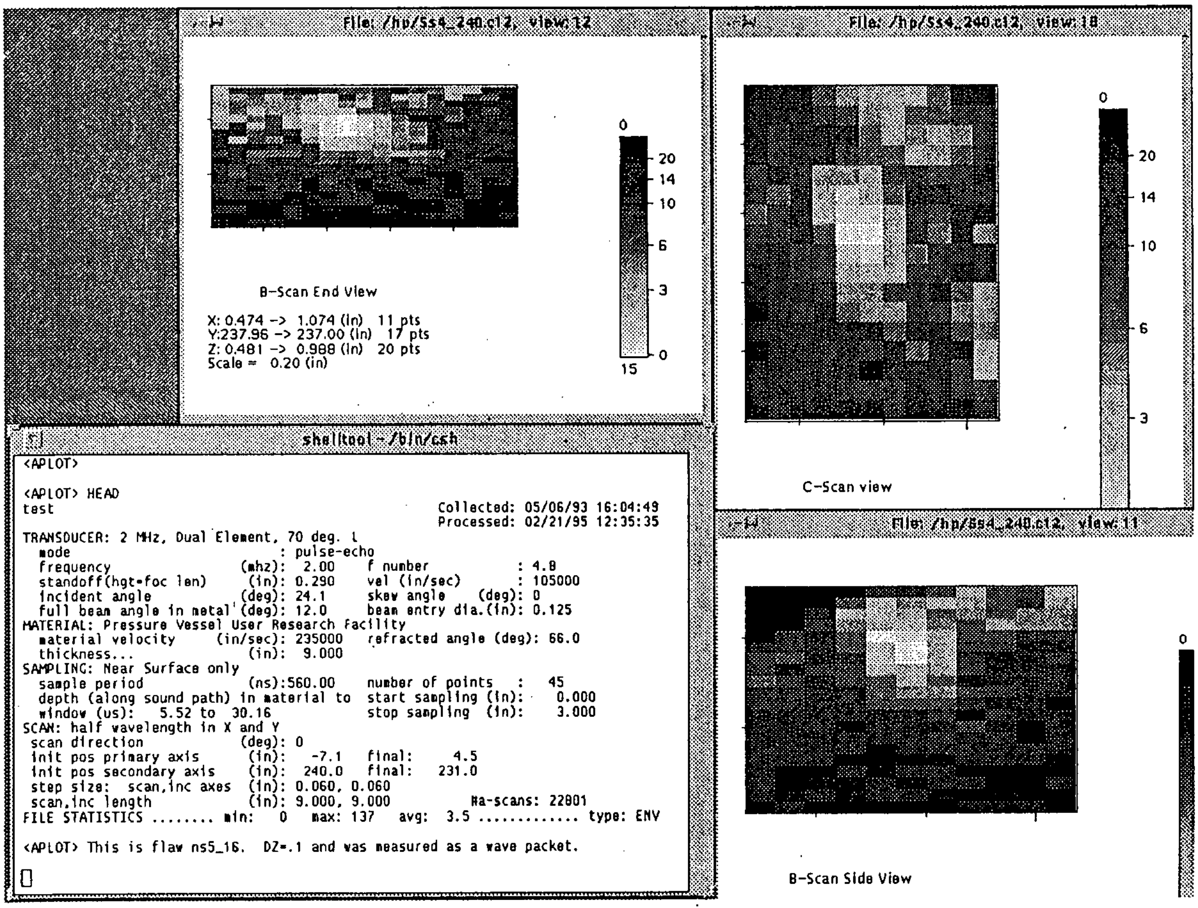


Figure A.25 - Planar indication #11 in the near surface base metal: mode 4

Figure A.26 shows planar indication #12 in the near surface base metal. This planar indication has a through-wall extent of 2.5 mm based on wave packet width. The detection was made in mode 8 where it had isolated TOF shape at a depth of 19 mm. There were no confirmations in other modes. The indication is characterized as planar based on lack of normal beam detection. There is some evidence of coin shape in the end view of mode 8. The length is 11 mm and was made to LOS in mode 8. The aspect ratio (length/depth) of this indication is 4 giving an orientation along the weld. The maximum amplitude-to-noise ratio is high at 216 to 45. With an X coordinate of 113 mm, the indication is clearly in the base metal. With a Z coordinate of 19 mm, the indication is clearly below the cladding.

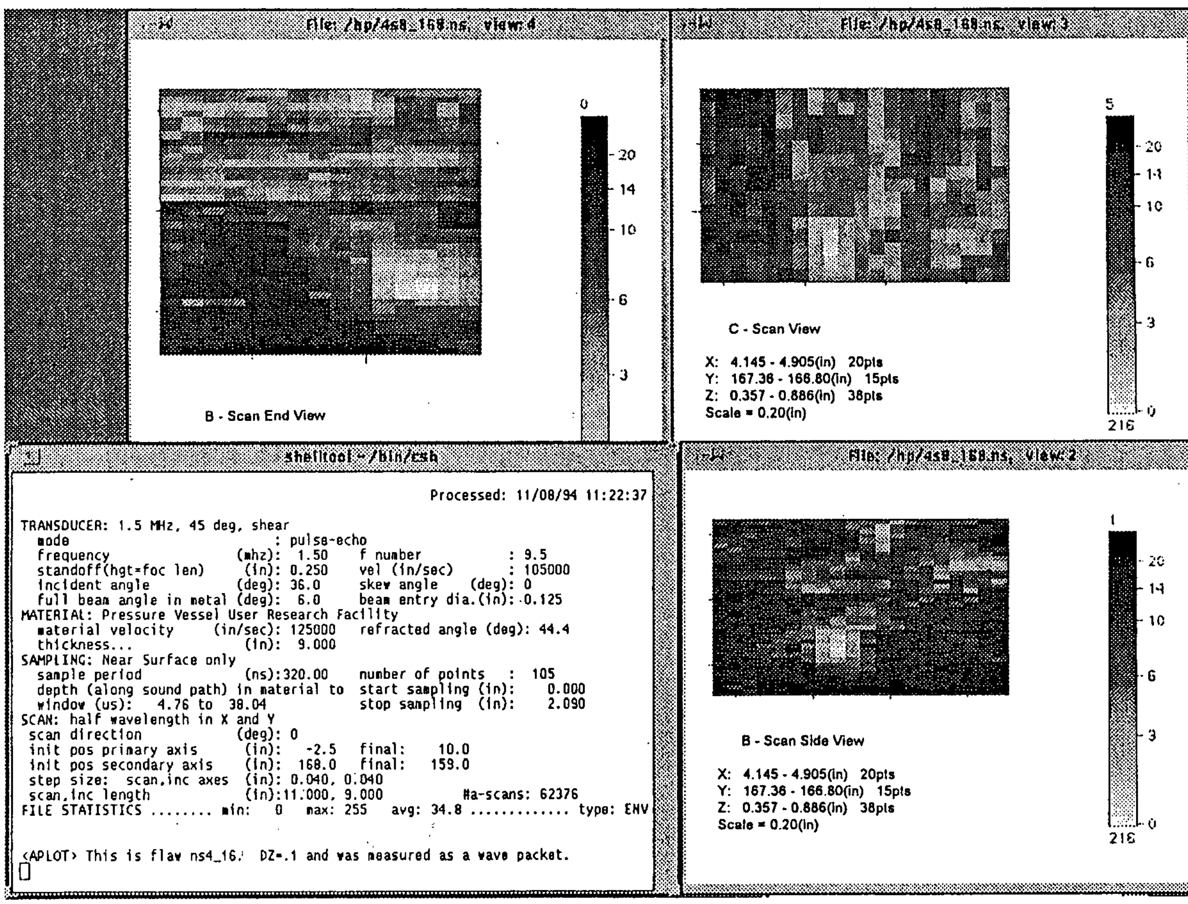


Figure A.26 - Planar indication #12 in the near surface base metal: mode 8

Figure A.27 shows planar indication #13 in the near surface base metal. This planar indication has a through-wall extent of 2.3 mm based on wave packet width, possibly 1.6 mm based on ring around pattern. The detection was made in mode 8 where it displayed TOF shape at a depth of 14 mm. The shape quality is good for this indication. There were no confirmations in other modes. The indication is characterized as planar based on lack of normal beam detection. There is no evidence of coin shape in the end view of mode 8. The length is 10 mm and was made to LOS in mode 8. The aspect ratio (length/depth) of this indication is 6 giving an orientation along the weld. The maximum amplitude-to-noise ratio is of medium range at 154 to 50. With an X coordinate of 142 mm, the indication is clearly in the base metal. With a Z coordinate of 14 mm, the indication is clearly below the cladding.

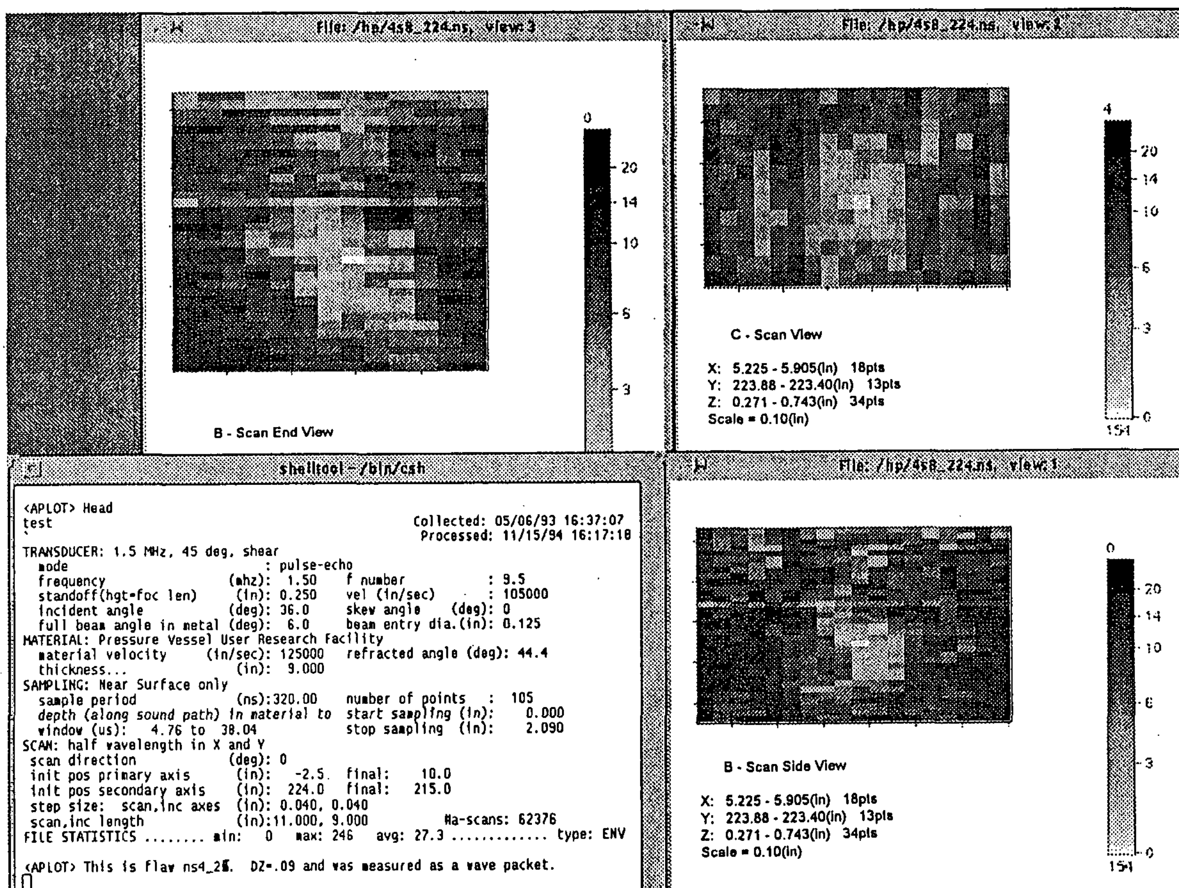


Figure A.27 - Planar indication #13 in the near surface base metal: mode 8

Figure A.28 shows planar indication #14 in the near surface base metal. This planar indication has a through-wall extent of 2.3 mm based on wave packet width. The detection was made in mode 8 where it had isolated TOF shape at a depth of 20 mm. The shape quality is good for this indication. There were no confirmations in other modes. The indication is characterized as planar based on lack of normal beam detection. There is some evidence of coin shape in the end view of mode 8. The length is 10 mm and was made to LOS in mode 8. The aspect ratio (length/depth) of this indication is 4 giving an orientation along the weld. The maximum amplitude-to-noise ratio is of medium range at 143 to 45. With an X coordinate of 43 mm, the indication is clearly in the base metal. With a Z coordinate of 20 mm, the indication is clearly below the cladding.

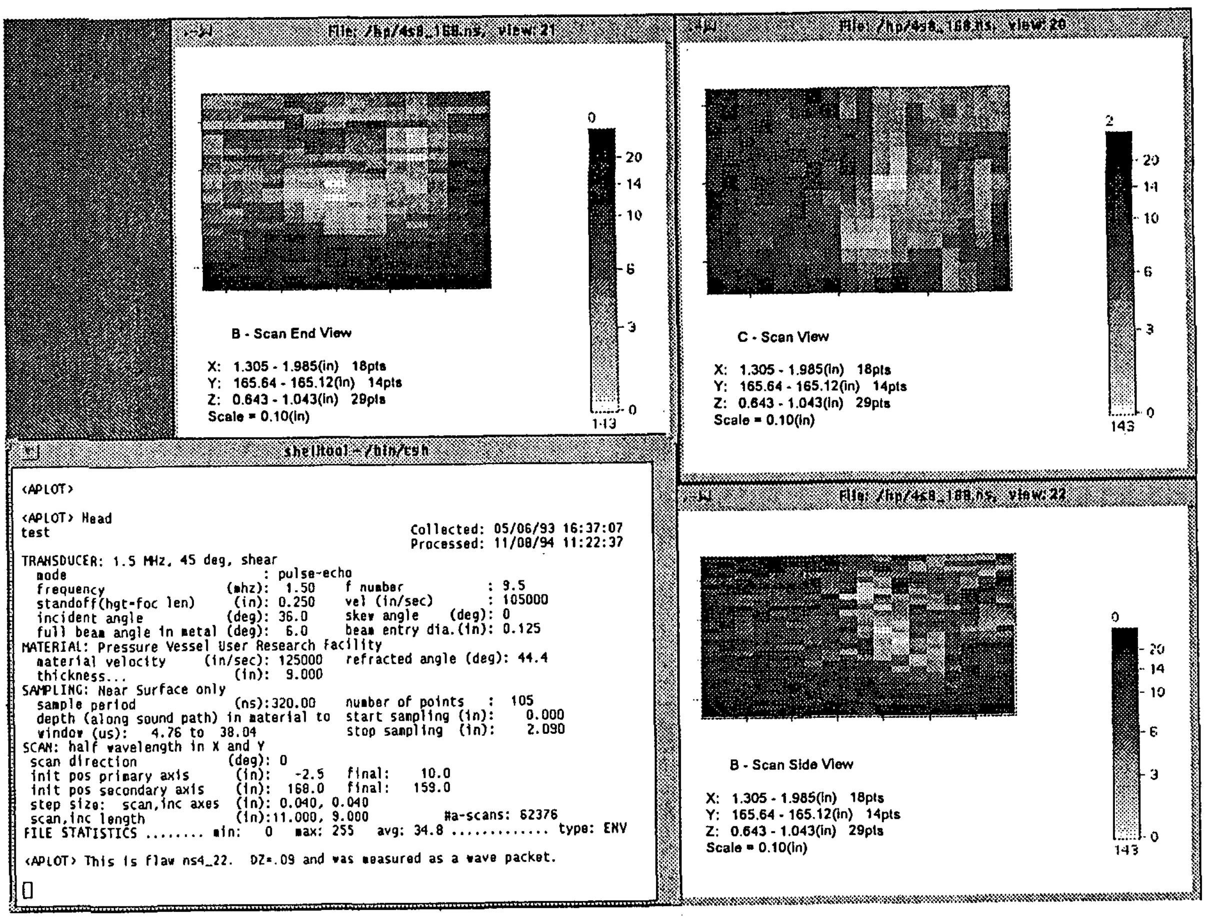


Figure A.28 - Planar indication #14 in the near surface base metal: mode 8

Figure A.29 shows planar indication #15 in the near surface base metal. This planar indication has a through-wall extent of 2.3 mm based on wave packet width. The detection was made in mode 2 where it had isolated TOF shape at a depth of 17 mm. The shape quality is good for this indication. There were no confirmations in other modes. The indication is characterized as planar based on lack of normal beam detection. There is no evidence of coin shape in the end view of mode 2. The length is 14 mm and was made to LOS in mode 2. The aspect ratio (length/depth) of this indication is 6 giving an orientation along the weld. The maximum amplitude-to-noise ratio is of medium range at 16 to 7. With an X coordinate of -30 mm, the indication is clearly in the base metal. With a Z coordinate of 17 mm, the indication is clearly below the cladding.

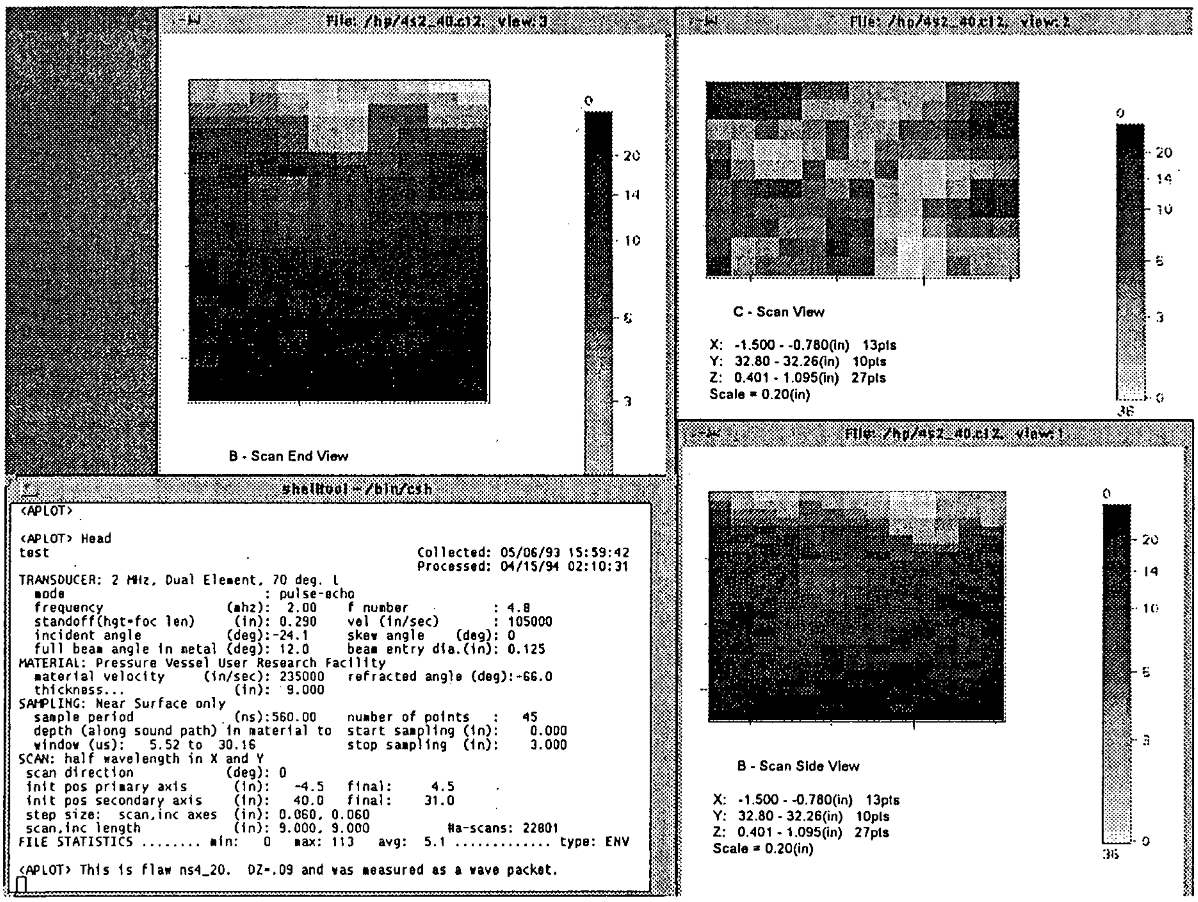


Figure A.29 - Planar indication #15 in the near surface base metal: mode 2

Figure A.30 shows planar indication #16 in the near surface base metal. This planar indication has a through-wall extent of 2.3 mm based on wave packet width. The detection was made in mode 3 where it had isolated TOF shape at a depth of 18 mm. The TOF shape may be artificial because of the limits of the scanning aperture; the shape quality is fair for this indication. There were no confirmations in other modes. The indication is characterized as planar based on lack of normal beam detection. There is no evidence of coin shape in the end view of mode 3. The width is 7 mm and was made to LOS in mode 3. The aspect ratio (width/depth) of this indication is 3 giving an orientation across the weld. The maximum amplitude-to-noise ratio is low at 12 to 6. With an X coordinate of -104 mm, the indication is clearly in the base metal. With a Z coordinate of 18 mm, the indication is clearly below the cladding.

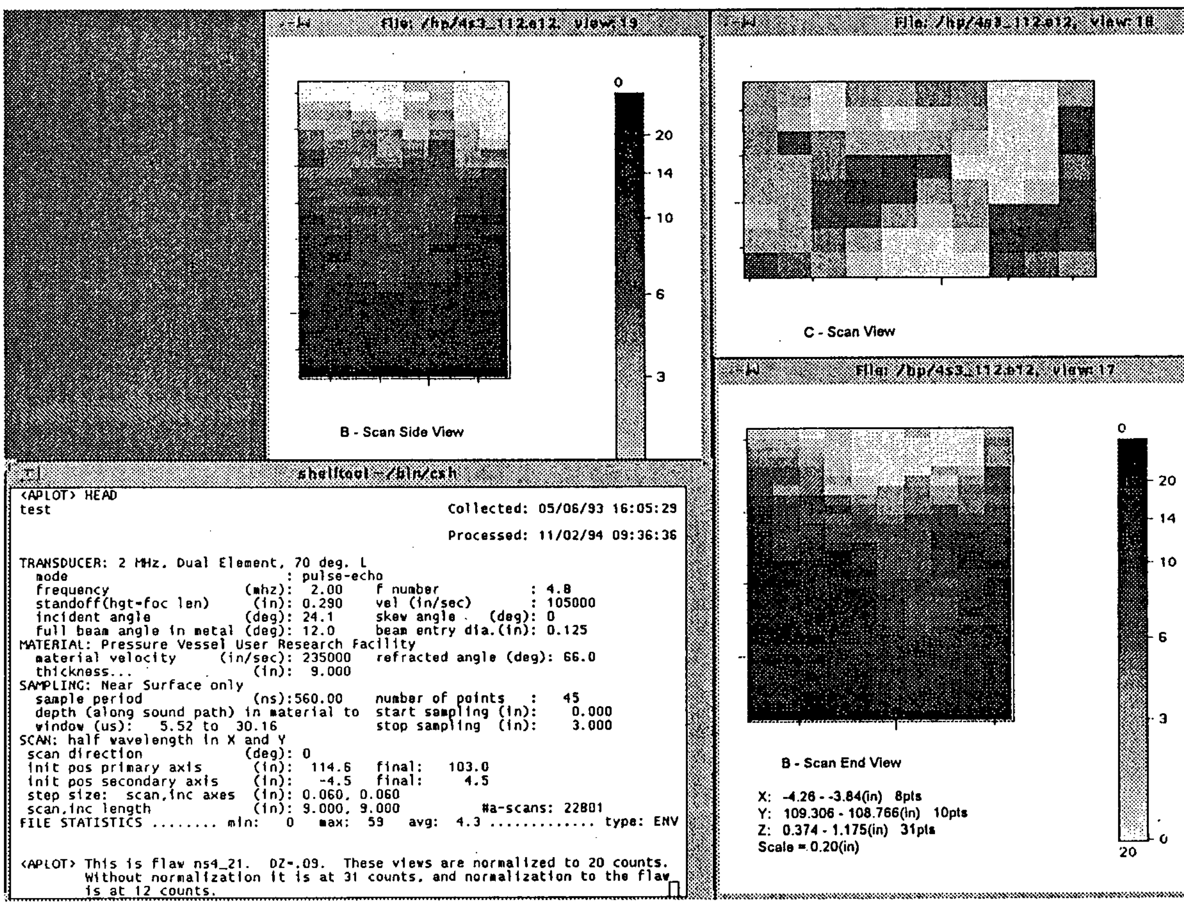


Figure A.30 - Planar indication #16 in the near surface base metal: mode 3

Figure A.31 shows planar indication #17 in the near surface base metal. This planar indication has a through-wall extent of 2.3 mm based on wave packet width. The detection was made in mode 8 where it had isolated TOF shape at a depth of 20 mm. The shape quality is poor for this indication. There were no confirmations in other modes. The indication is characterized as planar based on lack of normal beam detection. There is no evidence of coin shape in the end view of mode 8. The length is 8 mm and was made to LOS in mode 8. The aspect ratio (length/depth) of this indication is 3 giving an orientation along the weld. The maximum amplitude-to-noise ratio is of medium range at 130 to 50. With an X coordinate of 46 mm, the indication is clearly in the base metal. With a Z coordinate of 20 mm the indication is clearly below the cladding.

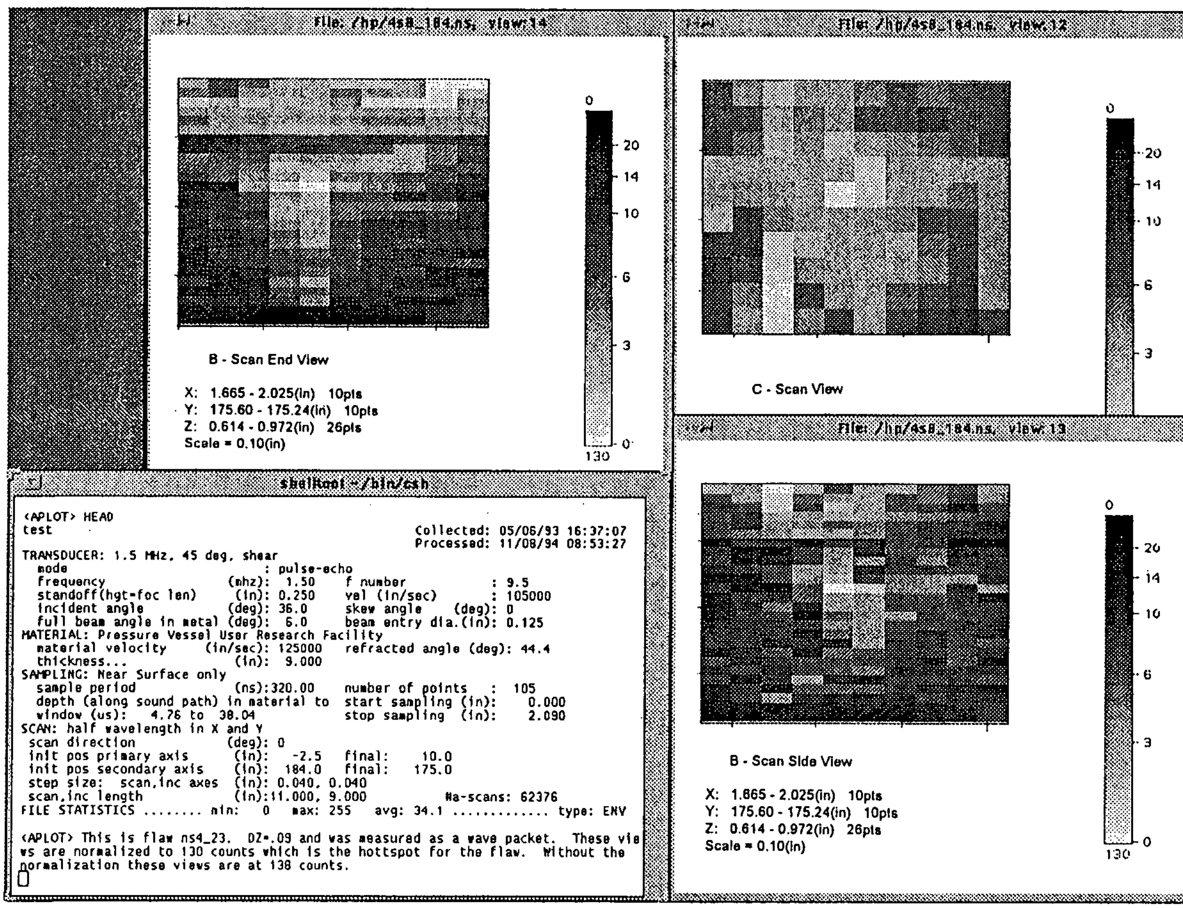


Figure A.31 - Planar indication #17 in the near surface base metal: mode 8

Figure A.32 shows planar indication #18 in the near surface base metal. This planar indication has a through-wall extent of 2 mm based on wave packet width. The detection was made in mode 7 where it had isolated TOF shape at a depth of 22 mm. The shape quality is fair for this indication. There were no confirmations in other modes. The indication is characterized as planar based on lack of normal beam detection. There is no evidence of coin shape in the side view of mode 7. The width is 11 mm and was made to LOS in mode 7. The aspect ratio (width/depth) of this indication is 6 giving an orientation across the weld. The maximum amplitude-to-noise ratio is of medium range at 85 to 30. With an X coordinate of 39 mm, the indication is clearly in the base metal. The Z coordinate of 22 mm shows that the indication is below the cladding.

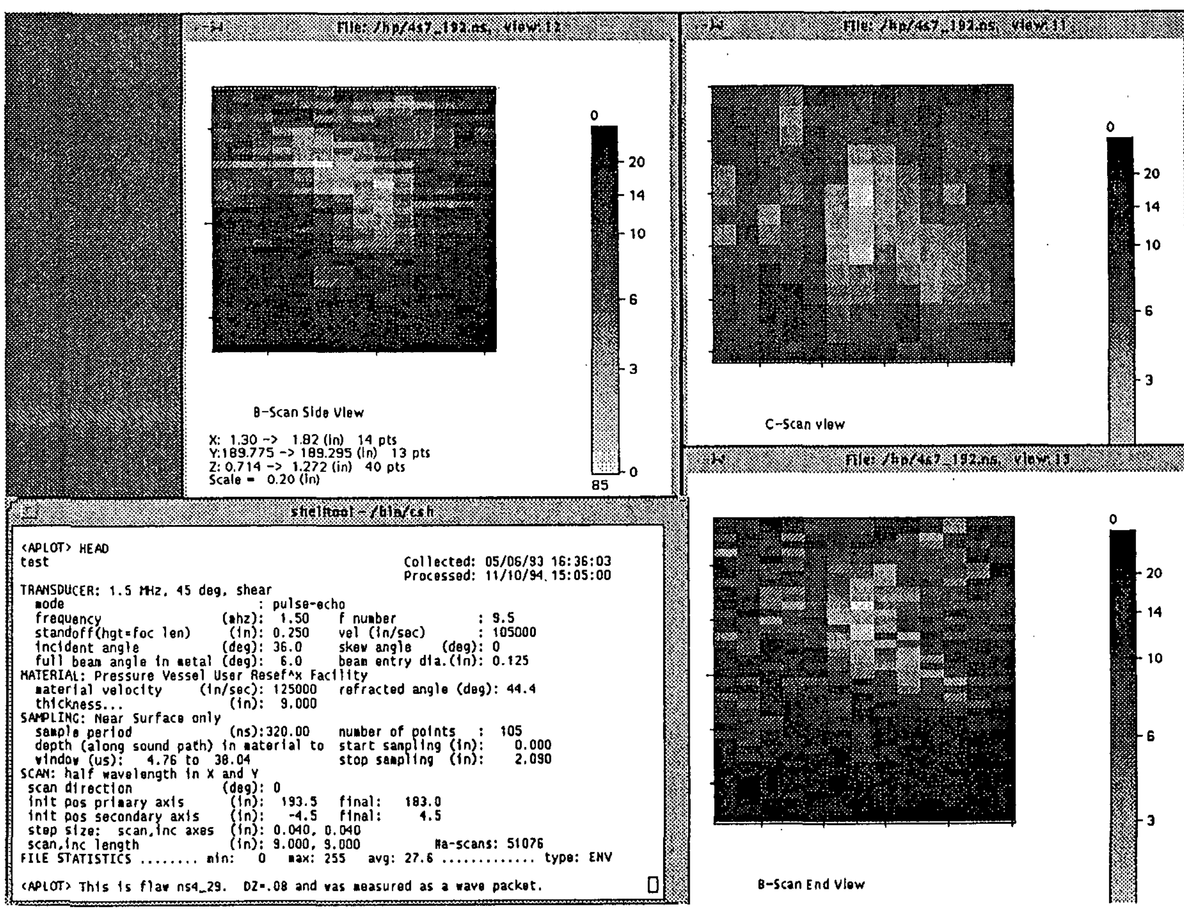


Figure A.32 - Planar indication #18 in the near surface base metal: mode 7

Figure A.33 shows planar indication #19 in the near surface base metal. This planar indication has a through-wall extent of 2 mm based on wave packet width. The detection was made in mode 7 where it had isolated TOF shape at a depth of 25 mm. The shape quality for this indication is poor and broken up, implying that more than one small flaw may be present There were no confirmations in other modes. The indication is characterized as planar based on lack of normal beam detection or detection of orthogonal modes. There is no evidence of coin shape in the side view of mode 7. The width is 16 mm and was made to LOS in mode 7. The aspect ratio (width/depth) of this indication is 8 which tends to confirm more than one small flaw. The maximum amplitude-to-noise ratio is of medium range at 91 to 40. With an X coordinate of 106 mm, the indication is clearly in the base metal. With a Z coordinate of 25 mm, the indication is clearly below the cladding.

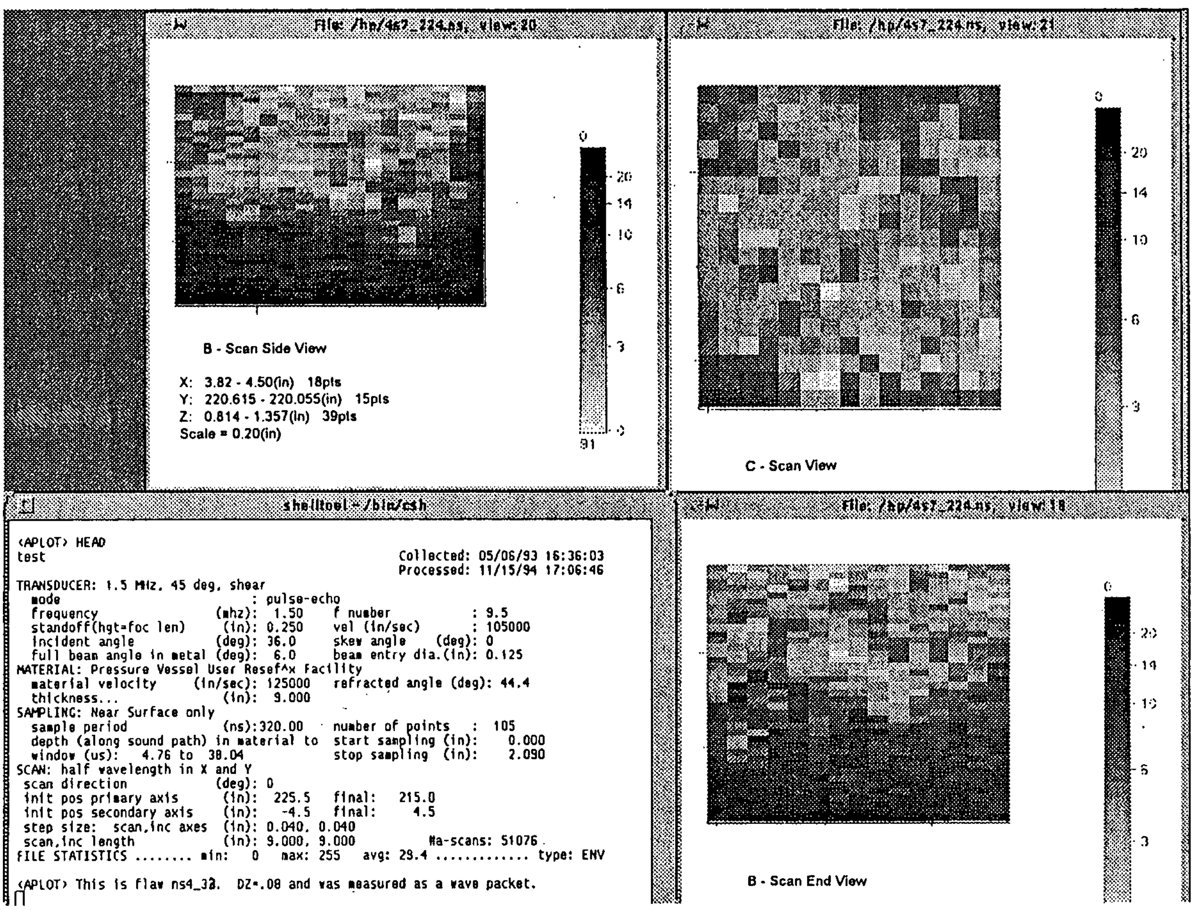


Figure A.33 - Planar indication #19 in the near surface base metal: mode 7

Figure A.34 shows planar indication #20 in the near surface base metal. This planar indication has a through-wall extent of 2 mm based on wave packet width. The detection was made in mode 3 where it had isolated TOF shape at a depth of 12 mm. The shape quality is fair for this indication. There were no confirmations in other modes. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. There is no evidence of coin shape in the side view of mode 3. The width is 8 mm and was made to LOS in mode 3. The aspect ratio (width/depth) of this indication is 4 giving an orientation across the weld. The maximum amplitude-to-noise ratio is of medium range at 24 to 8. With an X coordinate of 81 mm, the indication is clearly in the base metal. With a Z coordinate of 12 mm, the indication is below the cladding by 3 mm.

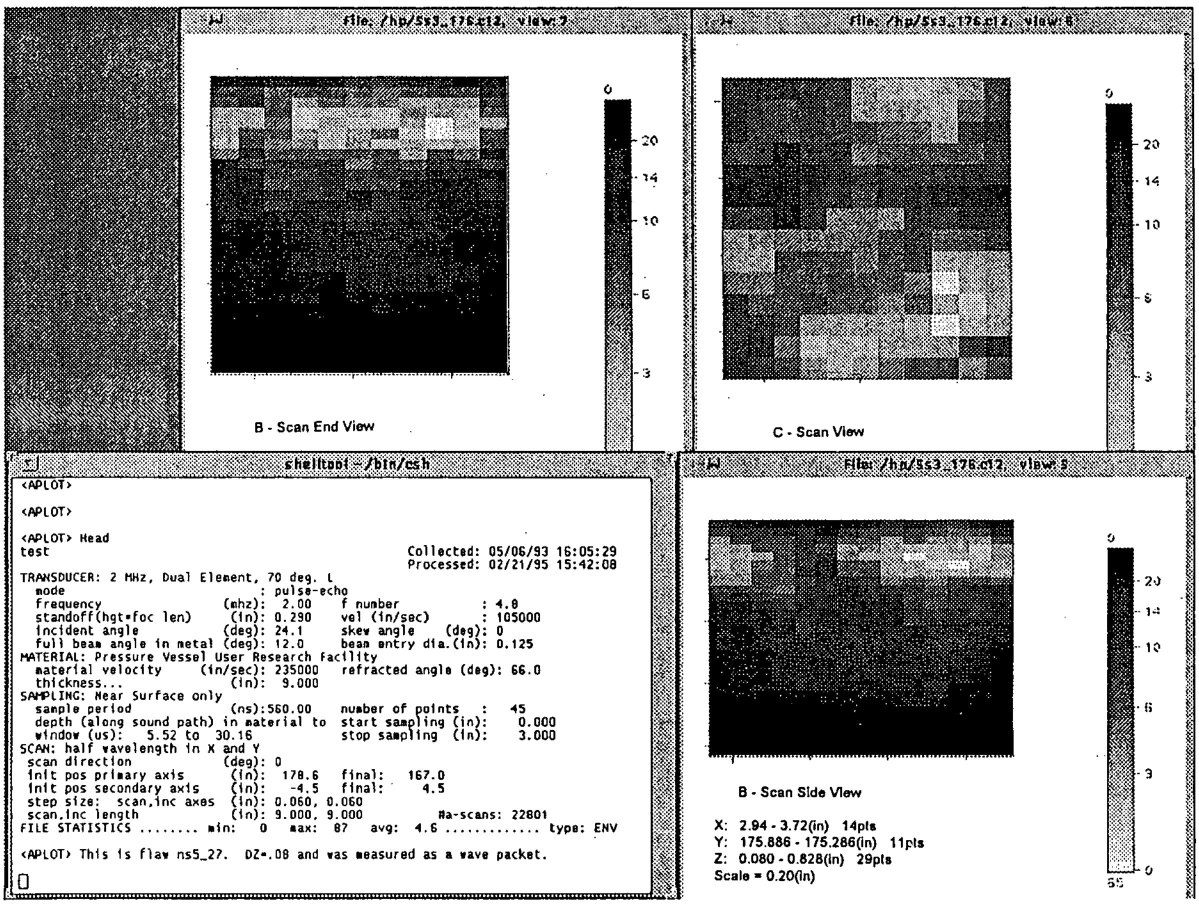


Figure A.34 - Planar indication #20 in the near surface base metal: mode 3

Figures A.35a-b show planar indication #21 in the near surface base metal. This planar indication has a through-wall extent of 1.5 mm based on wave packet width. The detections were made in modes 2 and 4 where they had isolated TOF shape at a depth of 8 mm. The TOF shape quality for this indication is fair. The indication is characterized as planar based on lack of normal beam detection. There is good evidence of coin shape in the end view of mode 4. The length is 8 mm and was made to LOS in mode 4. The aspect ratio (length/depth) of this indication is 5 giving an orientation along the weld. The maximum amplitude-to-noise ratio is high at 143 to 25. With an X coordinate of -24 mm, the indication is clearly in the base metal. The Z coordinate of 8 mm shows that the indication is in the base metal, possibly in the cladding.

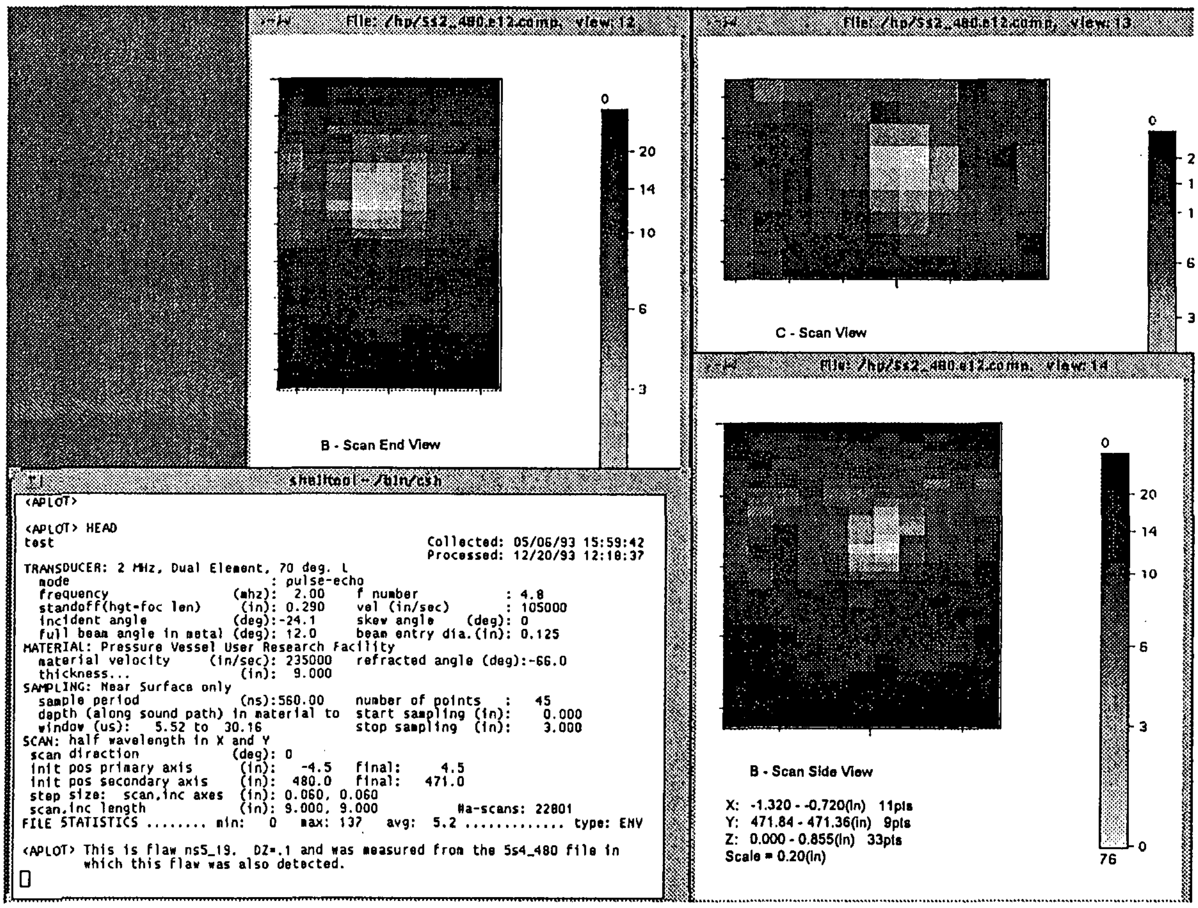


Figure A.35a - Planar indication #21 in the near surface base metal: mode 2

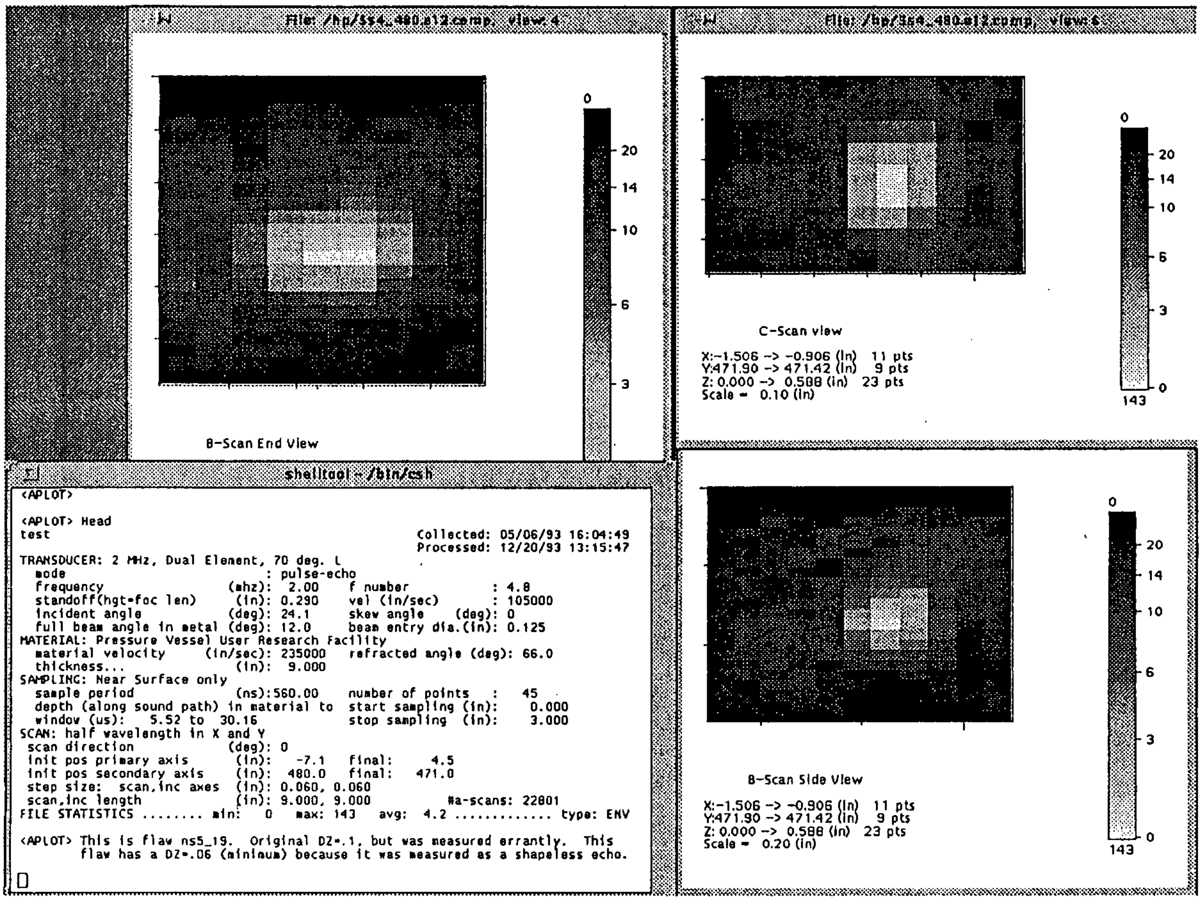


Figure A.35b - Planar indication #21 in the near surface base metal: mode 4

Volumetric Indications in the Near Surface Base Metal

Figures A.36a-b show volumetric indication #1 in the near surface base metal. This volumetric indication has a through-wall extent of 6 mm based LOS in a cloud like pattern. The detection was made in mode 9 where it failed to display TOF shape but looked more cloud like in nature at a depth of 20 mm. There was a confirmation in mode 1 at a depth of 19 mm. The indication is characterized as volumetric based on normal beam detection. There is no evidence of coin shape in the side view of mode 9. The length is 6 mm and was made to LOS in mode 1. The width is 7 mm and was made to LOS in mode 9. The aspect ratio (width/depth) of this indication is 1.2, and the length-to-depth ratio is 1.0. The maximum amplitude-to-noise ratio is low at 88 to 40. With an X coordinate of 28 mm, the indication is clearly in the base metal. With a Z coordinate of 20 mm, the indication is clearly below the cladding.

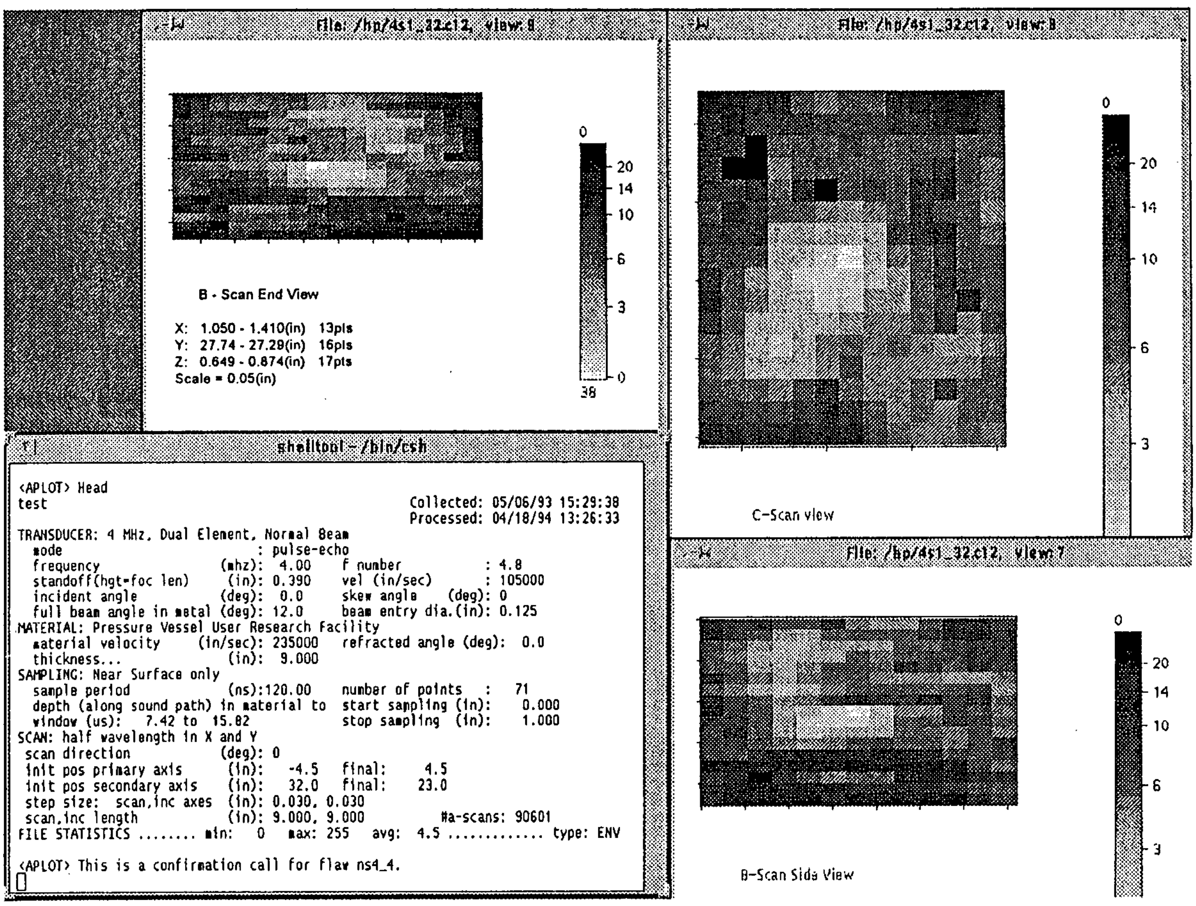


Figure A.36a - Volumetric indication #1 in the near surface base metal: mode 1

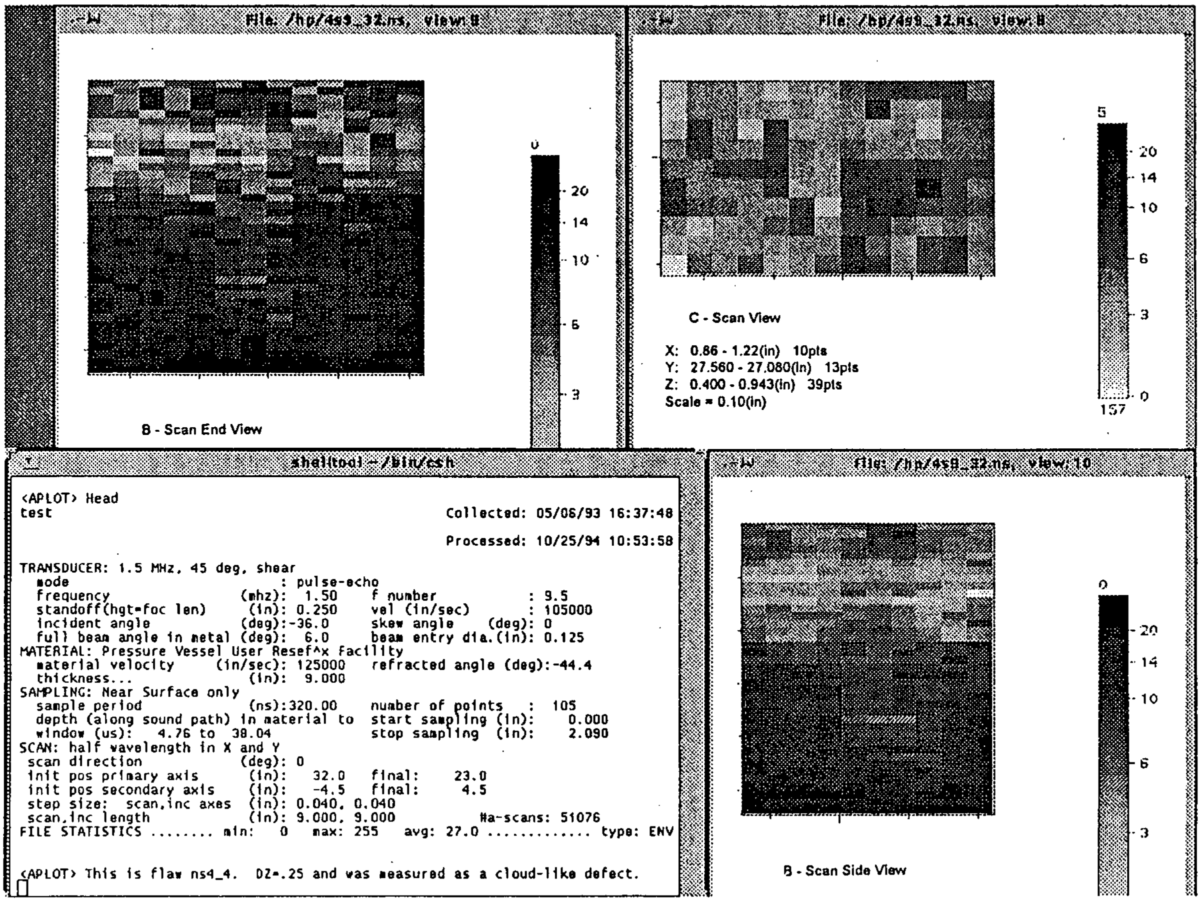


Figure A.36b - Volumetric indication #1 in the near surface base metal: mode 9

Figures A.37a-b show volumetric indication #2 in the near surface base metal. This volumetric indication has a through-wall extent of 3 mm based on wave packet width. The detection was made in mode 2 where it had isolated TOF shape at a depth of 20 mm. The shape quality is poor for this indication. There was a confirmation in mode 3 at a depth of 18 mm. The different Z values 18 to 20 give an alternate depth size of 2 mm. The indication is characterized as volumetric based on detection in orthogonal modes. There is no evidence of coin shape in the end view of mode 2 and side view of mode 3. The length is 13 mm and was made to LOS mode 2. The width is 7 mm and was made to LOS in mode 3. The aspect ratio (length/depth) of this indication is 4 giving an orientation along the weld. The maximum amplitude-to-noise ratio is of medium range at 8 to 3. With an X coordinate of 79 mm, the indication is clearly in the base metal. With a Z coordinate of 18 mm, the indication is clearly below the cladding.

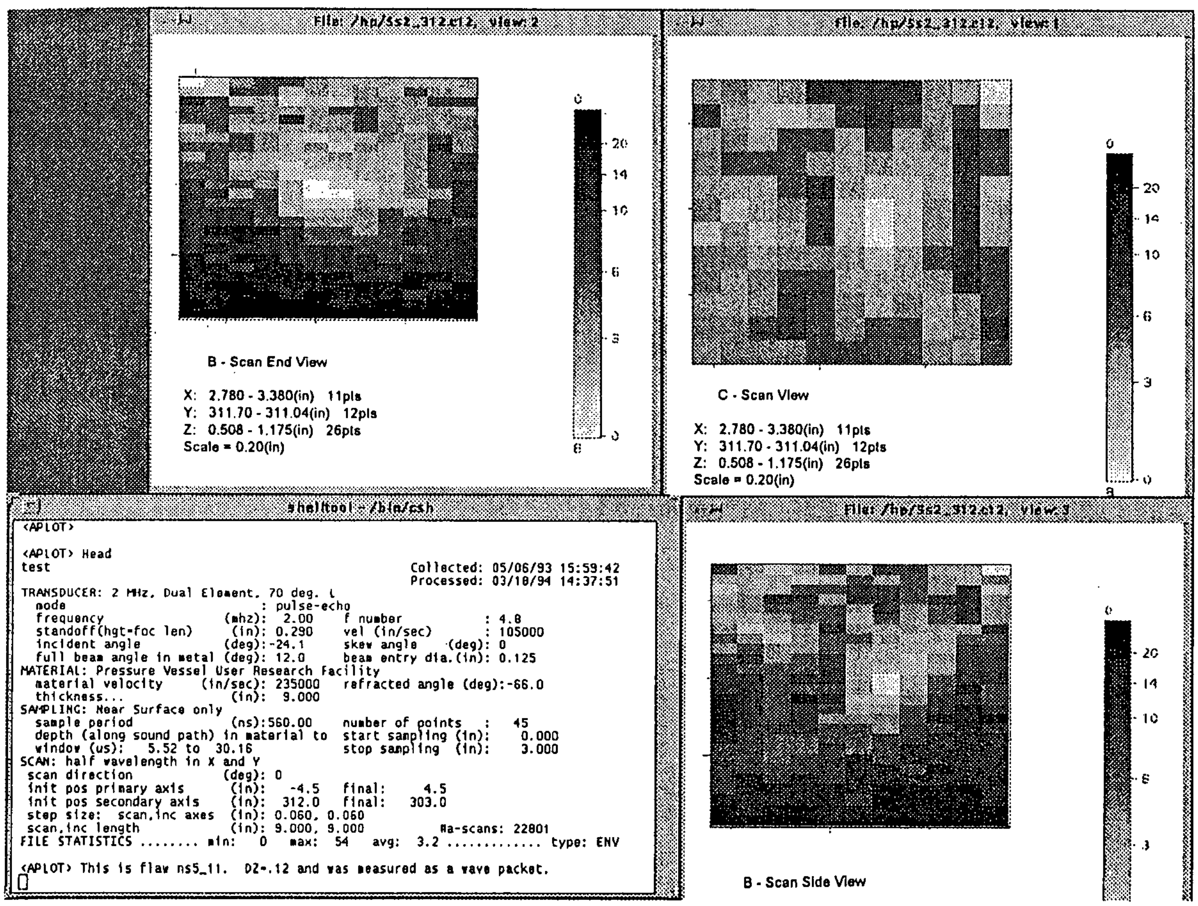


Figure A.37a - Volumetric indication #2 in the near surface base metal: mode 2

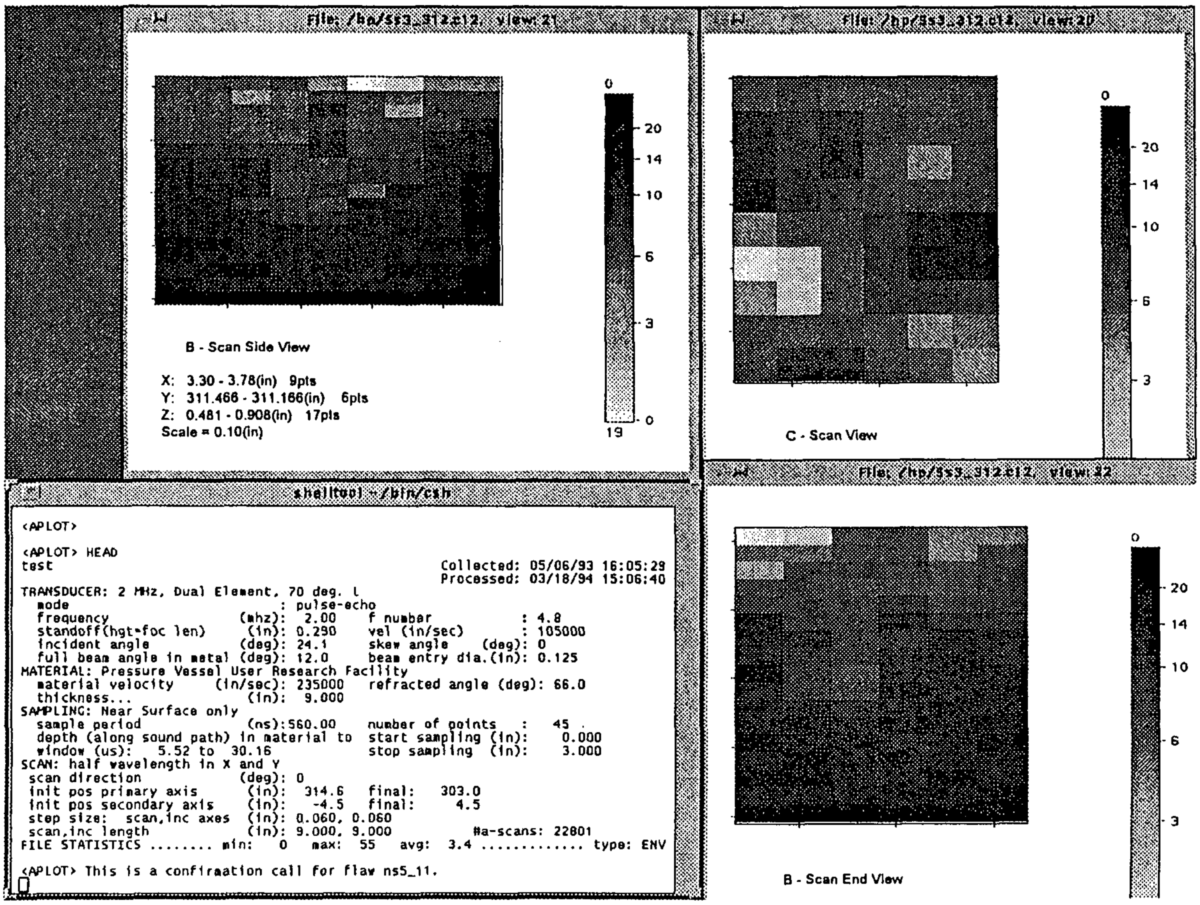


Figure A.37b - Volumetric indication #2 in the near surface base metal: mode 3

Figure A.38 shows volumetric indication #3 in the near surface base metal. This volumetric indication has a through-wall extent of 2.5 mm based on ring around pattern. The detection was made in mode 7 where it displayed a pair of TOF shapes at a depth of 20 mm. The shape quality is good for this indication. There were no confirmations in other modes. The indication is characterized as volumetric based on the detection of ring around shape. There is no evidence of coin shape in the side view of mode 7. The width is 12 mm and was made to LOS in mode 7. The aspect ratio (width/depth) of this indication is 5 giving an orientation across the weld. The maximum amplitude-to-noise ratio is high at 100 to 25. With an X coordinate of 71 mm, the indication is clearly in the base metal. With a Z coordinate of 20 mm, the indication is clearly below the cladding.

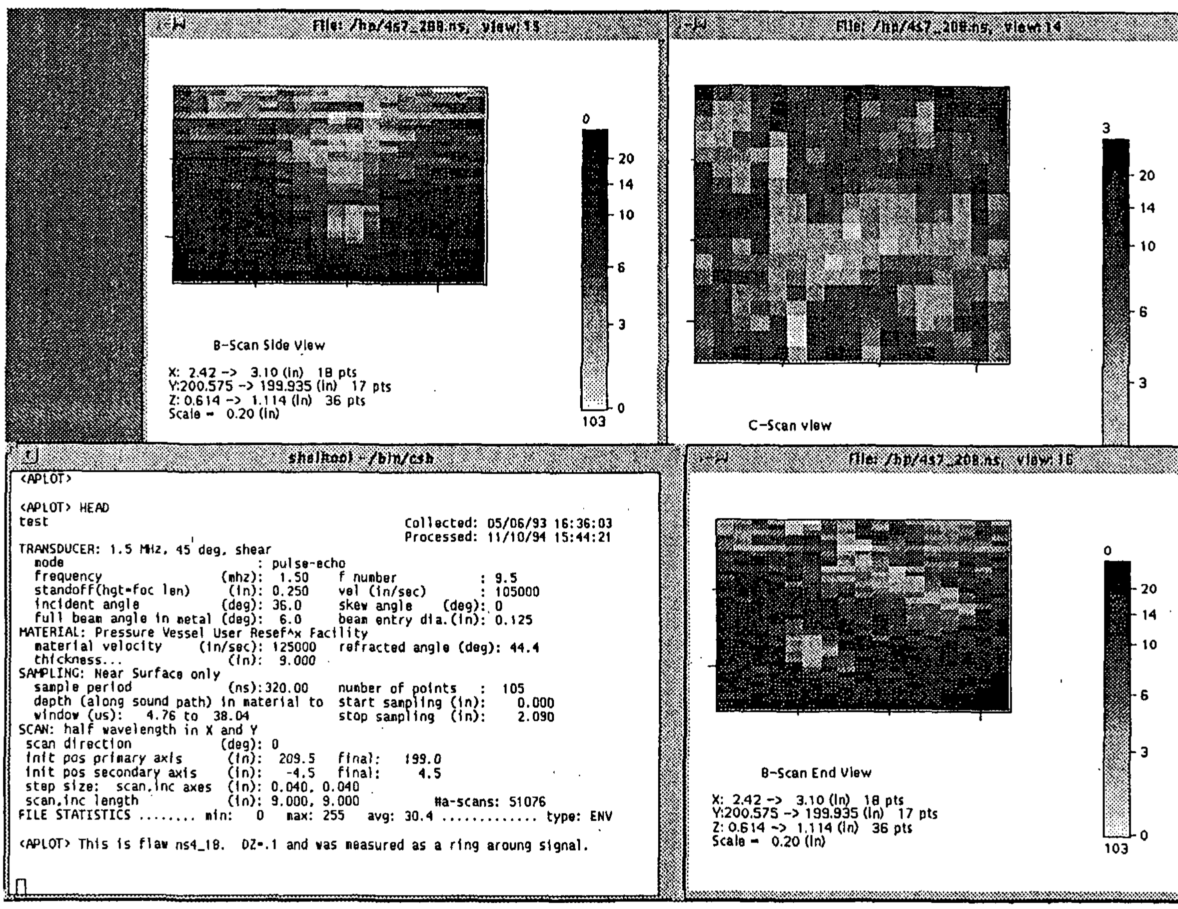


Figure A.38 - Volumetric indication #3 in the near surface base metal: mode 7

Figures A.39a-b show volumetric indication #4 in the near surface base metal. This volumetric indication has a through-wall extent of 2.3 mm based on wave packet width. The detection was made in mode 5 where it had isolated TOF shape at a depth of 16 mm. The shape quality is good for this indication. There was a confirmation in mode 2 at a depth of 16 mm. The two Z values of 16 mm give an alternate depth size of less than 1.5 mm. The indication is characterized as volumetric based on detection in orthogonal modes. There is no evidence of coin shape in the end view of mode 2 and side view of mode 5. The length is 12 mm and was made to LOS in mode 2. The width is 12 mm and was made to LOS in mode 5. The range of aspect ratios (length/depth) of this indication is 5 to 8. With an X coordinate of -64 mm, the indication is clearly in the base metal. With a Z coordinate of 16 mm, the indication is clearly below the cladding.

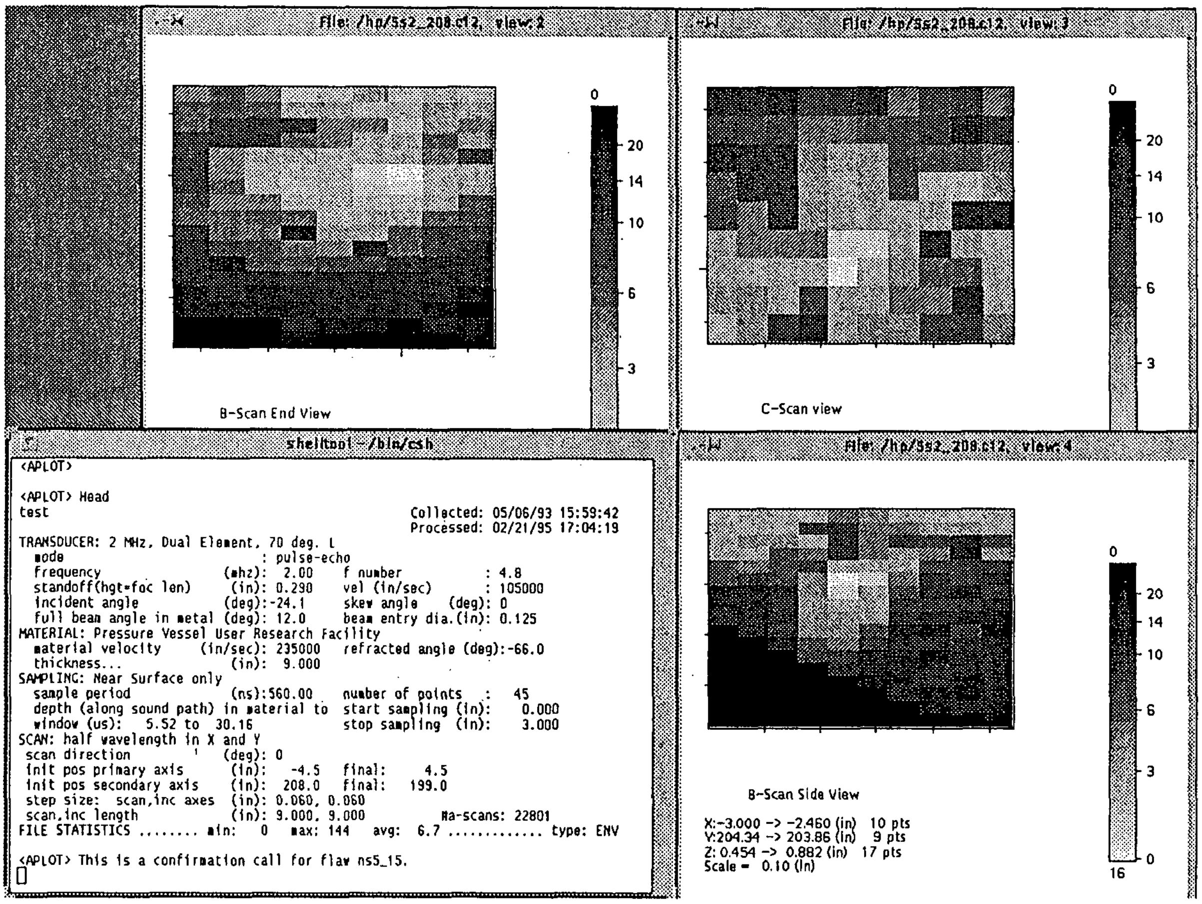


Figure A.39a - Volumetric indication #4 in the near surface base metal: mode 2

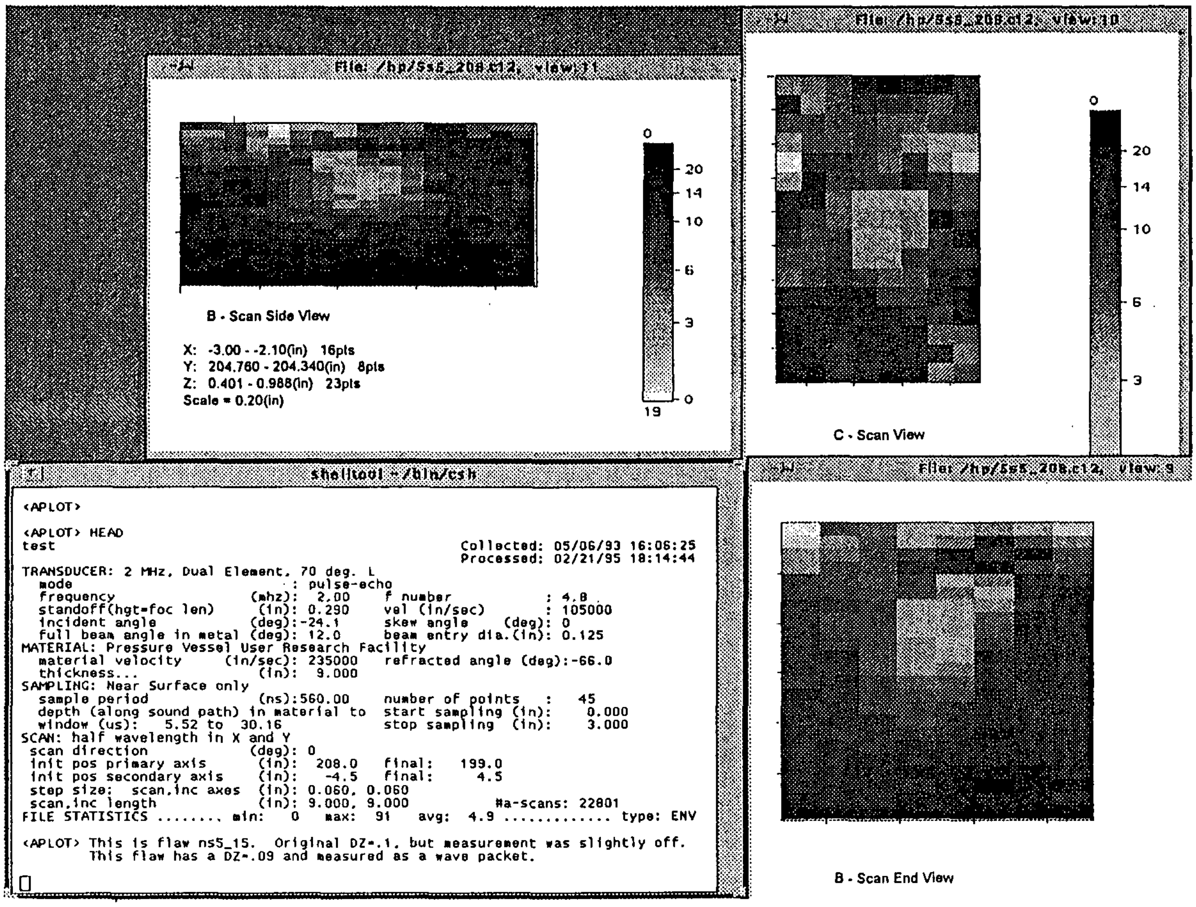


Figure A.39b - Volumetric indication #4 in the near surface base metal: mode 5

Figures A.40a-b show volumetric indication #5 in the near surface base metal. This volumetric indication has a through-wall extent of 2 mm based on wave packet width. The detection was made in mode 4 where it had isolated TOF shape at a depth of 11 mm. The shape quality is poor but not unusual for a shallow indication. There was a confirmation in mode 10 at a depth of 12 mm. The different Z values 10 to 11 mm give an alternate depth size of 1 mm. The indication is characterized as volumetric based on normal beam detection. There is no evidence of coin shape in the end view of mode 4. The length is 9 mm and was made to LOS in mode 4. The width is 5 mm and was made to LOS in mode 10. The aspect ratio (length/depth) of this indication is 4 giving an orientation along the weld. The maximum amplitude-to-noise ratio is high at 99 to 20. With an X coordinate of 26 mm, the indication is clearly in the base metal. With a Z coordinate of 10 to 11 mm, the indication is below the cladding by 1 to 2 mm.

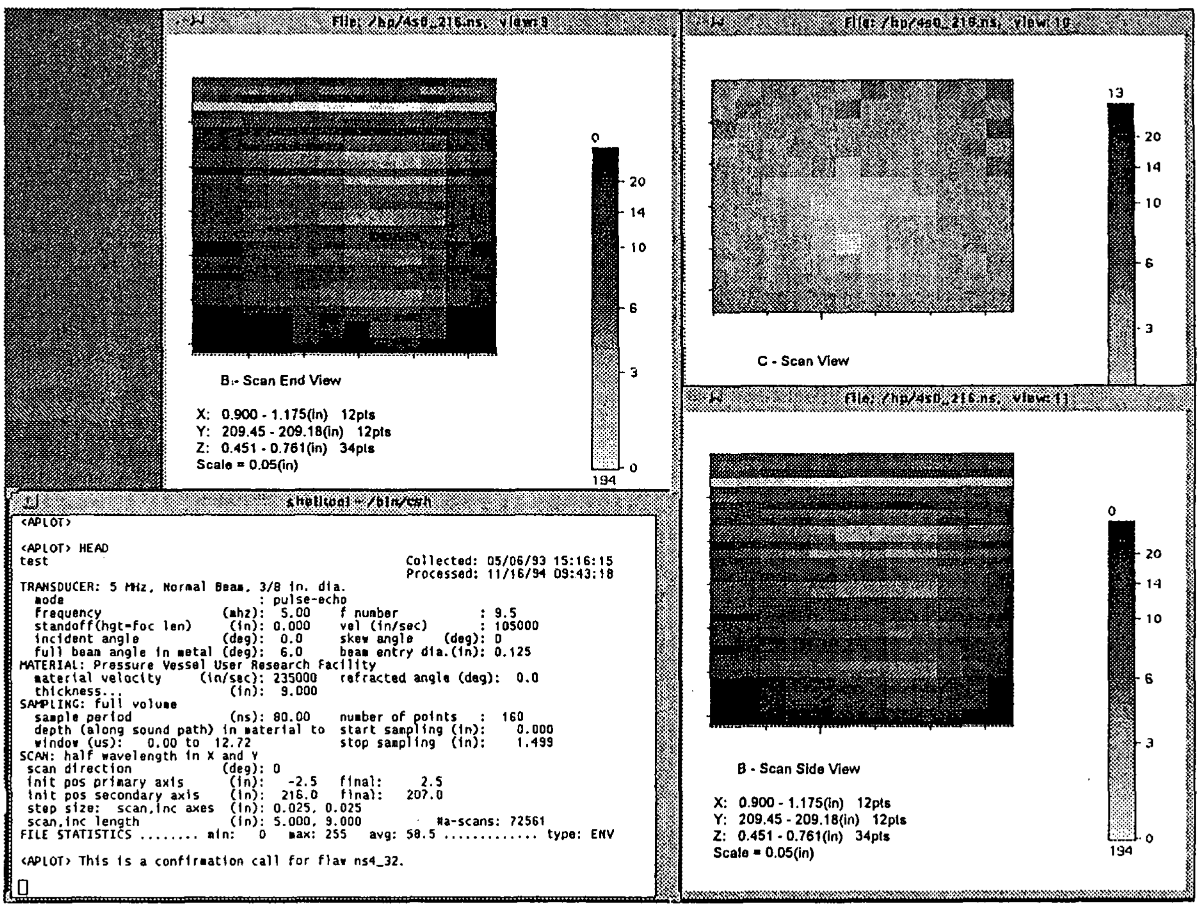


Figure A.40-a - Volumetric indication #5 in the near surface base metal: mode 10

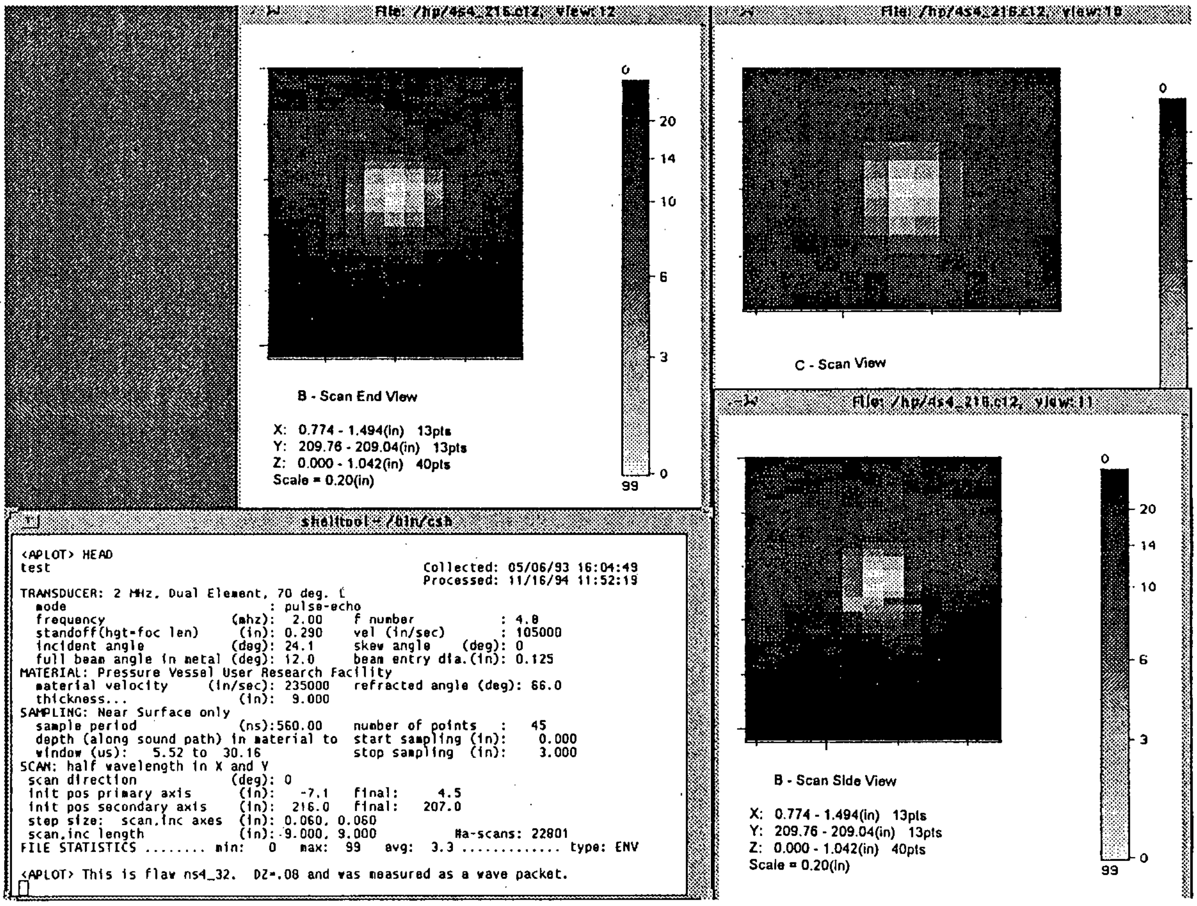


Figure A.40b - Volumetric indication #5 in the near surface base metal: mode 4

Figures A.4a-b show volumetric indication #6 in the near surface base metal. This volumetric indication has a through-wall extent of 2 mm based on different depth estimates, and an alternate size of 1 mm based on wave packet width. The detection was made in modes 1 and 7 where it had isolated TOF shape at depths of 17 and 19 mm. The shape quality is poor for this indication. There were no confirmations in other modes. The indication is characterized as volumetric based on normal beam detection. There is no evidence of coin shape in the side view of mode 7. The length is 5 mm and was made to LOS in mode 1. The width is 10 mm and was made to LOS in mode 7. The range of aspect ratios (width/depth) of this indication is 3 to 10. the maximum amplitude-to-noise ratio is of medium range at 119 to 30. With an X coordinate of 34 mm, the indication is clearly in the base metal. With a Z coordinate of 17 mm, the indication is clearly below the cladding.

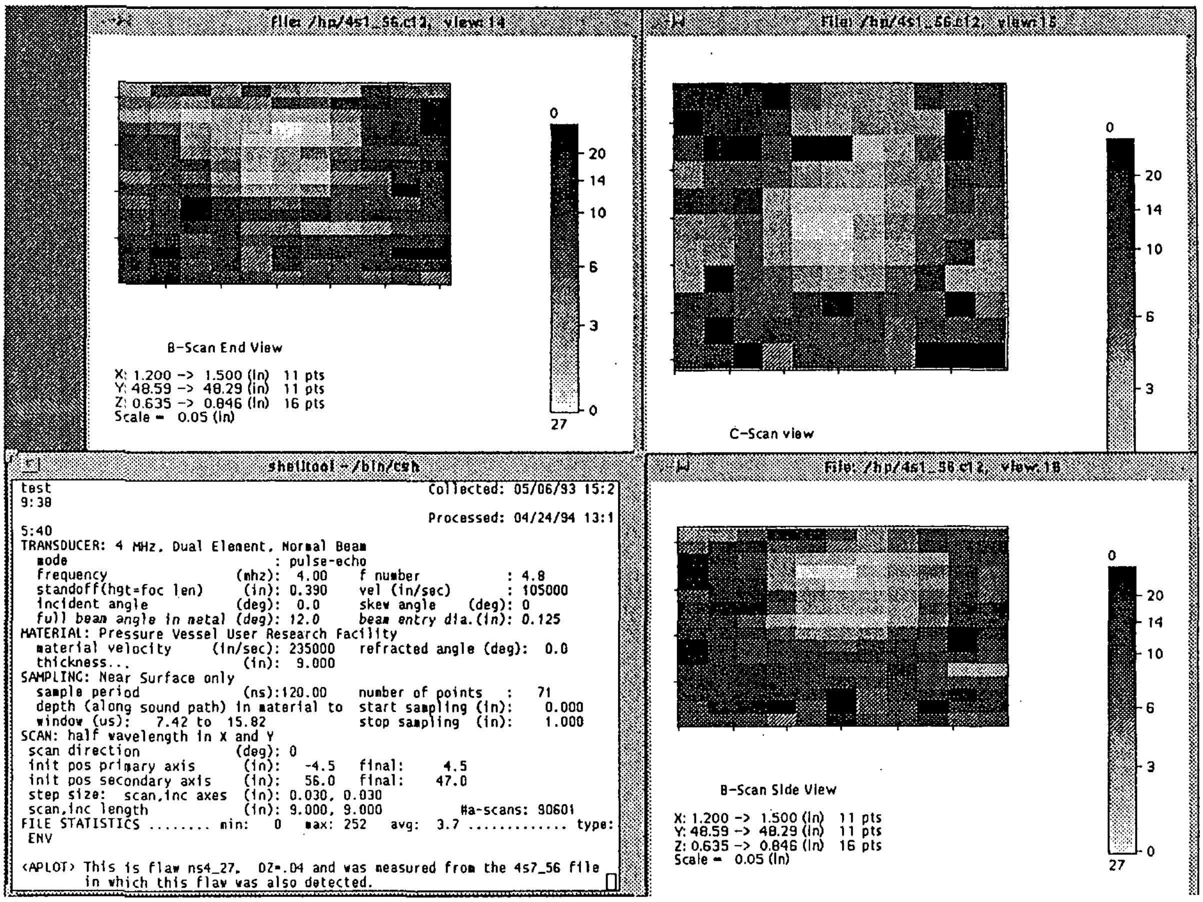


Figure A.41a – Volumetric indication #6 in the near surface base metal: model 1

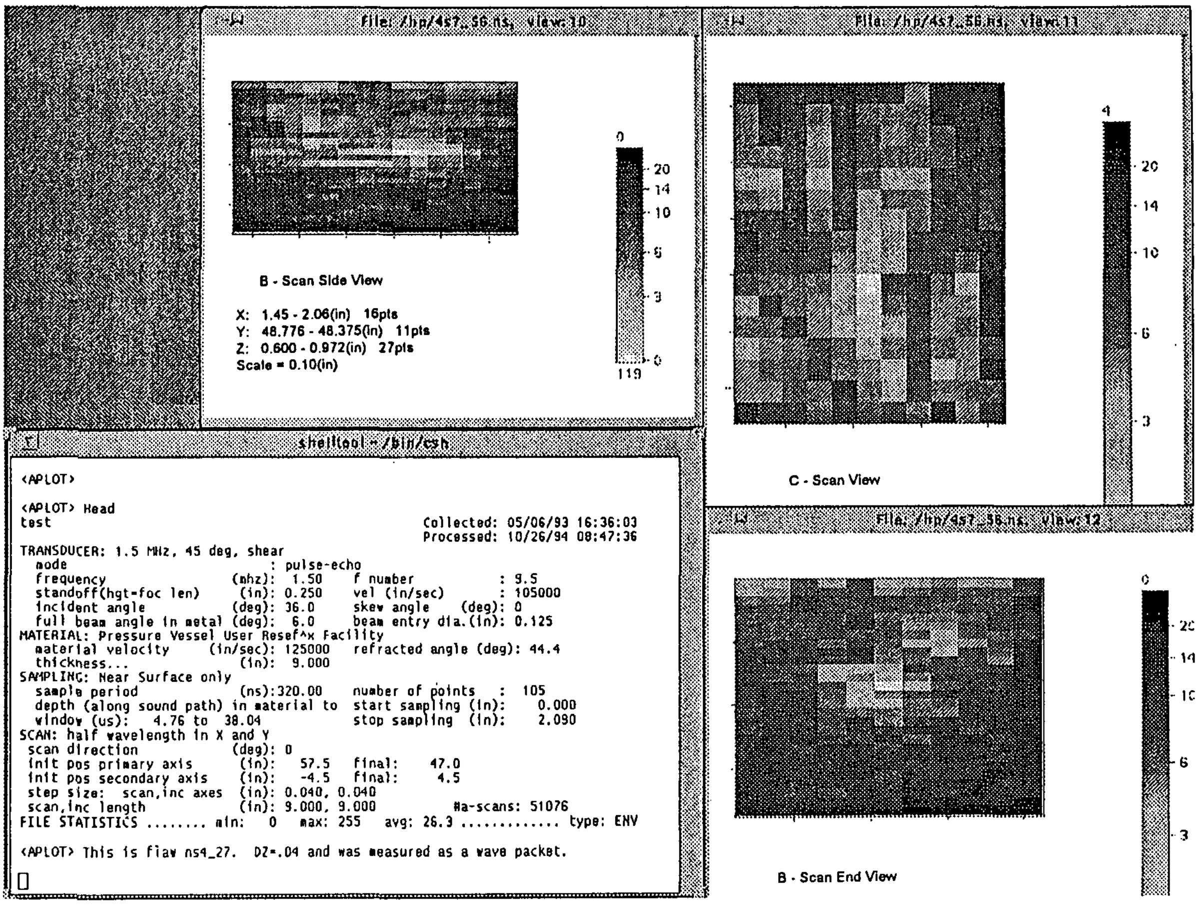


Figure A.41b - Volumetric indication #6 in the near surface base metal: mode 7

Figure A.42 shows volumetric indication #7 in the near surface base metal. This volumetric indication has a through-wall extent of 1.6 mm based on ring around pattern. The detection was made in mode 8 where it displayed a pair of TOF shapes at a depth of 19 mm. The shape quality is good for this indication. There were no confirmations in other modes. The indication is characterized as volumetric based on the detection of ring around shape. There is no evidence of coin shape in the end view of mode 8. The length is 8 mm and was made to LOS in mode 8. The aspect ratio (width/depth) of this indication is 5 giving an orientation along the weld. The maximum amplitude-to-noise ratio is high at 195 to 45. With an X coordinate of 123 mm, the indication is clearly in the base metal. With a Z coordinate of 19 mm, the indication is clearly below the cladding.

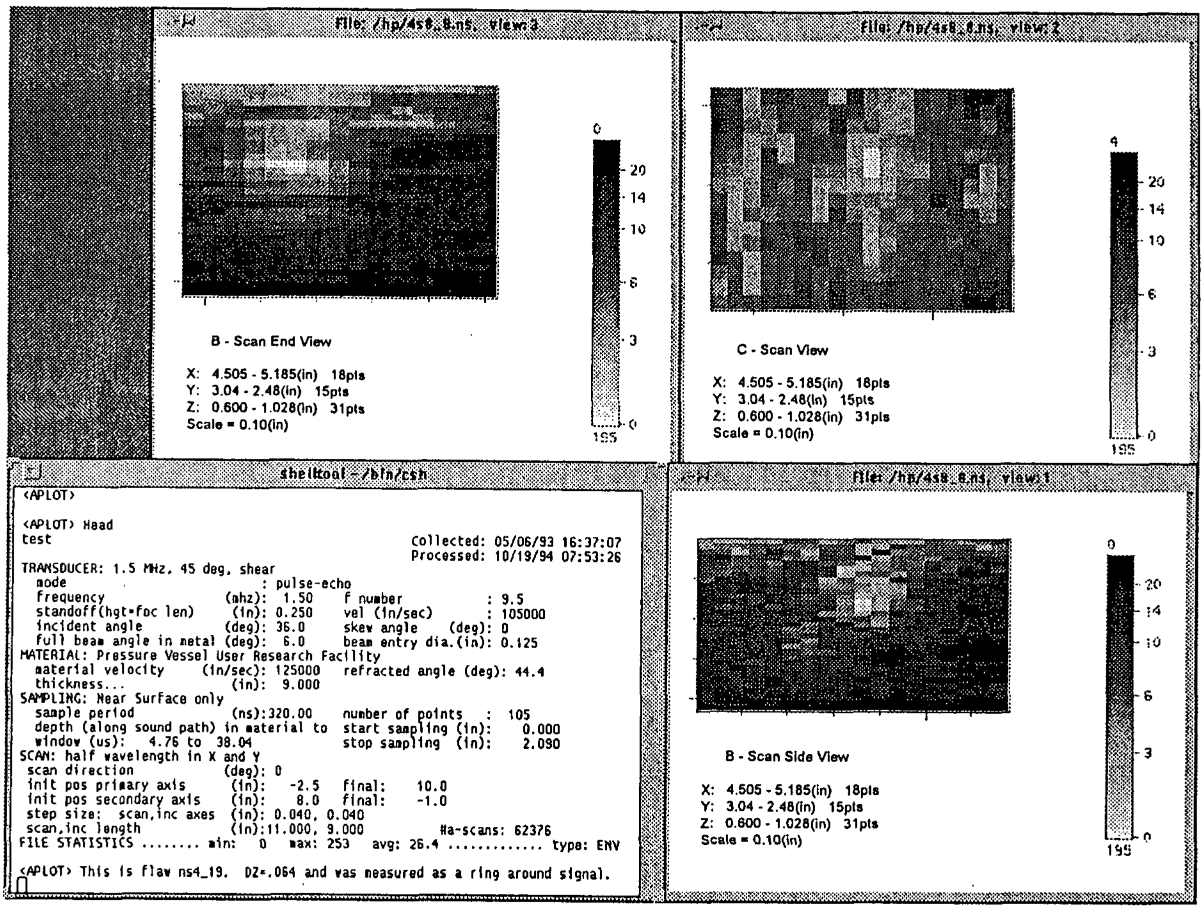


Figure A.42 - Volumetric indication #7 in the near surface base metal: mode 8

Figure A.43 shows volumetric indication #8 in the near surface base metal. This volumetric indication has a through-wall extent of 1.6 mm based on ring around pattern. The detection was made in mode 8 where it displayed a pair of TOF shapes at a depth of 14 mm. There were no confirmations in other modes. The indication is characterized as volumetric based on the detection of ring around shape. There is some evidence of coin shape in the end view of mode 8. The length is 12 mm and was made to LOS in mode 8. The aspect ratio (length/depth) of this indication is 3 giving an orientation along the weld. The maximum amplitude-to-noise ratio is of medium range at 148 to 40. With an X coordinate of 145 mm, the indication is clearly in the base metal. With a Z coordinate of 14 mm, the indication is clearly below the cladding.

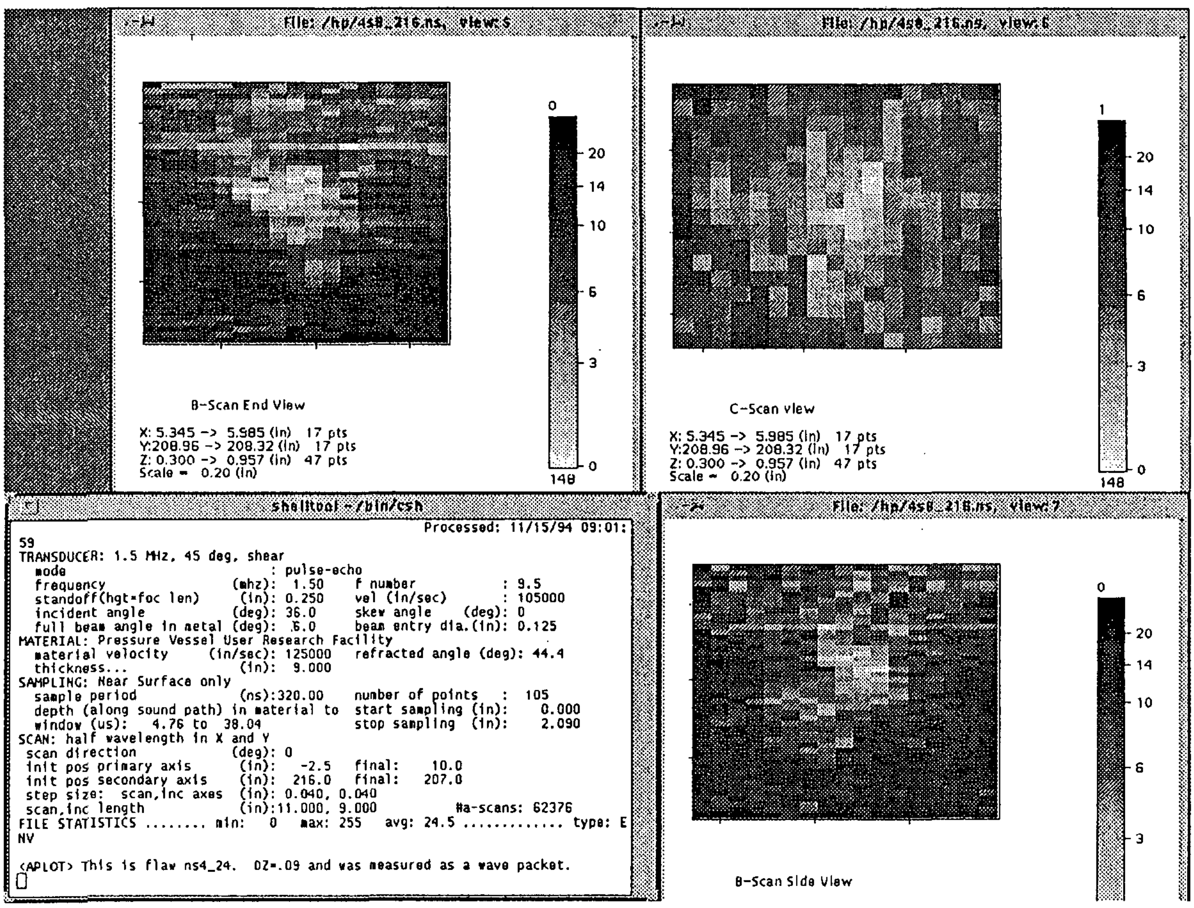


Figure A.43 - Volumetric indication #8 in the near surface base metal: mode 8

Figures A.44a-c show volumetric indication #10 in the near surface base metal. (Note: volumetric indication #9 in the near surface base metal was merged with volumetric indication #7). This volumetric indication has a through-wall extent of 1.5 mm based on wave packet width. Detections were made in modes 1 and 2. It had isolated TOF shape in mode 2 at a depth of 11 mm and normal beam shape in mode 1 at 10 mm. The shape quality is poor but not unusual for a shallow indication. There were confirmations in modes 3 and 4 at a depth of 11 mm. The different Z values 10 to 11 mm give an alternate depth size of 1 mm. The indication is characterized as volumetric based on normal beam detection. There is good evidence of coin shape in the end view of mode 2 which tends to characterize the indication as volumetric. The length is 11 mm and was made to LOS in mode 2. The width is 11 mm and was made to LOS in mode 3. The aspect ratio (length/depth) of this indication is 7 and the width-to-depth ratio is also 7 which tends to confirm volumetric orientation. The maximum amplitude-to-noise ratio is high at 212 to 25. With an X coordinate of 79 mm, the indication is clearly in the base metal. With a Z coordinate of 10 mm, the indication is below the cladding, and possibly connected to it.

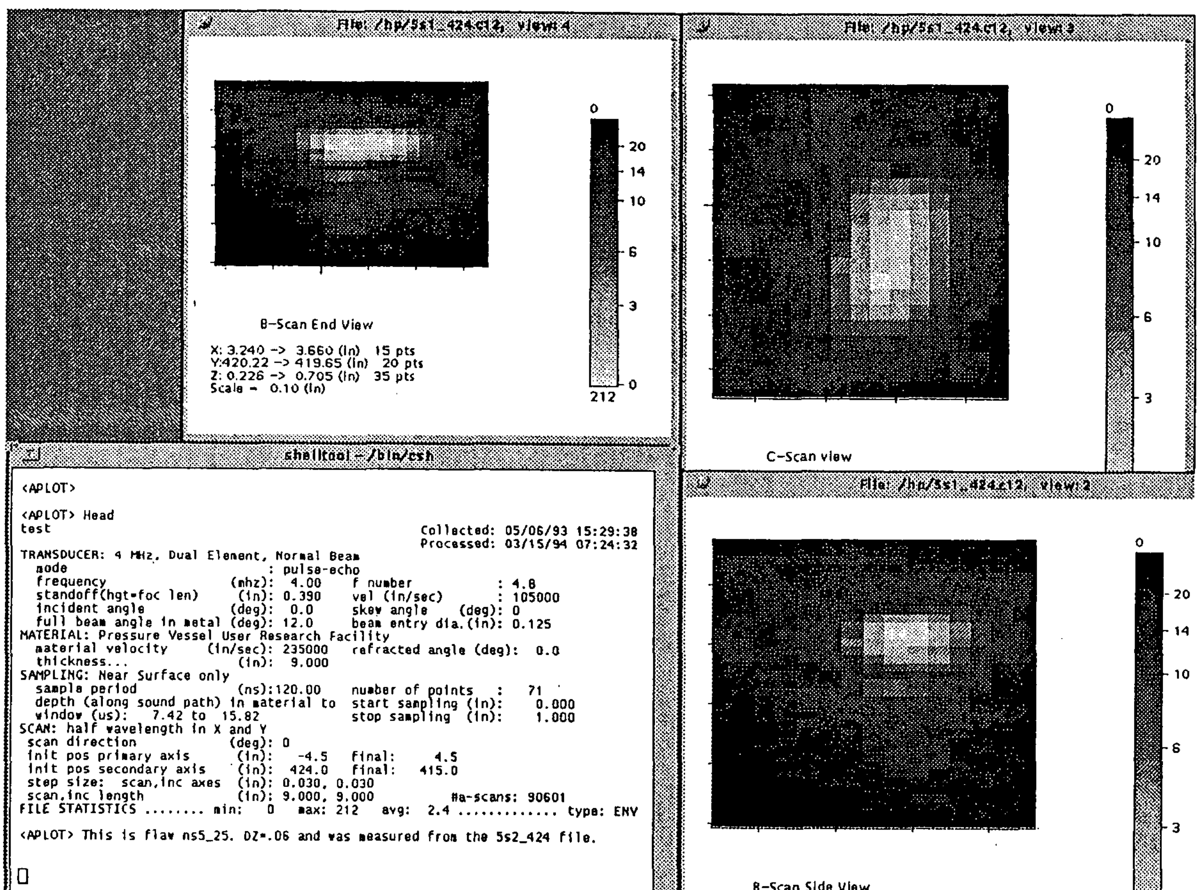


Figure A.44a - Volumetric indication #10 in the near surface base metal: mode 1

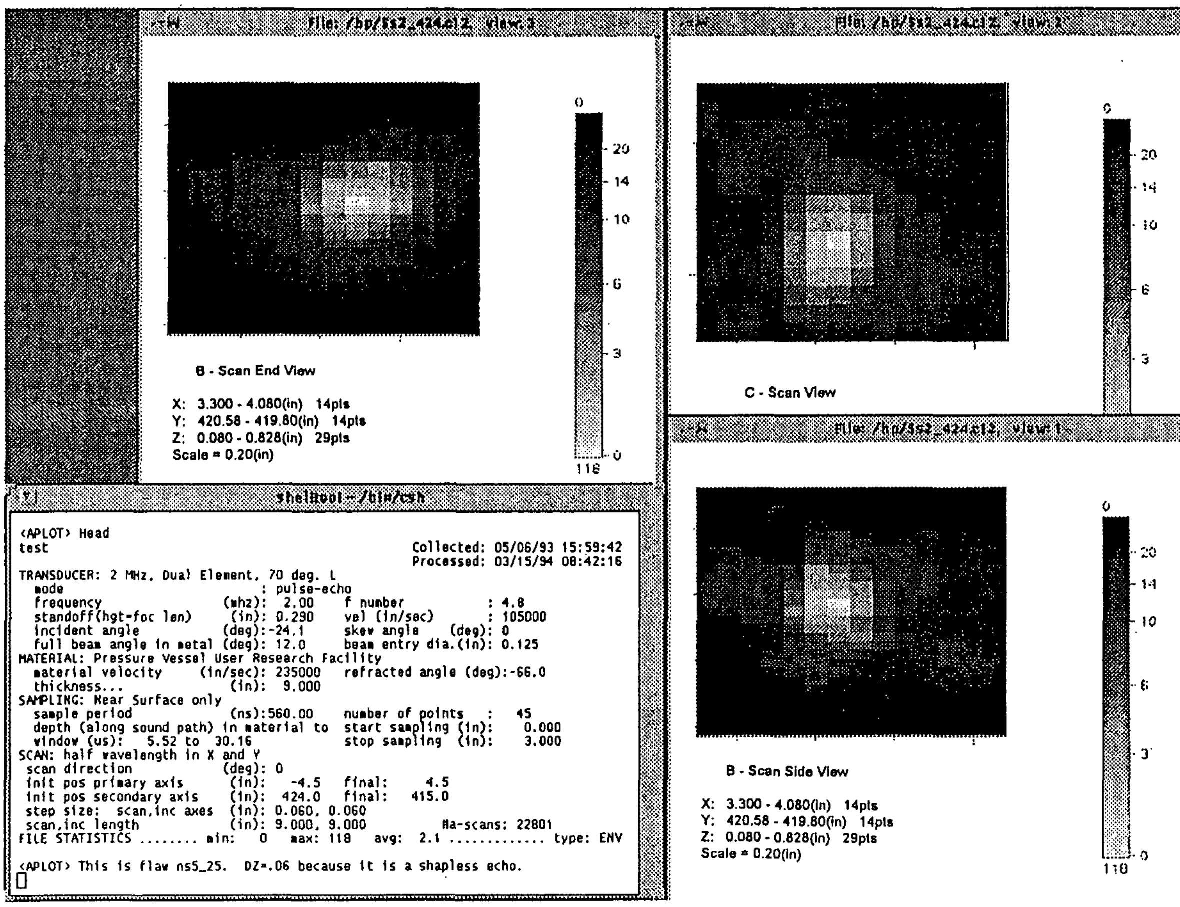


Figure A.44b - Volumetric indication #10 in the near surface base metal: mode 2

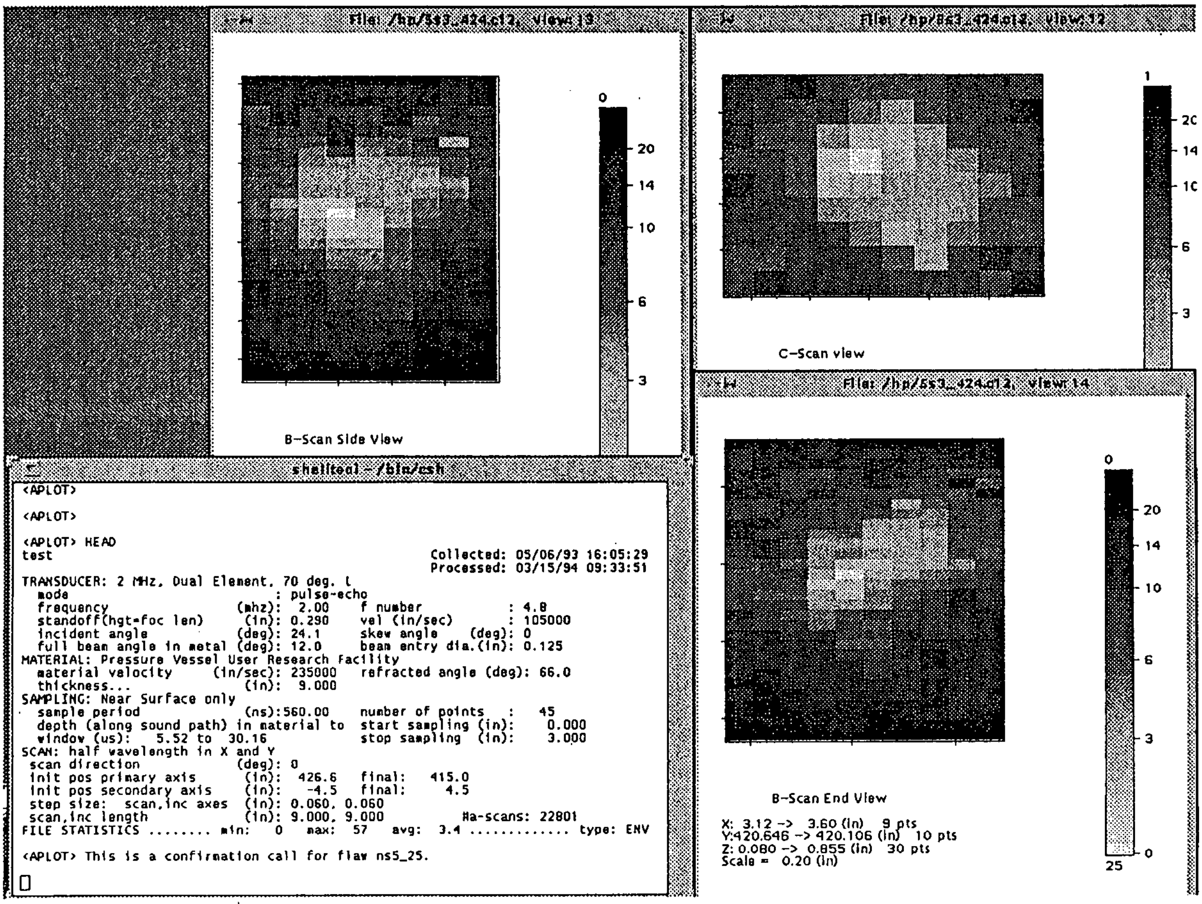


Figure A.44c - Volumetric indication #10 in the near surface base metal: mode 3

Figures A.45a-b show volumetric indication #11 in the near surface base metal. This volumetric indication has a through-wall extent of less than 1.5 mm based on a bright indication without TOF shape at depth of less than 10 mm. The detection was made in modes 1 and 2 where the bright, shallow indication failed to take shape at depths of 8 and 9 mm. There were no confirmations in other modes. The different Z values 8 to 9 give an alternate depth size of 1 mm. The indication is characterized as volumetric based on normal beam detection. There is no evidence of coin shape in the end view of mode 2. The length is 10 mm and was made to LOS in mode 2. The width is 7 mm and was made to LOS in mode 1. The aspect ratio (length/depth) of this indication is 7 giving an orientation along the weld. The maximum amplitude-to-noise ratio is high at 102 to 25. With an X coordinate of 24 mm, the indication is clearly in the base metal. The Z coordinate of 8 to 9 mm shows that the indication is below the cladding, and possibly connected to it.

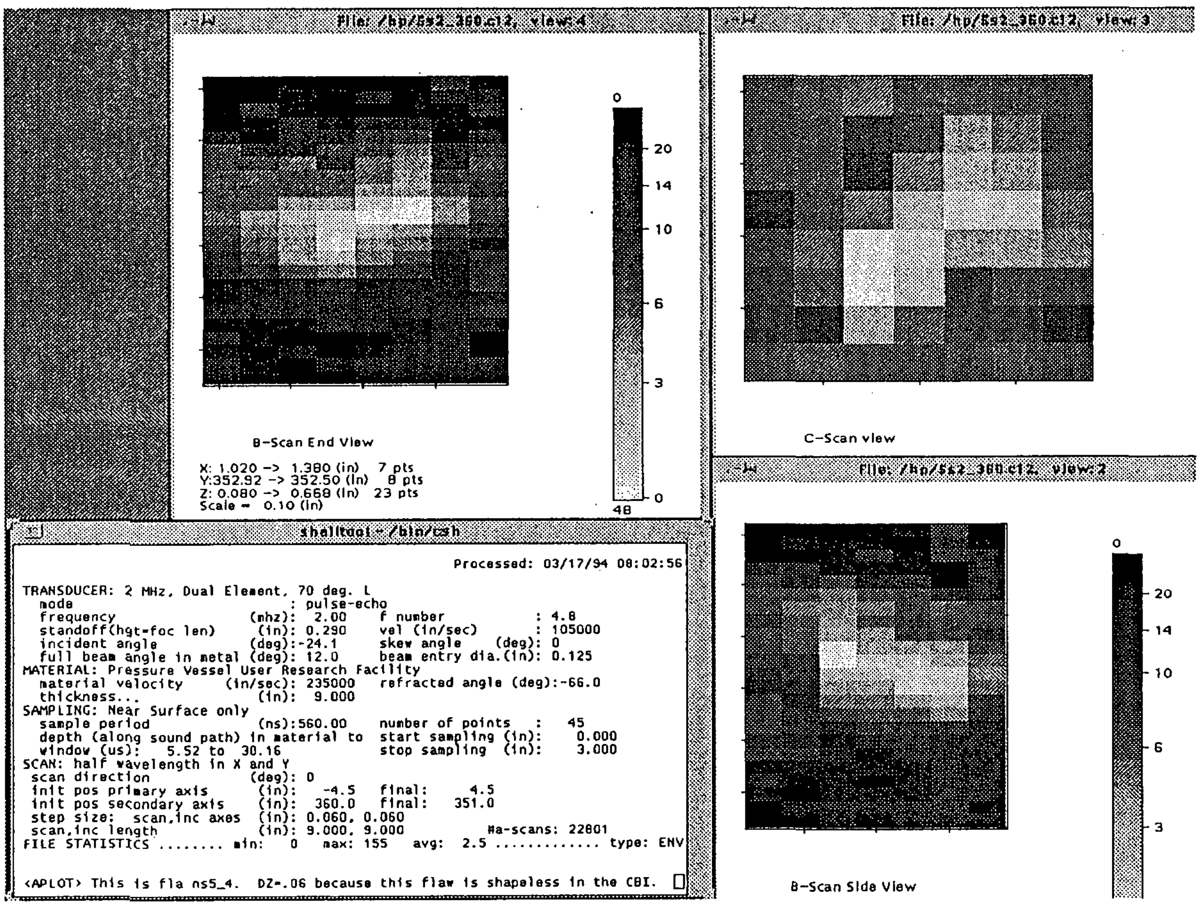


Figure A.45a - Volumetric indication #11 in the near surface base metal: mode 2

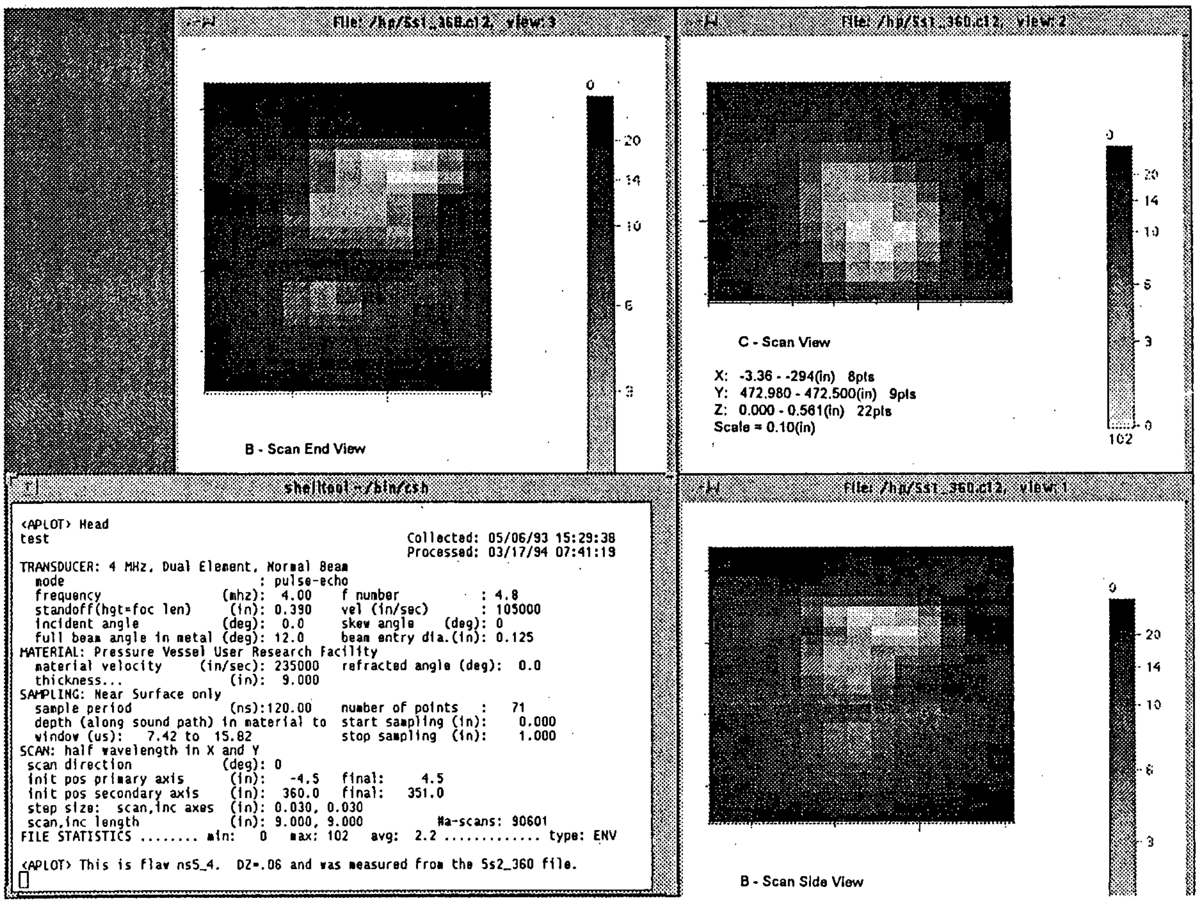


Figure A.45b - Volumetric indication #11 in the near surface base metal: mode 1

Planar Indications in the Cladding

Figure A.46 shows planar indication #1 in the cladding. This planar indication has a through-wall extent of less than 1.5 mm based on an indication without TOF shape at the clad to base metal interface. The detection was made in mode 2 where it lost TOF shape but remained brighter than 95 counts at a depth of 6 mm. There were no confirmations in other modes. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. There is no evidence of coin shape in the end view of mode 2. The length is 14 mm and was made to LOS in mode 2. The aspect ratio (length/depth) of this indication is 9. The maximum amplitude-to-noise ratio is high at 130 to 30. The Z coordinate of 6 mm shows that the indication is in the clad-to-base metal interface.

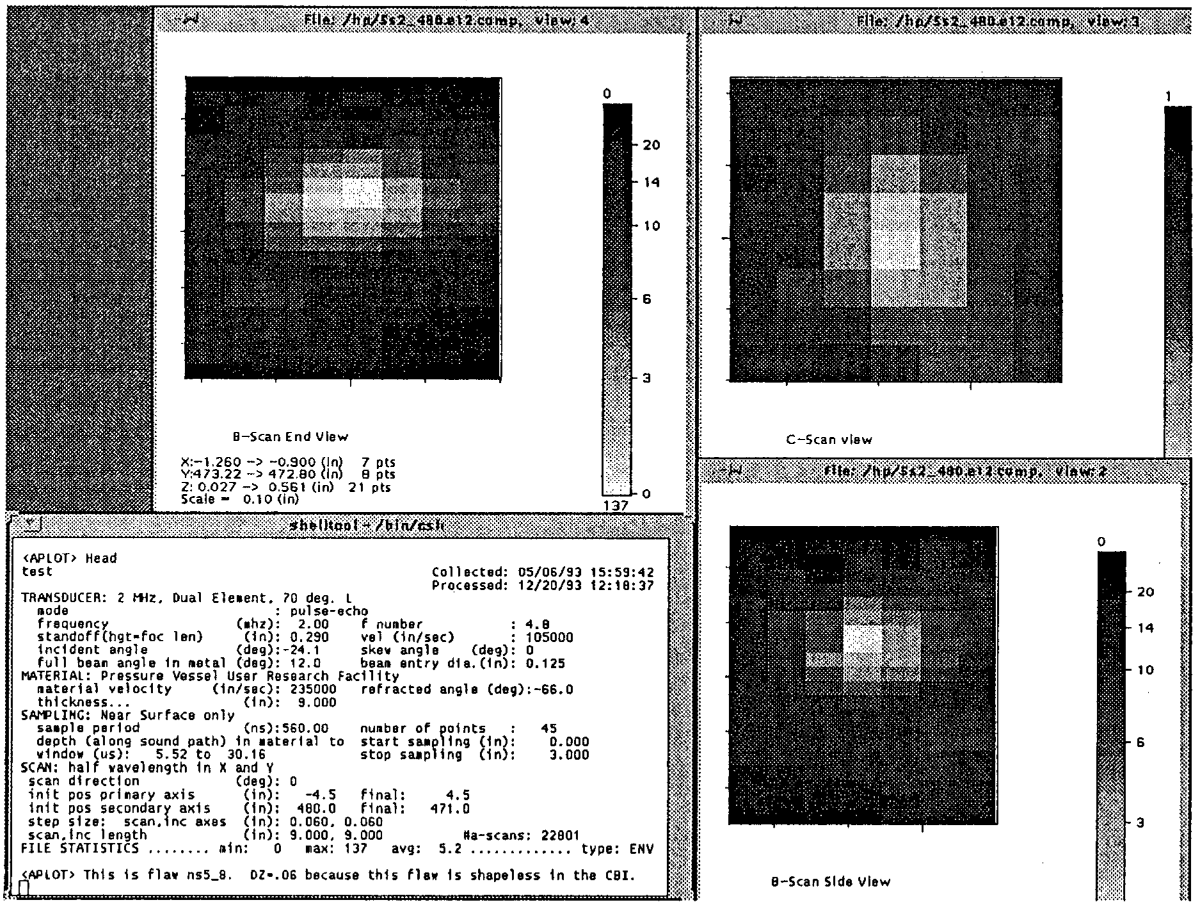


Figure A.46 - Planar indication #1 in the cladding: mode 2

Figures A.47a-b show planar indication #2 in the cladding. This planar indication has a through-wall extent of less than 1.5 mm based on an indication without TOF shape at the clad to base metal interface. The detection was made in modes 3 and 5 where it lost TOF shape but remained brighter than 95 counts at depths of 6 and 7 mm. There were no confirmations in other modes. The two Z values of 6 to 7 mm give an alternate depth size of 1 mm. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. There is no evidence of coin shape in the side view of modes 3 and 5. The width is 7 mm and was made to LOS in modes 3 and 5. The aspect ratio (width/depth) of this indication is 5. The maximum amplitude-to-noise ratio is high at 170 to 30. The Z coordinate of 6 to 7 mm shows that the indication is in the clad-to-base metal interface.

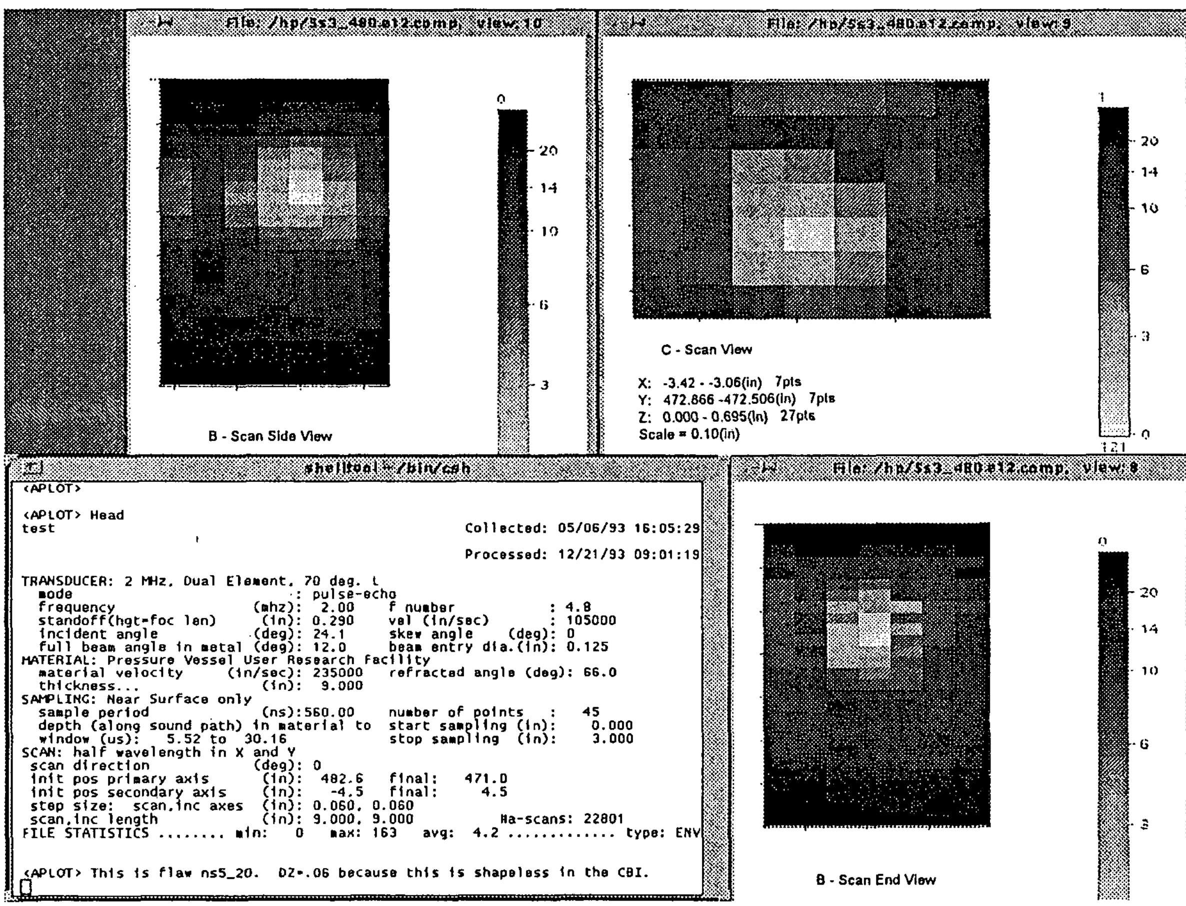


Figure A.47a - Planar indication #2 in the cladding: mode 3

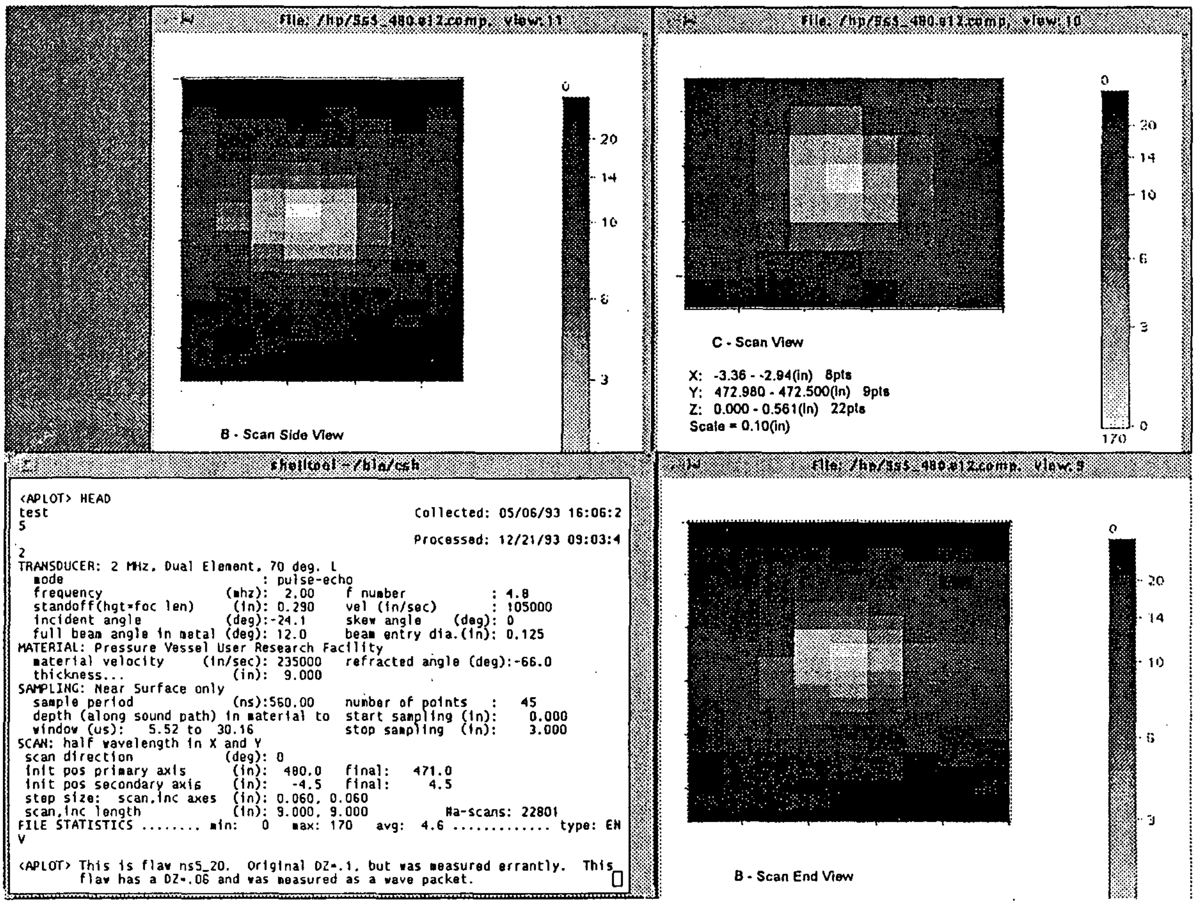


Figure A.47b - Planar indication #2 in the cladding: mode 5

Figure A.48 shows planar indication #3 in the cladding. This planar indication has a through-wall extent of less than 1.5 mm based on an indication without TOF shape at the clad to base metal interface. The detection was made in mode 2 where it failed to display TOF shape but remained brighter than 95 counts at a depth of 6 mm. There were no confirmations in other modes. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. There is no evidence of coin shape in the end view of mode 2. The length is 8 mm and was made to LOS in mode 2. The aspect ratio (length/depth) of this indication is 5 giving an orientation along the weld. The maximum amplitude-to-noise ratio is of medium range at 97 to 30. The Z coordinate of 6 mm shows that the indication is in the clad-to-base metal interface. The X coordinate of 9 mm shows that the indication is over the weld.

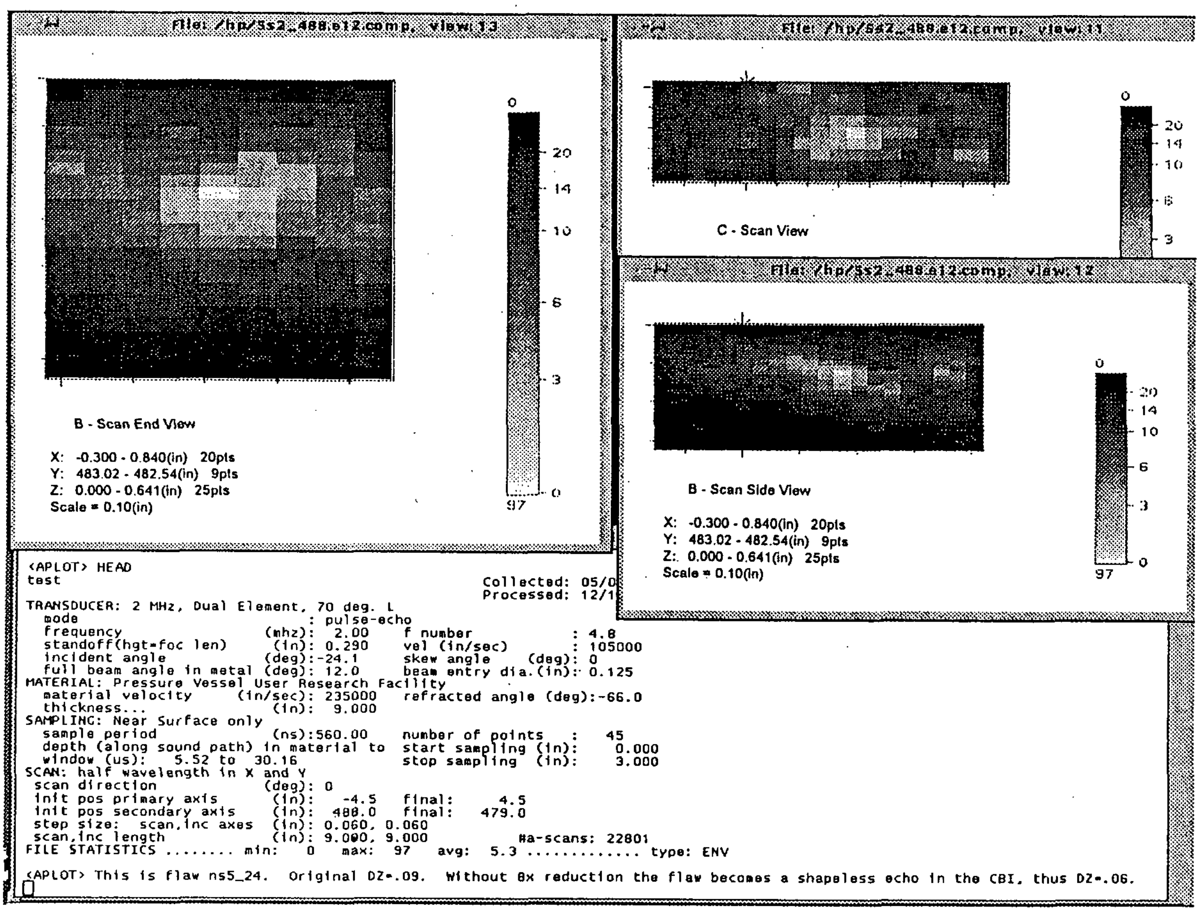


Figure A-48. Planar indication #3 in the cladding: mode 2

Figure A.49 shows planar indication #4 in the cladding. This planar indication has a through-wall extent of less than 1.5 mm based on an indication without TOF shape at the clad to base metal interface. The detection was made in mode 3 where it displayed evidence of coin shape at a depth of 6 mm. There were no confirmations in other modes. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. There is good evidence of coin shape in the side view of mode 3 which tends to confirm the indication as planar. The width is 16 mm and was made to LOS in mode 3. The aspect ratio (width/depth) of this indication is 11 which tends to indicate a larger through-wall extent than 1.5 mm. The maximum amplitude-to-noise ratio is high at 83 to 15. The Z coordinate of 6 mm shows that the indication is in the clad-to-base metal interface. The X coordinate of 14 mm shows that the indication is over the HAZ.

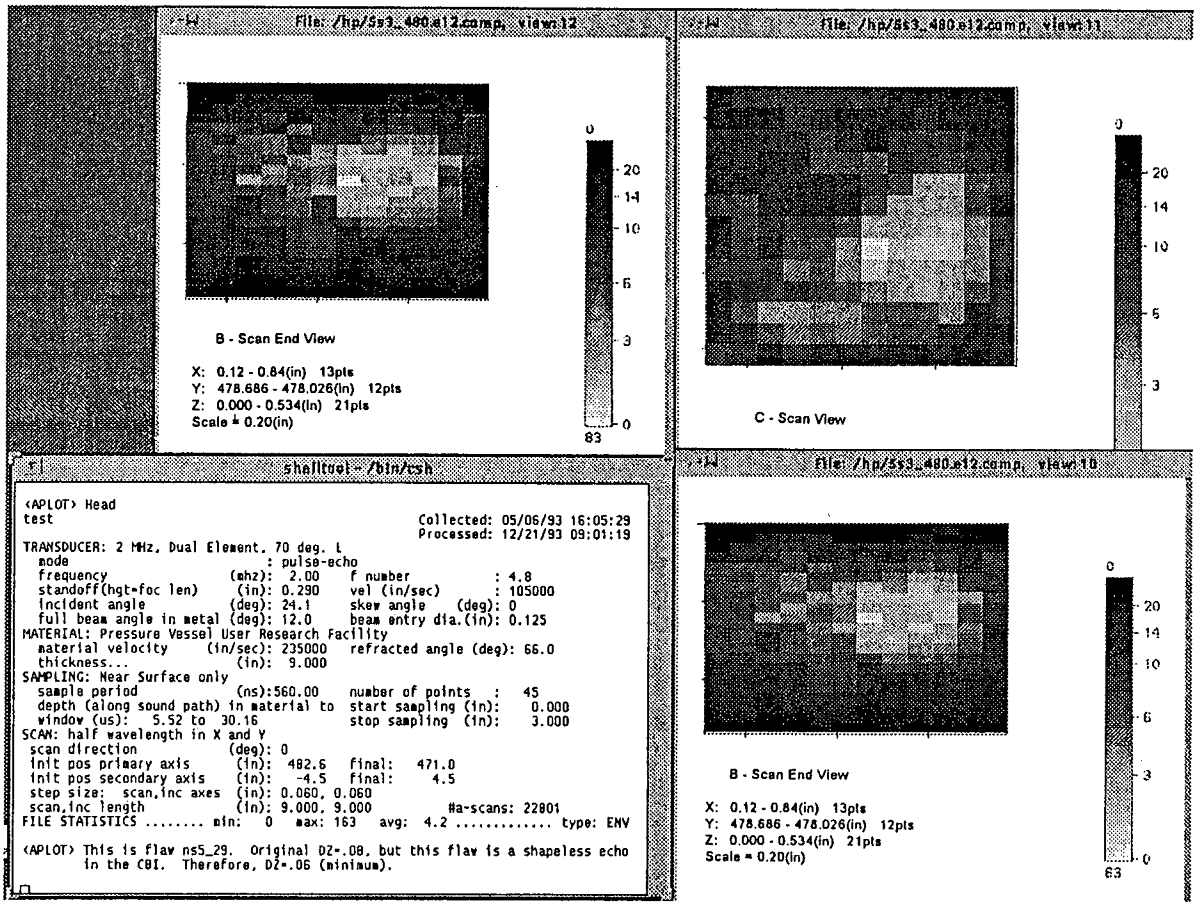


Figure A.49 - Planar indication #4 in the cladding: mode 3

Volumetric Indications in the Cladding

Figures A.50a-b show volumetric indication #1 in the cladding. This volumetric indication has a through-wall extent of 3 mm based on wave packet width. The detection was made in mode 2 where it had isolated TOF shape at a depth of 7 mm. The shape quality is good for this indication. There was a confirmation in mode 3 at a depth of 8 mm. The different Z values of 7 to 8 mm give an alternate depth size of 1 mm. The indication is characterized as volumetric based on detection in orthogonal modes. There is some evidence of coin shape in the end view of mode 2. The length is 12 mm and was made to LOS in mode 2. The width is 10 mm and was made to LOS in mode 3. The range of aspect ratios (length/depth) of this indication is 4 to 12 which tends to confirm the larger through-wall extent. The maximum amplitude-to-noise ratio is high at 162 to 20. The Z coordinate of 7 to 8 mm shows that the indication is in the clad-to-base metal interface. The X coordinate of -36 mm shows that the indication is over the base metal.

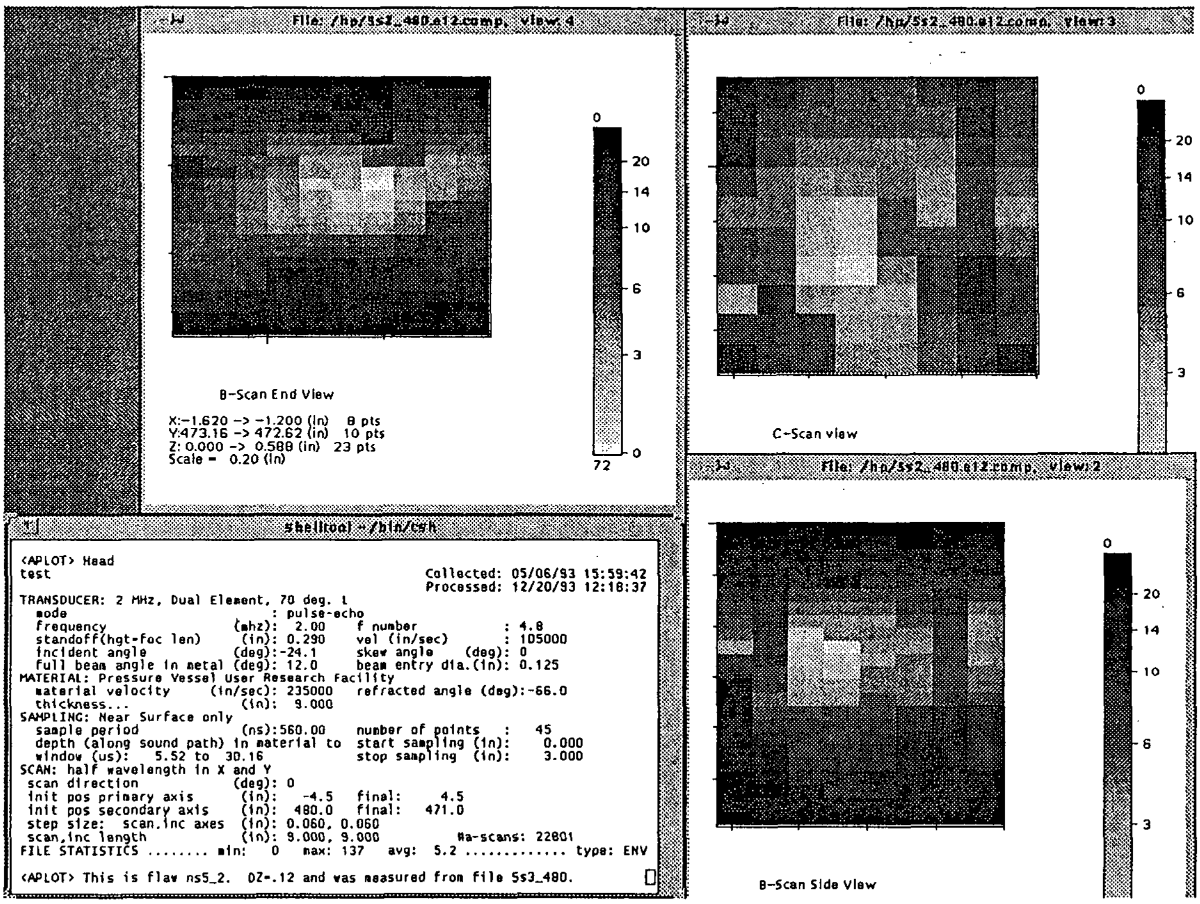


Figure A.50a - Volumetric indication #1 in the cladding: mode 2

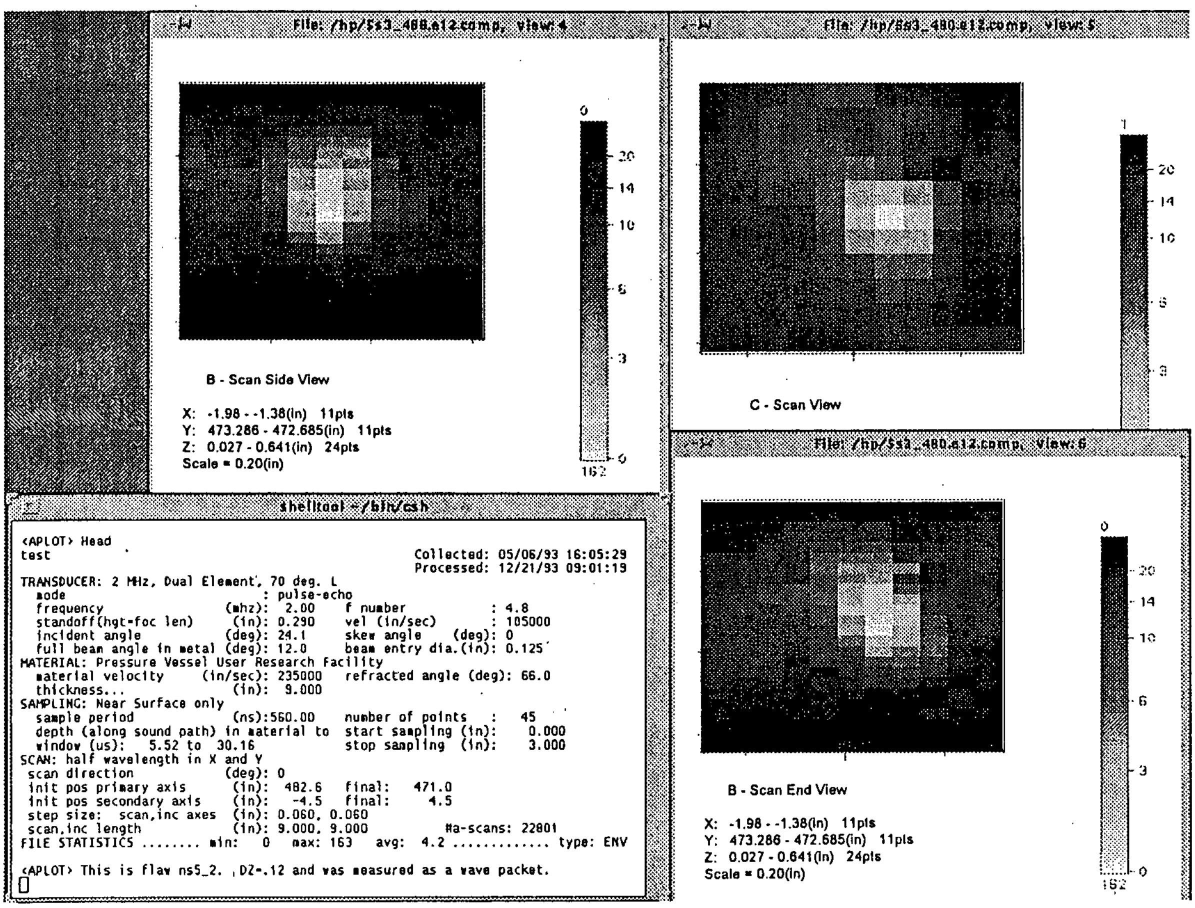


Figure A.50b - Volumetric indication #1 in the cladding: mode 3

Figures A.51a-d show volumetric indication #2 in the cladding. This volumetric indication has a through-wall extent of 3 mm based on different depth estimates of 5 to 8 mm and a smaller size of 2.3 mm based on wave packet width. The detection was made in modes 2 and 5 where it had isolated TOF shape at depths of 5 and 6 mm. The shape quality is poor but not unusual for a shallow indication and is broken up indicating that more than one small flaw is present. There were confirmations in modes 1 and 3 at depths of 6 and 8 mm. The indication is characterized as volumetric based on normal beam detection. There is no evidence of coin shape in the end view of modes 2, the side view of mode 3, and the side view of mode 5. The length is 11 mm and was made to LOS in mode 2. The width is 12 mm and was made to LOS in mode 5. The aspect ratio (width/depth) of this indication is 5 and the length-to-depth ratio is 5 which tends to confirm volumetric orientation. The maximum amplitude-to-noise ratio is of medium range at 92 to 30. The Z coordinates of 5 to 8 mm show that the indication is in the clad-to-base metal interface. The X coordinate of 15 mm shows that the indication is over the HAZ.

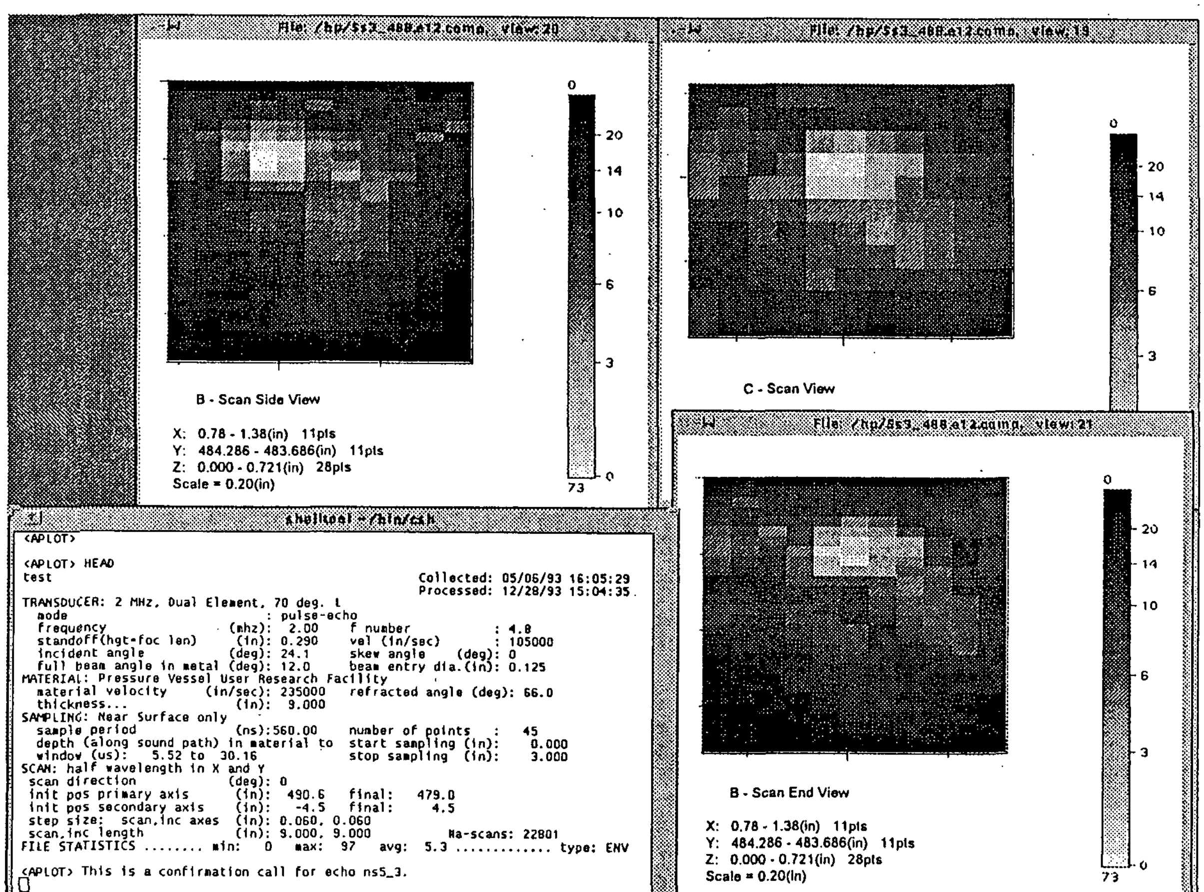


Figure A.51a - Volumetric indication #2 in the cladding: mode 3

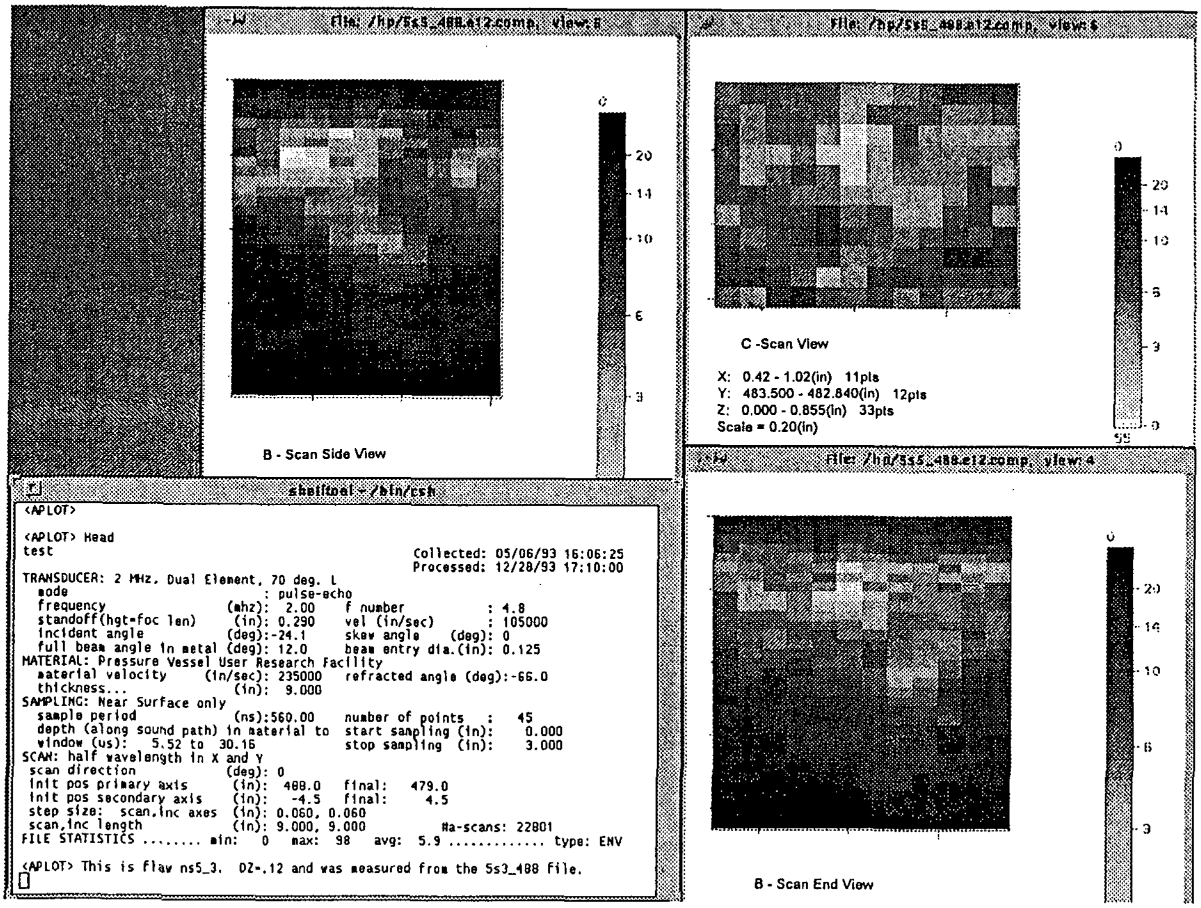


Figure A.51b - Volumetric indication #2 in the cladding: mode 5

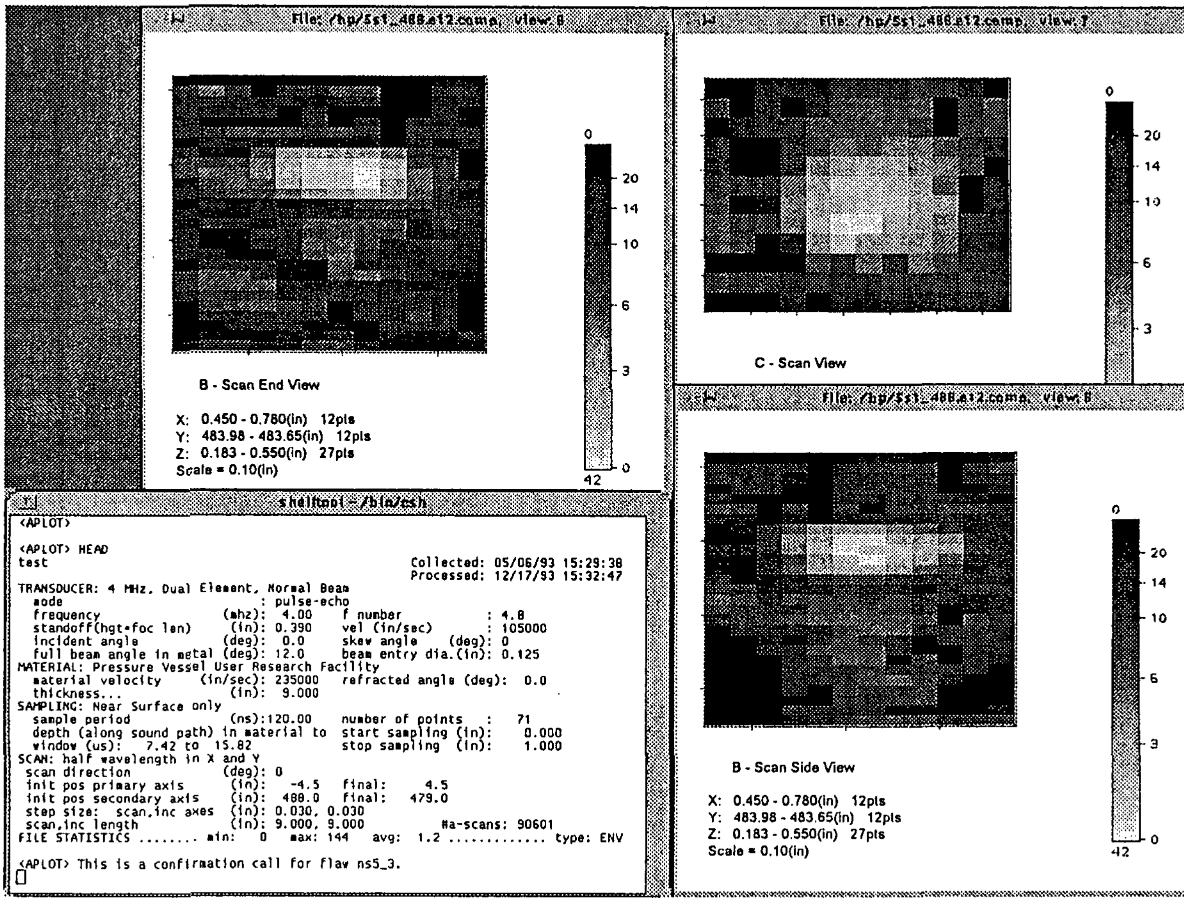


Figure A.51c - Volumetric indication #2 in the cladding: mode 1

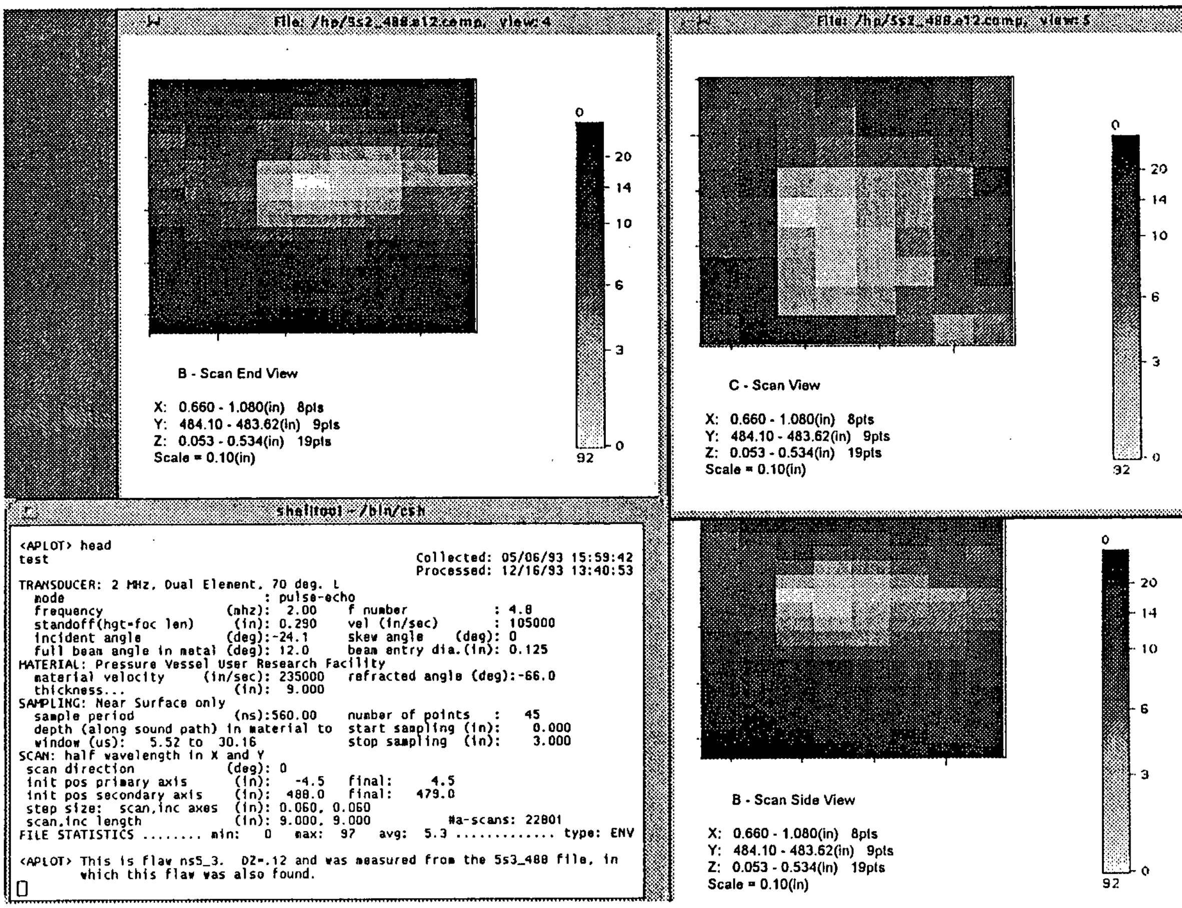


Figure A.51d - Volumetric indication #2 in the cladding: mode 2

Figures A.52a-c show volumetric indication #3 in the cladding. This planar indication has a through-wall extent of 2 mm based on different depth estimates and less than 1.5 mm based on a coin shaped indication at the clad to base metal interface. The detection was made in mode 3 where it displayed coin shape at a depth of 6 mm. There were confirmations in modes 1 and 5 at depths of 6 and 8 mm. The different Z values of 6 to 8 mm give an alternate depth size of 2 mm. The indication is characterized as volumetric based on normal beam detection. There is good evidence of coin shape in the side view of mode 3. The length is 6 mm and was made to LOS in mode 1. The width is 18 mm and was made to LOS in mode 1. The range of aspect ratios (width/depth) of this indication is 9 to 12. The maximum amplitude-to-noise ratio is of medium range at 83 to 25. The Z coordinate of 6 to 8 mm shows that the indication is in the clad-to-base metal interface. The X coordinate of 18 mm shows that the indication is over the base metal.

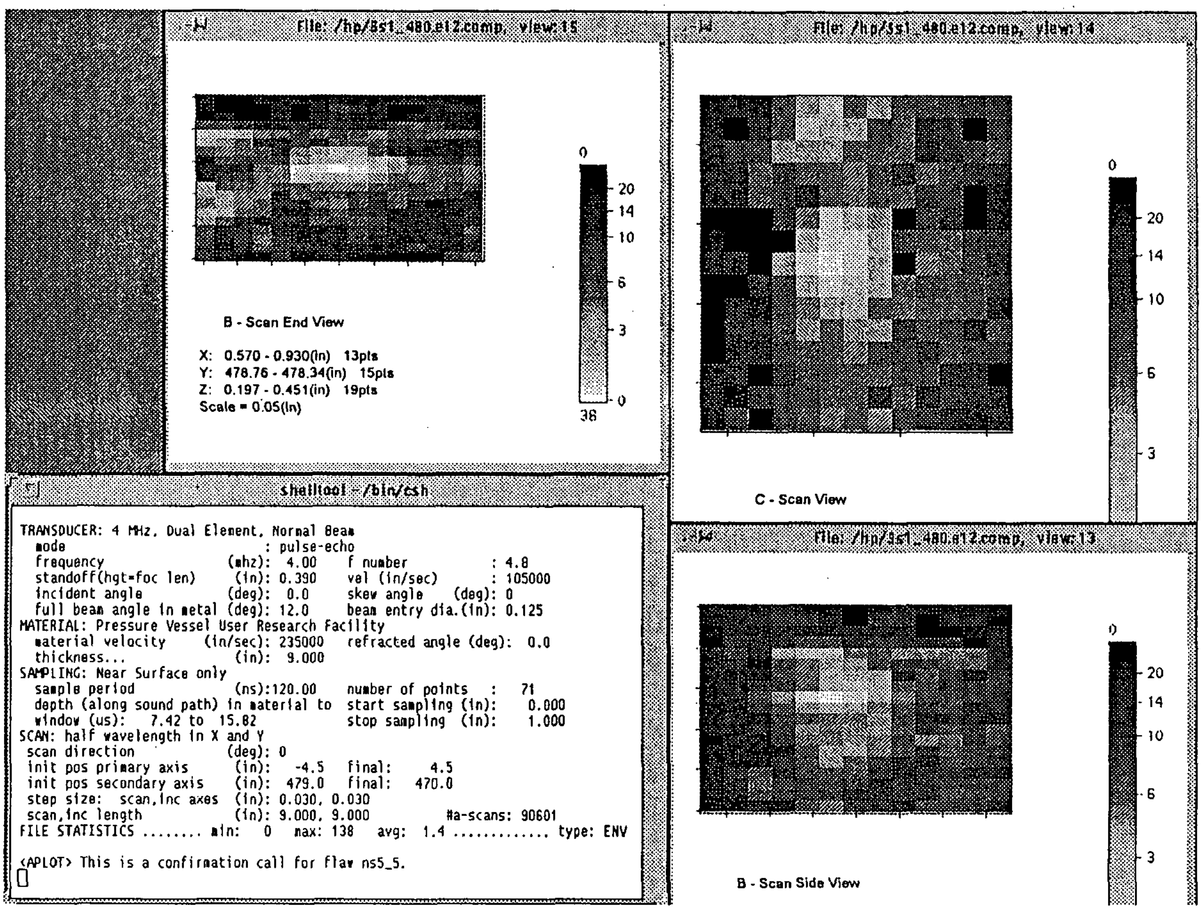


Figure A.52a - Volumetric indication #3 in the cladding: mode 1

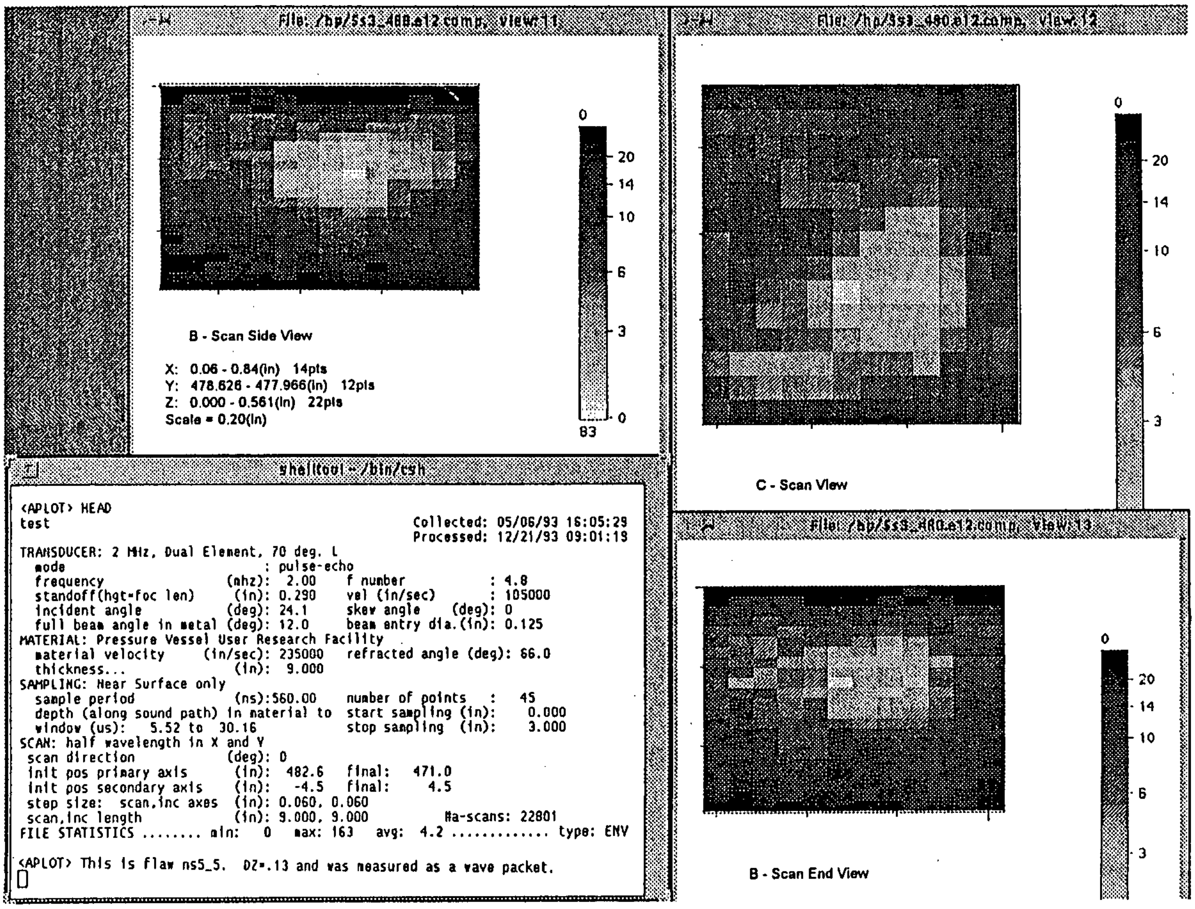


Figure A.52b - Volumetric indication #3 in the cladding: mode 3

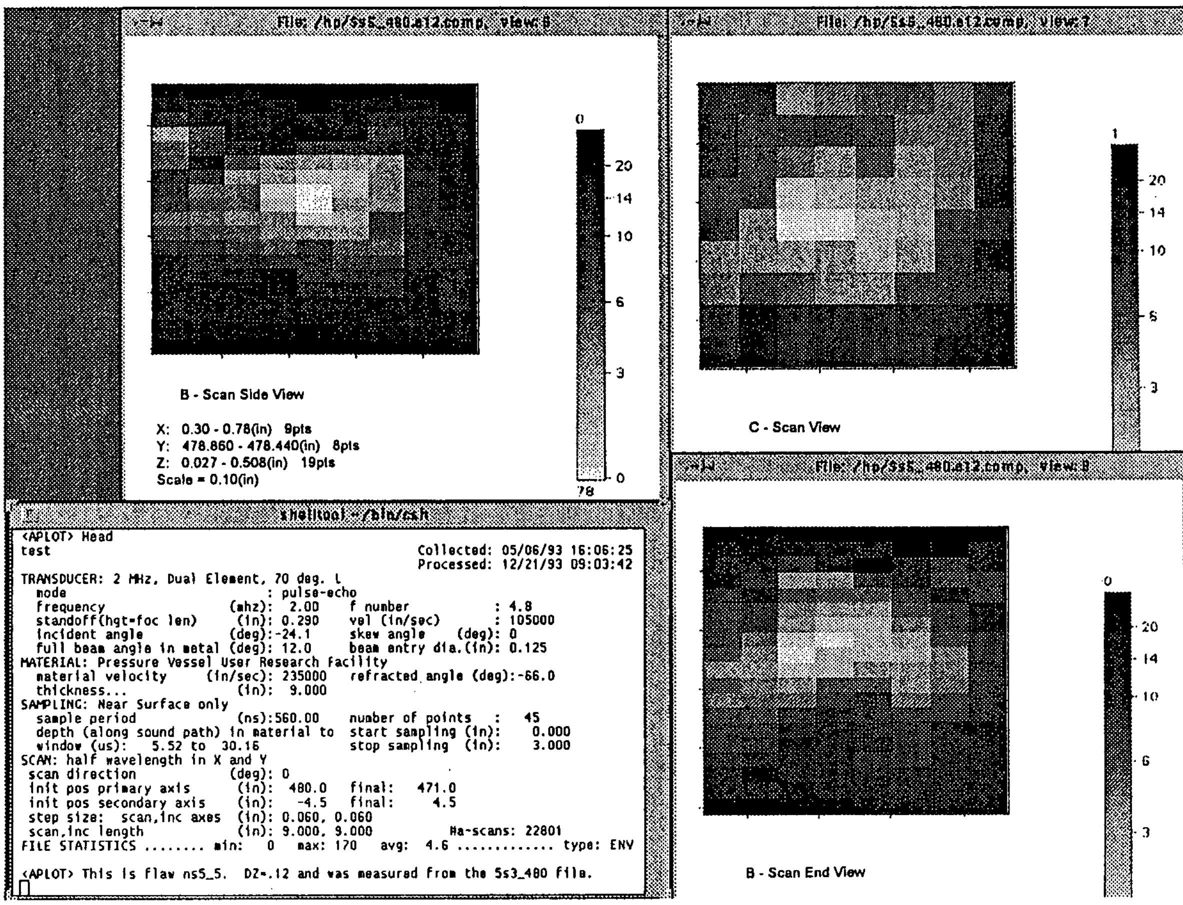


Figure A.52c - Volumetric indication #3 in the cladding: mode 5

Figures A.53a-d show volumetric indication #4 in the cladding. This volumetric indication has a through-wall extent of 2 mm based on different depth estimates of 7 to 9 mm and less than 1.5 mm based on an indication without TOF shape at the clad to base metal interface. The detection was made in modes 1 and 4 where it failed to display TOF shape but remained brighter than 95 counts at depths of 7 and 8 mm. There was a confirmation in mode 3 at a depth of 9 mm. The indication is characterized as volumetric based on normal beam detection. There is no evidence of coin shape in the side view of mode 3 and end view of mode 4. The length is 16 mm and was made to LOS in mode 4. The width is 8 mm and was made to LOS in mode 3. The range of aspect ratios (width/depth) of this indication is 9 to 11. The maximum amplitude-to-noise ratio is high at 210 to 20. The Z coordinate of 7 to 9 mm shows that this indication is in the clad-to-base metal interface. The X coordinate of 98 mm shows that the indication is over the base metal.

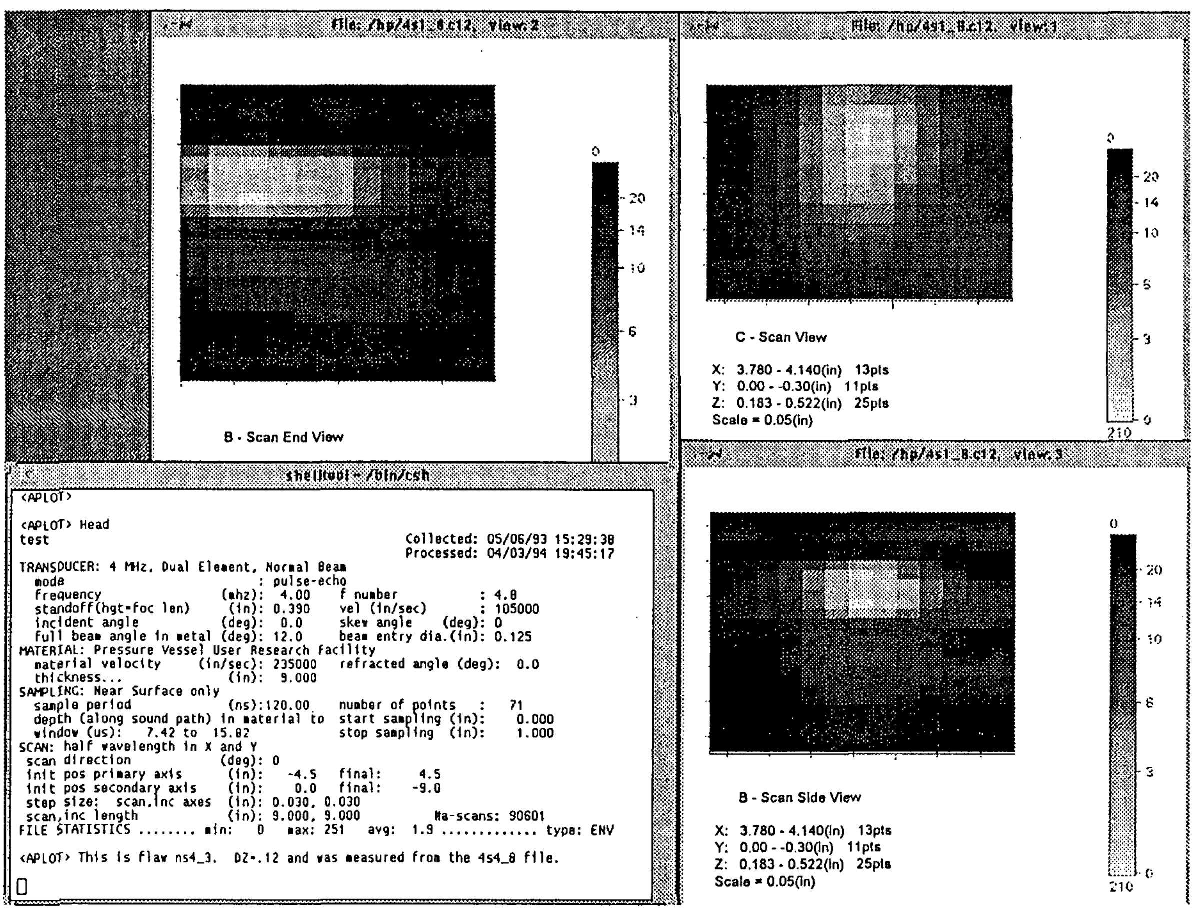


Figure A.53a - Volumetric indication #5 in the cladding: mode 1

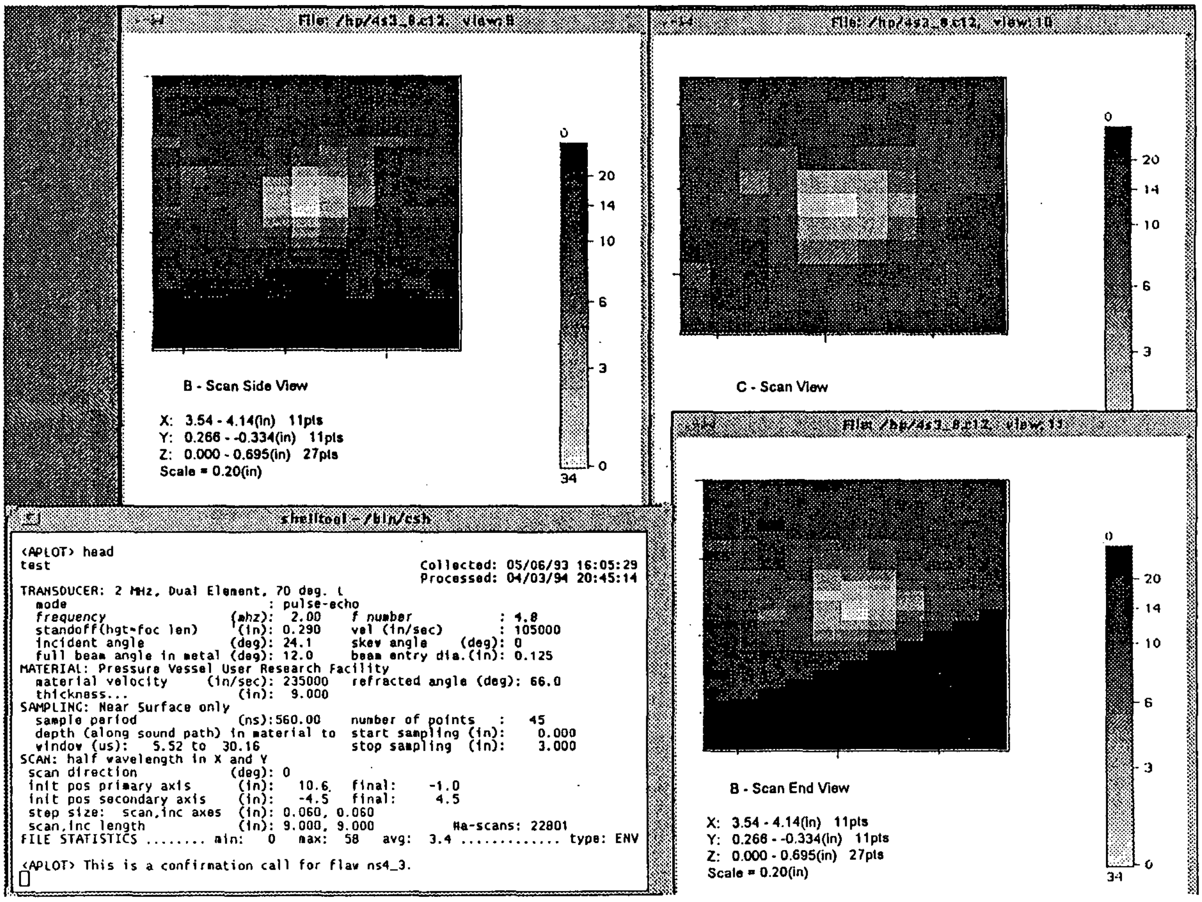


Figure A.53b - Volumetric indication #4 in the cladding: mode 3

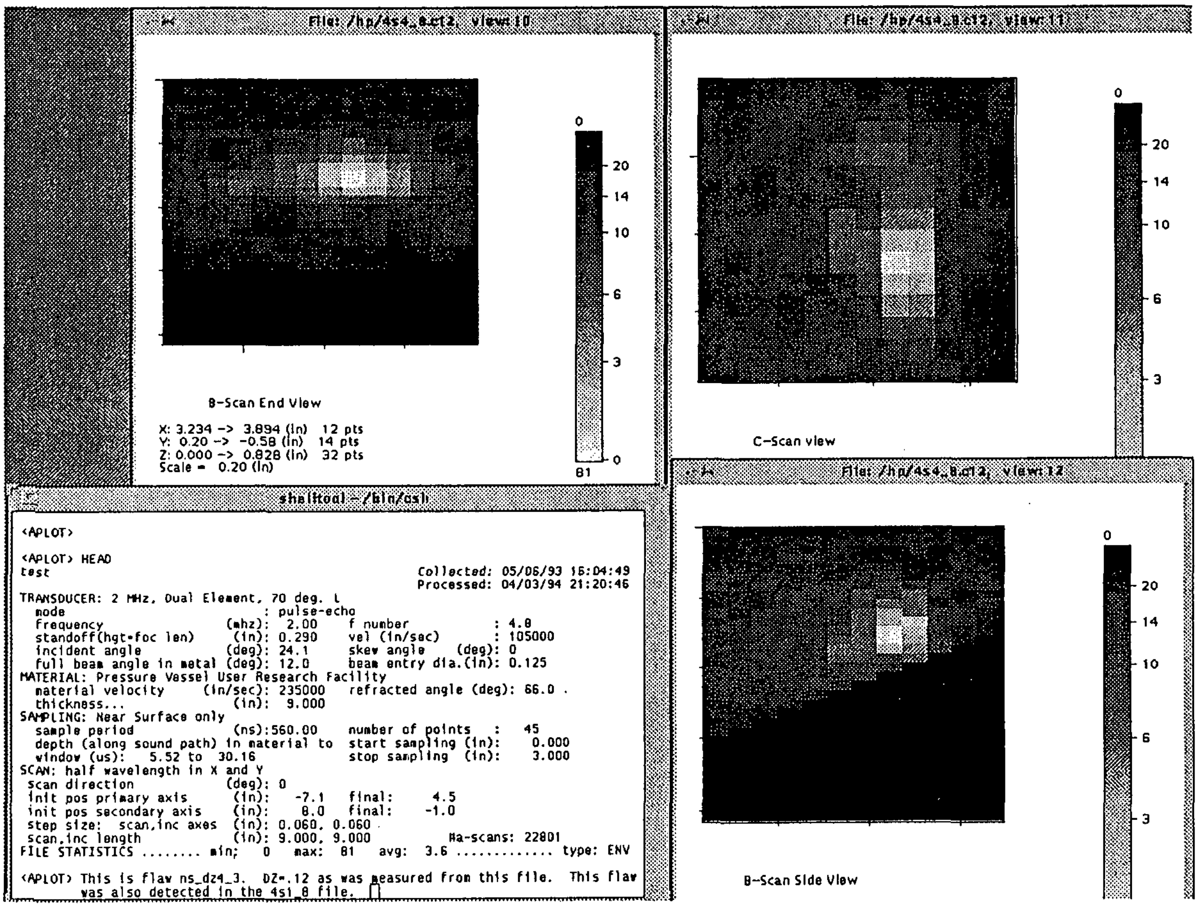


Figure A.53c - Volumetric indication #4 in the cladding: mode 4

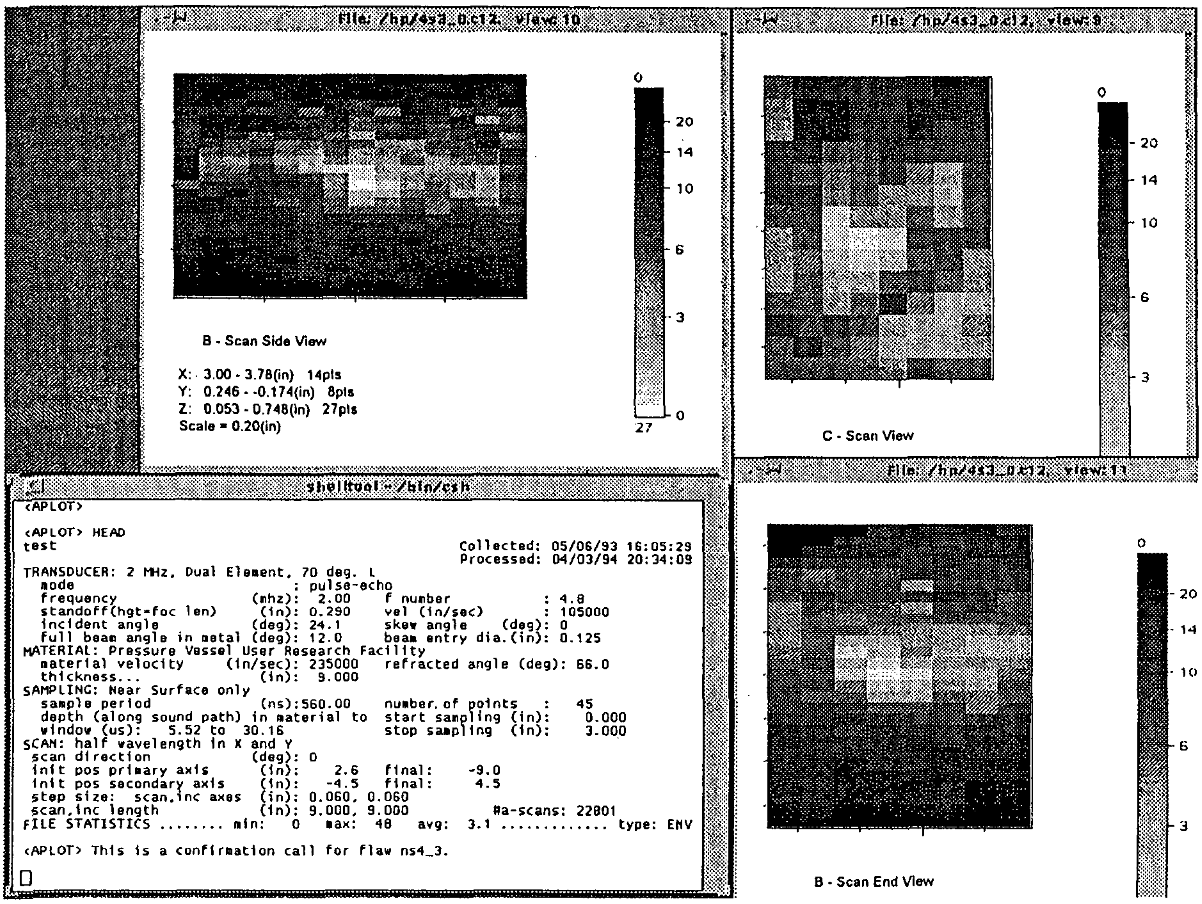


Figure A.53d - Volumetric indication #4 in the cladding: mode 3

Figures A.54a-c show volumetric indication #5 in the cladding. This volumetric indication has a through-wall extent of less than 1.5 mm based a bright indication without TOF shape in the clad to base metal interface. The detection was made in modes 2 and 5 where the bright, shallow indication failed to take shape at a depth of 6 mm. There was a confirmation in mode 3 at a depth of 6 mm. The three Z values of 6 mm give an alternate depth size of less than 1 mm. The indication is characterized as volumetric based on detection in orthogonal modes. There is some evidence of coin shape in the side view of mode 3. The length is 12 mm and was made to LOS in mode 2. The width is 11 mm and was made to LOS in mode 3. The maximum amplitude-to-noise ratio is of medium range at 112 to 40. The Z coordinate of 6 mm shows that the indication is in the clad-to-base metal interface. The X coordinate of 21 mm shows that the indication is over the base metal.

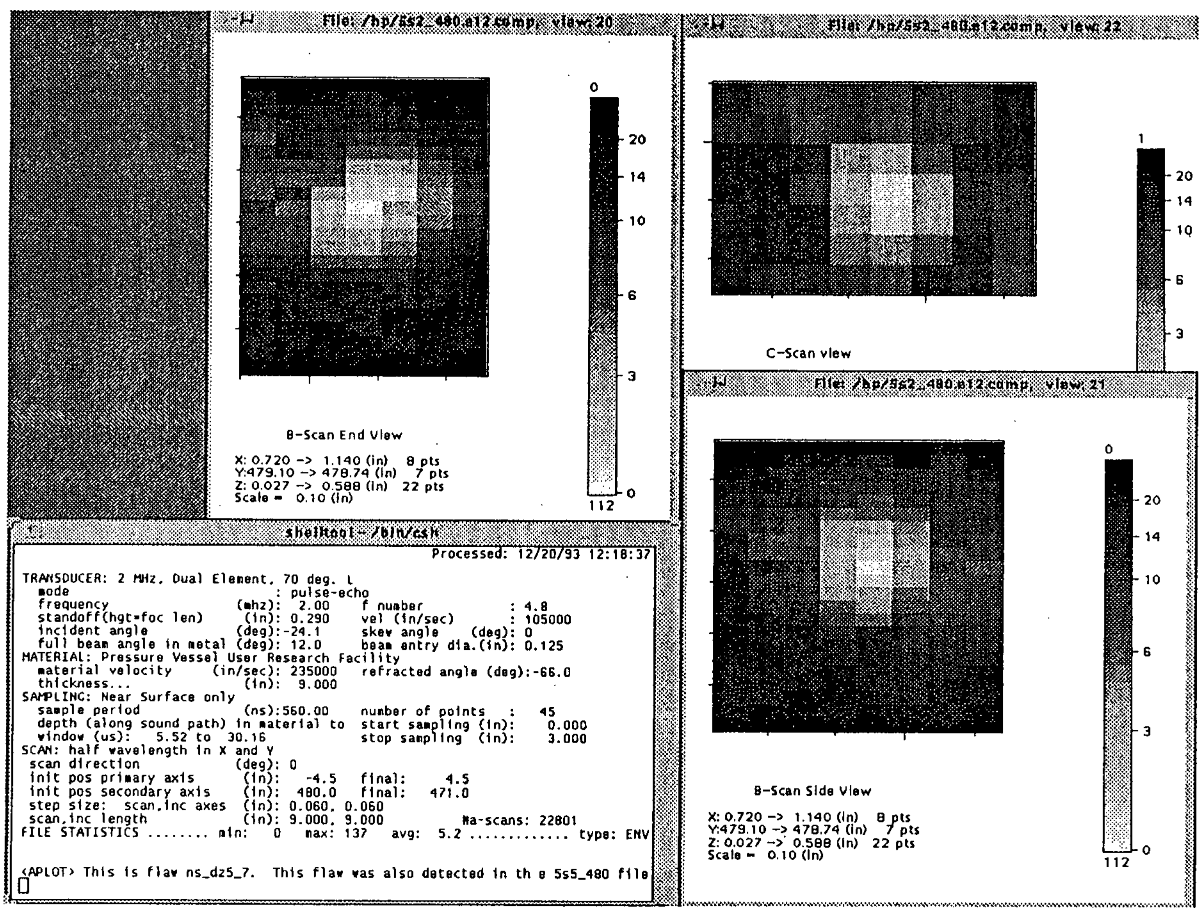


Figure A.54a - Volumetric indication #4 in the cladding: mode 2

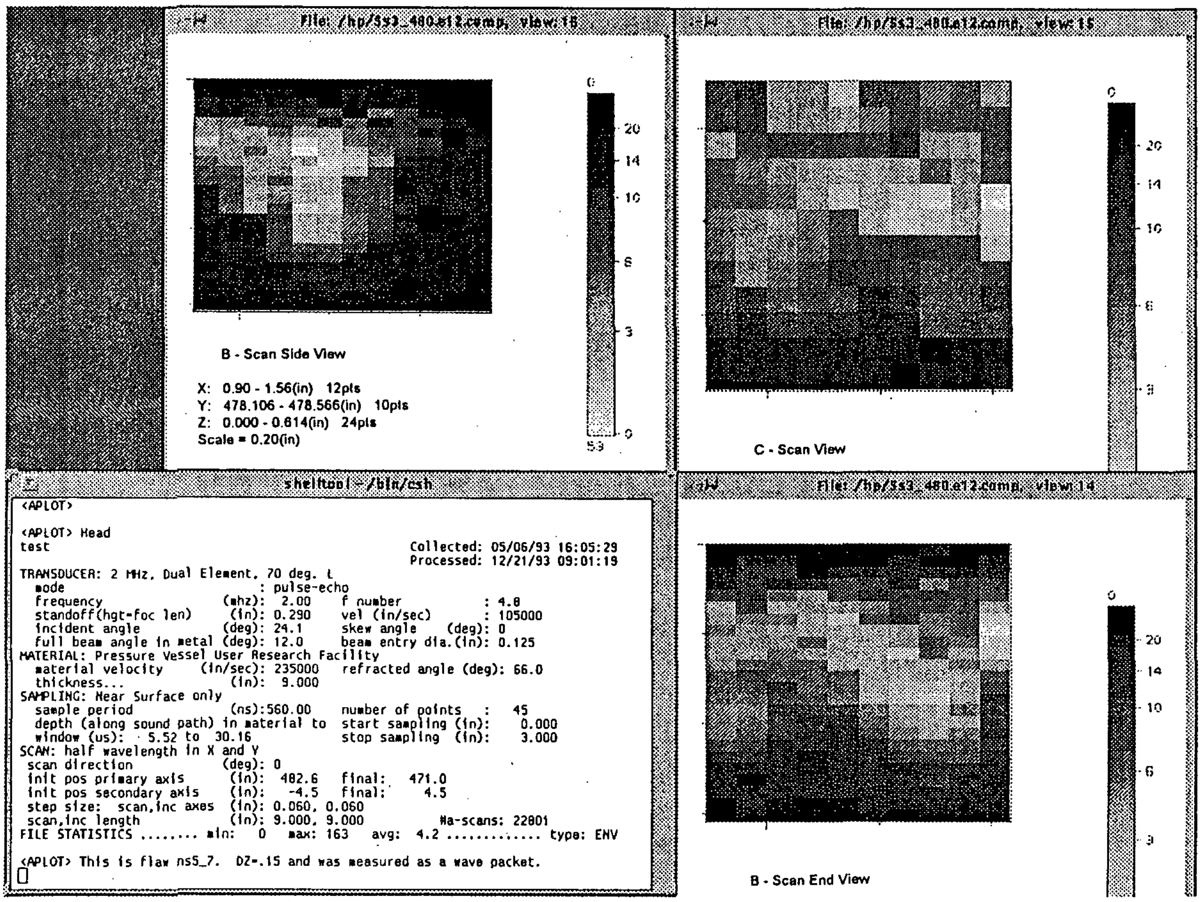


Figure A.54b - Volumetric indication #5 in the cladding: mode 3

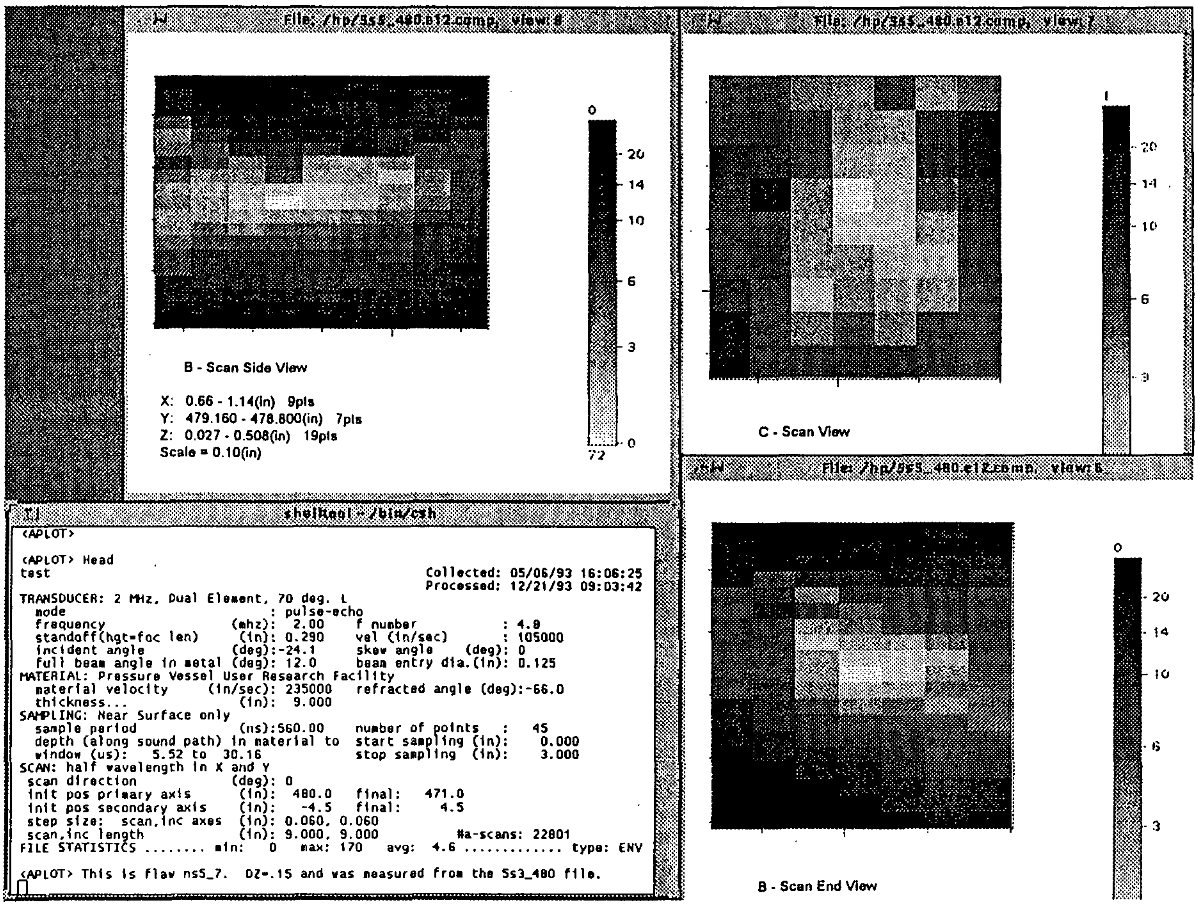


Figure A.54c - Volumetric indication #5 in the cladding: mode 5

Figures A.55a-c show volumetric indication #6 in the cladding. This volumetric indication has a through-wall extent of less than 1.5 mm based on an indication without TOF shape at the clad to base metal interface. The detection was made in modes 1 and 2 where the bright, shallow indication failed to take shape at a depth of 7 mm. There was a confirmation in mode 3 at a depth of 9 mm. The different Z values of 7 to 9 mm give an alternate depth size of 2 mm. The indication is characterized as volumetric based on normal beam detection. There is no evidence of coin shape in the end view of modes 2 and the side view of mode 3. The maximum amplitude-to-noise ratio is high at 255 to 20. The Z coordinate of 7 to 9 mm shows that the indication is in the clad-to-base metal interface. The X coordinate of 94 mm shows that the indication is over the base metal.

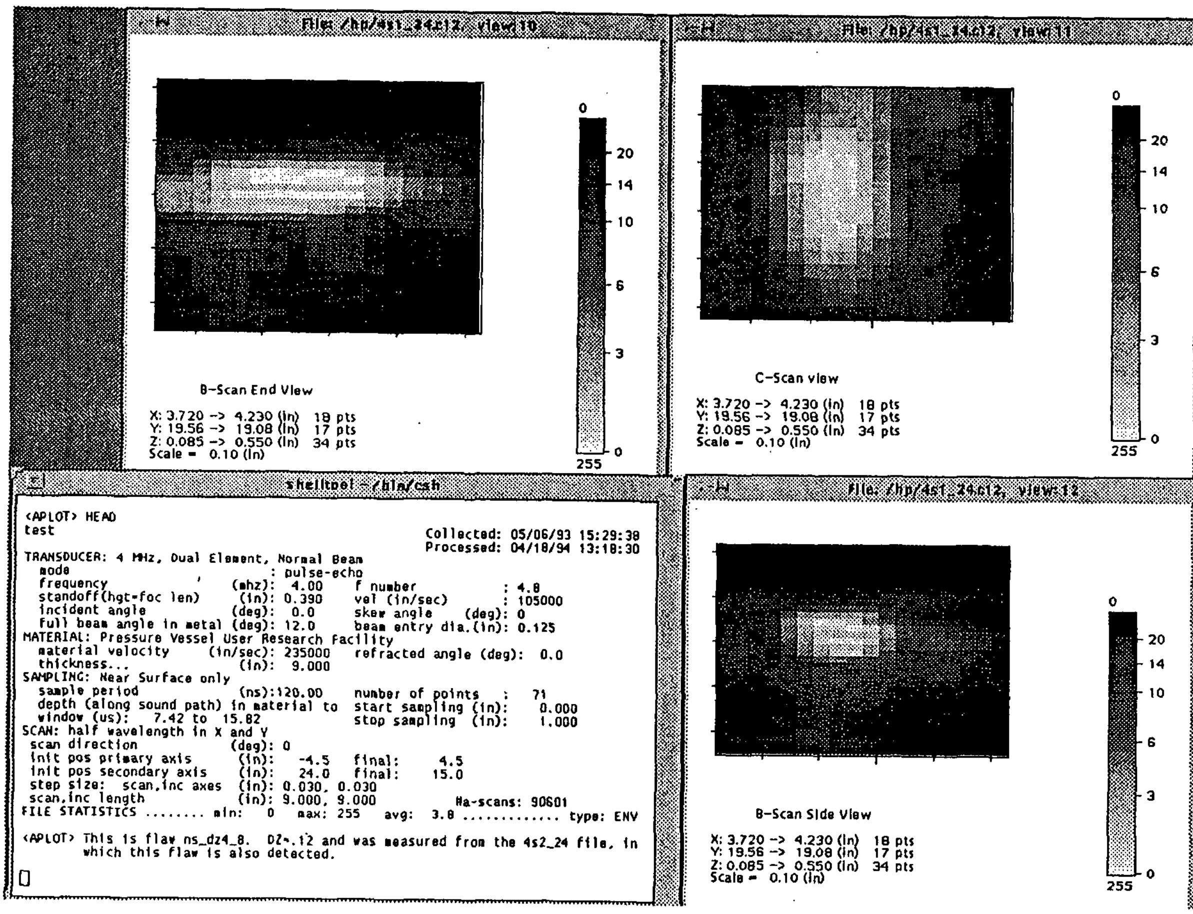


Figure A.55a - Volumetric indication #6 in the cladding: mode 1

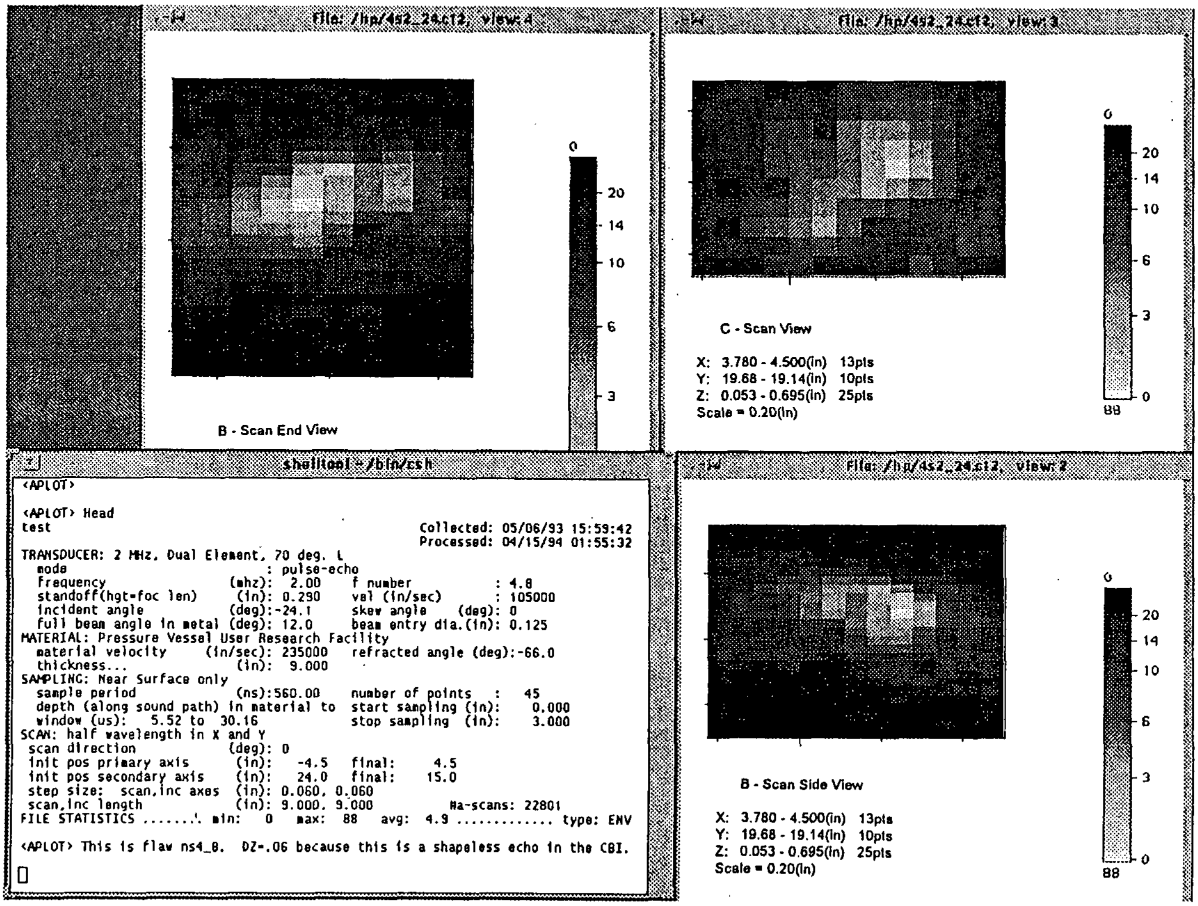


Figure A.55b - Volumetric indication #6 in the cladding: mode 2

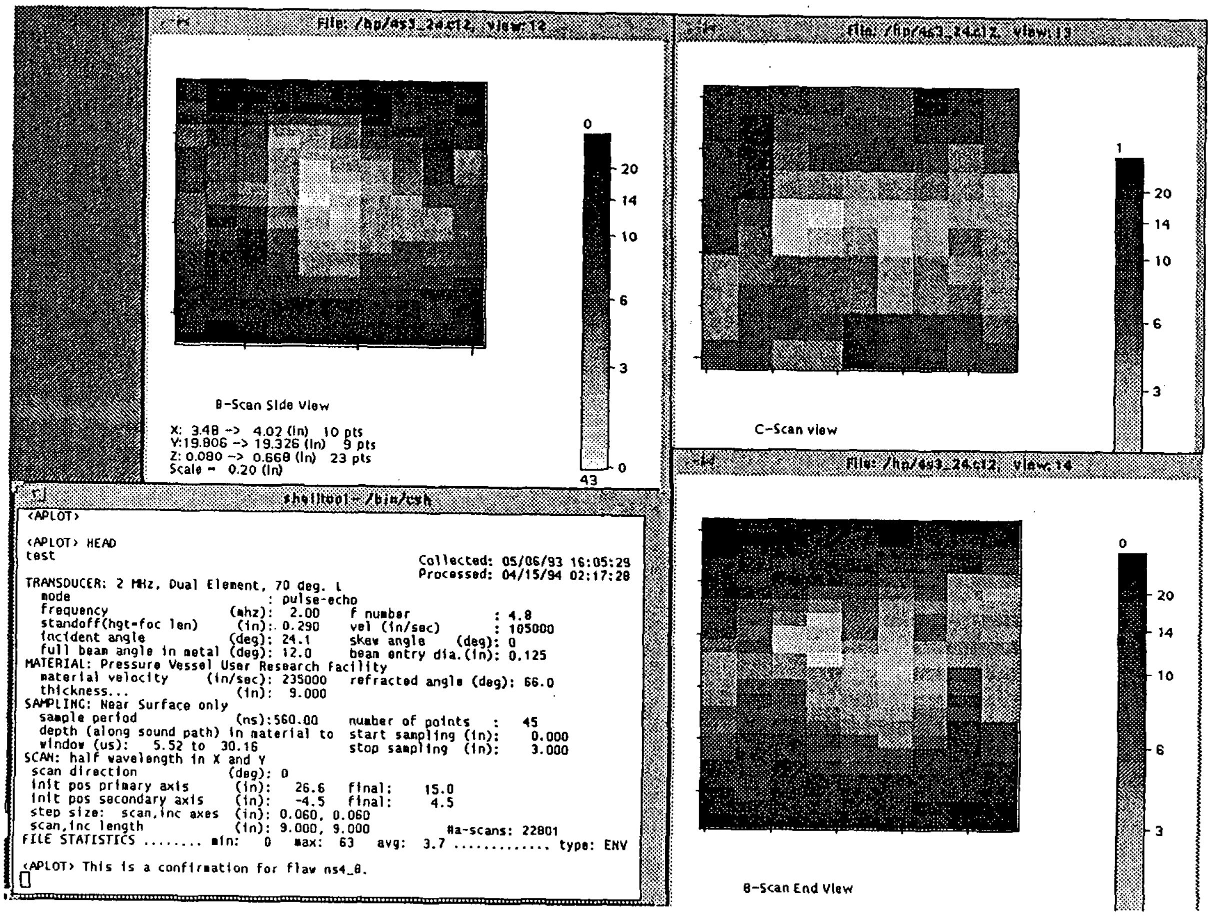


Figure A.55c - Volumetric indication #6 in the cladding: mode 3

Planar Indications in the Weldment Below 25 mm

Figure A.56 shows planar indication #1 in the weldment below 25 mm. This planar indication has a through-wall extent of 14 mm based on tip signal pattern. The detection was made in mode 6 where it displayed a pair of TOF shapes at a depth of 64 mm. The shape quality is good for this indication. There were no confirmations in other modes. The indication is characterized as planar based on the tip signal pattern. The length is 18 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 1.3. The maximum amplitude-to-noise ratio is high at 36 to 5. With an X coordinate of -8 mm, the indication is in the weld. With a Z coordinate of 64 mm, the indication is in the middle third of the vessel.

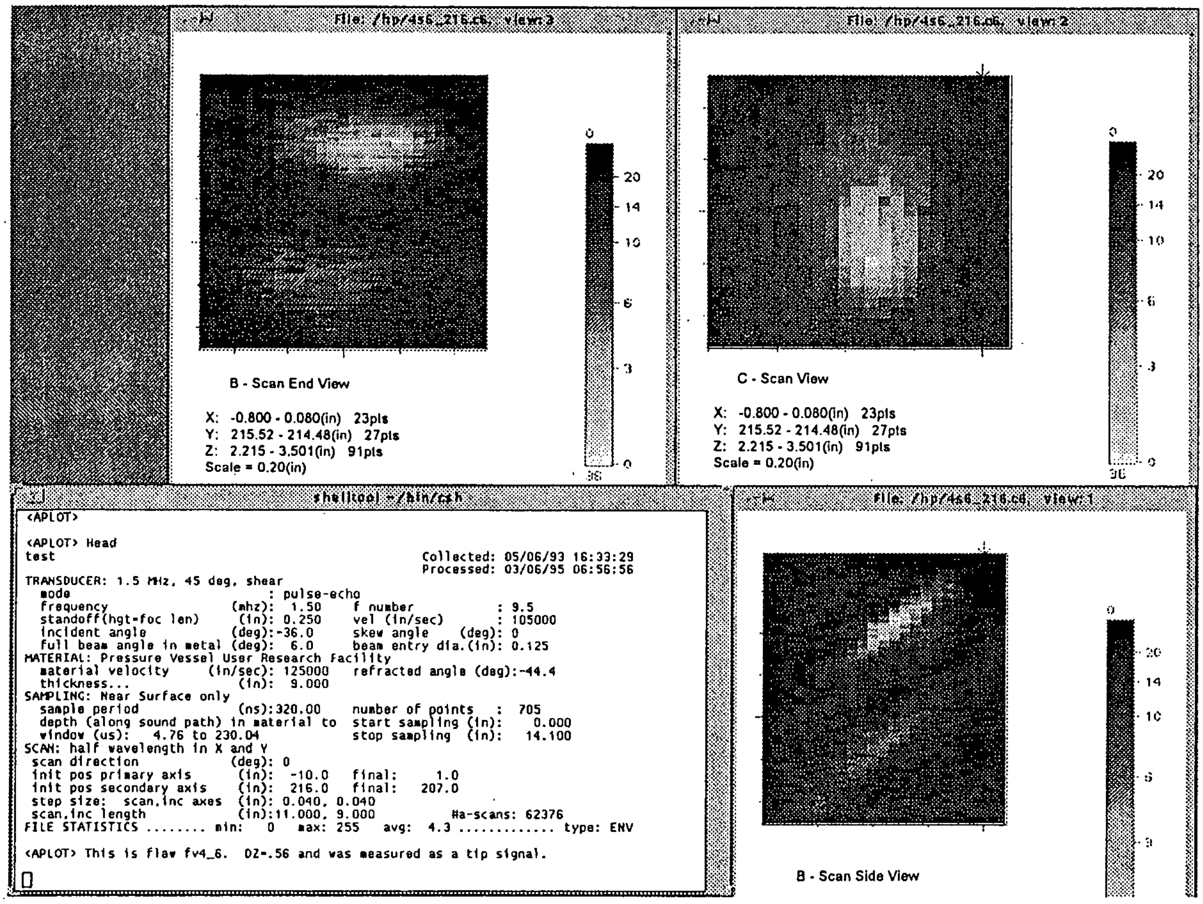


Figure A.56 - Planar indication #1 in the weldment below 25 mm: mode 6

Figures A.57a-b show planar indication #2 in the weldment below 25 mm. This planar indication has a through-wall extent of 13 mm based on tip signal pattern. The detection was made in mode 10 where it displayed normal beam shape at a depth of 115 mm. There was a confirmation in mode 6 at a depth of 112 mm. The confirmation mode detected the tip signal pattern. The indication is characterized as planar based on the tip pattern. The length is 25 mm and was made to LOS in mode 6. The width is 9 mm and was made to LOS in mode 10. The aspect ratio (length/depth) of this indication is 2. The maximum amplitude-to-noise ratio is high at 56 to 11. With an X coordinate of -8 mm, the indication is in the weld. With a Z coordinate of 115 mm, the indication is in the middle third of the vessel.

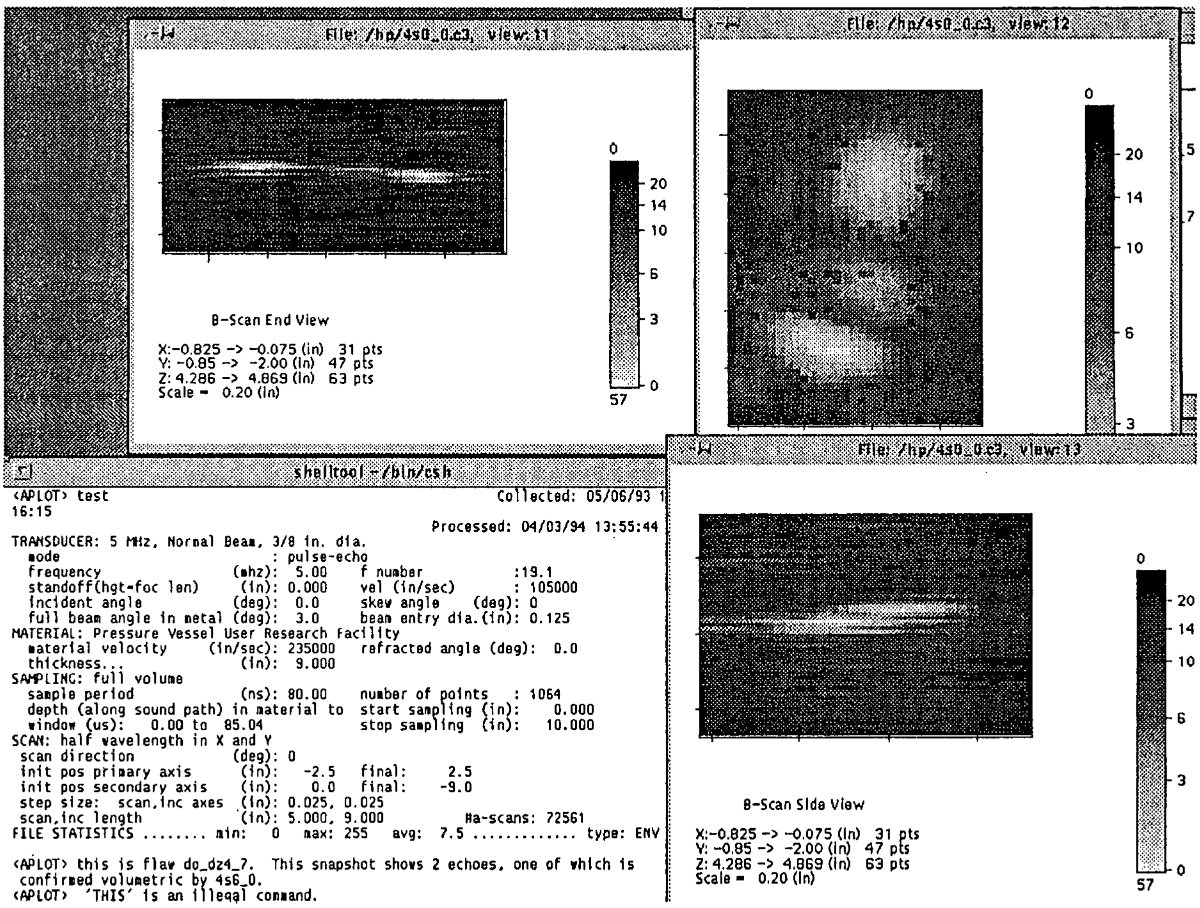


Figure A.57a - Planar indication #2 in the weldment below 25 mm: mode 10

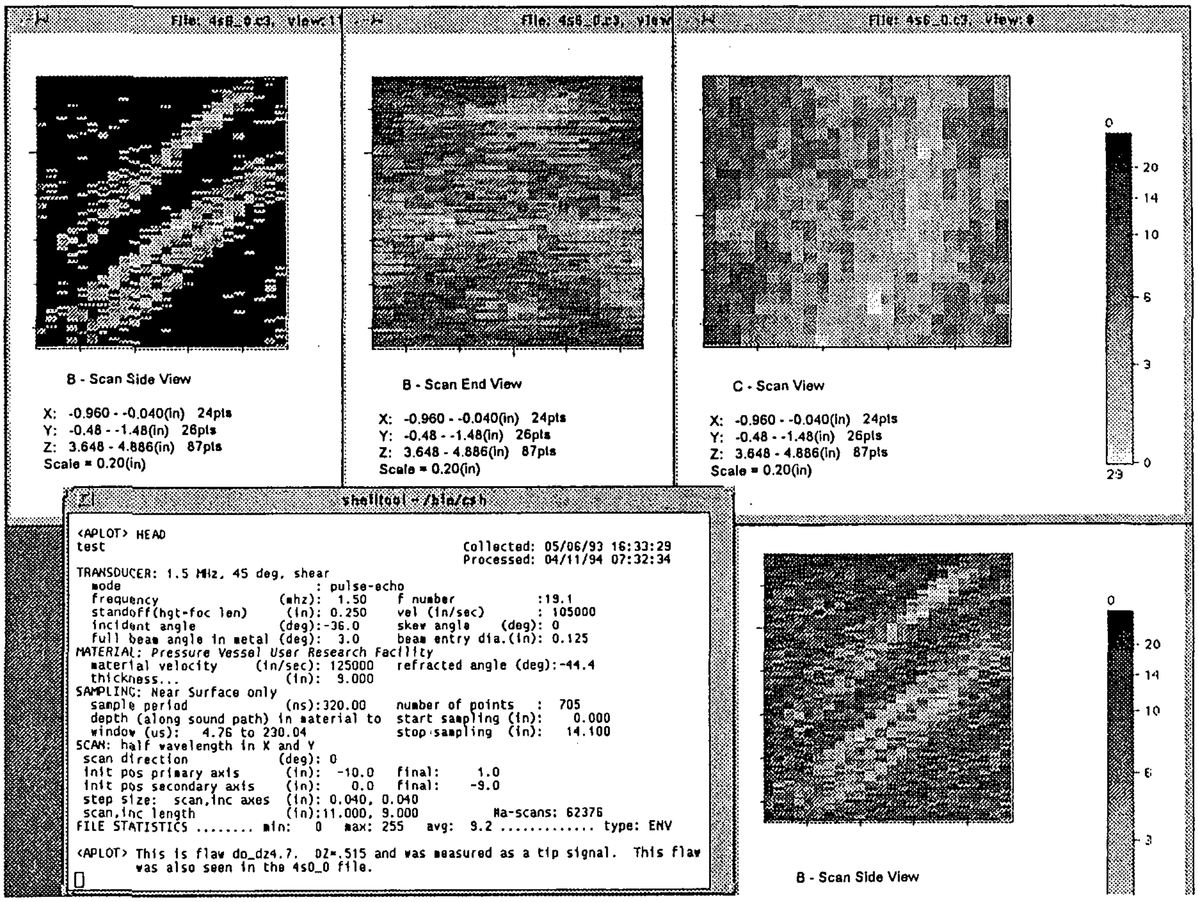


Figure A.57b - Planar indication #2 in the weldment below 25 mm: mode 6

Figures A.58a-b show planar indication #3 in the weldment below 25 mm. This planar indication has a through-wall extent of 11 mm based on tip signal pattern. The detection was made in mode 6 where it displayed a pair of TOF shapes at a depth of 75 mm. The shape quality is good for this indication. There was a confirmation in mode 8 at a depth of 74 mm. The different Z values of 74 to 75 mm give an alternate depth size of 1 mm. The indication is characterized as planar based on the tip signal pattern. The length is 18 mm and was made to LOS in mode 6. The range of aspect ratios (length/depth) of this indication is 1.6 to 18 which tends to confirm the larger through-wall extent. The maximum amplitude-to-noise ratio is high at 21 to 3. With an X coordinate of -7 mm, the indication is clearly in the weld. The Z coordinate of 75 mm shows that the indication is in the middle third of the vessel.

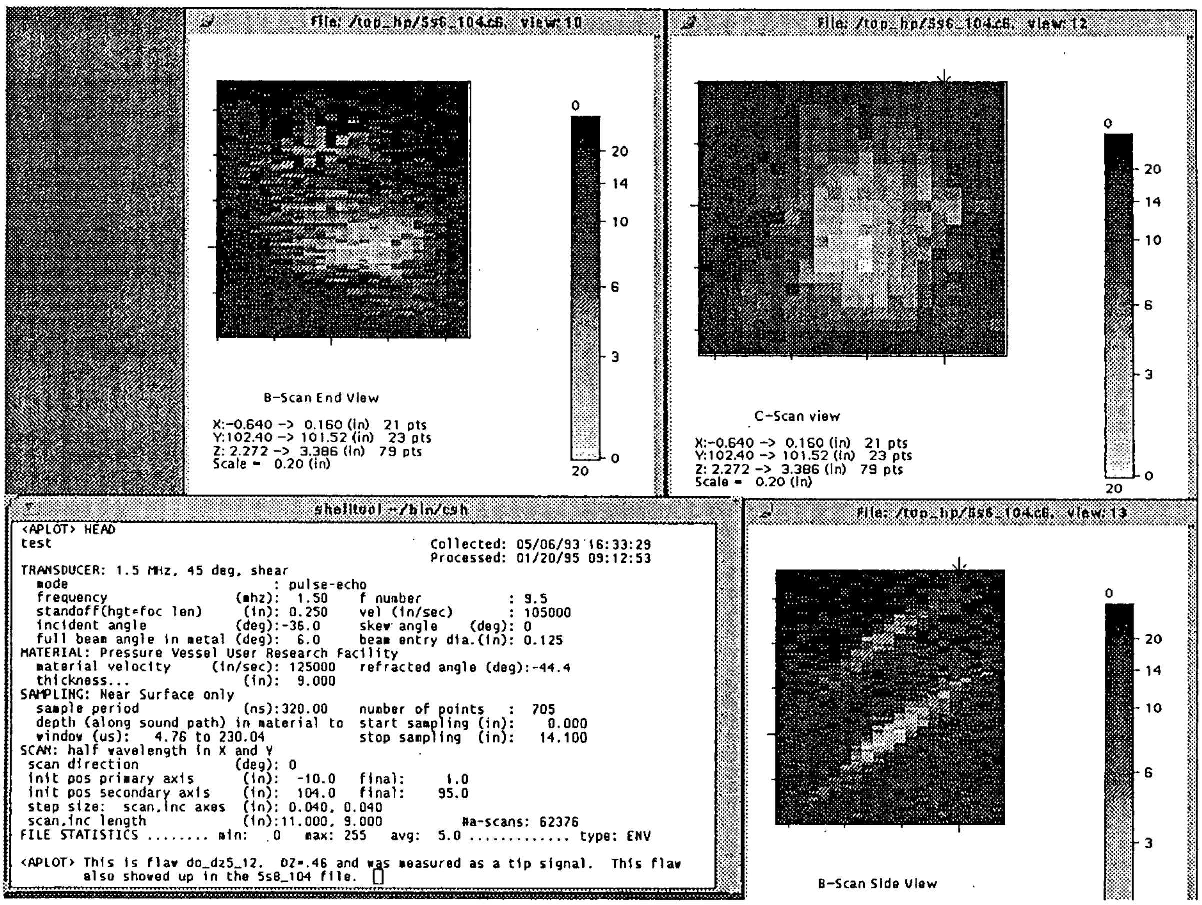


Figure A.58a - Planar indication #3 in the weldment below 25 mm: mode 6

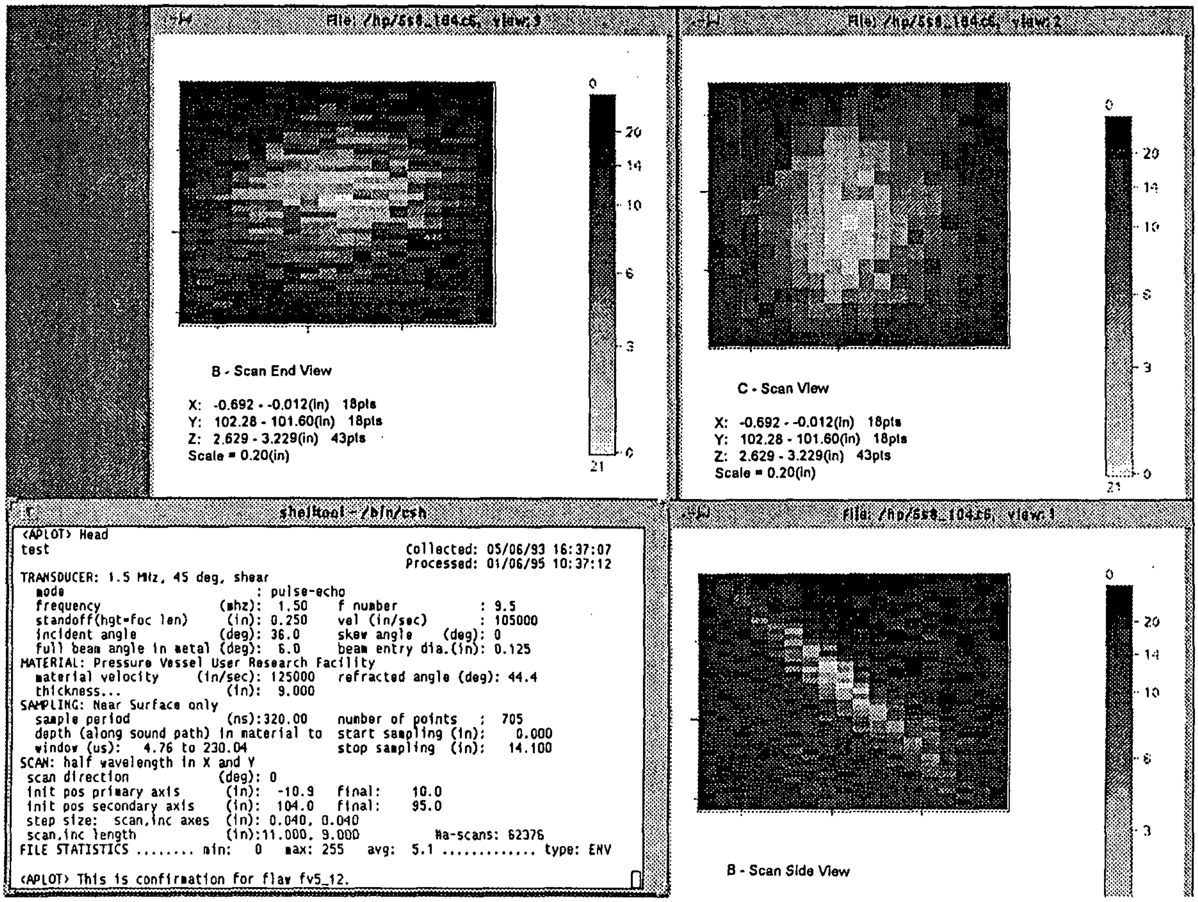


Figure A.58b - Planar indication #3 in the weldment below 25 mm: mode 8

Figure A.59 shows planar indication #4 in the weldment below 25 mm. This planar indication has a through-wall extent of 11 mm based on tip signal pattern. The detection was made in mode 6 where it displayed a pair of TOF shapes at a depth of 73 mm. The shape quality is good for this indication. There were no confirmations in other modes. The indication is characterized as planar based on the tip signal pattern. The length is 18 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 1.6. The maximum amplitude-to-noise ratio is high at 25 to 5. The X coordinate of -7 mm shows that the indication is in the weld. The Z coordinate of 73 mm shows that the indication is in the middle third of the vessel.

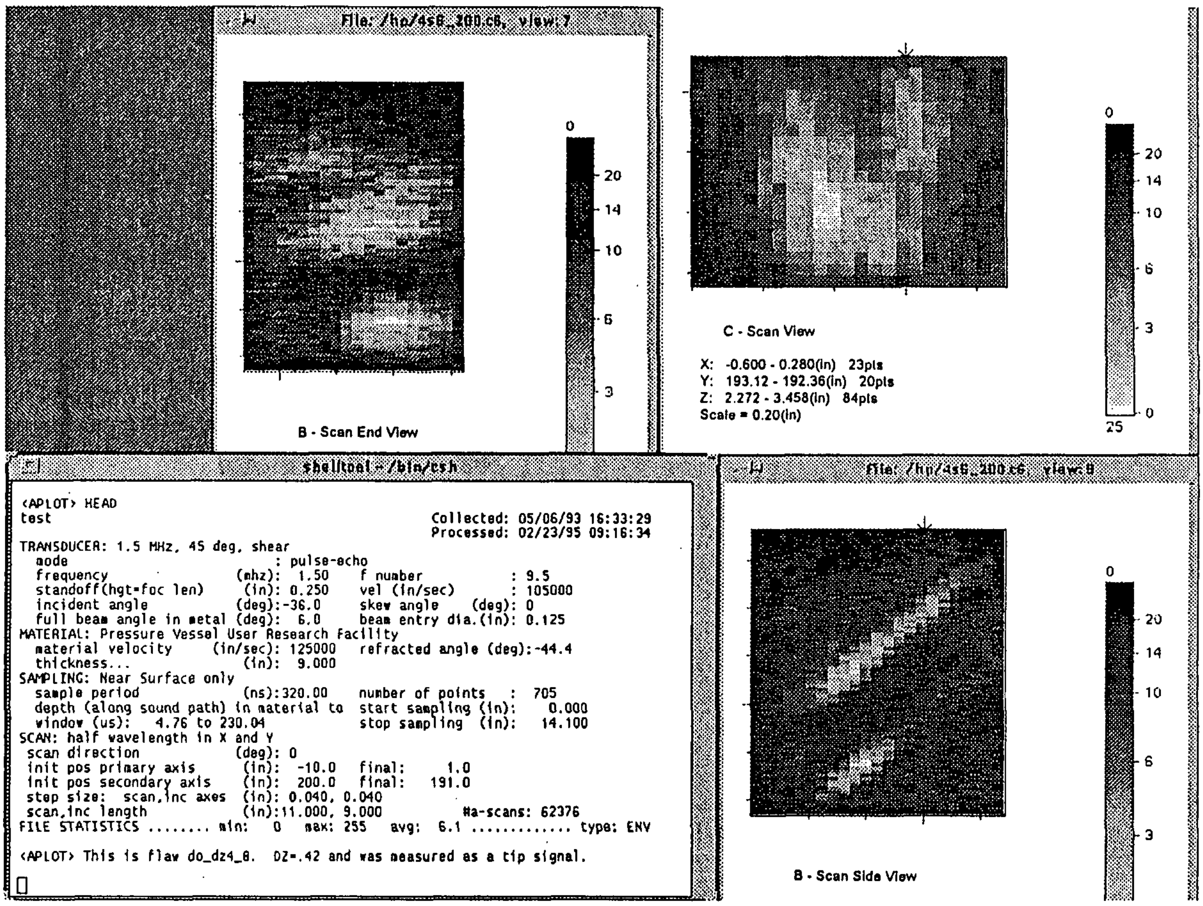


Figure A.59 - Planar indication #4 in the weldment below 25 mm: mode 6

Figure A.60 shows planar indication #5 in the weldment below 25 mm. This planar indication has a through-wall extent of 9 mm based on tip signal pattern. The detection was made in mode 6 where it displayed a pair of TOF shapes at a depth of 81 mm. The shape quality for this indication is good but broken up, implying that more than one small flaw may be present. There were no confirmations in other modes. The indication is characterized as planar based on the tip signal pattern. The length is 16 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 1.8. The maximum amplitude-to-noise ratio is high at 37 to 6. The X coordinate of -6 mm shows that the indication is in the weld. The Z coordinate of 81 mm shows that the indication is in the middle third of the vessel.

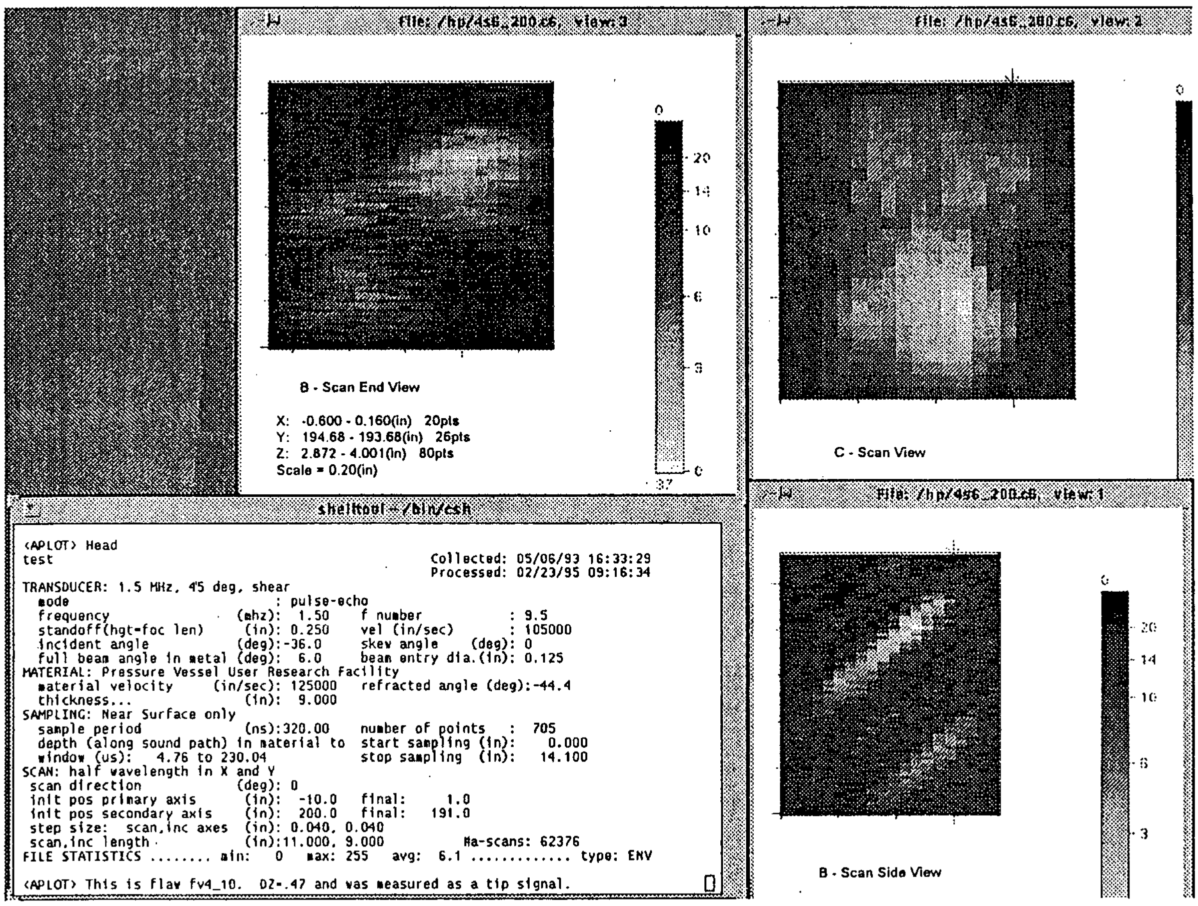


Figure A.60 - Planar indication #5 in the weldment below 25 mm: mode 6

Figure A.61 shows planar indication #6 in the weldment below 25 mm. This planar indication has a through-wall extent of 9 mm based on tip signal pattern. The detection was made in mode 6 where it displayed a pair of TOF shapes at a depth of 211 mm. The shape quality is good for this indication. There were no confirmations in other modes. The indication is characterized as planar based on the tip signal pattern. The length is 30 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 3. The maximum amplitude-to-noise ratio is of medium range at 27 to 11. The X coordinate of 23 mm shows that the indication is in the weld. The Z coordinate of 211 mm shows that the indication is near the outer wall of the vessel.

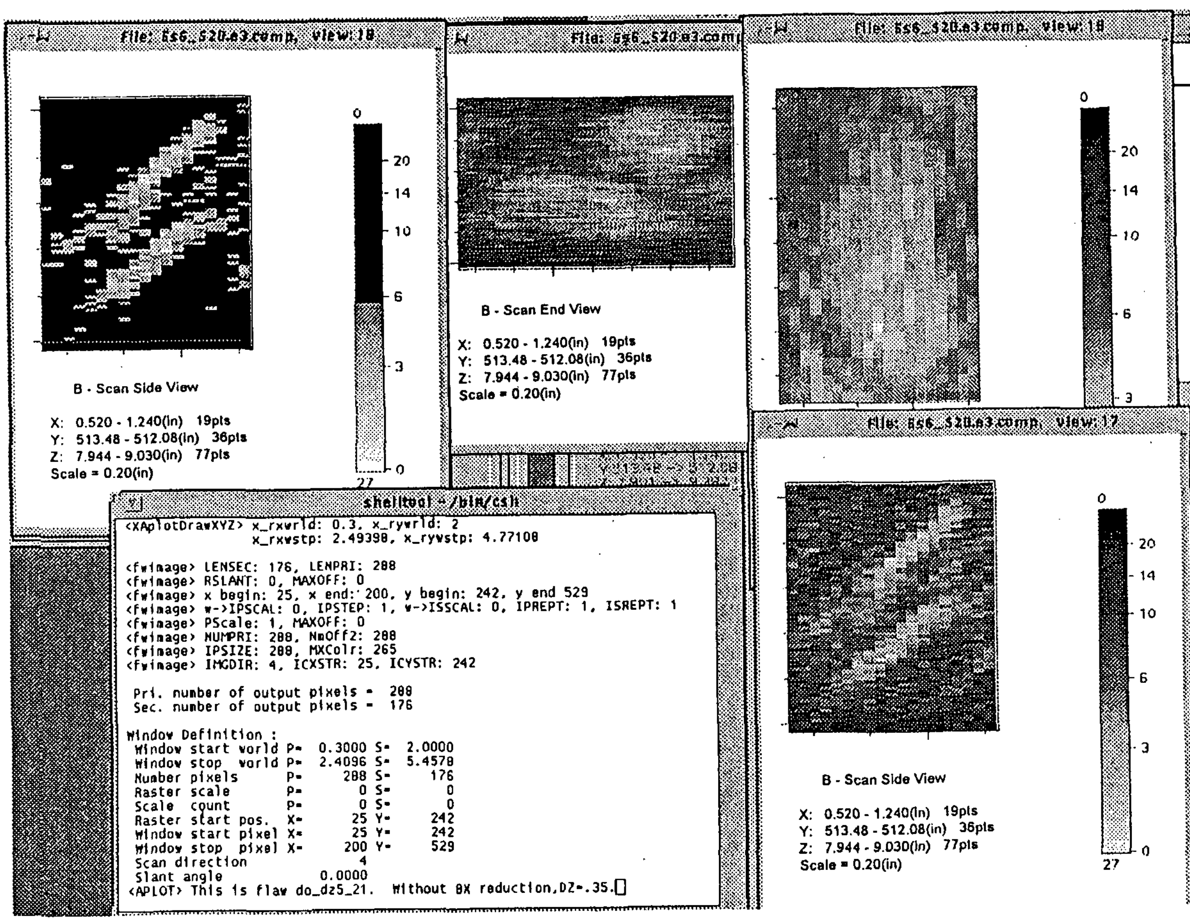


Figure A.61 - Planar indication #6 in the weldment below 25 mm: mode 6

Figures A.62a-b show planar indication #7 in the weldment below 25 mm. This planar indication has a through-wall extent of 9 mm based on tip signal pattern. The detection was made in modes 6 and 8 where it displayed a pair of TOF shapes at depths of 68 and 63 mm. The shape quality is good for this indication. There were no confirmations in other modes. The indication is characterized as planar based on the tip signal pattern. The length is 16 mm and was made to LOS in mode 8. The aspect ratio (length/depth) of this indication is 1.8. The maximum amplitude-to-noise ratio is high at 15 to 5. The X coordinate of -8 mm shows that the indication is in the weld. The Z coordinate of 63 to 68 mm shows that the indication is in the middle third of the vessel.

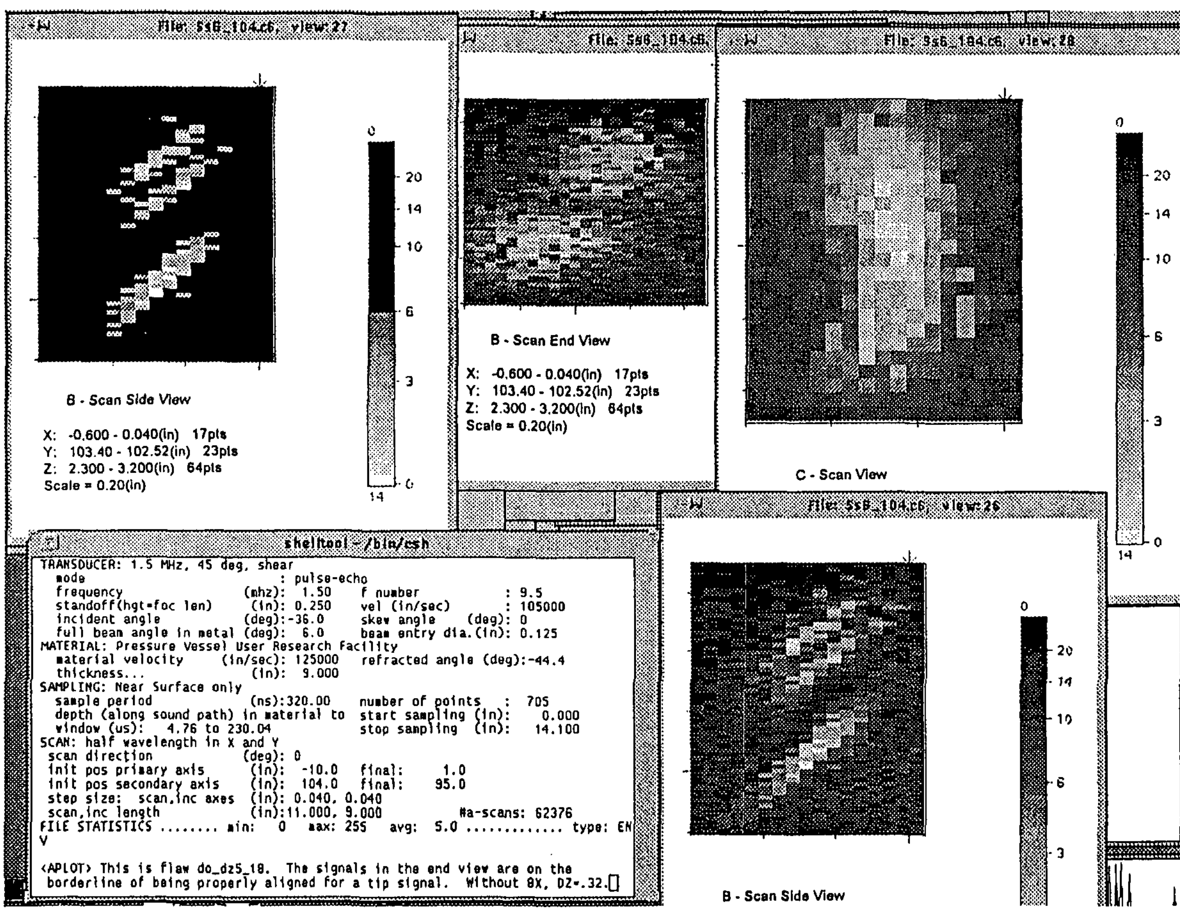


Figure A.62a - Planar indication #7 in the weldment below 25 mm: mode 6

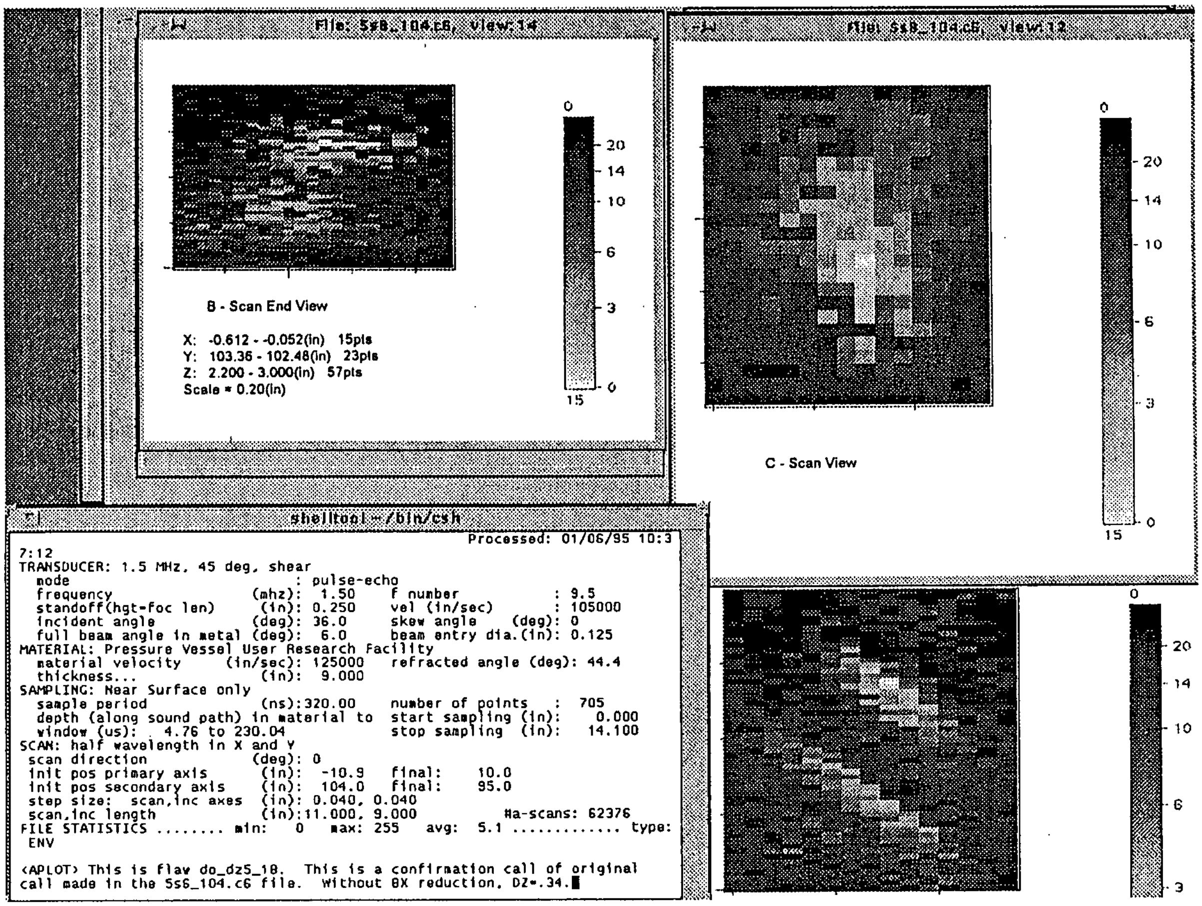


Figure A.62b - Planar indication #7 in the weldment below 25 mm: mode 8

Figures A.63a-b show planar indication #8 in the weldment below 25 mm. This planar indication has a through-wall extent of 7 mm based on wave packet width. The detection was made in modes 6 and 8 where it had isolated TOF shapes at depths of 213 and 218 mm. The shape quality is good for this indication and is broken up indicating that more than one small flaw may be present. There were no confirmations in other modes. The two Z values of 213 to 218 mm give an alternate depth size of 5 mm. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. The length is 24 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 3. The maximum amplitude-to-noise ratio is of medium range at 31 to 13. The X coordinate of 6 mm shows that the indication is in the weld. The Z coordinate of 213 to 218 mm shows that the indication is near the outer wall of the vessel.

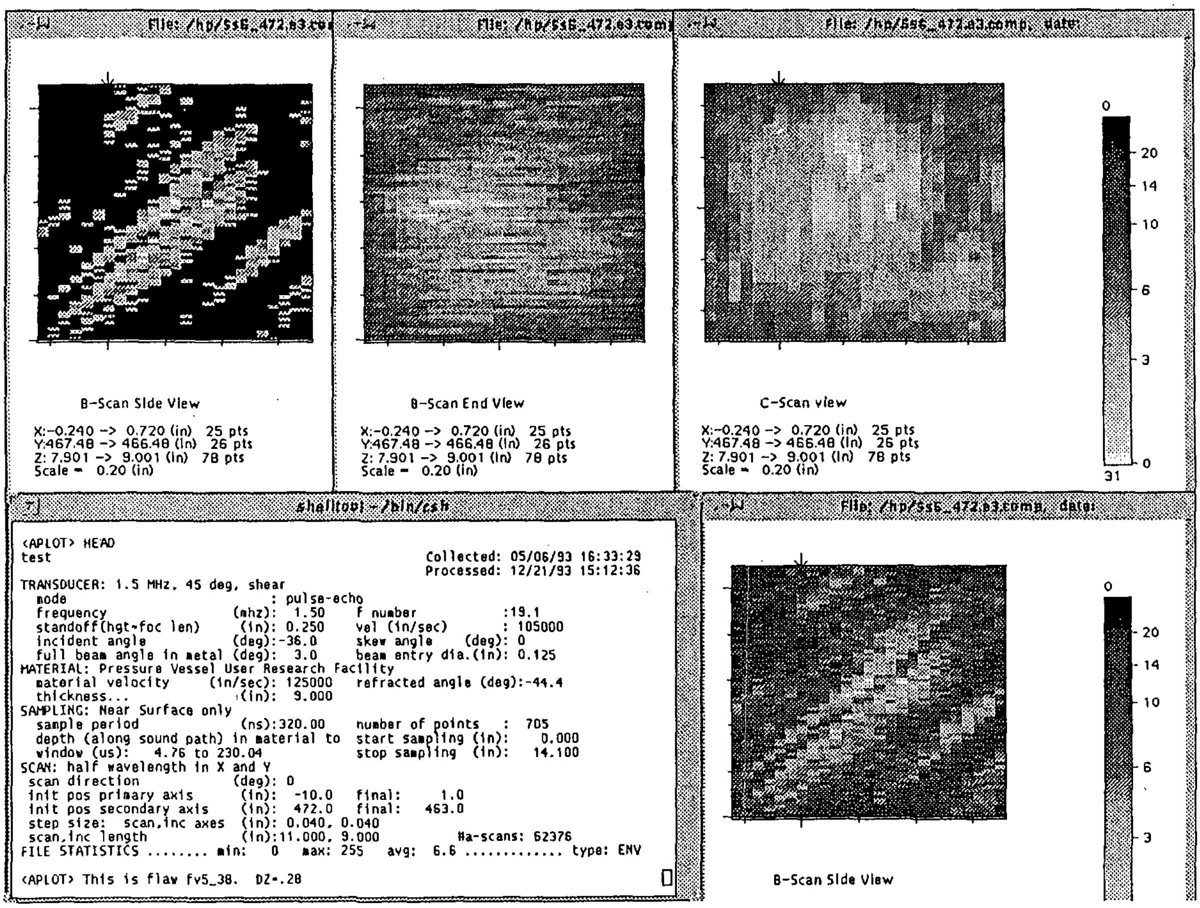


Figure A.63a - Planar indication #8 in the weldment below 25 mm: mode 6

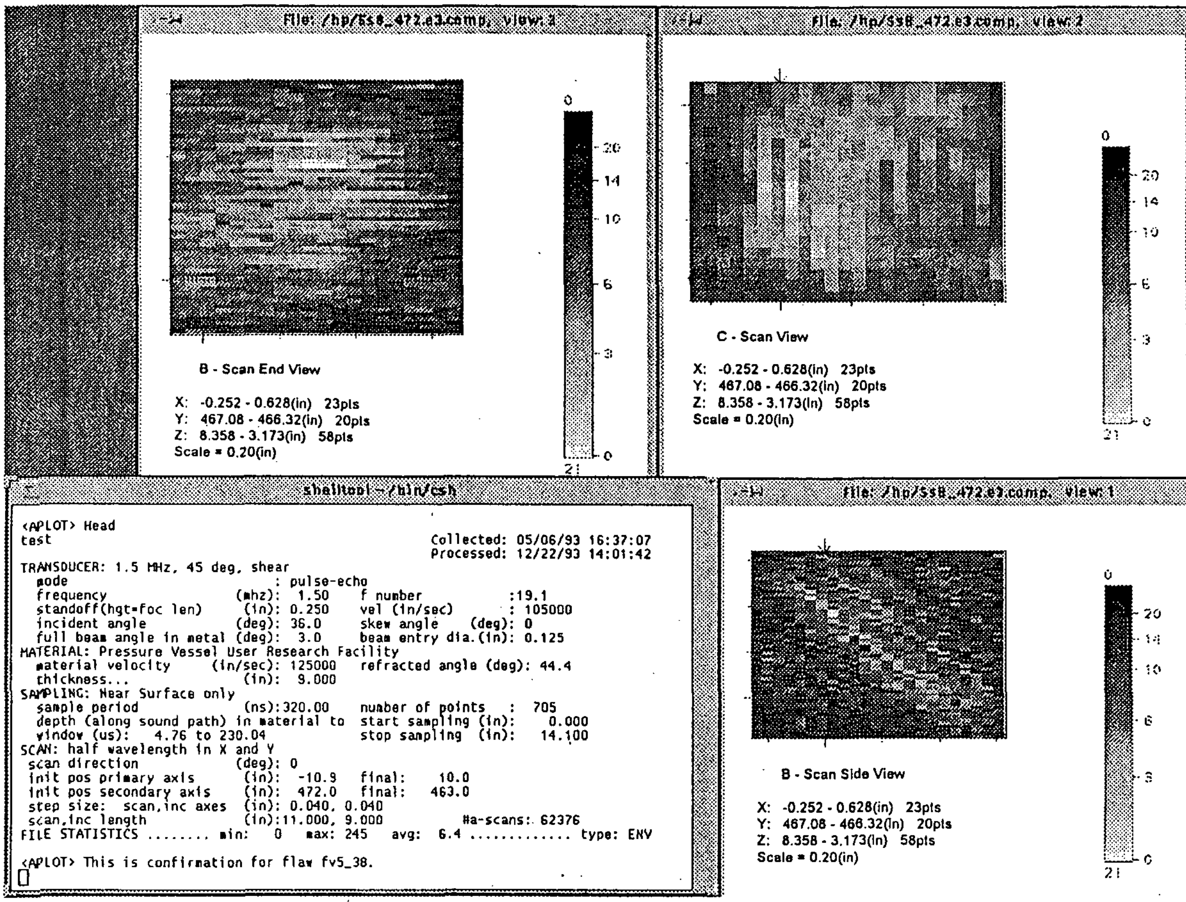


Figure A.63b - Planar indication #8 in the weldment below 25 mm: mode 8

Figure A.64 shows planar indication #9 in the weldment below 25 mm. This planar indication has a through-wall extent of 7 mm based on wave packet width. The detection was made in mode 6 where it had isolated TOF shape at a depth of 213 mm. The shape quality for this indication is good but broken up, implying that more than one small flaw may be present. There were no confirmations in other modes. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. The length is 30 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 4 which tends to confirm the large through-wall extent. The maximum amplitude-to-noise ratio is high at 121 to 15. The X coordinate of 24 mm shows that the indication is in the weld. The Z coordinate of 213 mm shows that the indication is near the outer wall of the vessel.

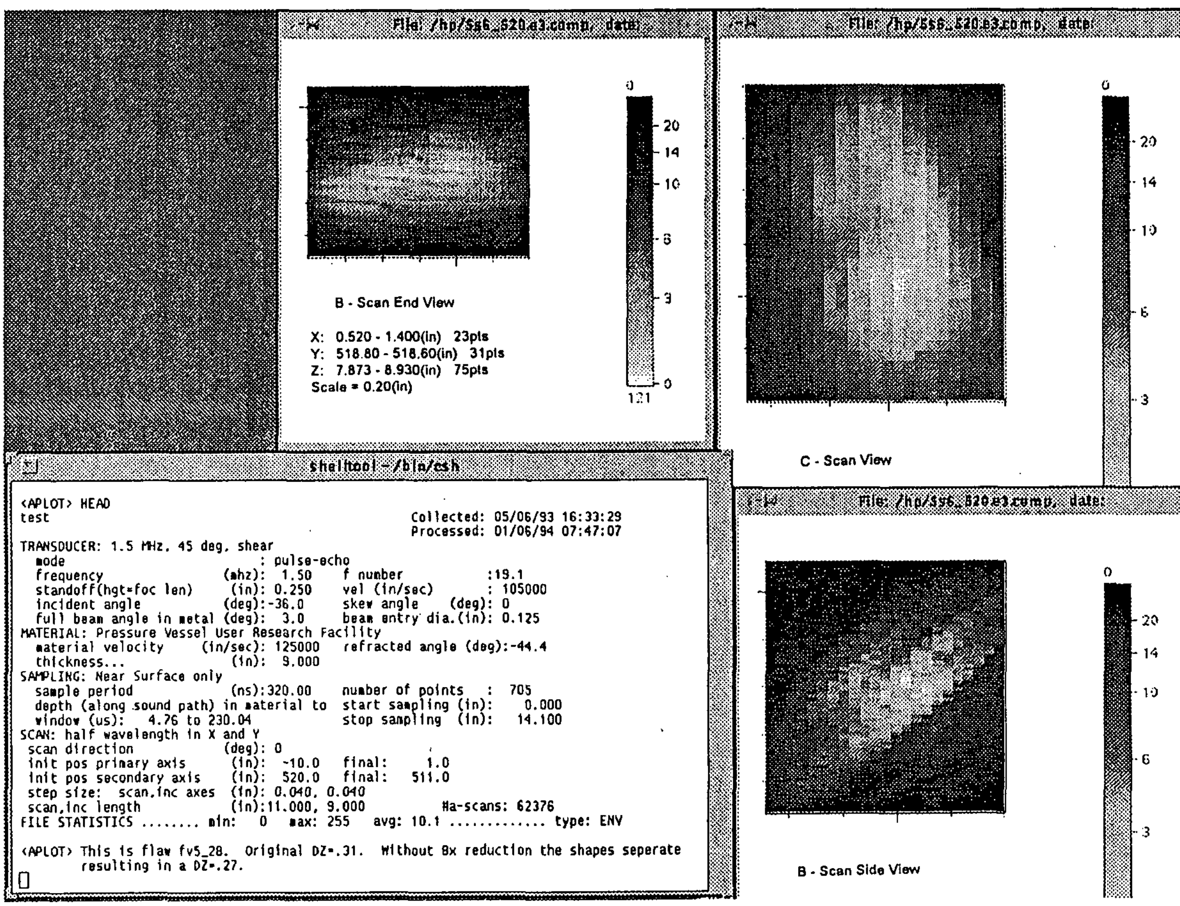


Figure A.64 - Planar indication #9 in the weldment below 25 mm: mode 6

Figure A.65 shows planar indication #10 in the weldment below 25 mm. This planar indication has a through-wall extent of 6 mm based on tip signal pattern. The detection was made in mode 6 where it displayed a pair of TOF shapes at a depth of 117 mm. The shape quality is good for this indication. There were no confirmations in other modes. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. The length is 19 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 3. The maximum amplitude-to-noise ratio is high at 60 to 12. The X coordinate of -7 mm shows that the indication is in the weld. The Z coordinate of 117 mm shows that the indication is in the middle third of the vessel.

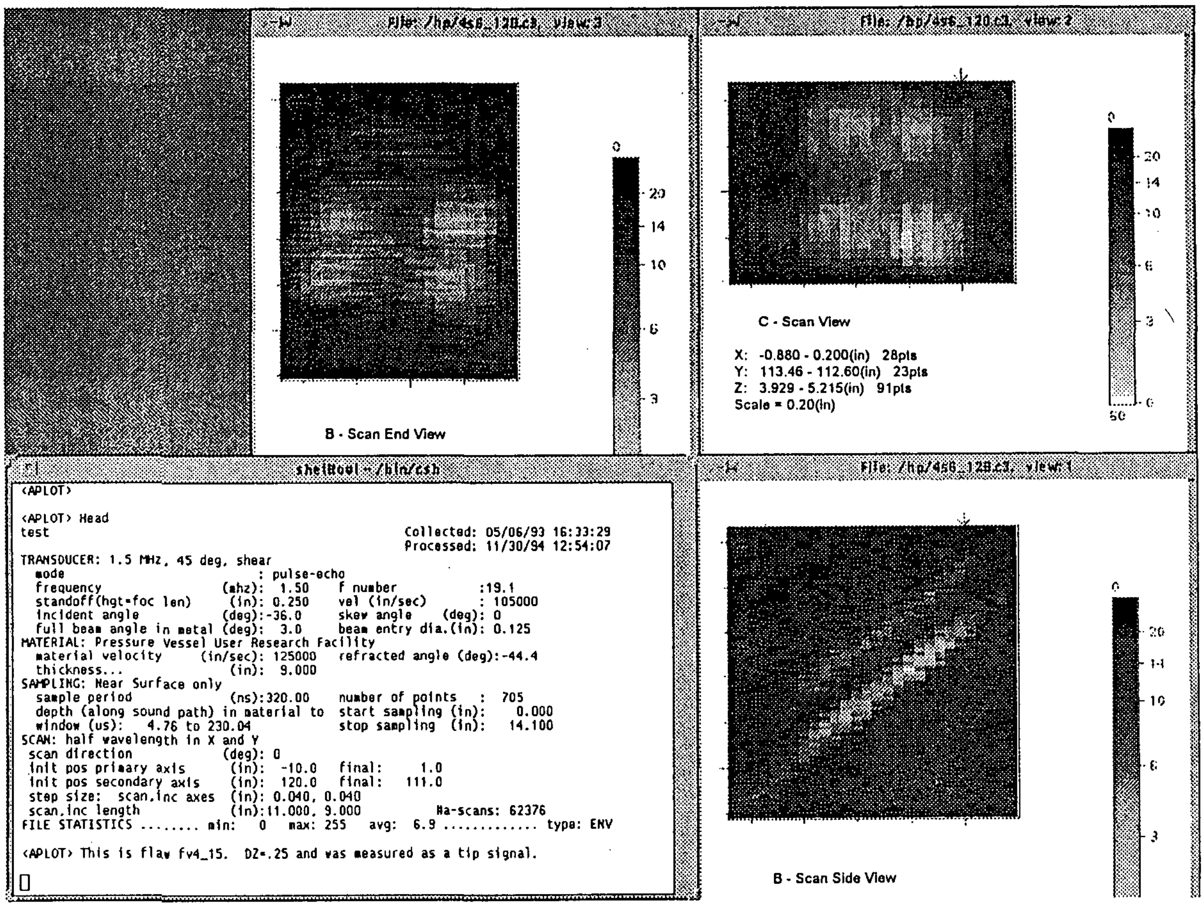


Figure A.65 - Planar indication #10 in the weldment below 25 mm: mode 6

Figure A.66 shows planar indication #11 in the weldment below 25 mm. This planar indication has a through-wall extent of 6 mm based on wave packet width. The detection was made in mode 6 where it had isolated TOF shape at a depth of 213 mm. The shape quality is good for this indication. There were no confirmations in other modes. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. The length is 17 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 3. The maximum amplitude-to-noise ratio is low at 90 to 45. The X coordinate of 16 mm shows that the indication is in the weld. The Z coordinate of 213 mm shows that the indication is near the outer wall of the vessel.

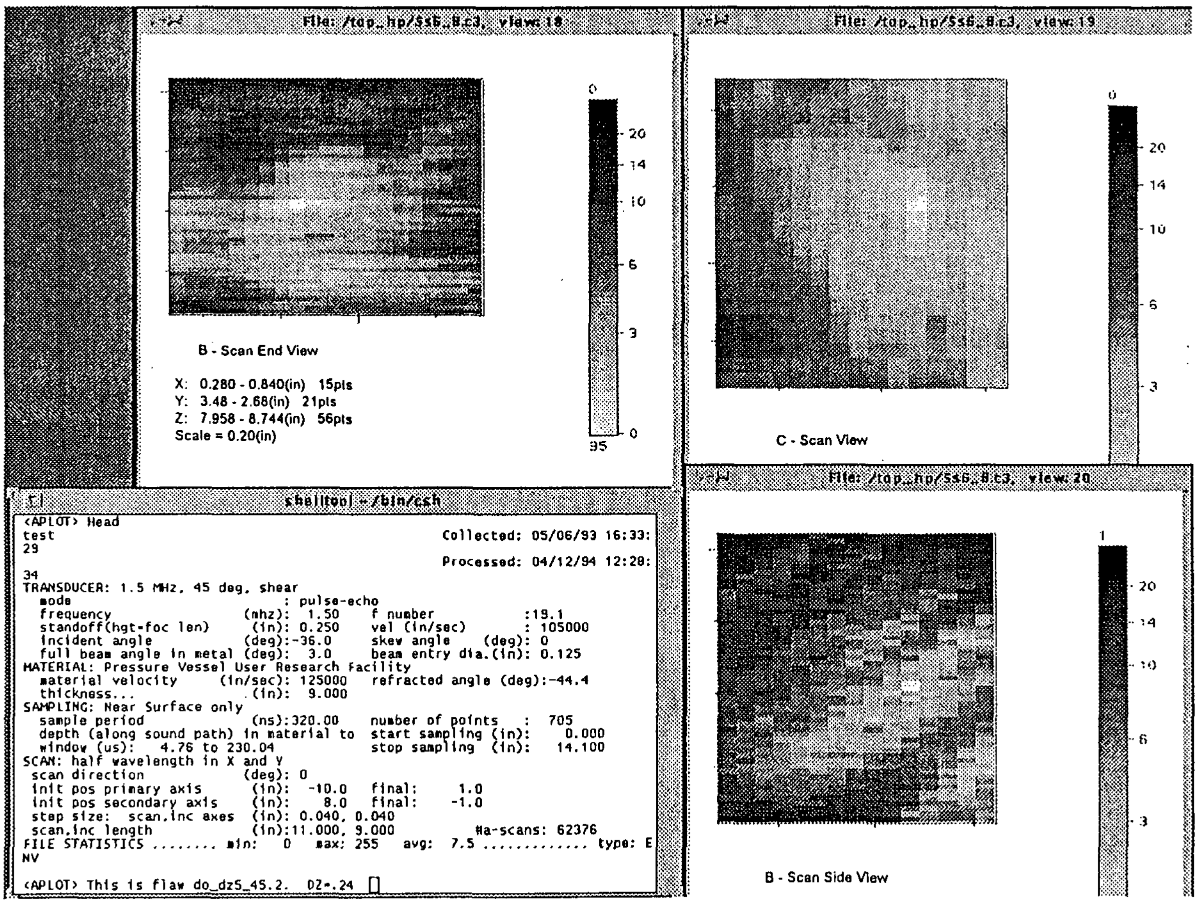


Figure A.66 - Planar indication #11 in the weldment below 25 mm: mode 6

Figures A.67a-b show planar indication #12 in the weldment below 25 mm. This planar indication has a through-wall extent of 6 mm based on wave packet width. The detection was made in mode 6 where it had isolated TOF shape at a depth of 215 mm. The shape quality is good for this indication. There was a confirmation in mode 8 at a depth of 213 mm. The two Z values of 213 to 215 mm give an alternate depth size of 2 mm. The indication is characterized as planar based on lack of normal beam detection or detection in orthogonal modes. The length is 25 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 4 which tends to confirm the large through-wall extent. The maximum amplitude-to-noise ratio is of medium range at 109 to 40. The X coordinate of 16 mm shows that the indication is in the weld. The Z coordinate of 213 to 215 mm shows that the indication is near the outer wall of the vessel.

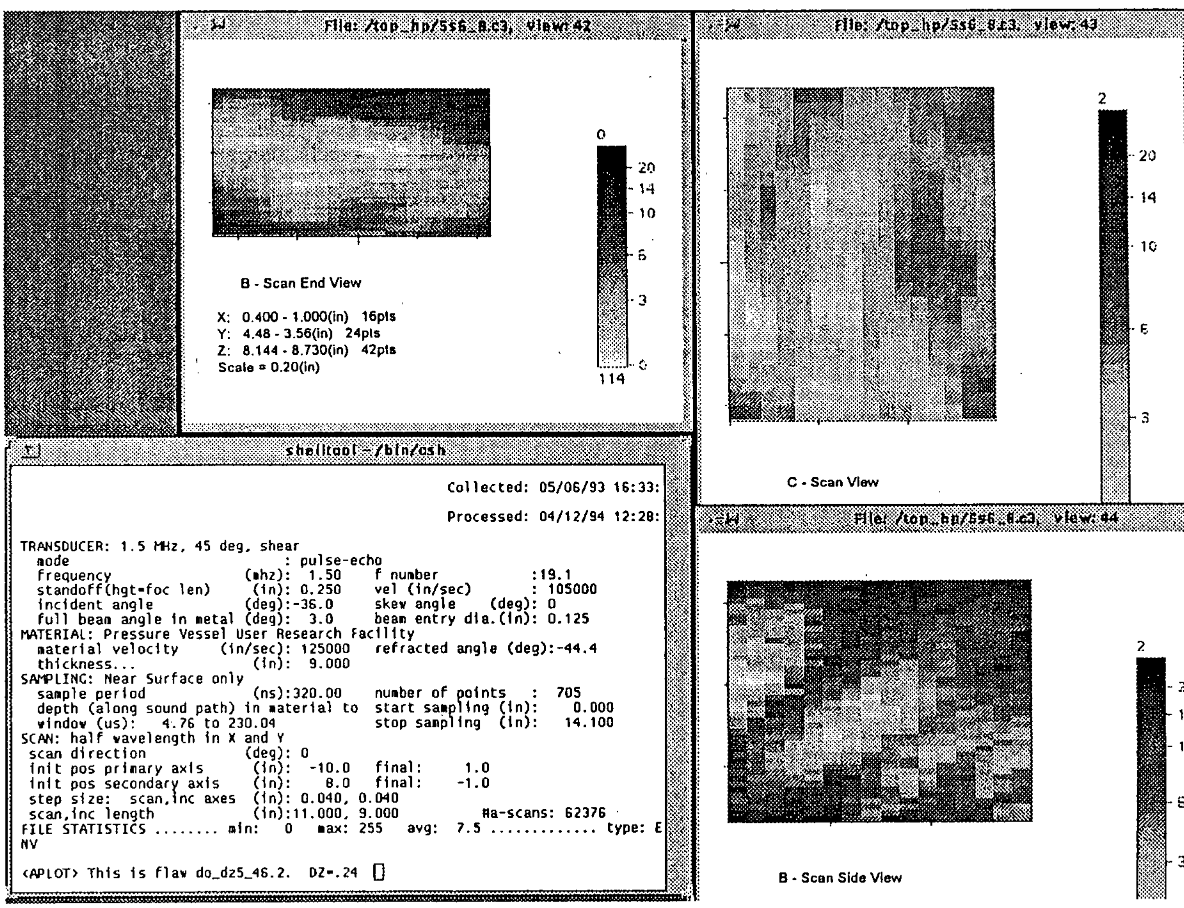


Figure A.67 - Planar indication #12 in the weldment below 25 mm: mode 6

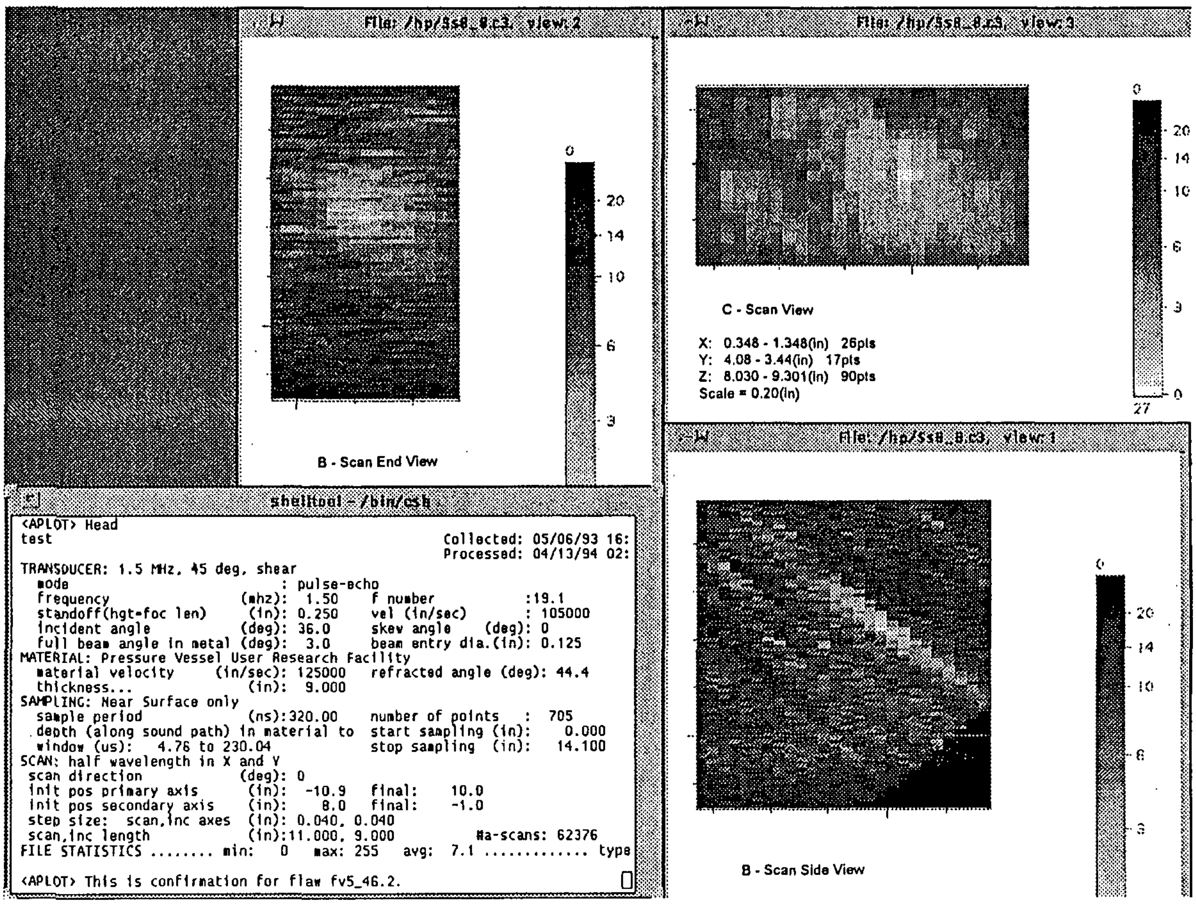


Figure A.67b - Planar indication #12 in the weldment below 25 mm: mode 8

Figure A.68 shows planar indication #13 in the weldment below 25 mm. This planar indication has a through-wall extent of 6 mm based on wave packet width. The detection was made in mode 6 where it had isolated TOF shape at a depth of 209 mm. The shape quality is good for this indication. There were no confirmations in other modes. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. The length is 15 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 2.5. The maximum amplitude-to-noise ratio is high at 43 to 10. The X coordinate of 10 mm shows that the indication is in the weld. The Z coordinate of 209 mm shows that the indication is near the outer wall of the vessel.

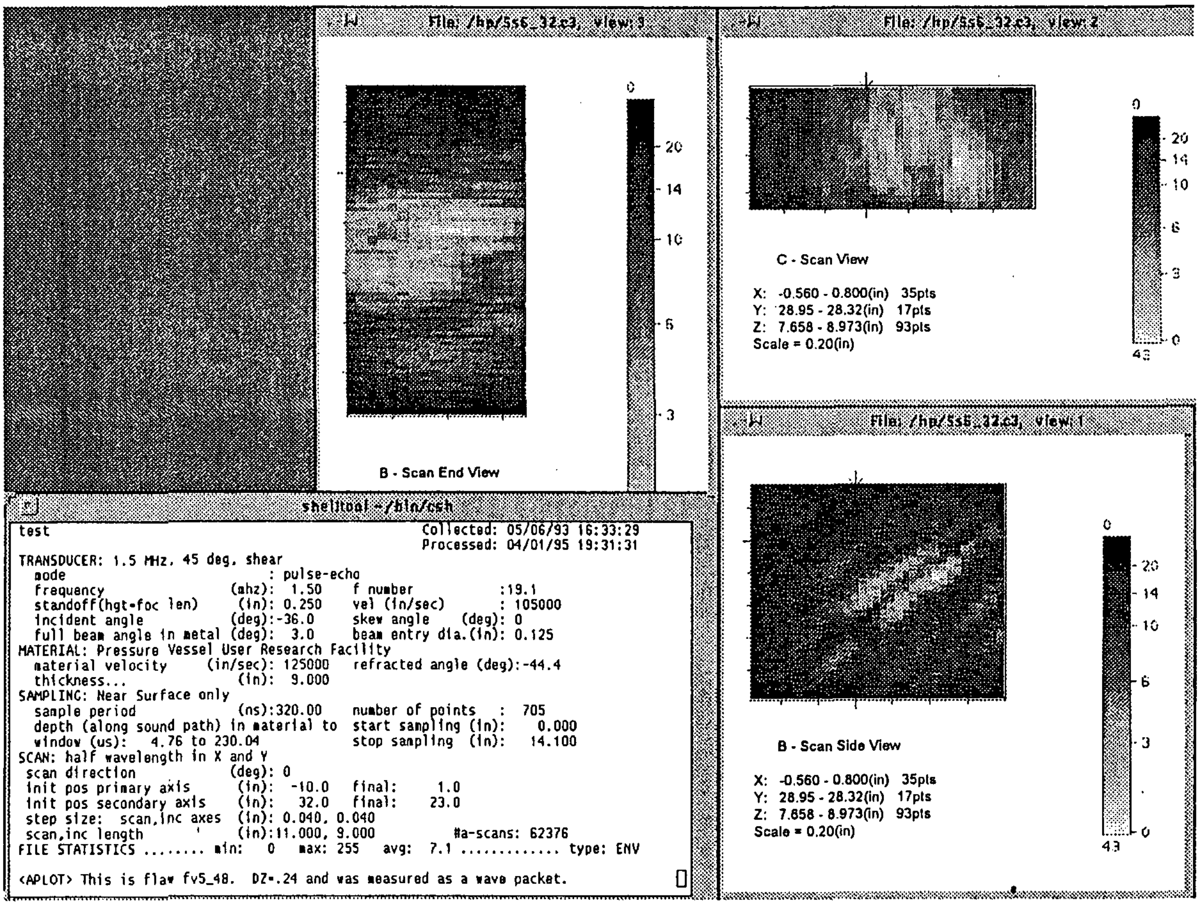


Figure A.68 - Planar indication #13 in the weldment below 25 mm: mode 6

Figure A.69 shows planar indication #14 in the weldment below 25 mm. This planar indication has a through-wall extent of 6 mm based on wave packet width. The detection was made in mode 6 where it had isolated TOF shape at a depth of 212 mm. The shape quality is good for this indication. There were no confirmations in modes. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. The length is 27 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 4.5 which tends to confirm the large through-wall extent. The maximum amplitude-to-noise ratio is of medium range at 115 to 40. The X coordinate of 9 mm shows that the indication is in the weld. The Z coordinate of 212 mm shows that the indication is near the outer wall of the vessel.

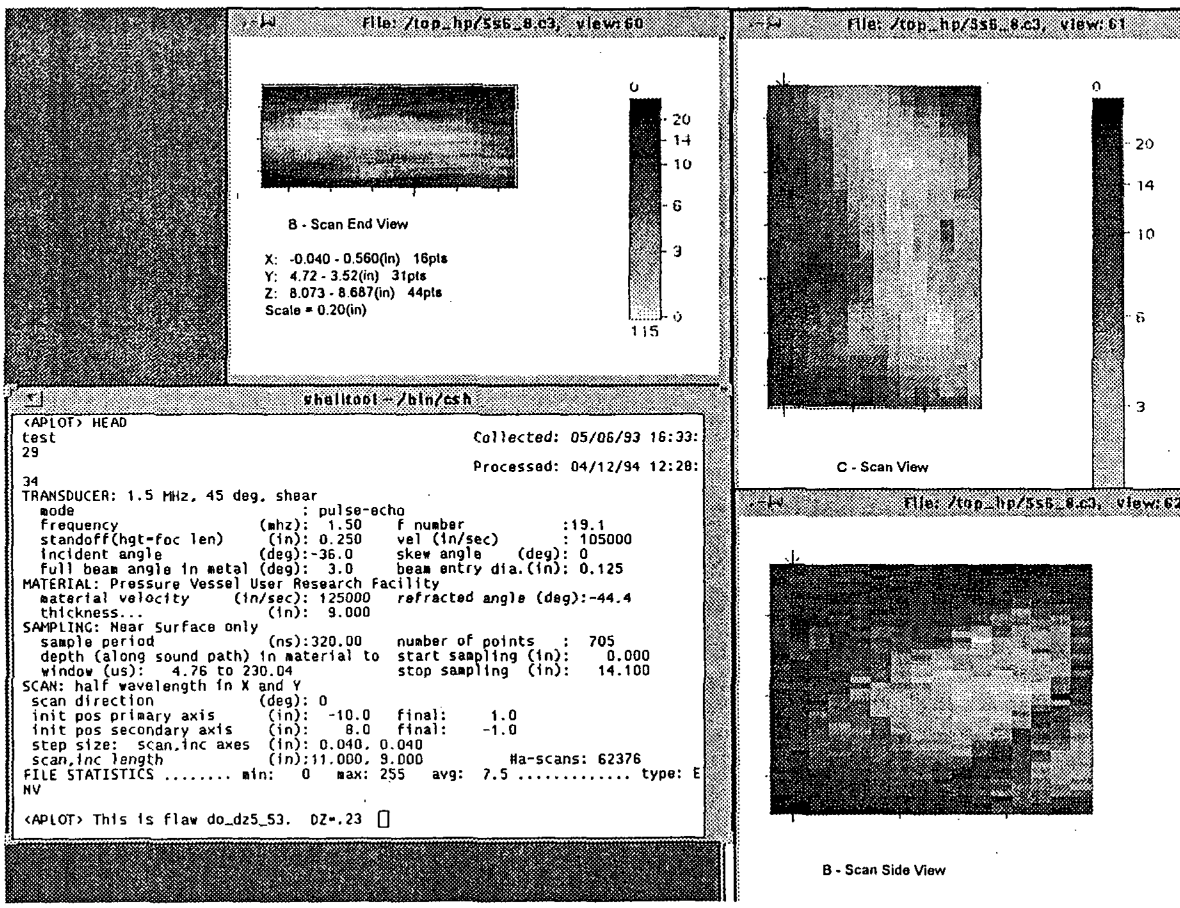


Figure A.69 - Planar indication #14 in the weldment below 25 mm: mode 6

Figure A.70 shows planar indication #15 in the weldment below 25 mm. This planar indication has a through-wall extent of 4 mm based on LOS in a cloud like pattern. The detection was made in mode 6 where the shape appeared cloud like in nature at a depth of 212 mm. The shape quality for this indication is fair but broken up, indicating that more than one small flaw may be present. There were no confirmations in other modes. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. The length is 42 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 10. The maximum amplitude-to-noise ratio is high at 53 to 13. The X coordinate of 10 mm shows that the indication is in the weld. The Z coordinate of 212 mm shows that the indication is near the outer wall of the vessel.

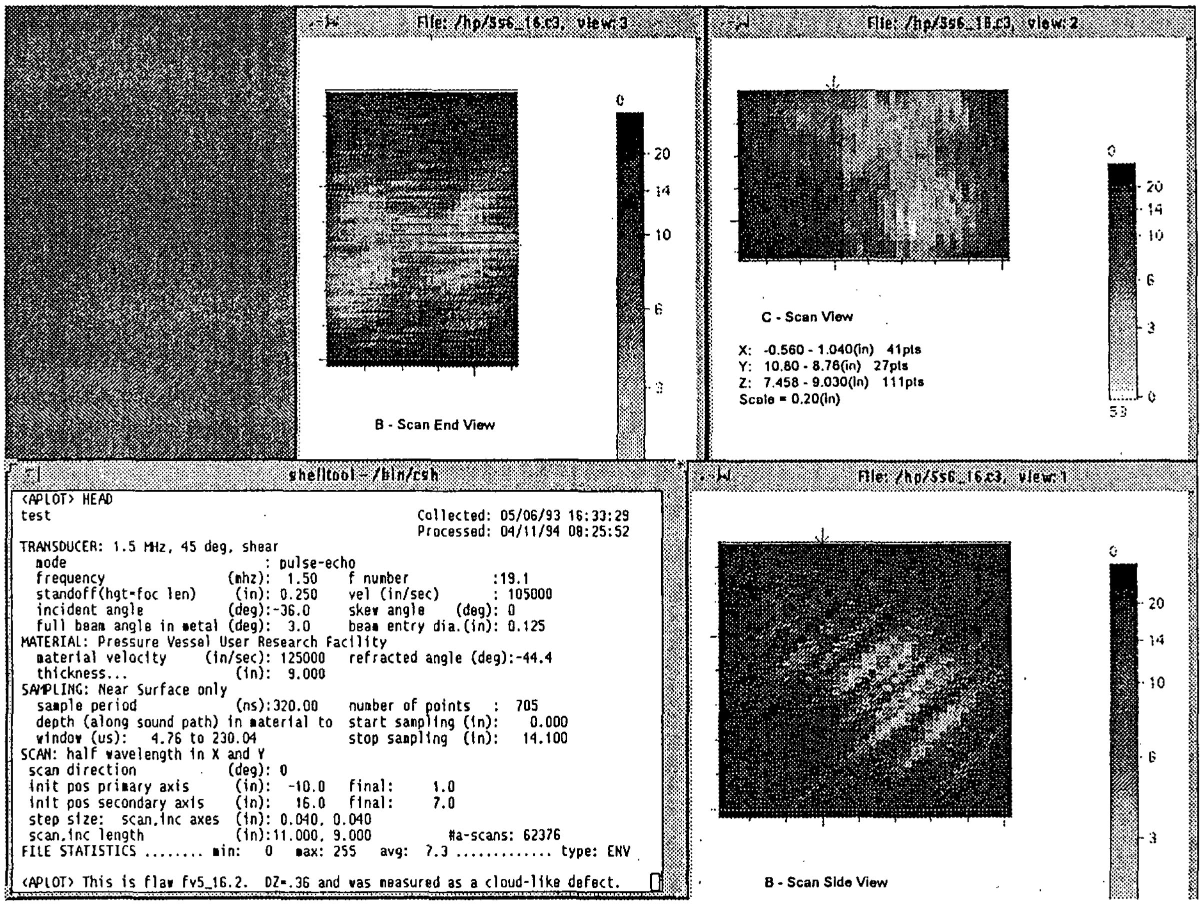


Figure A.70 - Planar indication #15 in the weldment below 25 mm: mode 6

Figure A.71 shows planar indication #16 in the weldment below 25 mm. This planar indication has a through-wall extent of 4 mm based on LOS in a cloud like pattern. The detection was made in mode 6 where the shape appeared cloud like in nature at a depth of 203 mm. The shape quality is poor and broken up indicating that more than one small flaw is present. There were no confirmations in other modes. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. The length is 25 mm and was made to LOS in mode 6. The aspect ratio (length/depth) is 6 which tends to confirm the large through-wall extent. The maximum amplitude-to-noise ratio is high at 44 to 10. The X coordinate of -8 mm shows that the indication is clearly in the weld. The Z coordinate of 203 mm shows that the indication is near the vessel outer wall.

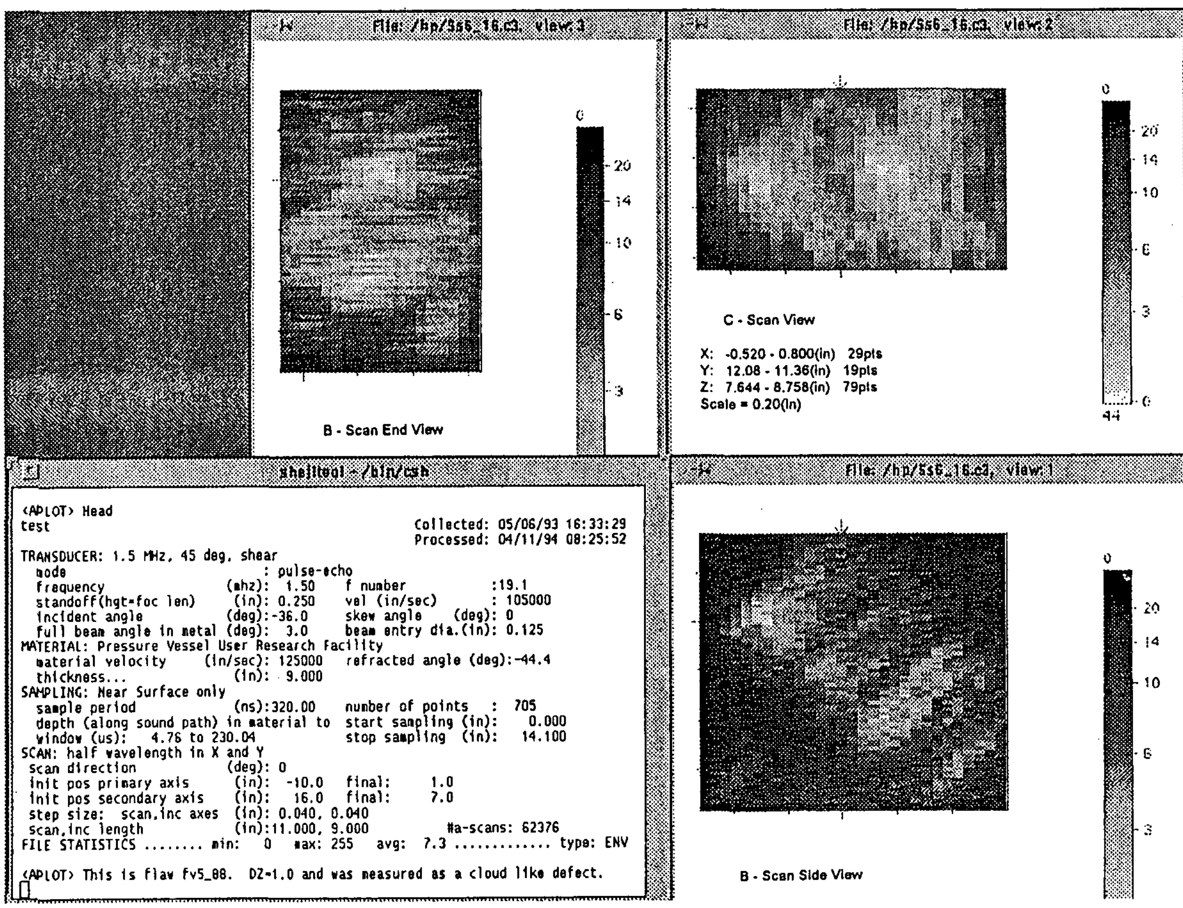


Figure A.71 - Planar indication #16 in the weldment below 25 mm: mode 6

Volumetric Indications in the Weldment Below 25 mm

Figures A.72a-b show volumetric indication #1 in the weldment below 25 mm. This volumetric indication has a through-wall extent of 5 mm based on ring around pattern. The detection was made in mode 9 where it displayed a pair of TOF shapes at a depth of 116 mm. The shape quality is good for this indication. There was a confirmation in mode 8 at a depth of 121 mm. The confirmation mode gave a through-wall extent of 5 mm based on wave packet width. The two Z values of 116 to 121 mm give an alternate depth size of 5 mm. The indication is characterized as volumetric based on the detection of ring around shape. The length is 23 mm and was made to LOS in mode 8. The width is 17 mm and was made to LOS in mode 9. The aspect ratio (length/depth) of this indication is 5 and the width-to-depth ratio is 3 which tends to confirm volumetric orientation. The maximum amplitude-to-noise ratio is high at 51 to 10. The X coordinate of 12 mm shows that the indication is in the weld. The Z coordinate of 116 to 121 mm shows that the indication is in the middle third of the vessel.

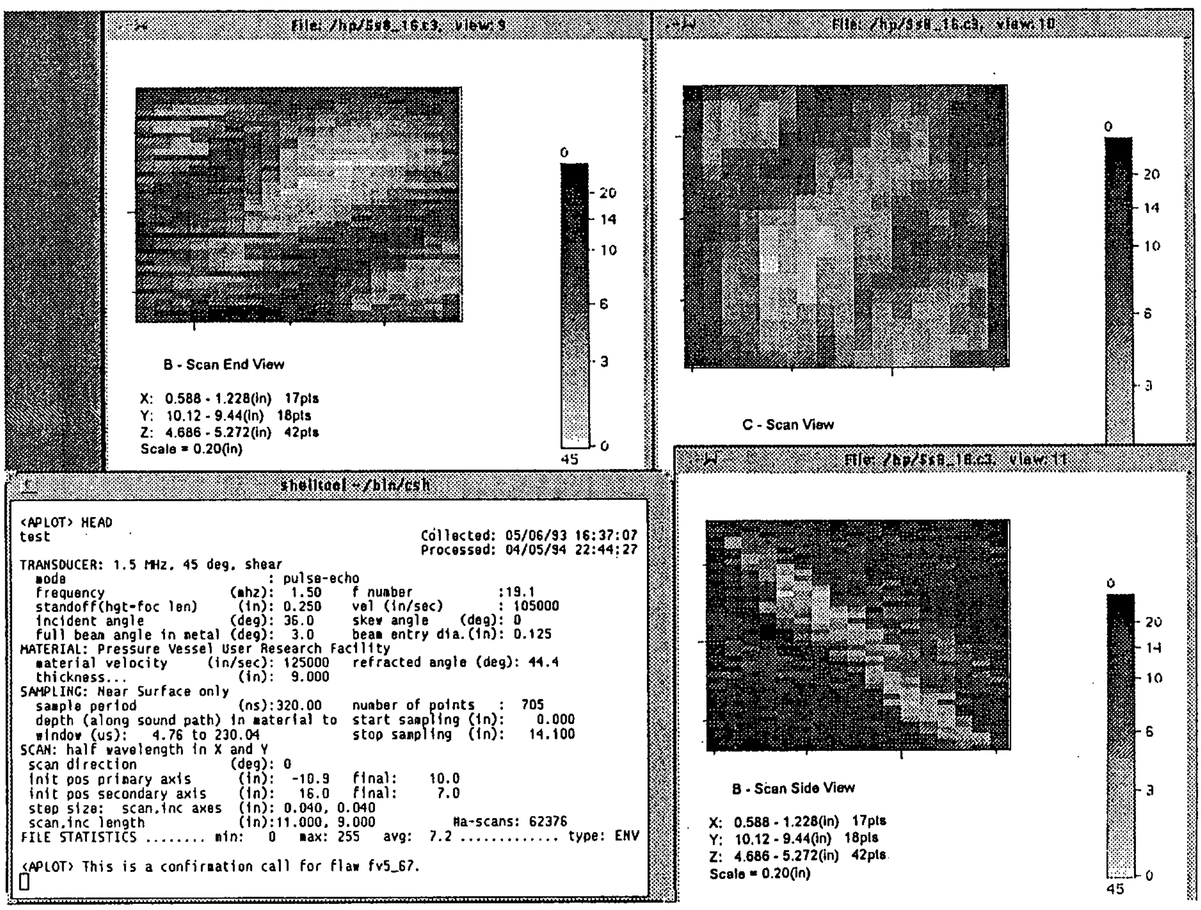


Figure A.72a - Volumetric indication #1 in the weldment below 25 mm: mode 8

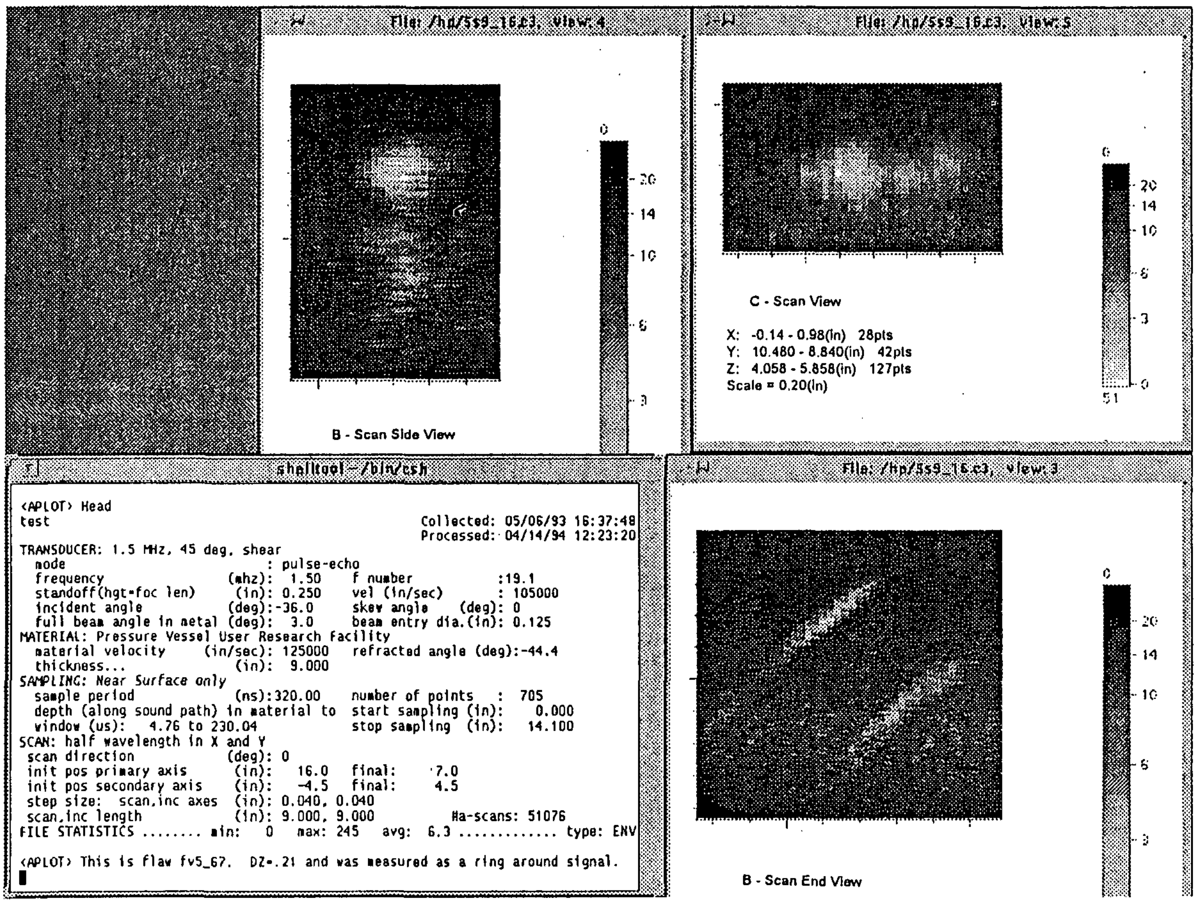


Figure A.72b - Volumetric indication #1 in the weldment below 25 mm: mode 9

Figure A.73 shows volumetric indication #2 in the weldment below 25 mm. This volumetric indication has a through-wall extent of 4 mm based on ring around pattern. The detection was made in mode 6 where it displayed a pair of TOF shapes at a depth of 213 mm. The shape quality is good for this indication. There were no confirmations in other modes. The indication is characterized as volumetric based on the detection of ring around shape. The length is 9 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 2. The maximum amplitude-to-noise ratio is of medium range at 43 to 13. The X coordinate of 6 mm shows that the indication is in the weld. The Z coordinate of 213 mm shows that the indication is near the outer wall of the vessel.

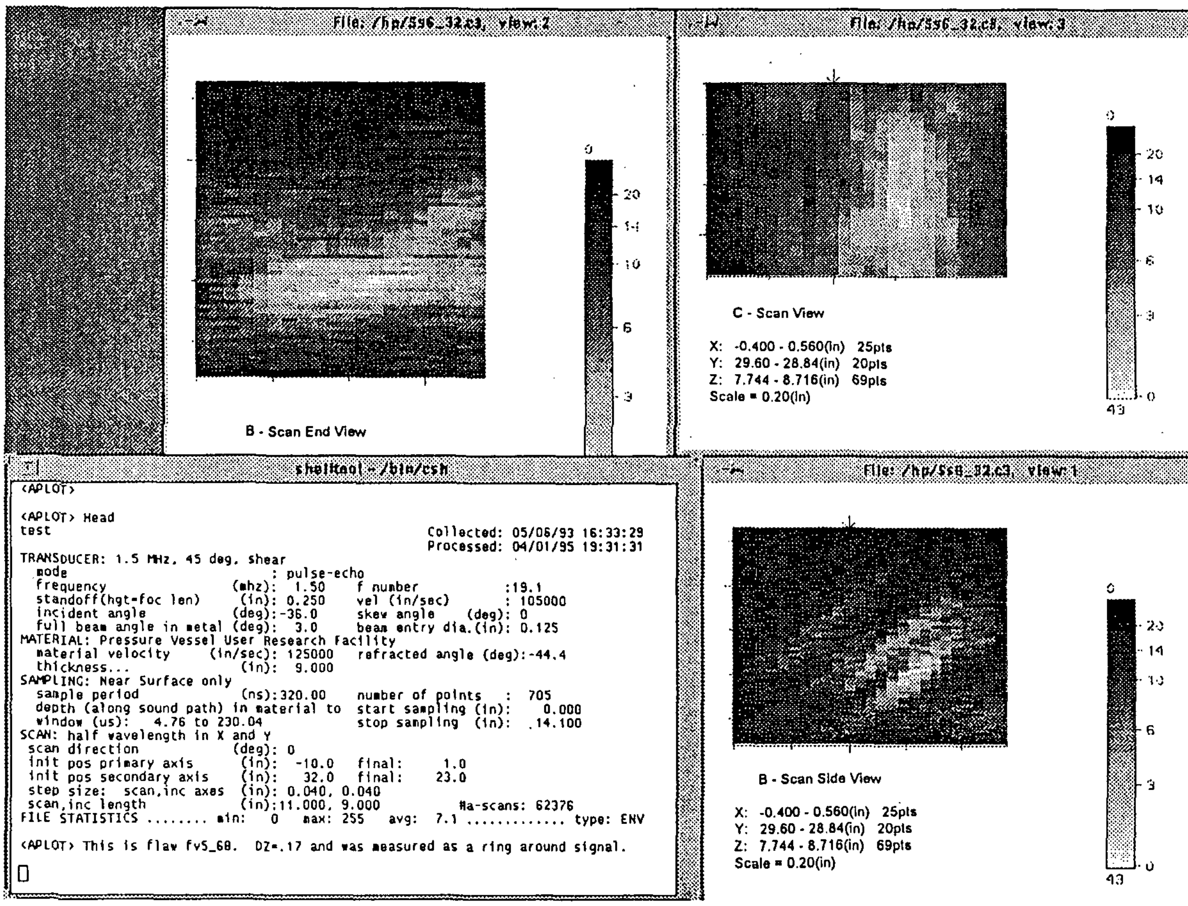


Figure A.73 - Volumetric indication #2 in the weldment below 25 mm: mode 6

Planar Indications in the HAZ Below 25 mm

Figure A.74 shows planar indication #1 in the heat affected zone below 25 mm. This planar indication has a through-wall extent of 34 mm based on tip signal pattern. The detection was made in mode 6 where it displayed a pair of TOF shapes at a depth of 135 mm. The shape quality is good for this indication. There were no confirmations in other modes. The indication is characterized as planar based on the tip signal pattern. Using LOS in mode 6, the length was measured as greater than 15 mm but was limited by the edge of the available aperture (data). The aspect ratio (length/depth) of this indication is greater than 0.4; the loss of data probably limits the length measurement. The maximum amplitude-to-noise ratio is high at 31 to 4. The X coordinate of 20 mm shows that the indication is probably in the HAZ. The Z coordinate of 135 mm shows that the indication is in the middle third of the vessel.

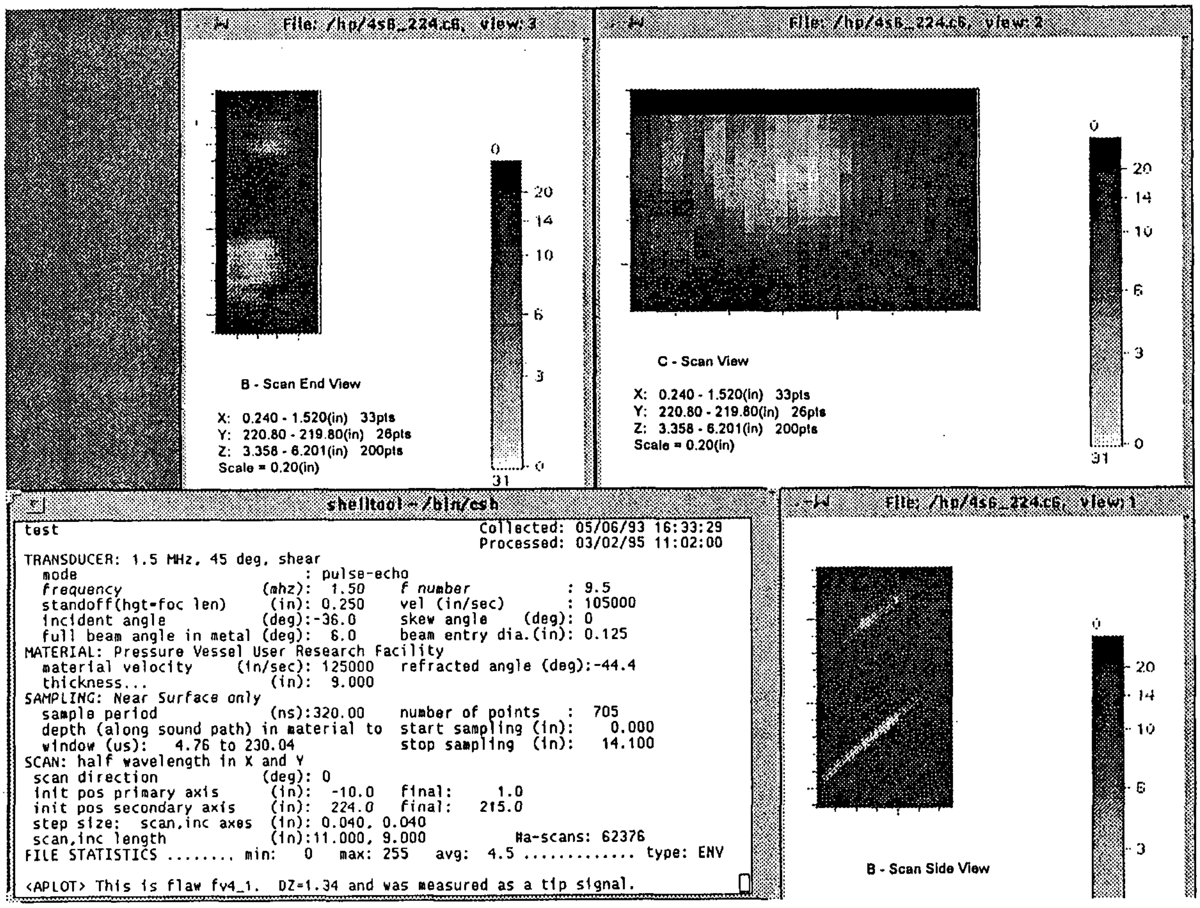


Figure A.74 - Planar indication #1 in the HAZ below 25 mm: mode 6

Figure A.75 shows planar indication #2 in the heat affected zone below 25 mm. This planar indication has a through-wall extent of 18 mm based on tip signal pattern. The detection was made in mode 8 where it displayed a pair of TOF shapes at a depth of 48 mm. The shape quality for this indication is good but broken up, implying that more than one small flaw may be present. There were no confirmations in other modes. The indication is characterized as planar based on the tip signal pattern. The length is 75 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 4 which tends to confirm the large through-wall extent. The maximum amplitude-to-noise ratio is high at 38 to 3. The X coordinate of 17 mm shows that the indication is probably in the HAZ. The Z coordinate of 48 mm shows that the indication is in the inner third of the vessel.

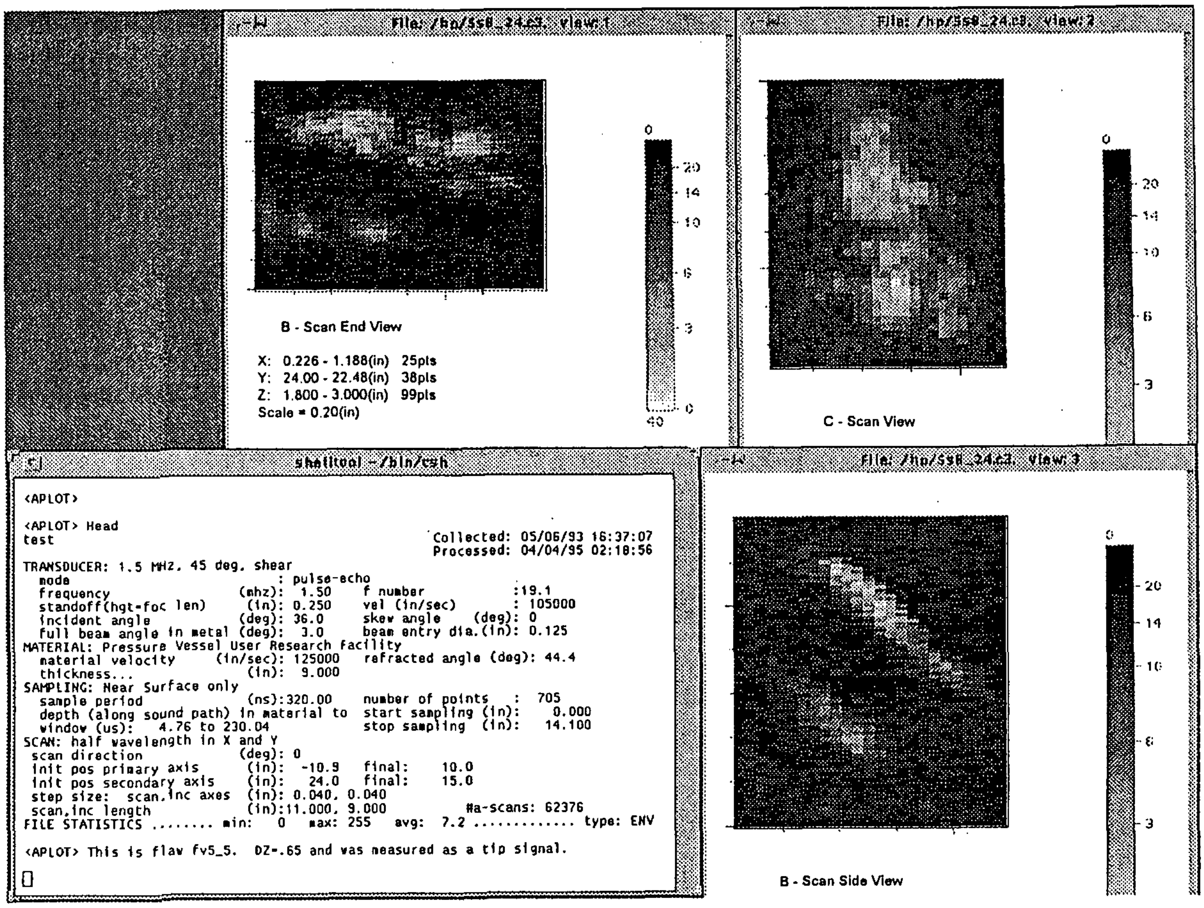


Figure A.75 - Planar indication #2 in the HAZ below 25 mm: mode 8

Figure A.76 shows planar indication #3 in the heat affected zone below 25 mm. This planar indication has a through-wall extent of 10 mm based on tip signal pattern. The detection was made in mode 6 where it displayed a pair of TOF shapes at a depth of 73 mm. The shape quality is good for this indication. There were no confirmations in other modes. The indication is characterized as planar based on the tip signal pattern. The length is 18 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 1.8. The maximum amplitude-to-noise ratio is high at 22 to 4. The X coordinate of -17 mm shows that the indication is probably in the HAZ. The Z coordinate of 73 mm shows that the indication is in the middle third of the vessel.

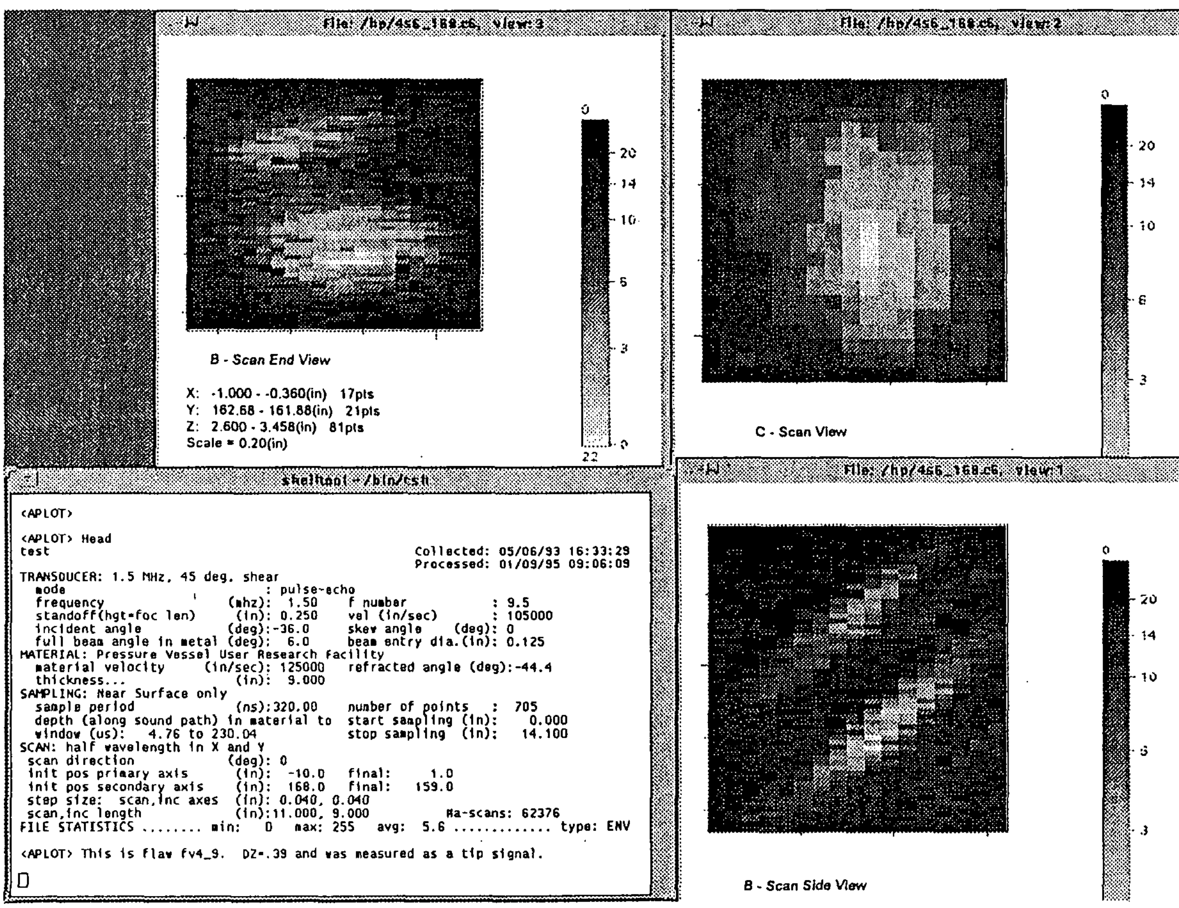


Figure A.76 - Planar indication #3 in the HAZ below 25 mm: mode 6

Figure A.77 shows planar indication #4 in the heat affected zone below 25 mm. This planar indication has a through-wall extent of 9 mm based on LOS in a cloud like pattern. The detection was made in mode 6 where the shape appeared cloud like in nature at a depth of 213 mm. The shape quality is good for this indication. There were no confirmations in other modes. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. The length is 21 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 2. The maximum amplitude-to-noise ratio is of medium range at 43 to 15. The X coordinate of 26 mm shows that the indication is probably in the HAZ. The Z coordinate of 213 mm shows that the indication is near the outer wall of the vessel.

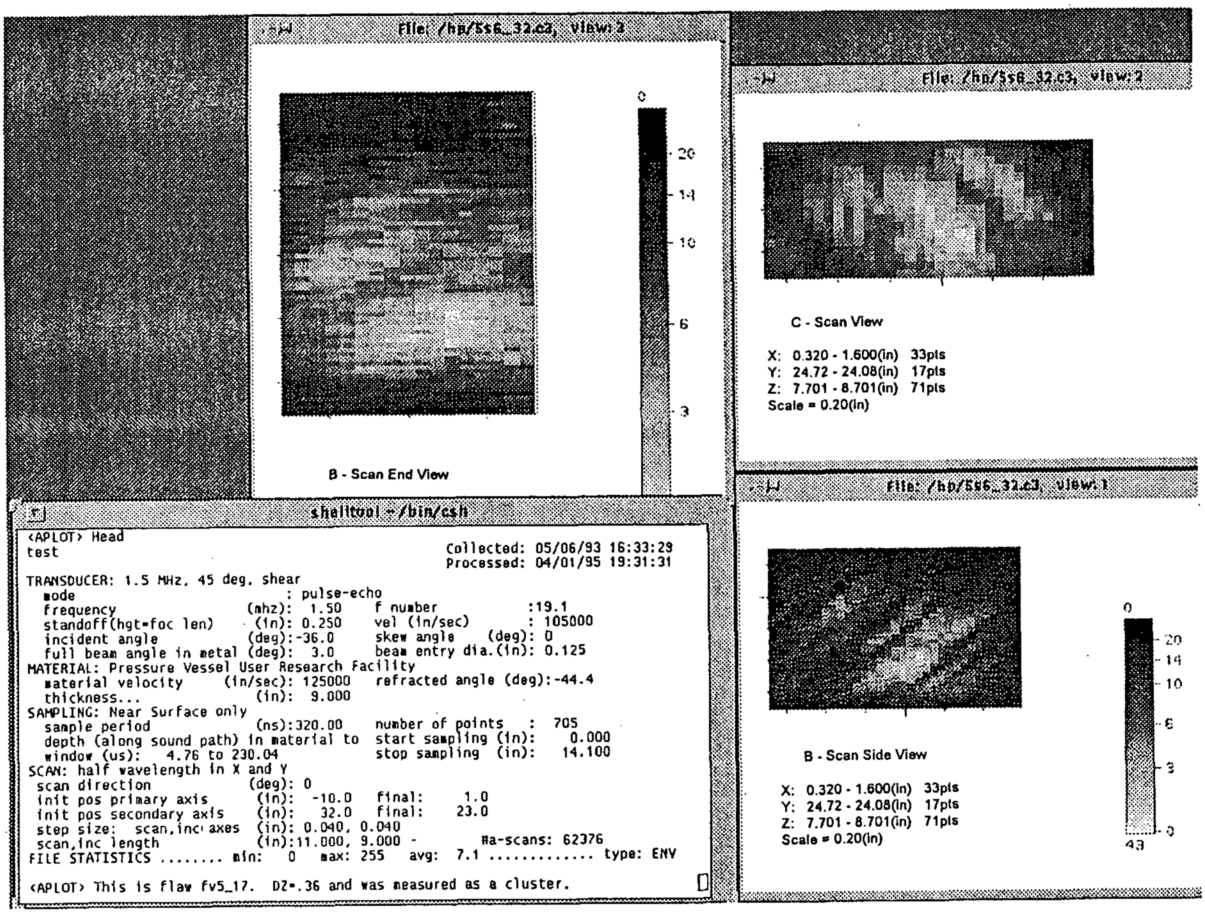


Figure A.77 - Planar indication #4 in the HAZ below 25 mm: mode 6

Figure A.78 shows planar indication #5 in the heat affected zone below 25 mm. This planar indication has a through-wall extent of 9 mm based on tip signal pattern. The detection was made in mode 6 where it displayed a pair of TOF shapes at a depth of 224 mm. The shape quality is good for this indication. There were no confirmations in other modes. The indication is characterized as planar based on the tip signal pattern. The length is 27 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 3. The maximum amplitude-to-noise ratio is of medium range at 29 to 8. The X coordinate of 24 mm shows that the indication is probably in the HAZ. The Z coordinate of 224 mm shows that the indication is near the outer wall.

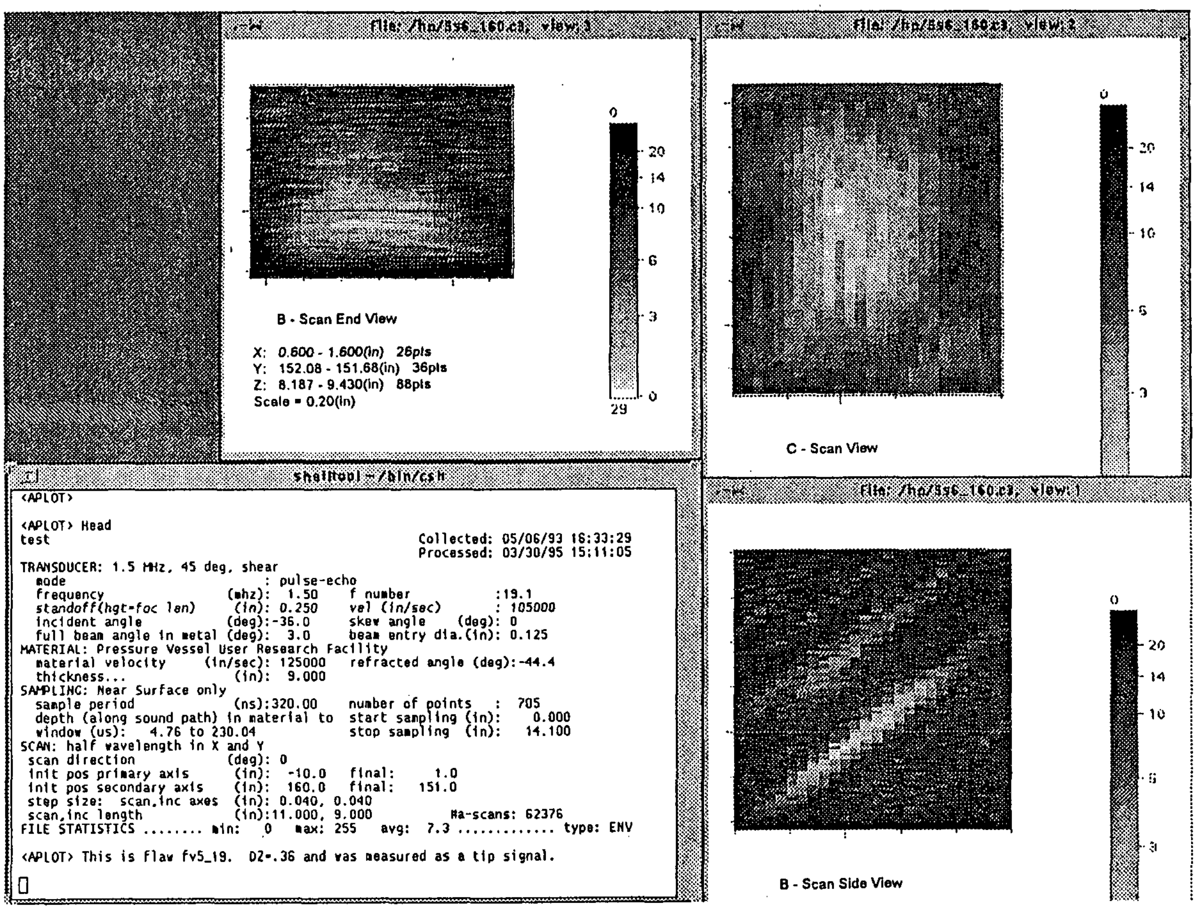


Figure A.78 - Planar indication #5 in the HAZ below 25 mm: mode 6

Figure A.79 shows planar indication #6 in the heat affected zone below 25 mm. This planar indication has a through-wall extent of 8 mm based on wave packet width. The detection was made in mode 6 at a depth of 216 mm. The shape has the appearance of a cluster or cloud. There were no confirmations in other modes. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. The length is 22 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 3. The maximum amplitude-to-noise ratio is high at 120 to 25. The X coordinate of 26 mm shows that the indication is probably in the HAZ. The Z coordinate of 216 mm shows that the indication is near the outer wall of the vessel.

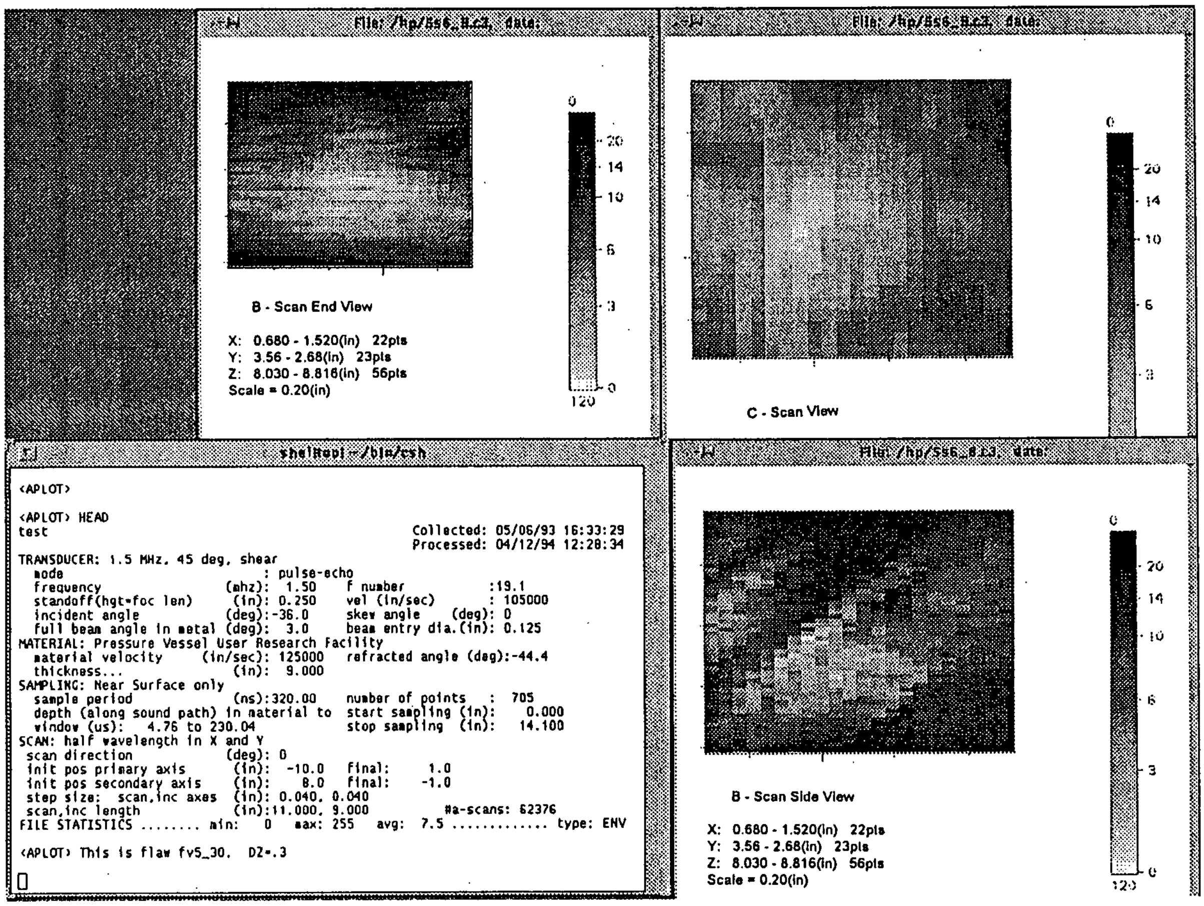


Figure A.79 - Planar indication #6 in the HAZ below 25 mm: mode 6

Figure A.80 shows planar indication #7 in the heat affected zone below 25 mm. This planar indication has a through-wall extent of 7 mm based on tip signal pattern. The detection was made in mode 6 where it displayed a pair of TOF shapes at a depth of 76 mm. The shape quality is good for this indication. There were no confirmations in modes. The indication is characterized as planar based on the tip signal pattern. The length is 14 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 2. The maximum amplitude-to-noise ratio is of medium range at 17 to 5. The X coordinate of 16 mm shows that the indication is probably in the HAZ. The Z coordinate of 76 mm shows that the indication is in the middle third of the vessel.

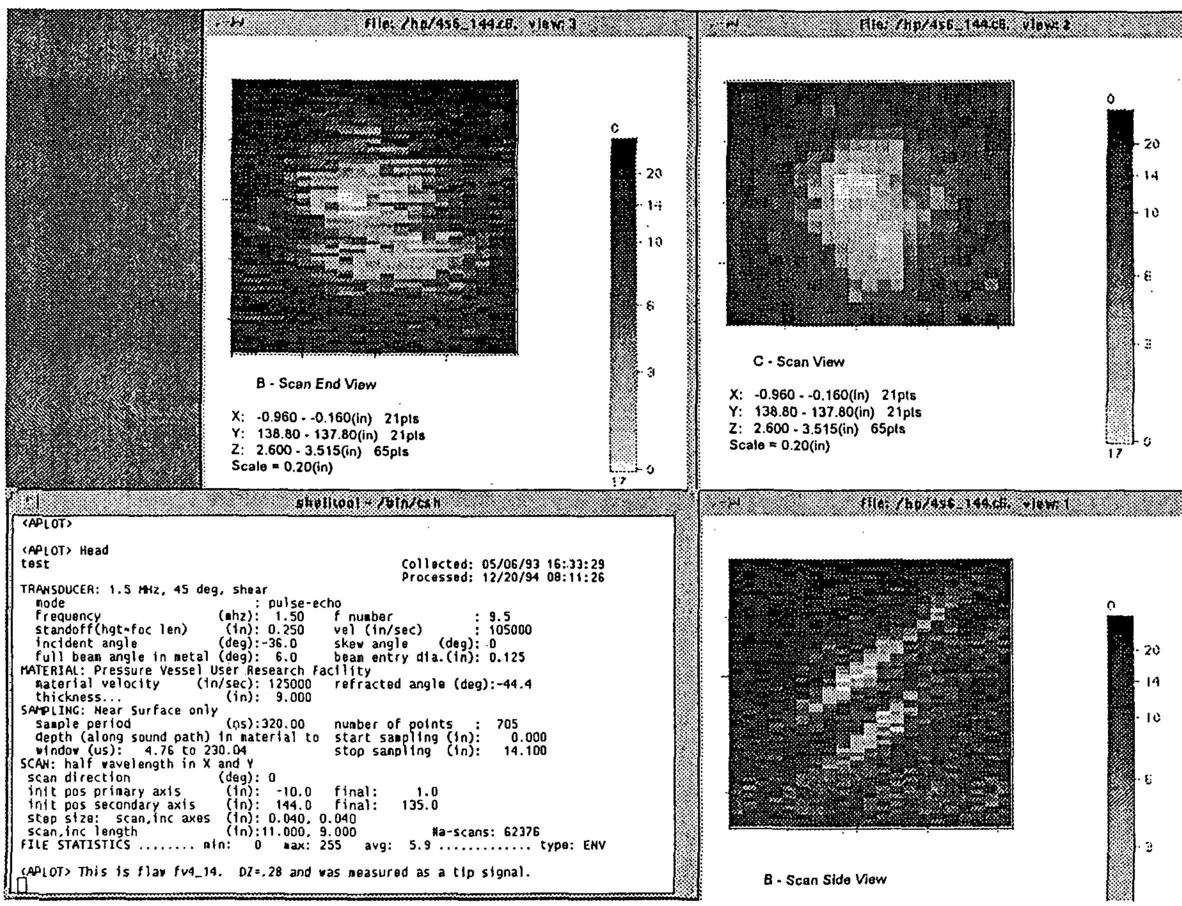


Figure A.80 - Planar indication #7 in the HAZ below 25 mm: mode 6

Figure A.81 shows planar indication #8 in the heat affected zone below 25 mm. This planar indication has a through-wall extent of 7 mm based on wave packet width. The detection was made in mode 6 where it had isolated TOF shape at a depth of 214 mm. The shape quality is good for this indication. There were no confirmations in other modes. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. The length is 10 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 1.4. The maximum amplitude-to-noise ratio is of medium range at 92 to 25. The X coordinate of 30 mm shows that the indication is probably in the HAZ. The Z coordinate of 214 mm shows that the indication is near the outer wall of the vessel.

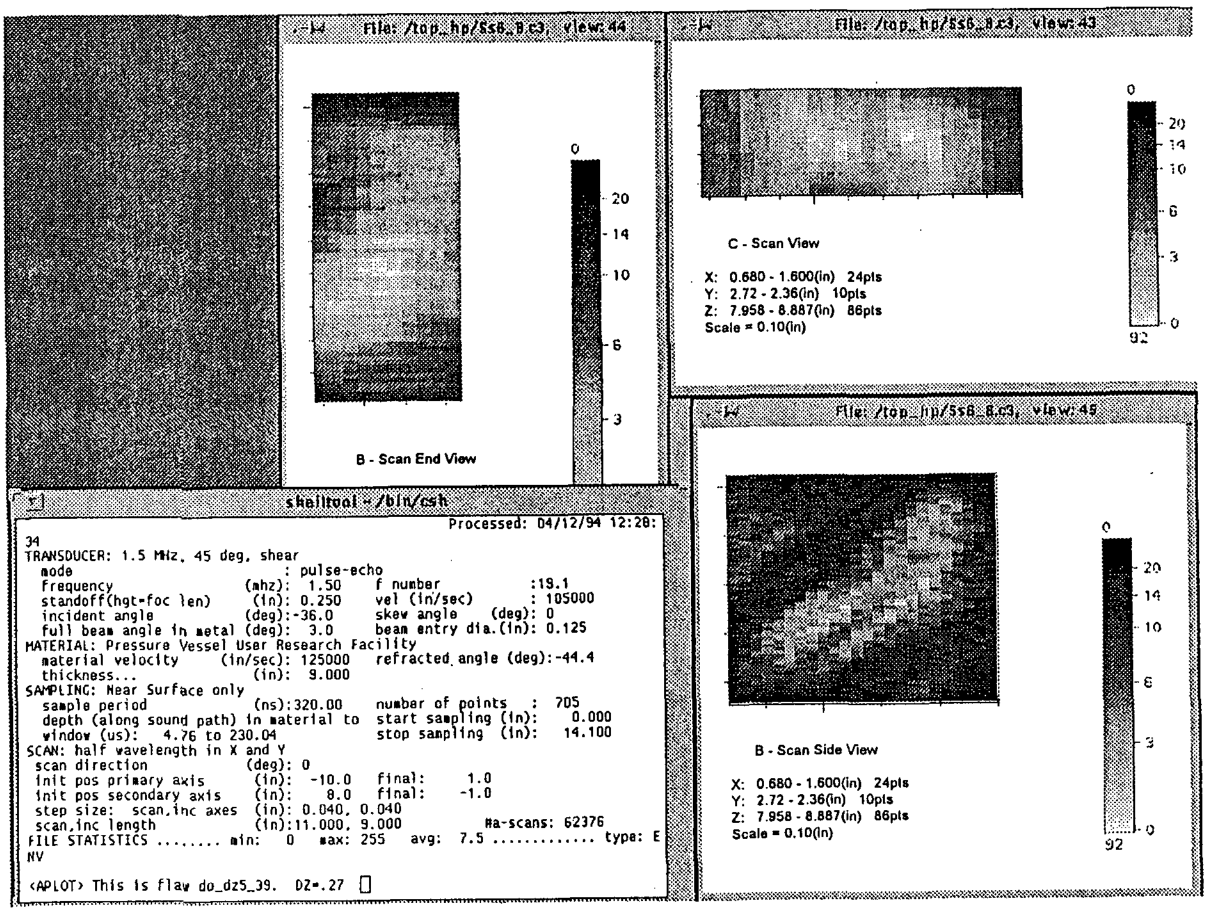


Figure A.81 - Planar indication #8 in the HAZ below 25 mm: mode 6

Figures A.82a-b show planar indication #9 in the heat affected zone below 25 mm. This planar indication has a through-wall extent of 5 mm based on wave packet width. The detection was made in mode 6 where it had isolated TOF shape at a depth of 218 mm. The shape quality is good but more than one TOF shape was present for this indication. There was a confirmation in mode 8 at depth of 216 mm. The confirmation mode gave a through-wall extent estimate of 4 mm based on wave packet width. The two Z values of 216 to 218 mm give an alternate depth size of 2 mm. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. The length is 22 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 4 which tends to confirm the large through-wall extent. The maximum amplitude-to-noise ratio is of medium range at 88 to 35. The X coordinate of 24 mm shows that the indication is probably in the HAZ. The Z coordinate of 216 to 218 mm shows that the indication is near the outer wall of the vessel.

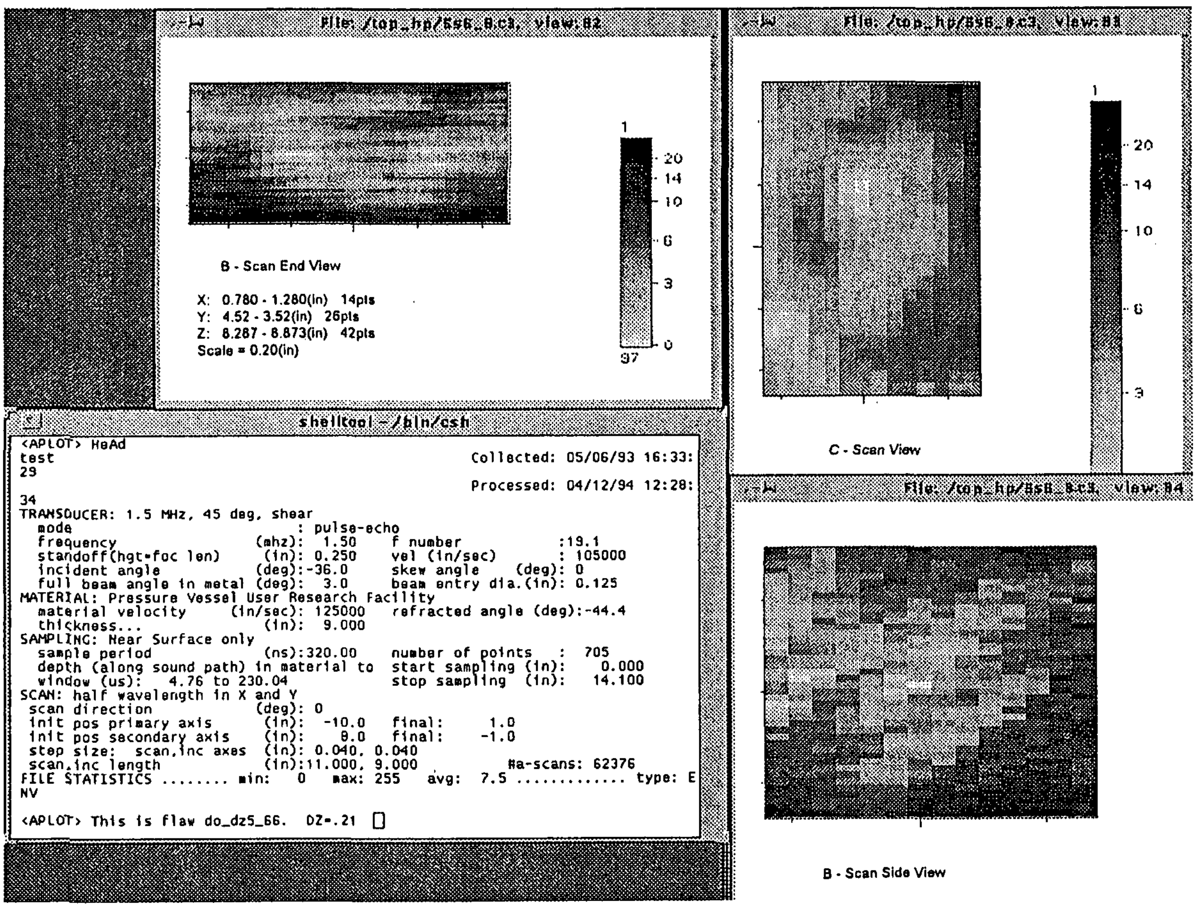


Figure A.82a - Planar indication #9 in the HAZ below 25 mm: mode 6

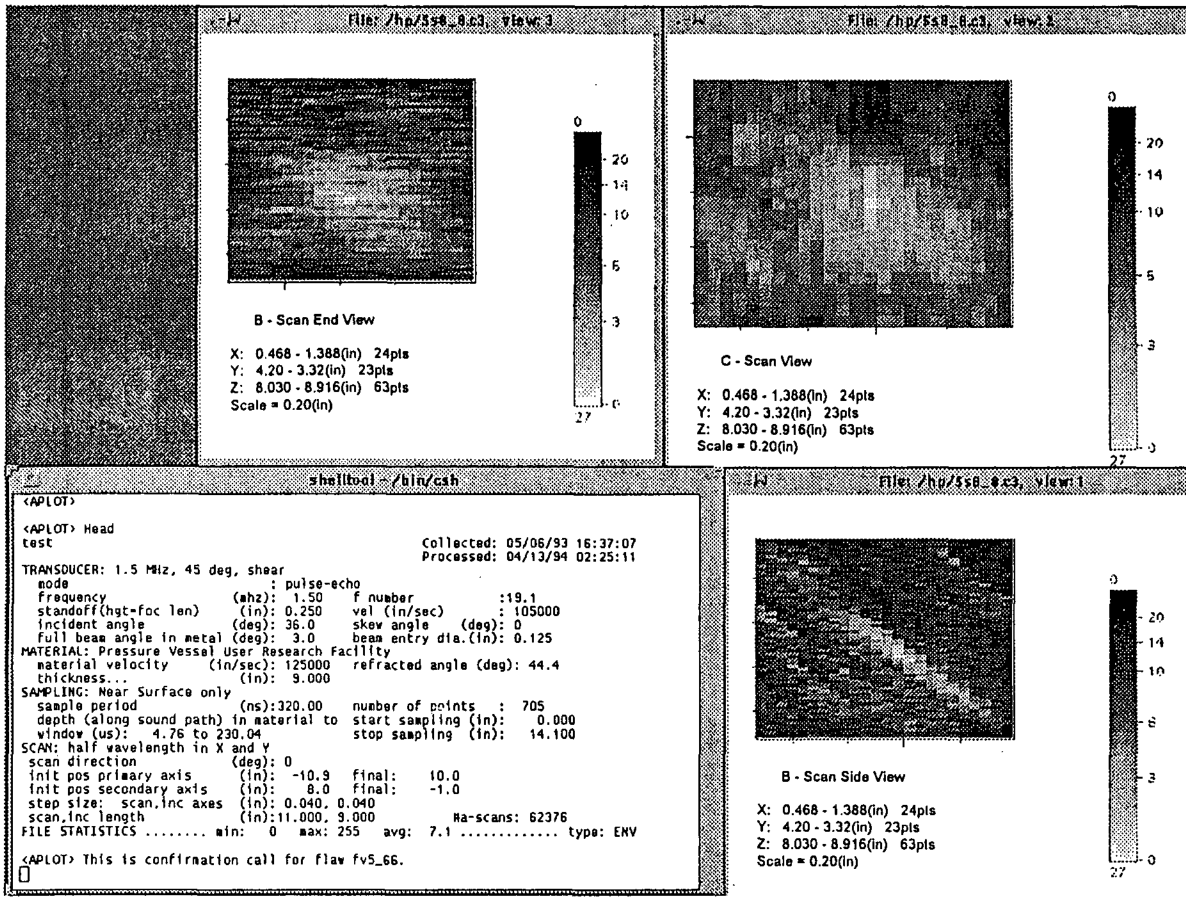


Figure A.82b - Planar indication #9 in the HAZ below 25 mm: mode 8

Figure A.83 shows planar indication #10 in the heat affected zone below 25 mm. This planar indication has a through-wall extent of 5 mm based on wave packet width. The detection was made in mode 6 where it had isolated TOF shape at a depth of 134 mm. The shape quality is good and more than one TOF shape was present for this indication. There were no confirmations in other modes. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. The length is 19 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 4 which tends to confirm the large through-wall extent. The maximum amplitude-to-noise ratio is of medium range at 57 to 18. The X coordinate of 23 mm shows that the indication is probably in the HAZ. The Z coordinate of 134 mm shows that the indication is in the middle third of the vessel.

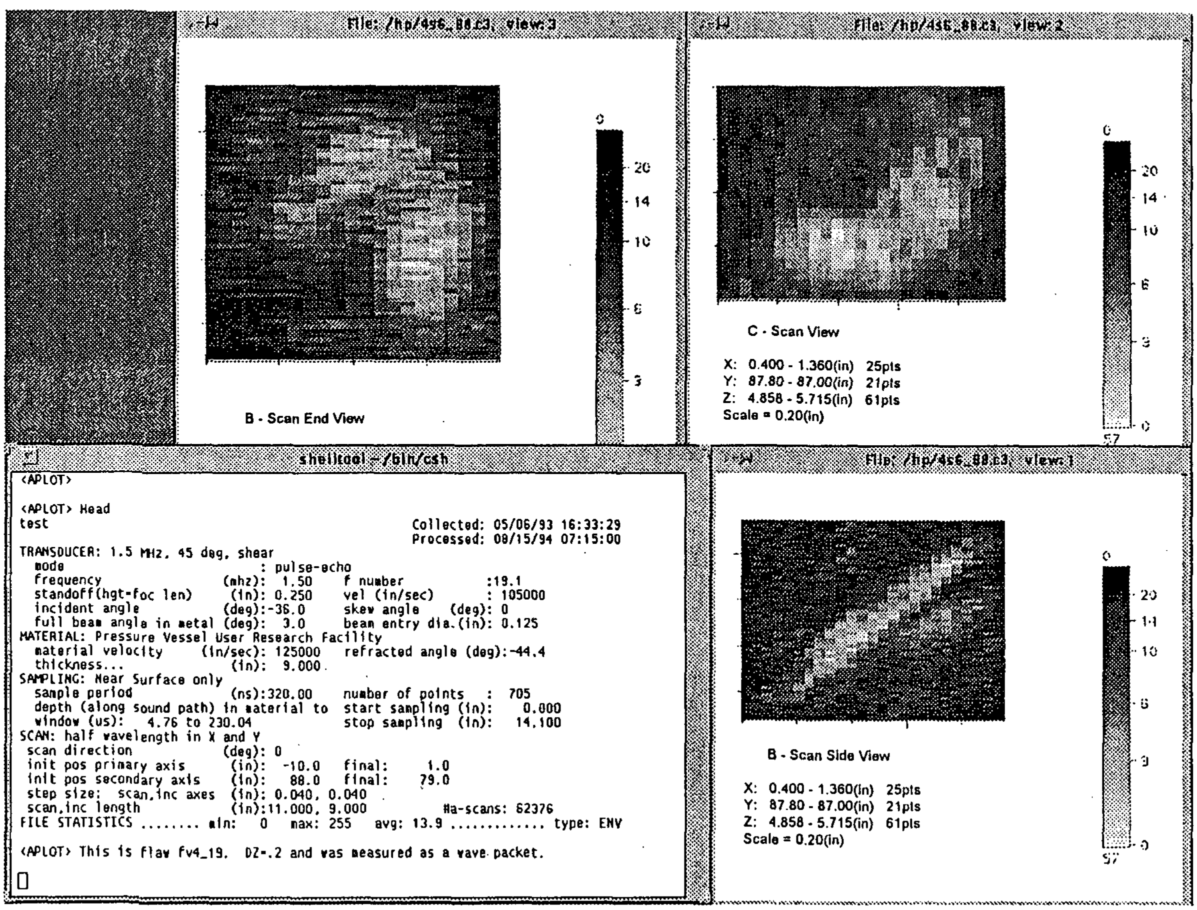


Figure A.83 - Planar indication #10 in the HAZ below 25 mm: mode 6

Figure A.84 shows planar indication #11 in the heat affected zone below 25 mm. This planar indication has a through-wall extent of 5 mm based on wave packet width. The detection was made in mode 6 where it had isolated TOF shape at a depth of 208 mm. The shape quality is good but more than one TOF shape was present for this indication. There were no confirmations in other modes. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. The length is 26 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 5 which tends to confirm the large through-wall extent. The maximum amplitude-to-noise ratio is of medium range at 38 to 10. The X coordinate of 23 mm shows that the indication is probably in the HAZ. The Z coordinate of 21 mm shows that the indication is near the outer wall of the vessel.

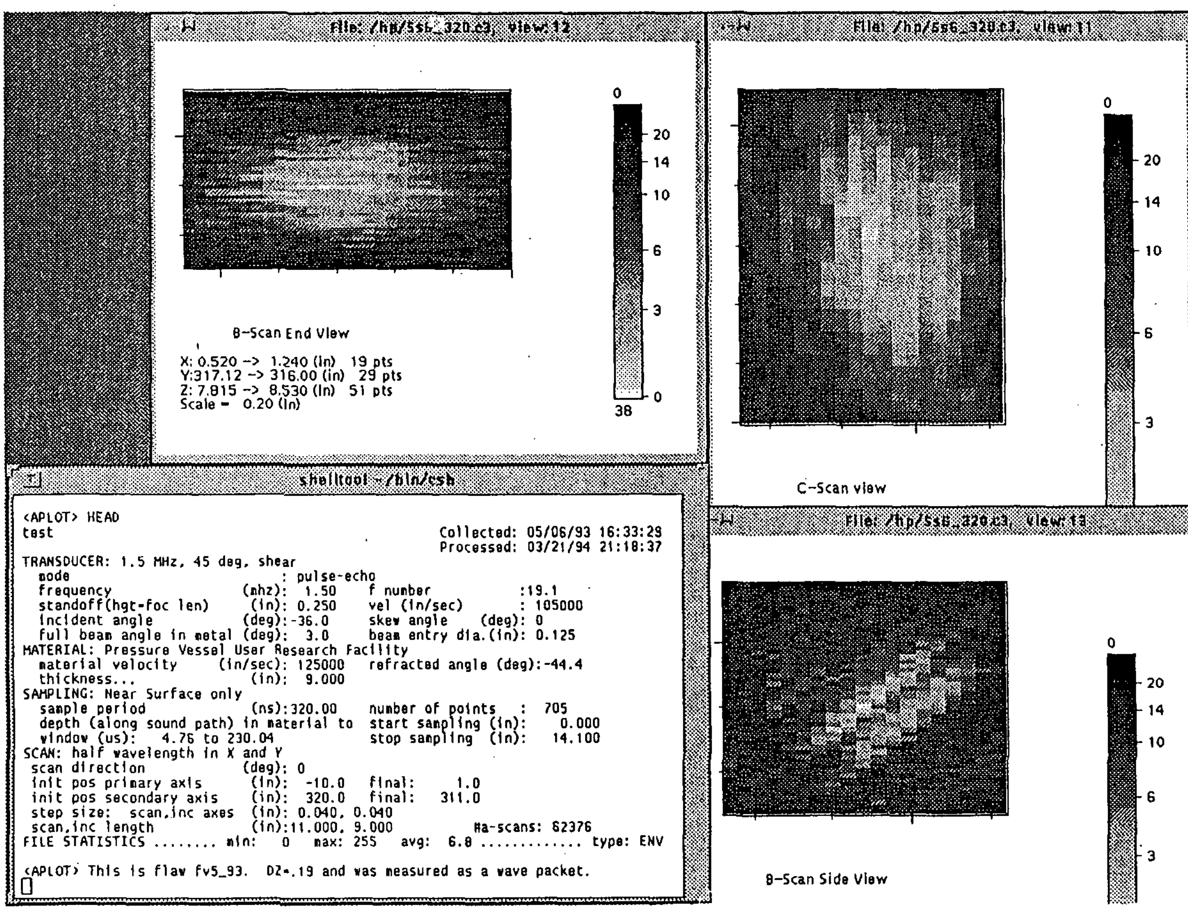


Figure A.84 - Planar indication #11 in the HAZ below 25 mm: mode 6

Figure A.85 shows planar indication #12 in the heat affected zone below 25 mm. This planar indication has a through-wall extent of 4 mm based on wave packet width. The detection was made in mode 6 where it had isolated TOF shape at a depth of 215 mm. The shape quality is good but more than one TOF shape was present for this indication. There were no confirmations in other modes. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. The length is 20 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 5 which tends to confirm the large through-wall extent. The maximum amplitude-to-noise ratio is of medium range at 71 to 20. The X coordinate of 30 mm shows that the indication is probably in the HAZ. The Z coordinate of 215 mm shows that the indication near the outer wall of the vessel.

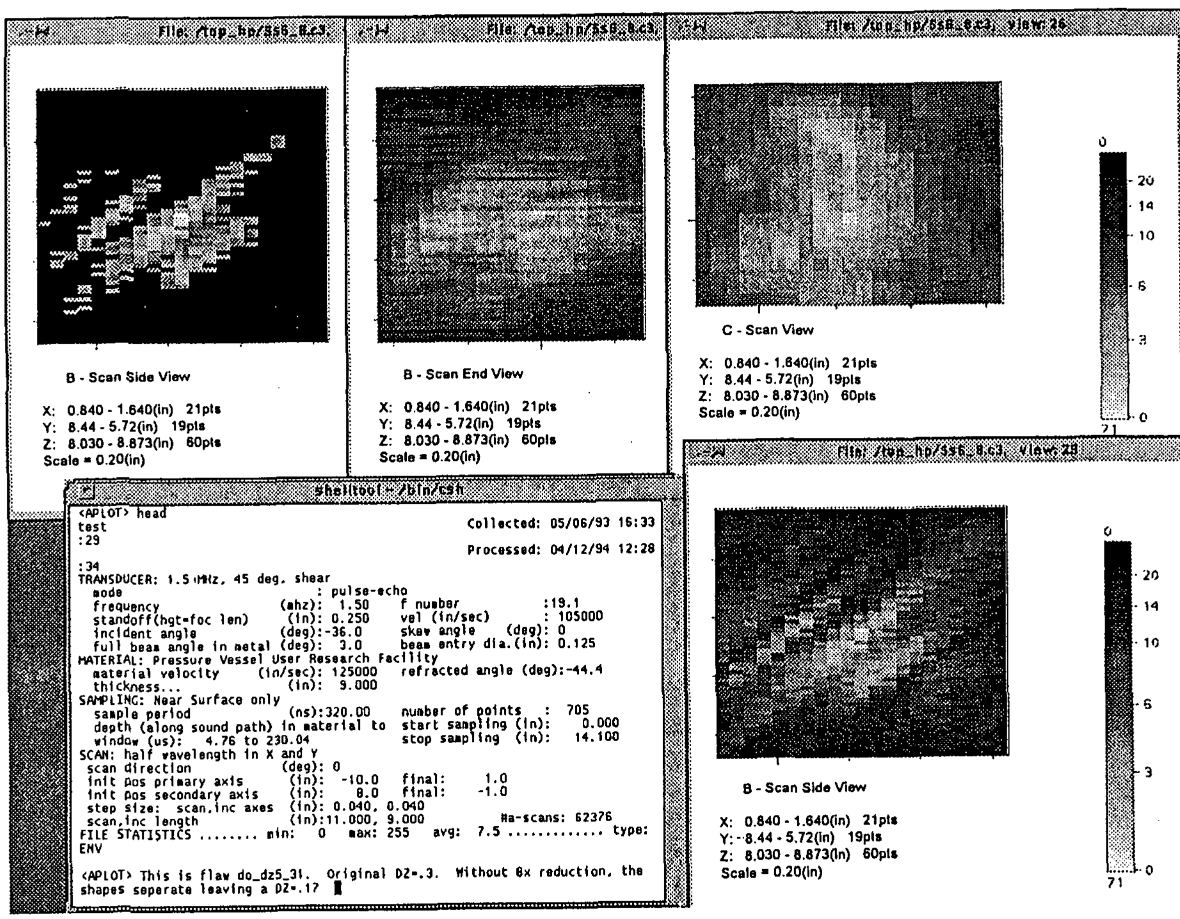


Figure A.85 - Planar indication #12 in the HAZ below 25 mm: mode 6

Figure A.86 shows planar indication #13 in the heat affected zone below 25 mm. This planar indication has a through-wall extent of 4 mm based on wave packet width. The detection was made in mode 6 where it had isolated TOF shape at a depth of 232 mm. The shape quality is good but more than one TOF shape was present for this indication. There were no confirmations in other modes. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. The length is 33 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 8 which tends to confirm the large through-wall extent. The maximum amplitude-to-noise ratio is of medium range at 26 to 10. The X coordinate of -28 mm shows that the indication is probably in the HAZ. The Z coordinate of 232 mm shows that the indication is near the outer wall, possibly connected to the outer wall of the vessel.

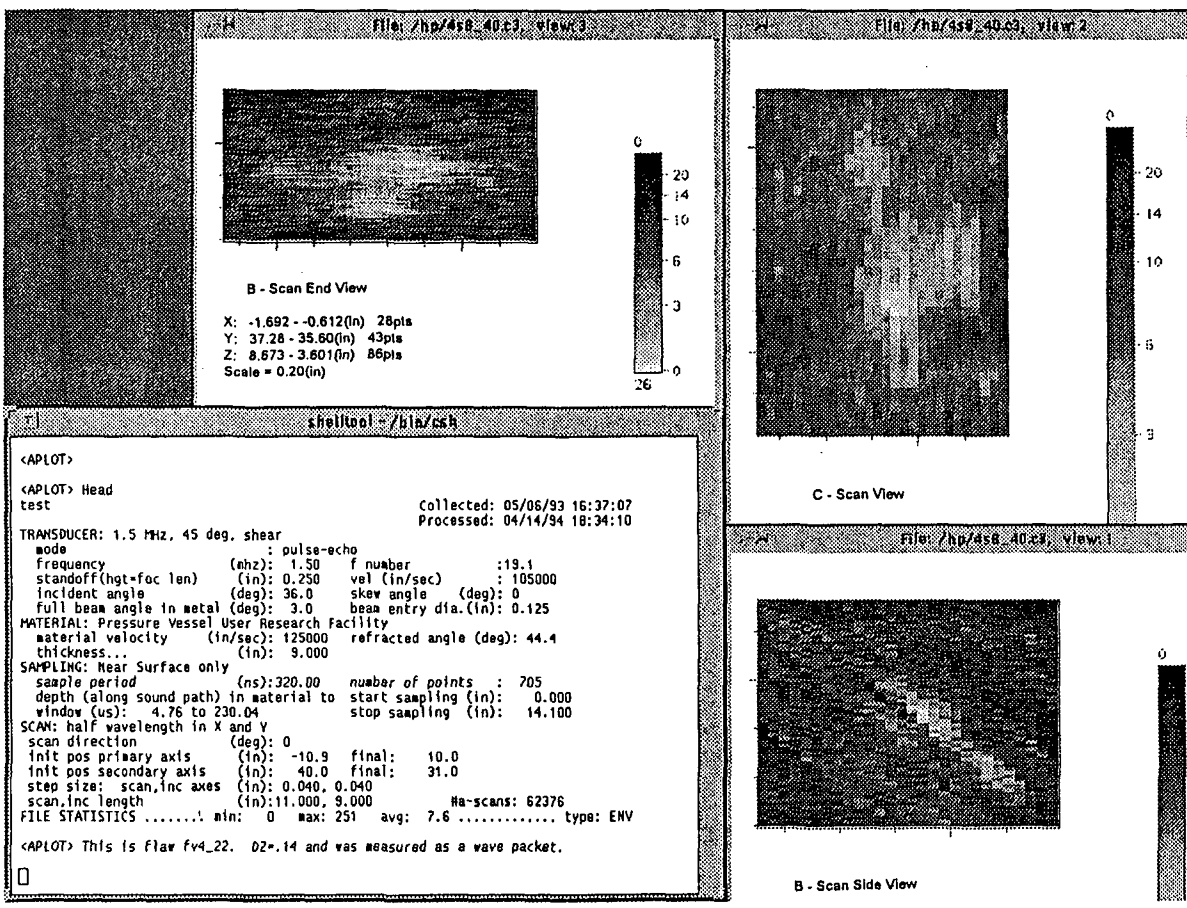


Figure A.86 - Planar indication #13 in the HAZ below 25 mm: mode 8

Figures A.87a-b show planar indication #14 in the heat affect zone below 25 mm. This planar indication has a through-wall extent of 4 mm based on LOS in a cloud like pattern. The detection was made in mode 8 where the shape appeared cloud like in nature at a depth of 189 mm. There was a confirmation in mode 6 at depth of 192 mm. The confirmation mode gave a through-wall extent estimate of 3 mm based on wave packet width. The two Z values of 189 to 192 mm give an alternate depth size of 3 mm. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. The length is 18 mm and was made to LOS in mode 8. The aspect ratio (length/depth) of this indication is 4.5 which tends to confirm the large through-wall extent. The maximum amplitude-to-noise ratio is of medium range at 32 to 12. The X coordinate of -14 mm shows that the indication is probably in the HAZ. The Z coordinate of 189 to 192 mm shows that the indication is in the outer third of the vessel.

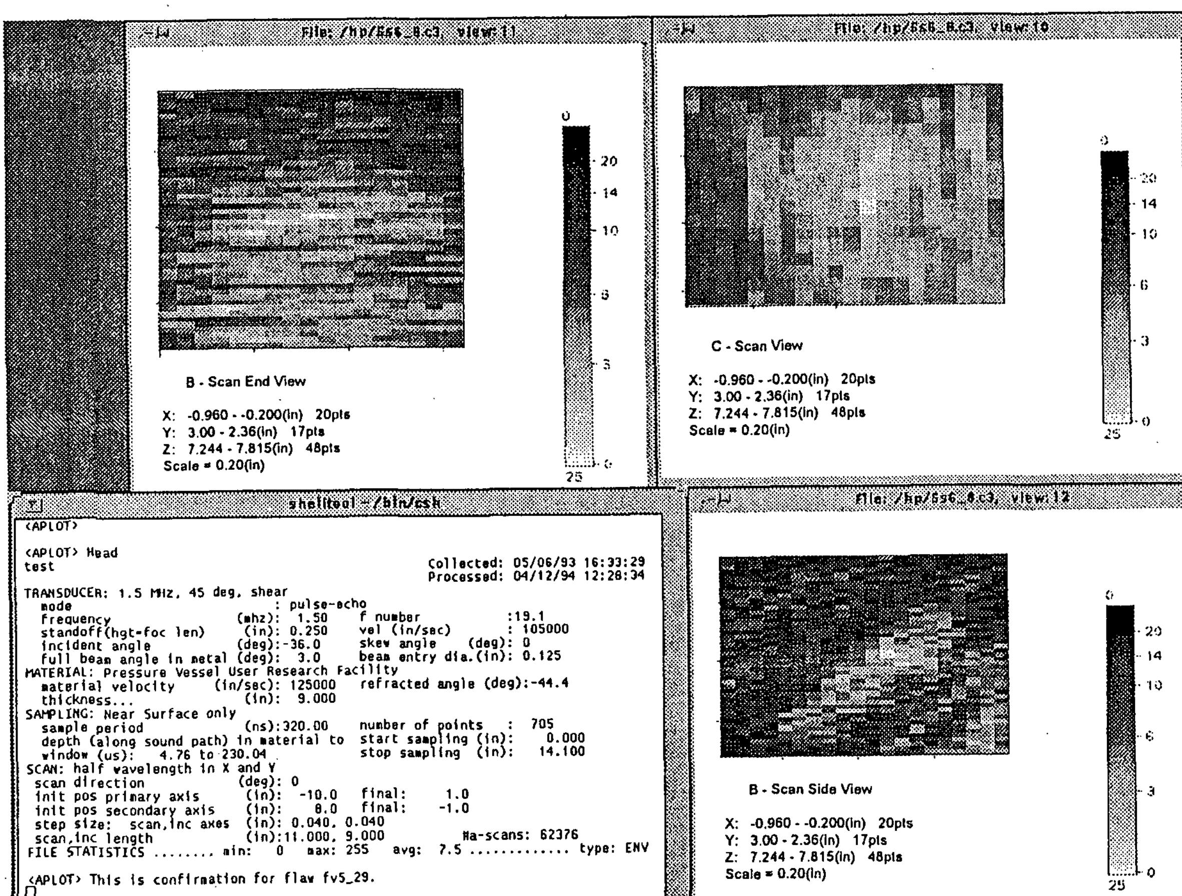


Figure A.87a - Planar indication #14 in the HAZ below 25 mm: mode 6

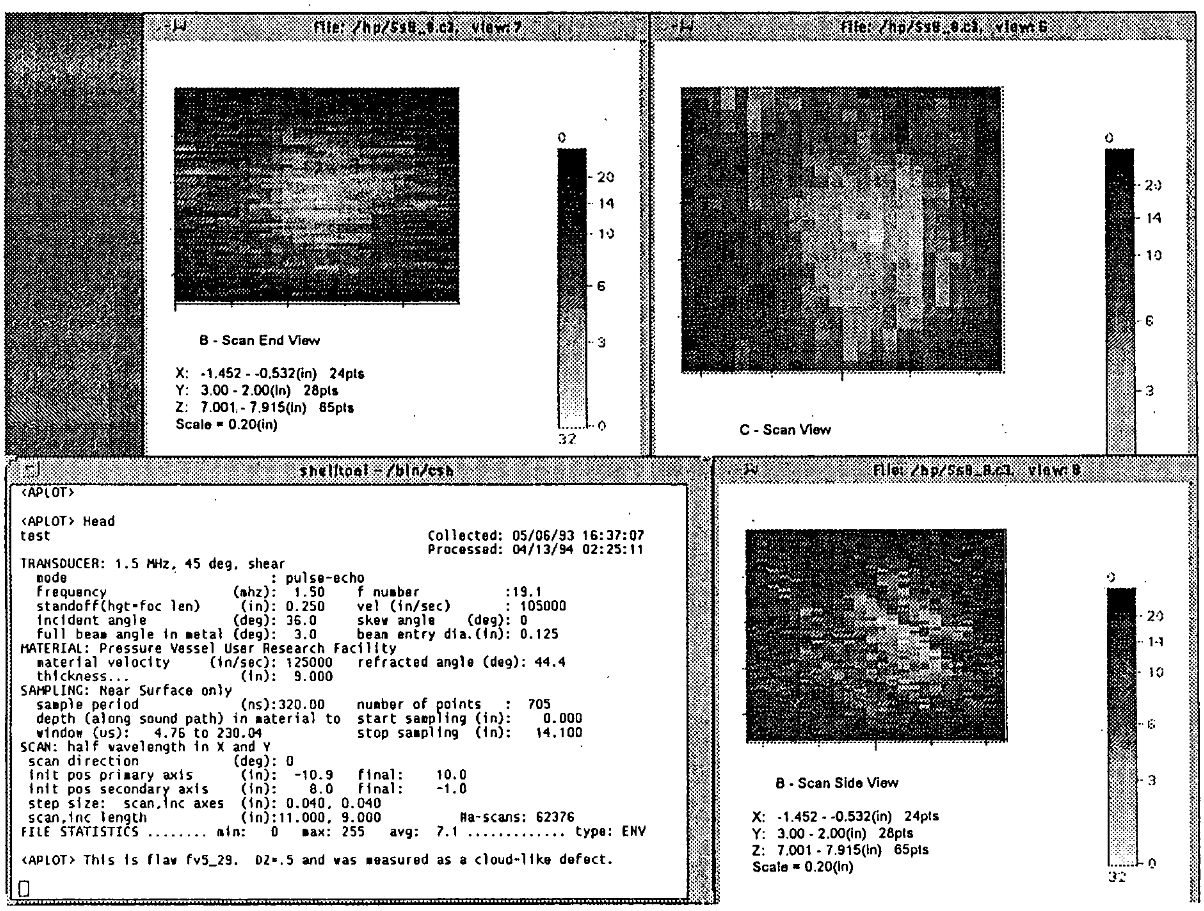


Figure A.87b - Planar indication #14 in the HAZ below 25 mm: mode 8

Planar Indications in the Base Metal Below 25 mm

Figures A.88a-b show planar indication #1 in the base metal below 25 mm. This planar indication has a through-wall extent of 26 mm based on tip signal pattern. The detection was made in mode 6 where it displayed a pair of TOF shapes at a depth of 136 mm. The shape quality is good for this indication. There was a confirmation in mode 8 at depth of 123 mm. The confirmation mode gave a through-wall extent estimate of 1 mm based on wave packet width. The two Z values of 123 to 136 mm give an alternate depth size of 13 mm. The indication is characterized as planar based on the tip signal pattern. The length is 23 mm and was made to LOS in mode 6. The range of aspect ratios (length/depth) of this indication is 0.9 to 1.8. The maximum amplitude-to-noise ratio is high at 27 to 5. The X coordinate of 28 mm shows that the indication is in the base metal, possibly HAZ. The Z coordinate of 123 to 136 mm shows that the indication is in the middle third of the vessel.

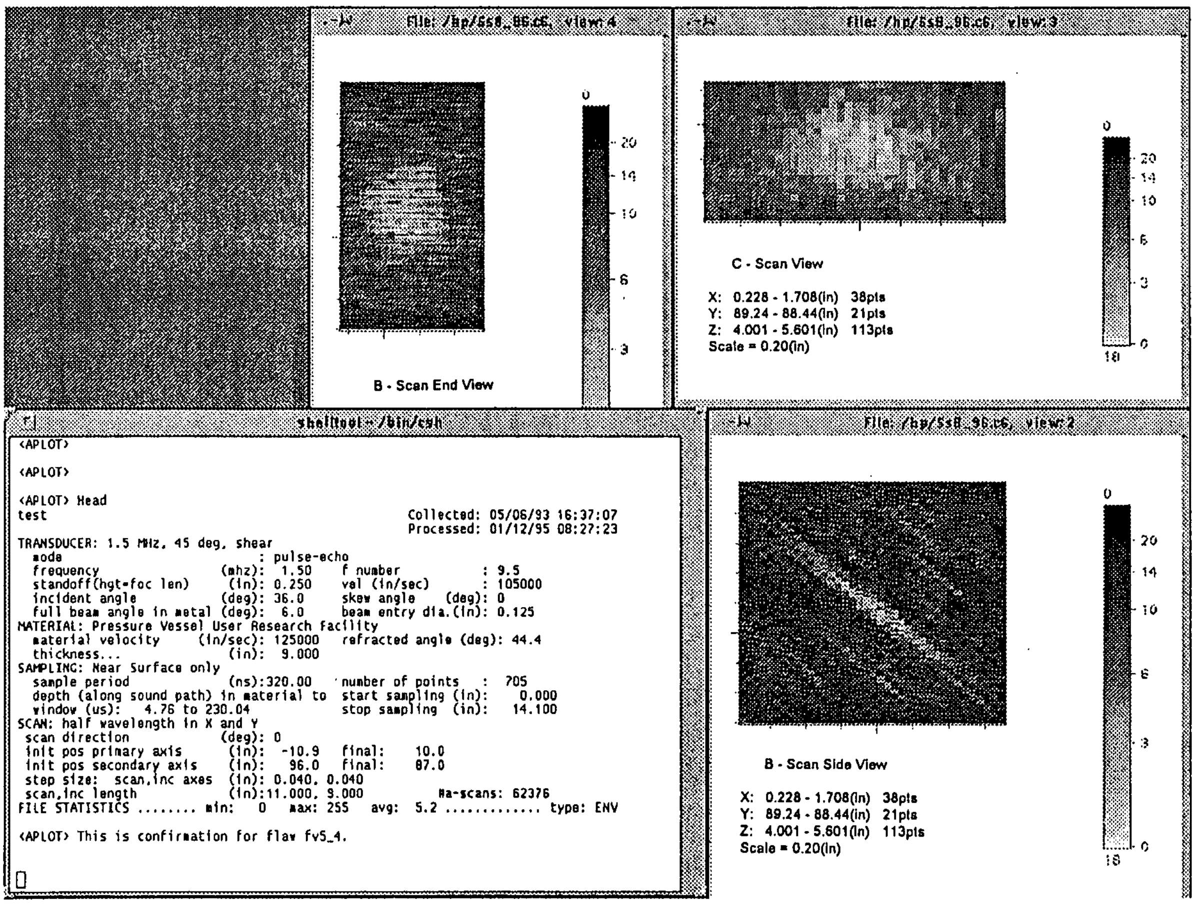


Figure A.88a - Planar indication #1 in the base metal below 25 mm: mode 8

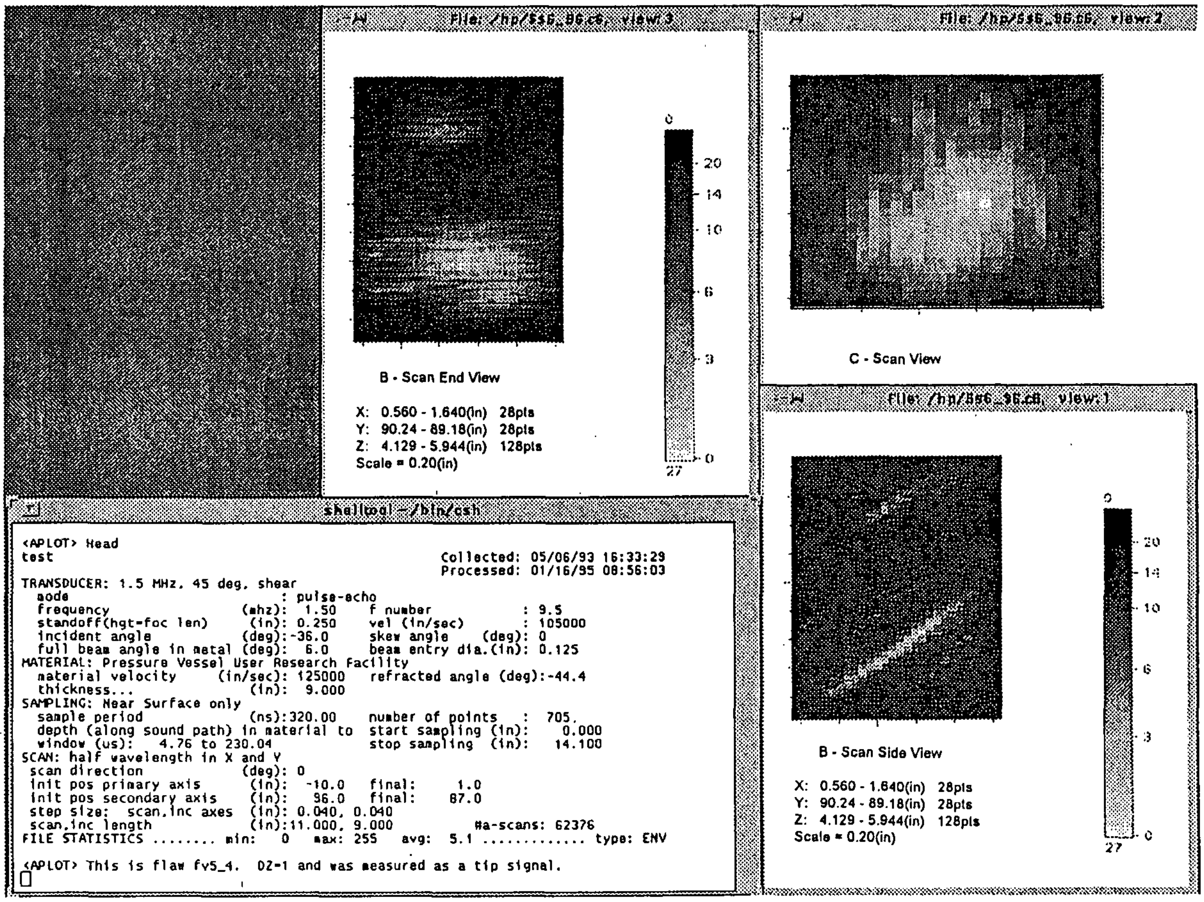


Figure A.88b - Planar indication #1 in the base metal below 25 mm: mode 6

Figures A.89a-b show planar indication #2 in the base metal below 25 mm. This planar indication has a through-wall extent of 15 mm based on tip signal pattern. The detection was made in mode 6 where it displayed a pair of TOF shapes at a depth of 121 mm. The shape quality is good for this indication. There was a confirmation in mode 8 at a depth of 122 mm. The confirmation mode gave a through-wall extent estimate of 3 mm based on ring around pattern. The two Z values of 121 to 122 mm give an alternate depth size of 1 mm. The indication is characterized as planar based on the tip signal pattern. The length is 41 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 3. The maximum amplitude-to-noise ratio is of medium range at 30 to 8. The X coordinate of 24 mm shows that the indication is in the base metal, possibly in the HAZ. The Z coordinate of 121 to 122 mm shows that the indication is in the middle third of the vessel.

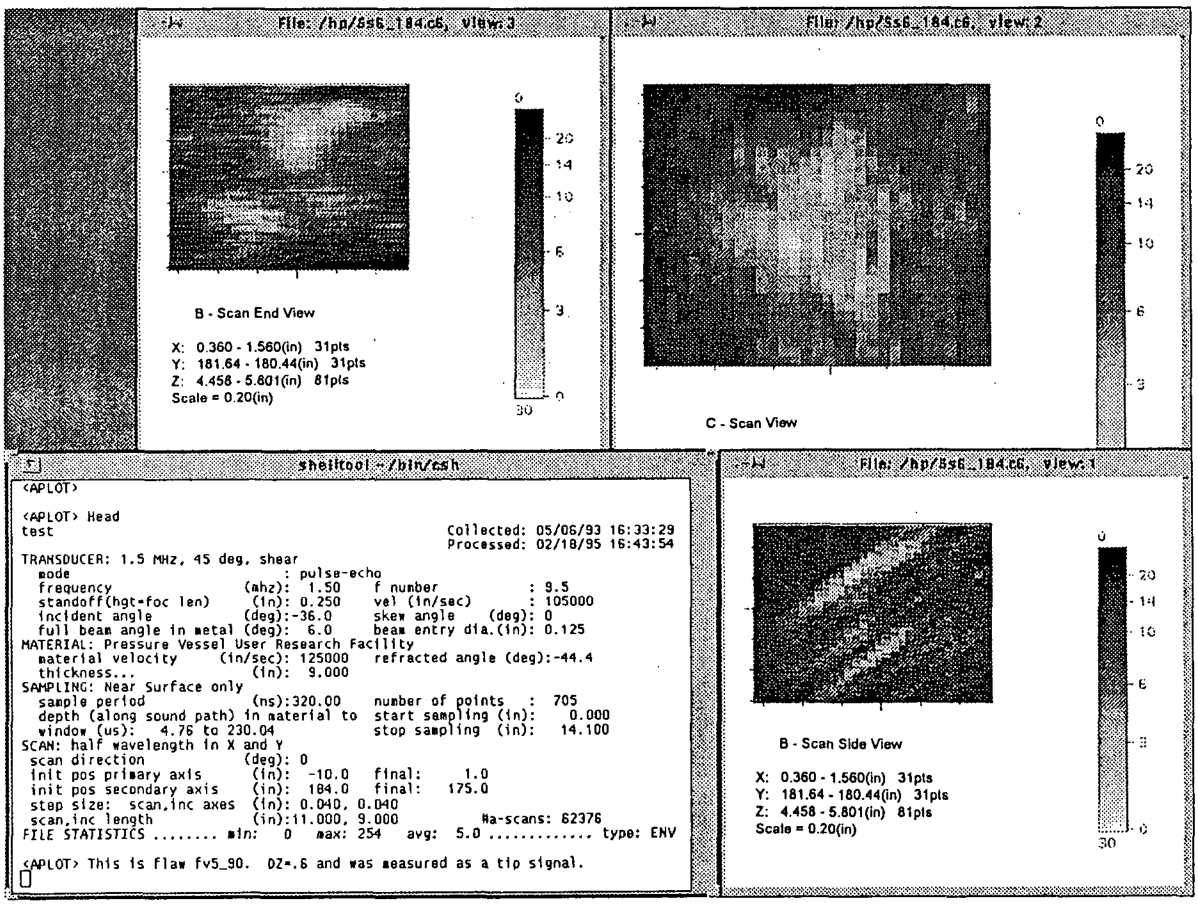


Figure A.89a - Planar indication #2 in the base metal below 25 mm: mode 6

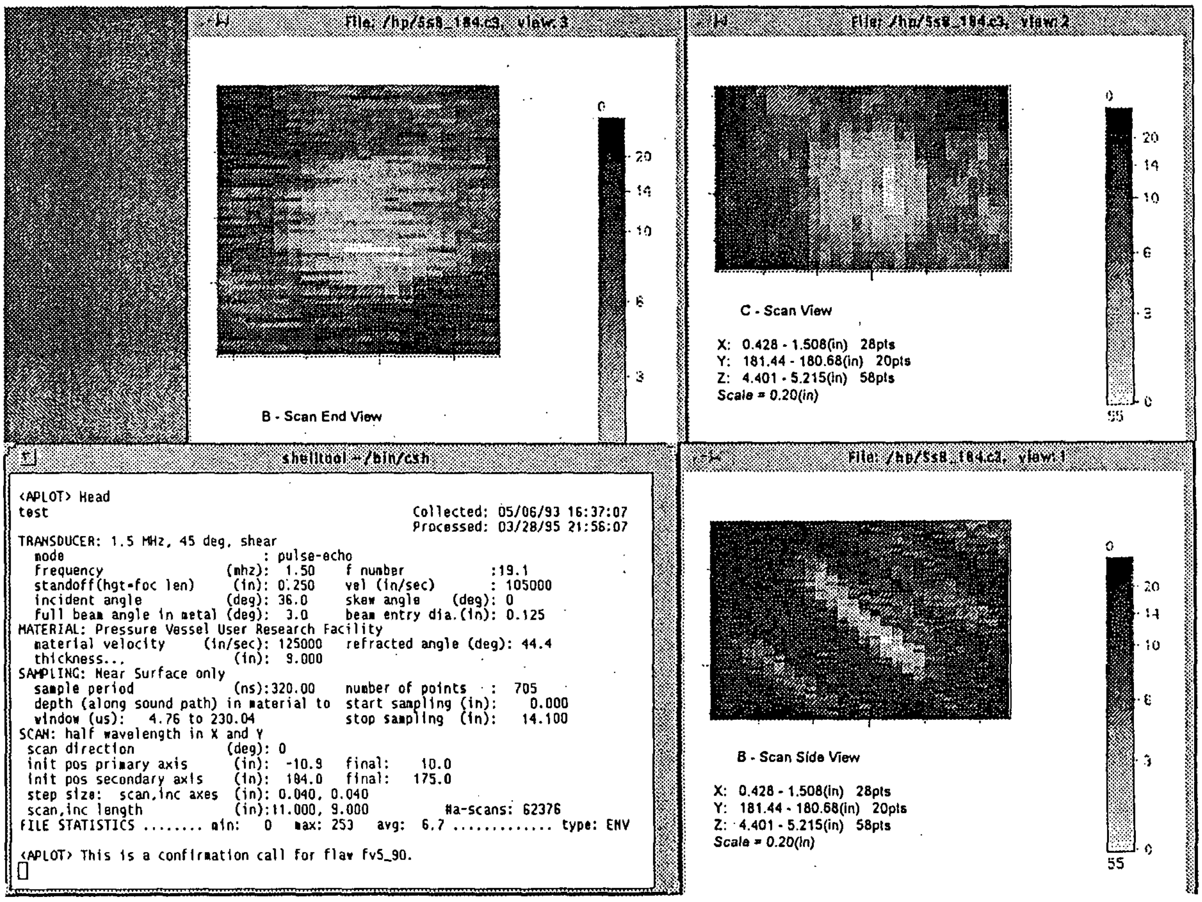


Figure A.89b - Planar indication #2 in the base metal below 25 mm: mode 8

Figure A.90 shows planar indication #3 in the base metal below 25 mm. This planar indication has a through-wall extent of 13 mm based on tip signal pattern. The detection was made in mode 7 where it displayed a pair of TOF shapes at a depth of 145 mm. The shape quality is good for this indication. There were no confirmations in other modes. The indication is characterized as planar based on the tip signal pattern. The width is 15 mm and was made to LOS in mode 7. The aspect ratio (width/depth) of this indication is 1.2. The maximum amplitude-to-noise ratio is of medium range at 51 to 14. The X coordinate of 58 mm shows that the indication is clearly in the base metal. The Z coordinate of 145 mm shows that the indication is in the middle third of the vessel.

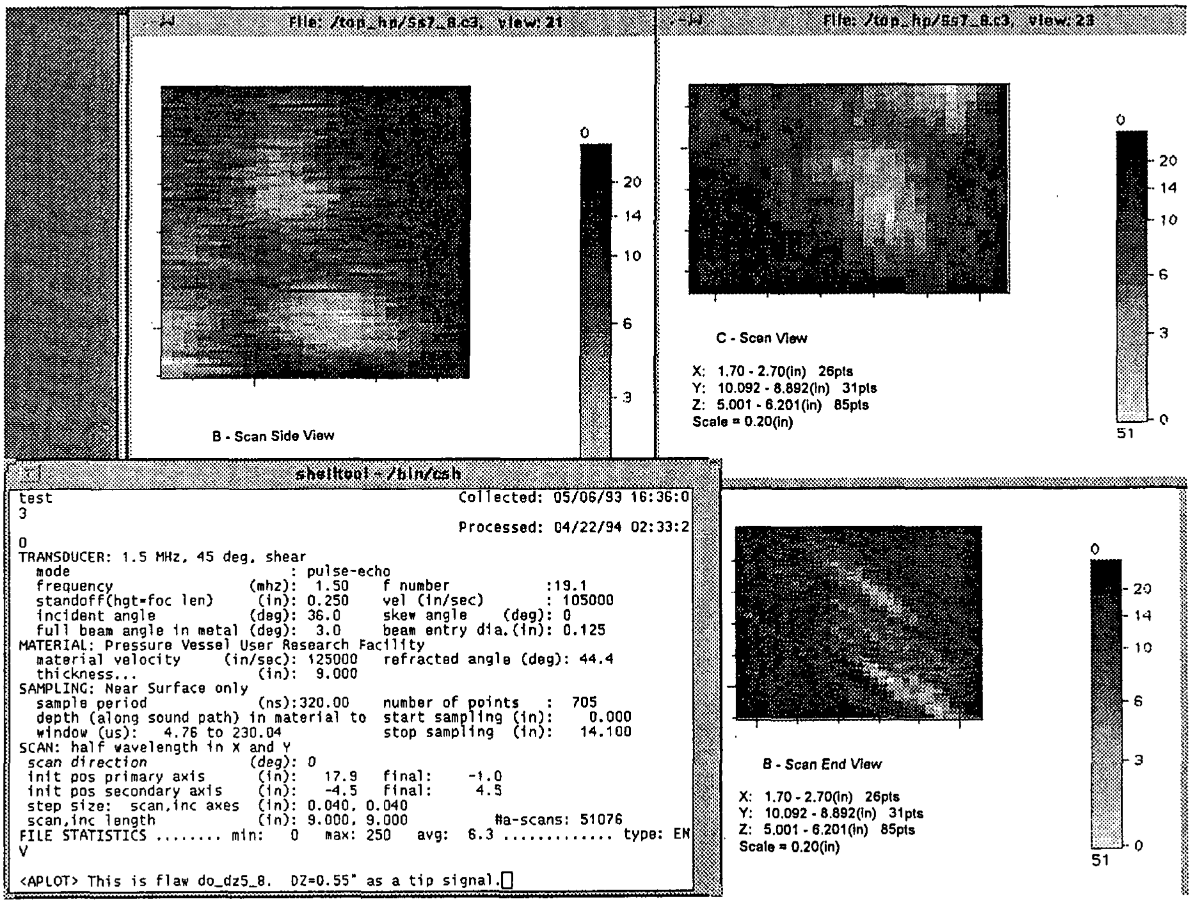


Figure A.90 - Planar indication #3 in the base metal below 25 mm: mode 7

Figure A.91 shows planar indication #4 in the base metal below 25 mm. This planar indication has a through-wall extent of 11 mm based on wave packet width. The detection was made in mode 6 where it had isolated TOF shape at a depth of 214 mm. The shape quality for this indication is good. Because more than one TOF shape was present the indication is broken up, implying that more than one small flaw may be present. There were no confirmations in other modes. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. The length is 30 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 3. The maximum amplitude-to-noise ratio is of medium range at 45 to 12. The X coordinate of 43 mm shows that the indication is clearly in the base metal. The Z coordinate of 214 mm shows that the indication is near the outer wall of the vessel.

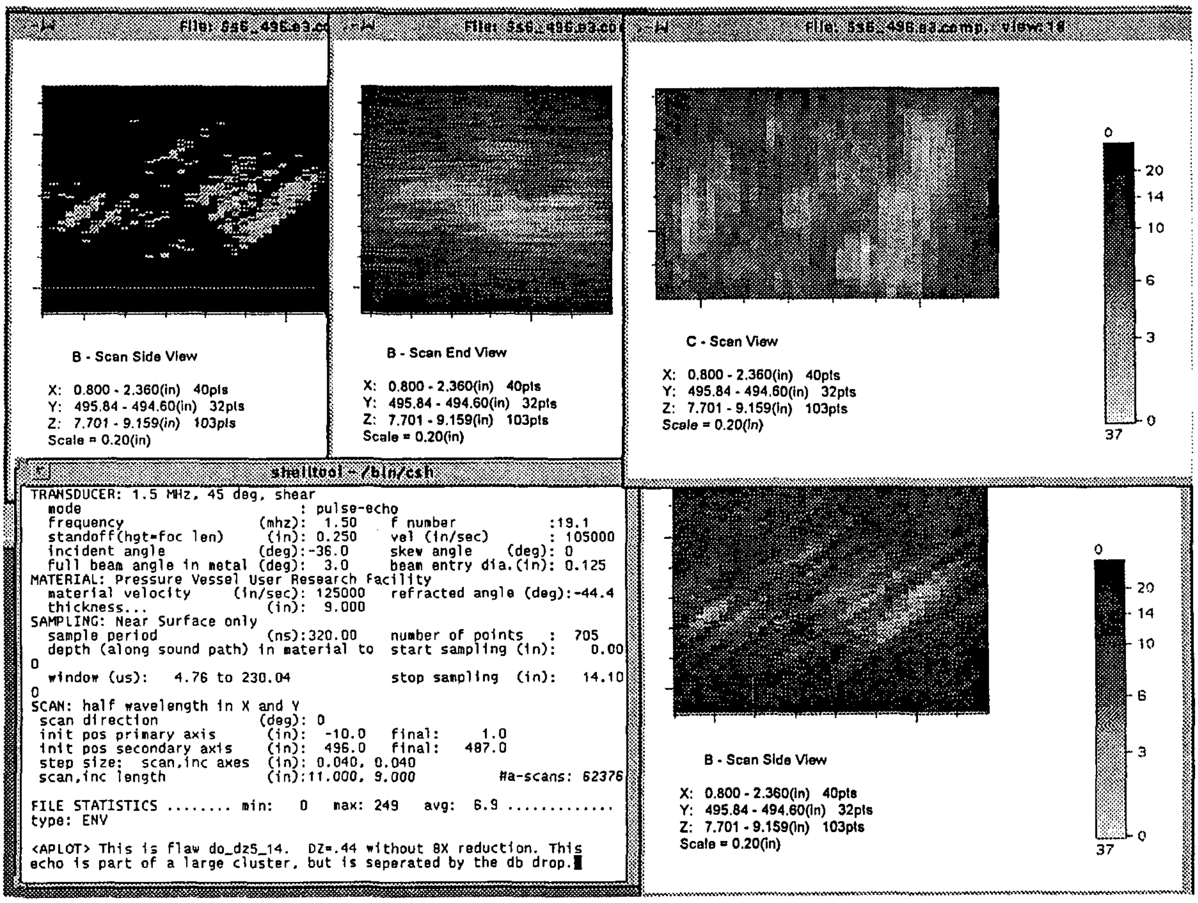


Figure A.91 - Planar indication #4 in the base metal below 25 mm: mode 6

Figure A.92 shows planar indication #5 in the base metal below 25 mm. This planar indication has a through-wall extent of 8 mm based on wave packet width. The detection was made in mode 6 where it had isolated TOF shape at a depth of 211 mm. The shape quality is good. More than one TOF shape was present for this indication, implying that more than one small flaw may be present. There were no confirmations in other modes. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. The length is 27 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 3. The maximum amplitude-to-noise ratio is high at 59 to 12. The X coordinate of 31 mm shows that the indication is in the base metal, possibly HAZ. The Z coordinate of 211 mm shows that the indication is near the outer wall of the vessel.

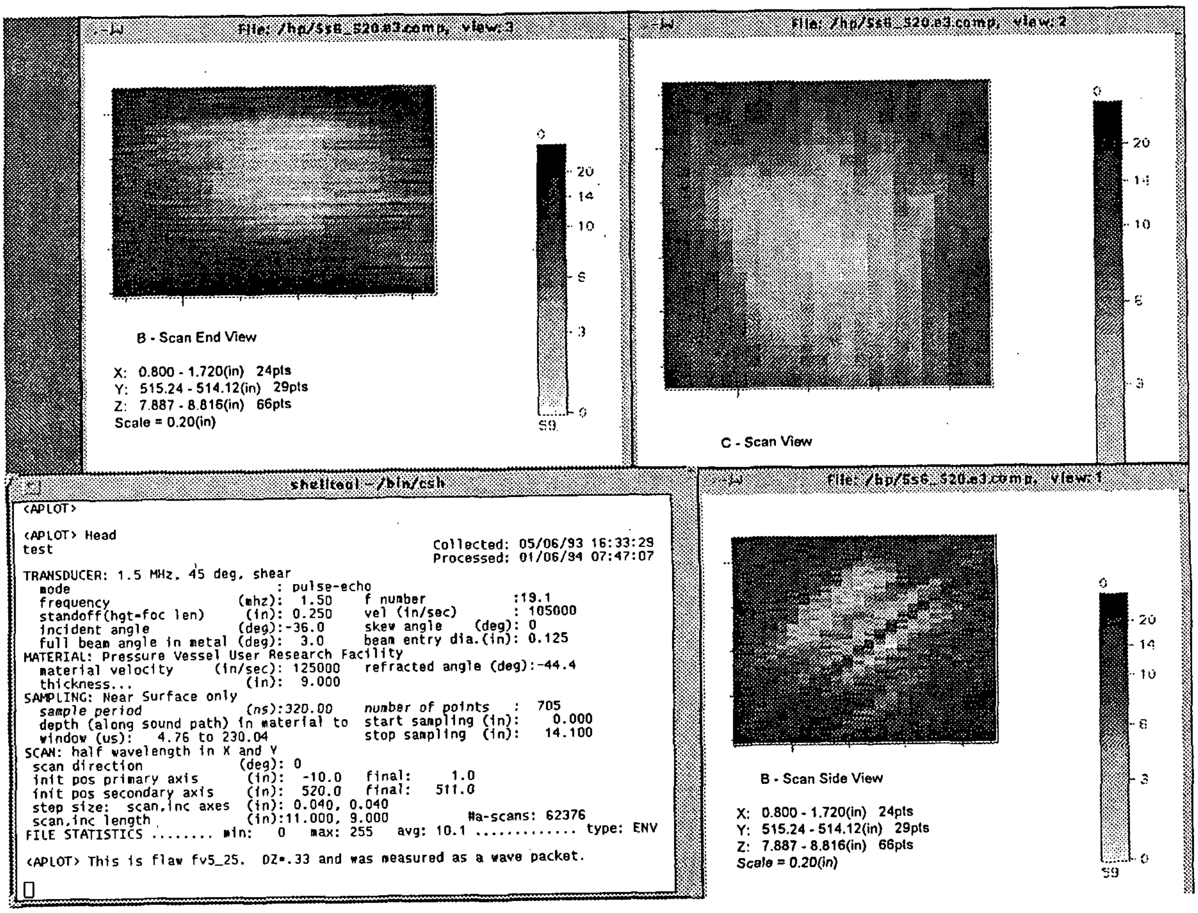


Figure A.92 - Planar indication #5 in the base metal below 25 mm: mode 6

Figure A.93 shows planar indication #6 in the base metal below 25 mm. This planar indication has a through-wall extent of 7 mm based on wave packet width. The detection was made in mode 8 where it had isolated TOF shape at a depth of 113 mm. More than one TOF shape was present. The shape quality for this indication is good but broken up, implying that more than one small flaw may be present. There were no confirmations in other modes. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. The length is 16 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 2. The maximum amplitude-to-noise ratio is high at 65 to 15. The X coordinate of 46 mm shows that the indication is clearly in the base metal. The Z coordinate of 113 mm shows that the indication is in the middle third of the vessel.

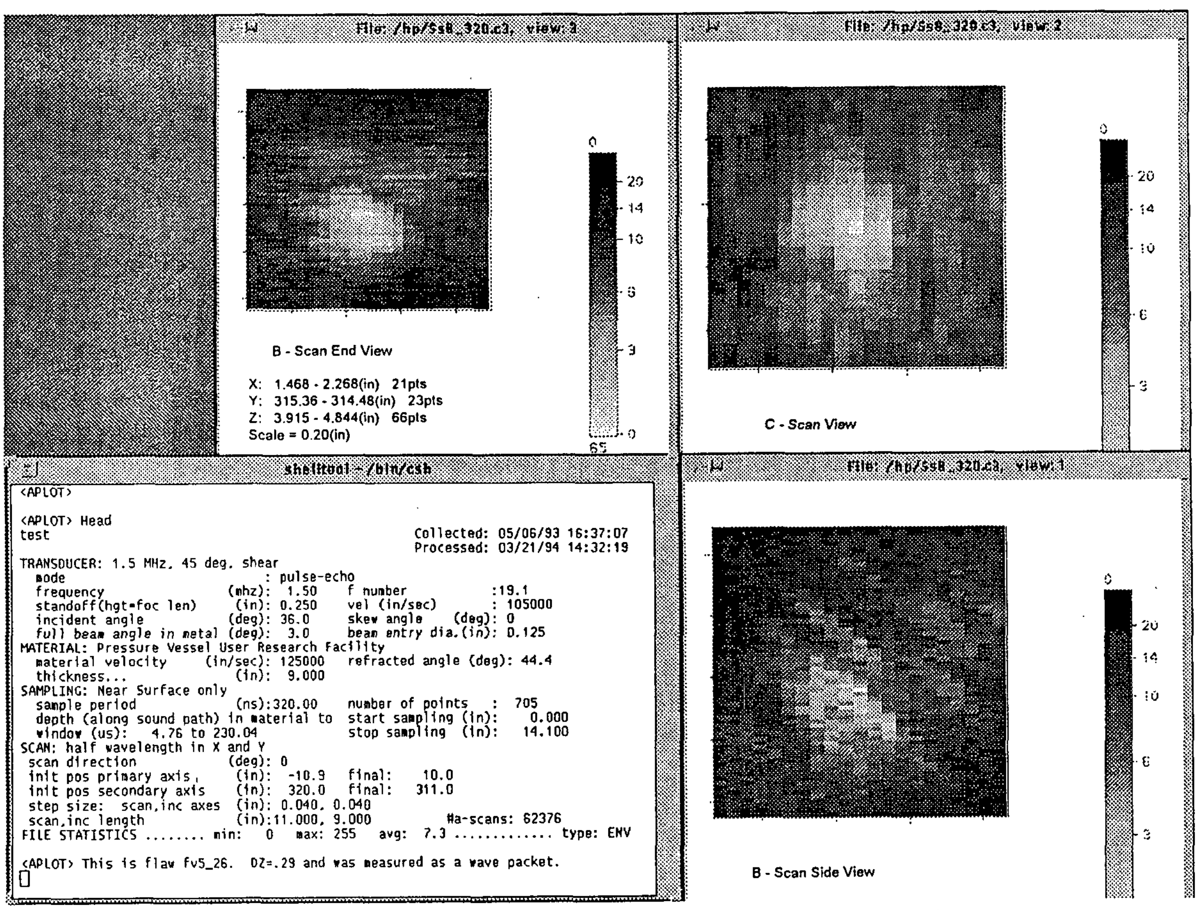


Figure A.93 - Planar indication #6 in the base metal below 25 mm: mode 8

Figure A.94 shows planar indication #7 in the base metal below 25 mm. This planar indication has a through-wall extent of 7 mm based on wave packet width. The detection was made in mode 8 where it had isolated TOF shape at a depth of 113 mm. More than one TOF shape was present. The shape quality for this indication is good but broken up, implying that more than one small flaw may be present. There were no confirmations in other modes. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. The length is 16 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 2. The maximum amplitude-to-noise ratio is high at 65 to 15. The X coordinate of 46 mm shows that the indication is clearly in the base metal. The Z coordinate of 113 mm shows that the indication is in the middle third of the vessel.

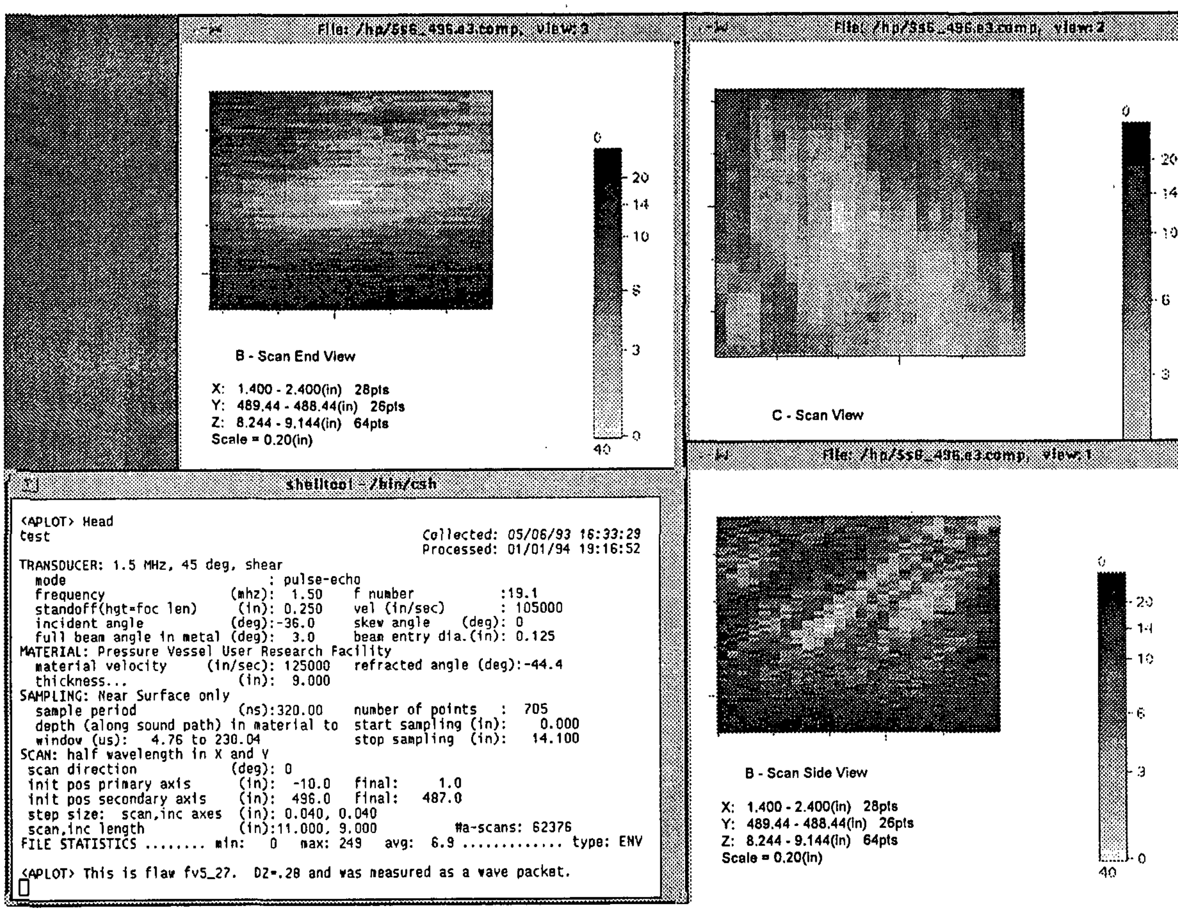


Figure A.94 - Planar indication #7 in the base metal below 25 mm: mode 6

Figure A.95 shows planar indication #8 in the base metal below 25 mm. This planar indication has a through-wall extent of 7 mm based on wave packet width. The detection was made in mode 8 where it had isolated TOF shape at a depth of 238 mm. More than one TOF shape was present. The shape quality for this indication is good but broken up, implying that more than one small flaw may be present. There were no confirmations in other modes. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. The length is 28 mm and was made to LOS in mode 8. The aspect ratio (length/depth) of this indication is 4 which tends to confirm the large through-wall extent. The maximum amplitude-to-noise ratio is high at 84 to 20. The X coordinate of 31 mm shows that the indication is in the base metal, possibly HAZ. The Z coordinate of 238 mm shows that the indication is near the outer wall, possibly connected to the outer wall of the vessel.

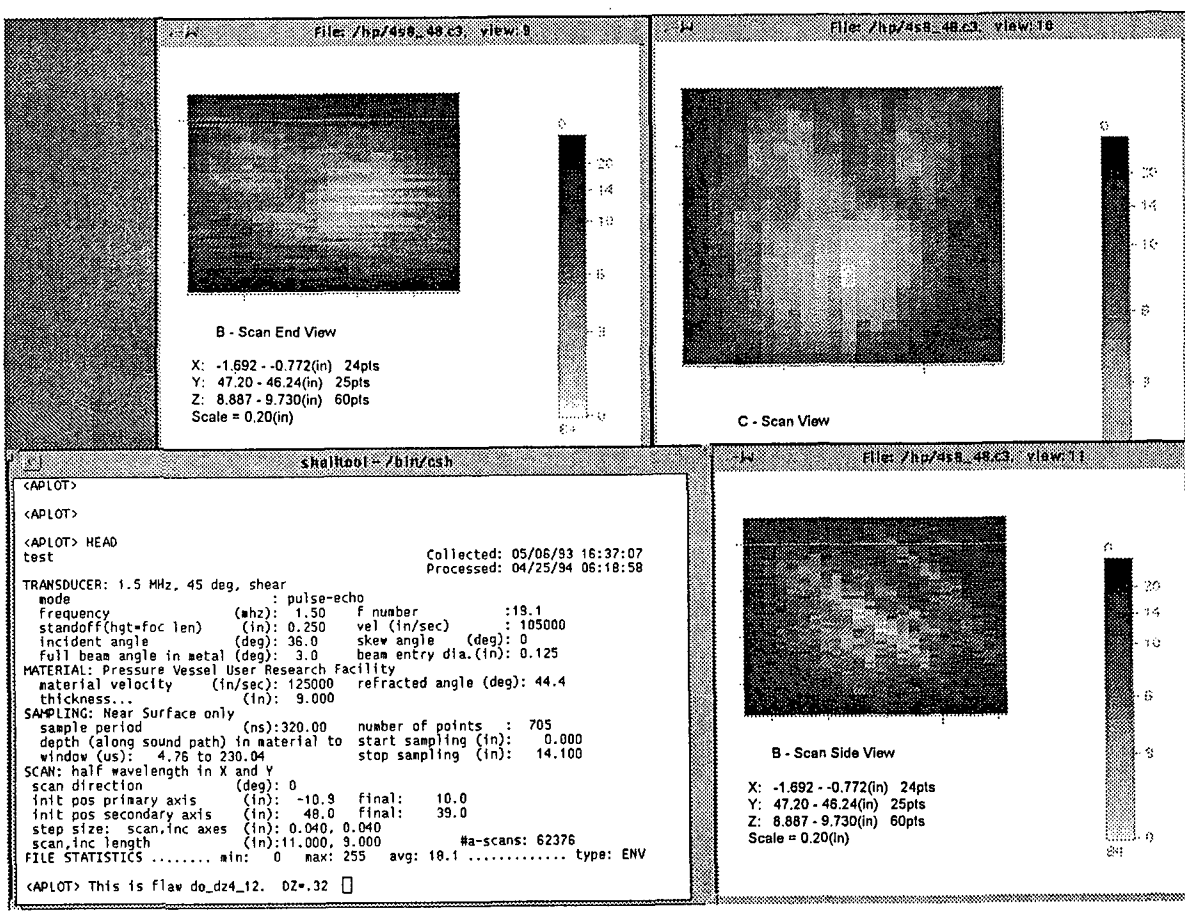


Figure A.95 - Planar indication #8 in the base metal below 25 mm: mode 8

Figures A.96a-b show planar indication #9 in the base metal below 25 mm. This planar indication has a through-wall extent of 7 mm based on tip signal pattern. The detection was made in mode 8 where it displayed a pair of TOF shapes at a depth of 110 mm. The shape quality is good for this indication. There was a confirmation in mode 6 at a depth of 111 mm. The confirmation mode gave a through-wall extent estimate of 4 mm based on wave packet width. The two Z values of 110 to 111 mm give an alternate depth size of 1 mm. The indication is characterized as planar based on the tip signal pattern. The length is 16 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 2. The maximum amplitude-to-noise ratio is of medium range at 62 to 20. The X coordinate of 37 mm shows that the indication is clearly in the base metal. The Z coordinate of 110 mm shows that the indication is in the middle third of the vessel.

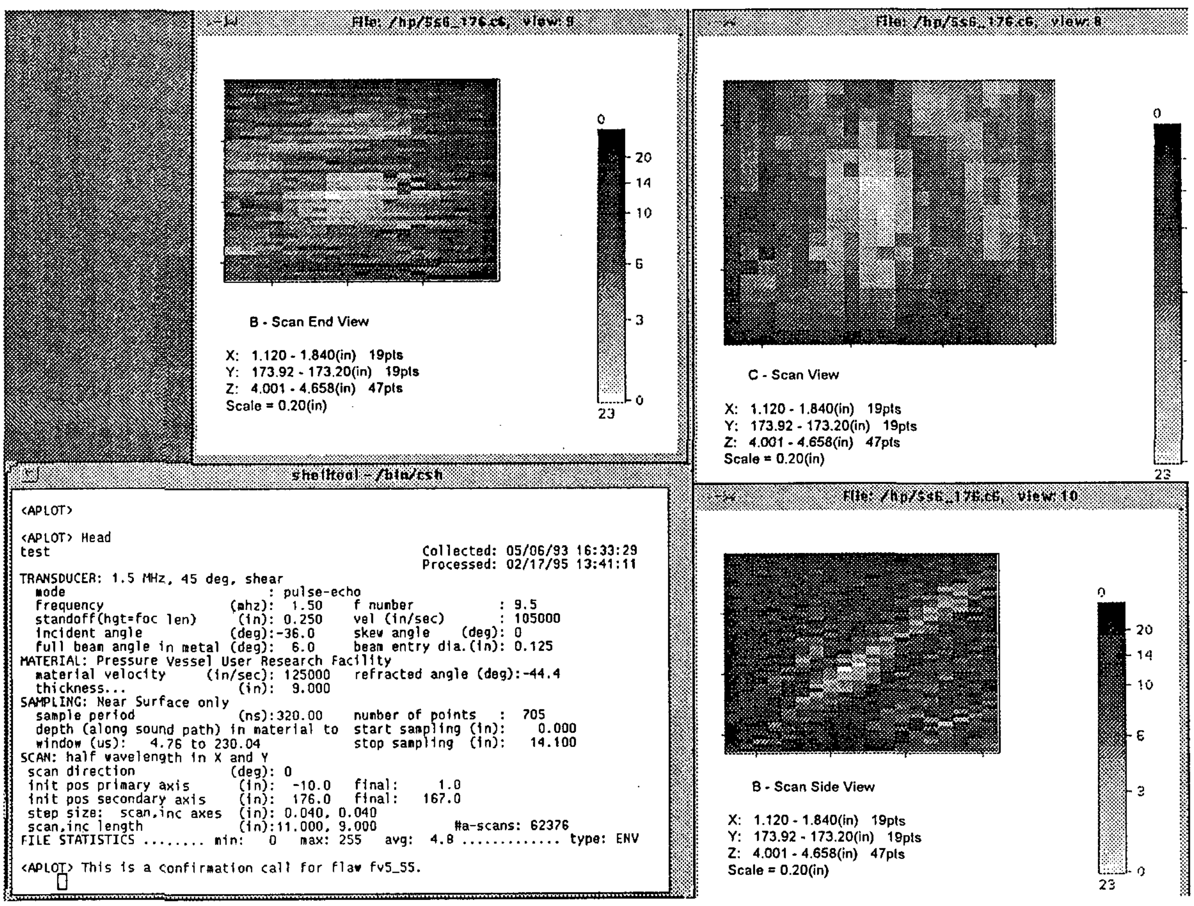


Figure A.96a - Planar indication #9 in the base metal below 25 mm: mode 6

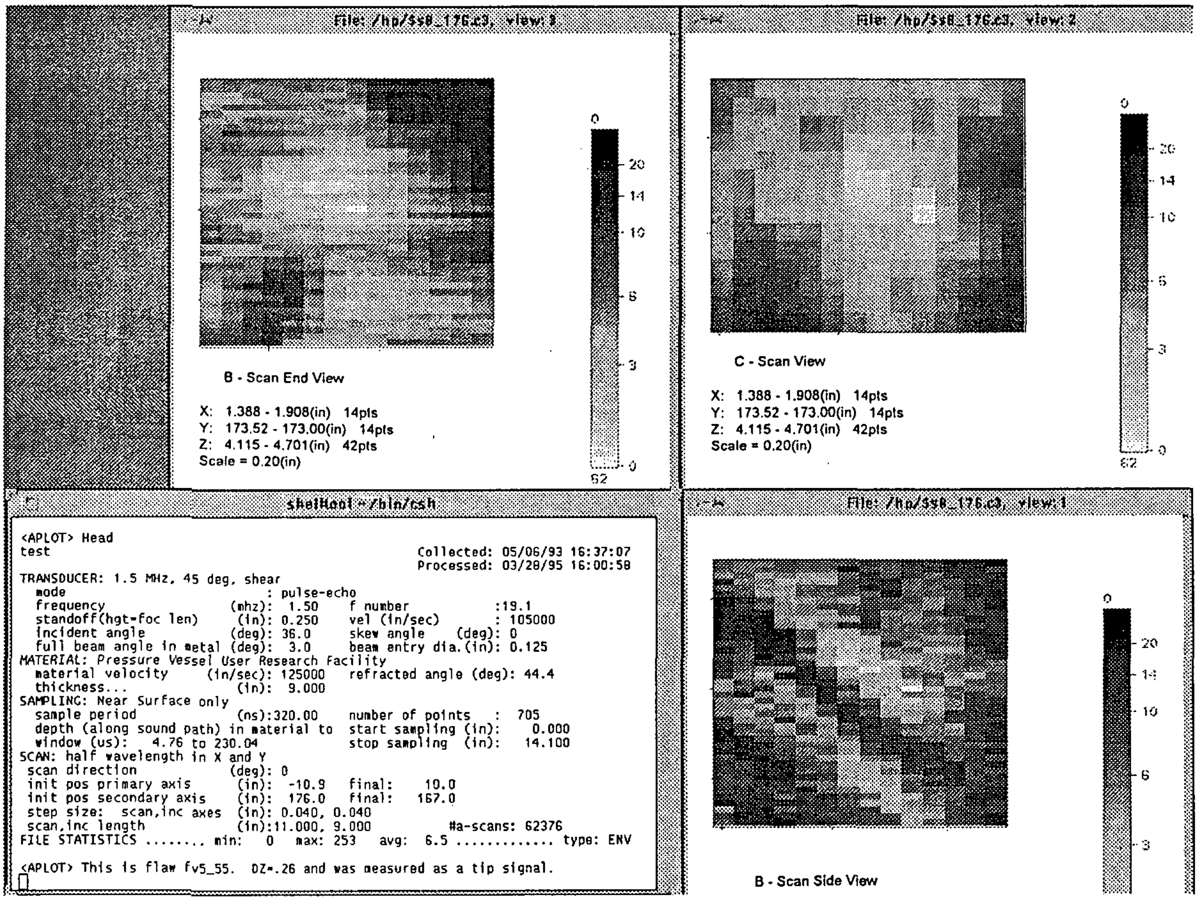


Figure A.96b - Planar indication #9 in the base metal below 25 mm: mode 8

Figure A.97 shows planar indication #10 in the base metal below 25 mm. This planar indication has a through-wall extent of 6 mm based on tip signal pattern. The detection was made in mode 8 where it displayed a pair of TOF shapes at a depth of 201 mm. The shape quality is good for this indication. There were no confirmations in other modes. The indication is characterized as planar based on the tip signal pattern. The length is 20 mm and was made to LOS in mode 8. The aspect ratio (length/depth) of this indication is 3. The maximum amplitude-to-noise ratio is of medium range at 53 to 20. The X coordinate of -159 mm shows that the indication is clearly in the base metal. The Z coordinate of 201 mm shows that the indication is in the outer third of the vessel.

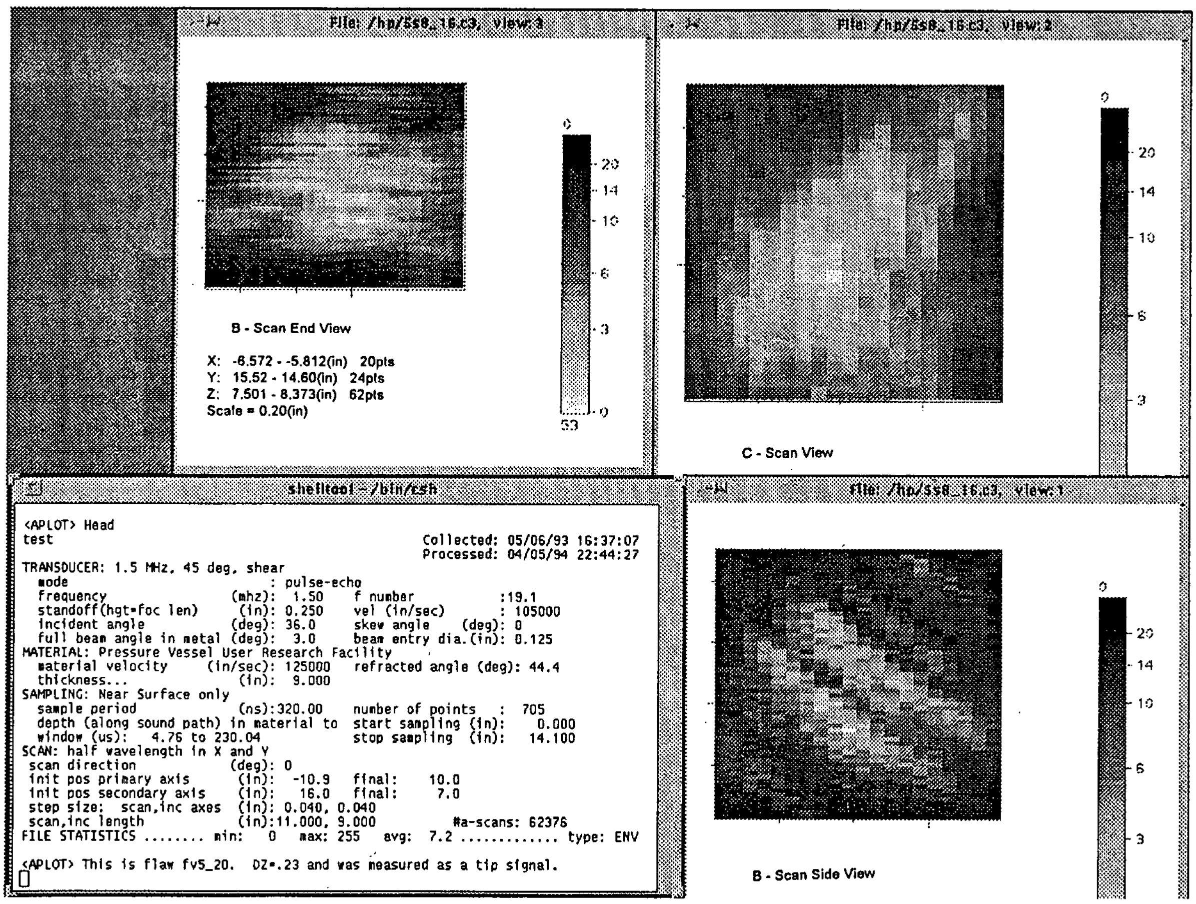


Figure A.97 - Planar indication #10 in the base metal below 25 mm: mode 8

Figures A.98a-b show planar indication #11 in the base metal below 25 mm. This planar indication has a through-wall extent of 6 mm based on tip signal pattern. The detection was made in mode 8 where it displayed a pair of TOF shapes. The shape quality is good for this indication. There were no confirmations in other modes. The indication is characterized as planar based on the tip signal pattern. The length is 23 mm and was made to LOS in mode 8. The aspect ratio (length/depth) of this indication is 4 which tends to confirm the large through-wall extent. The maximum amplitude-to-noise ratio is of medium range at 68 to 25. The X coordinate of -70 mm shows that the indication is in the base metal. The Z coordinate of 203 mm shows that the indication is in the outer third of the vessel.

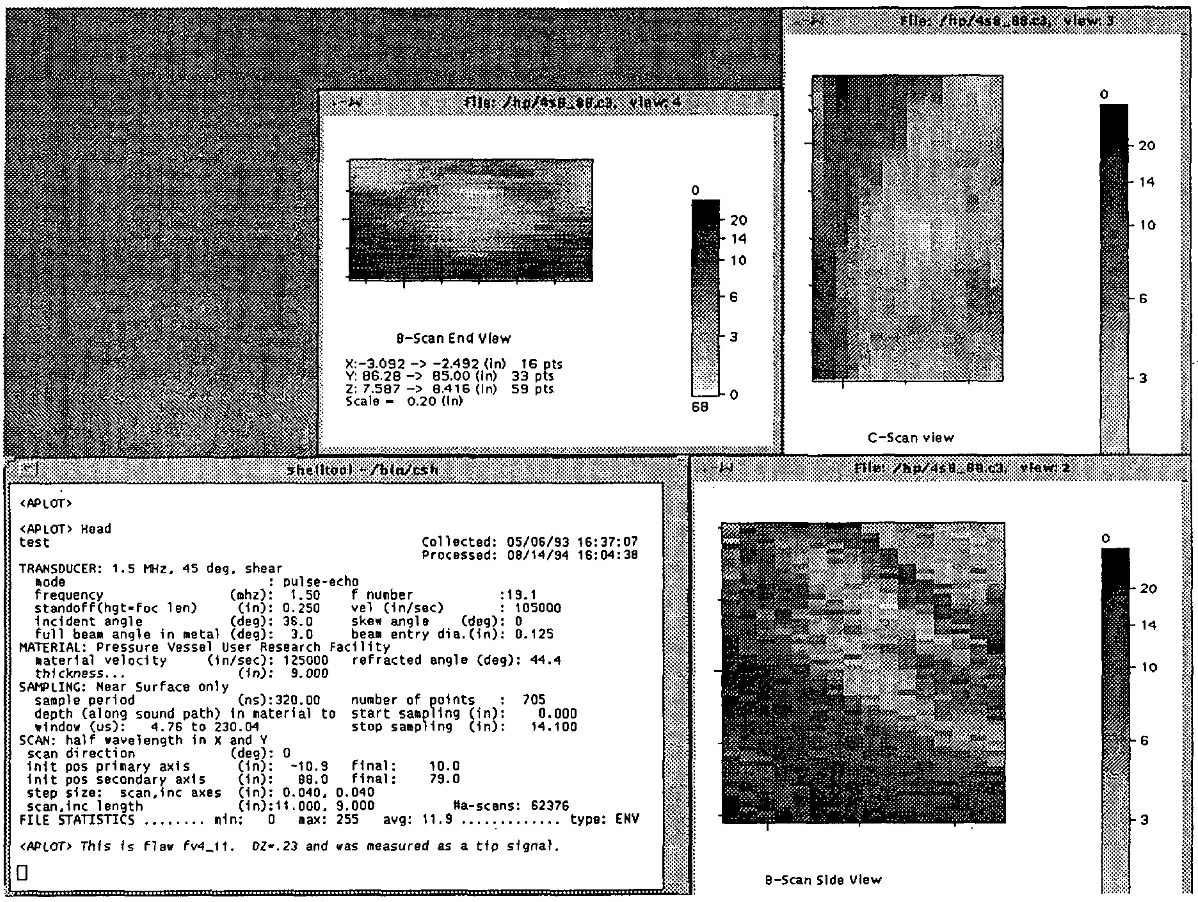


Figure A.98a - Planar indication #11 in the base metal below 25 mm: mode 8

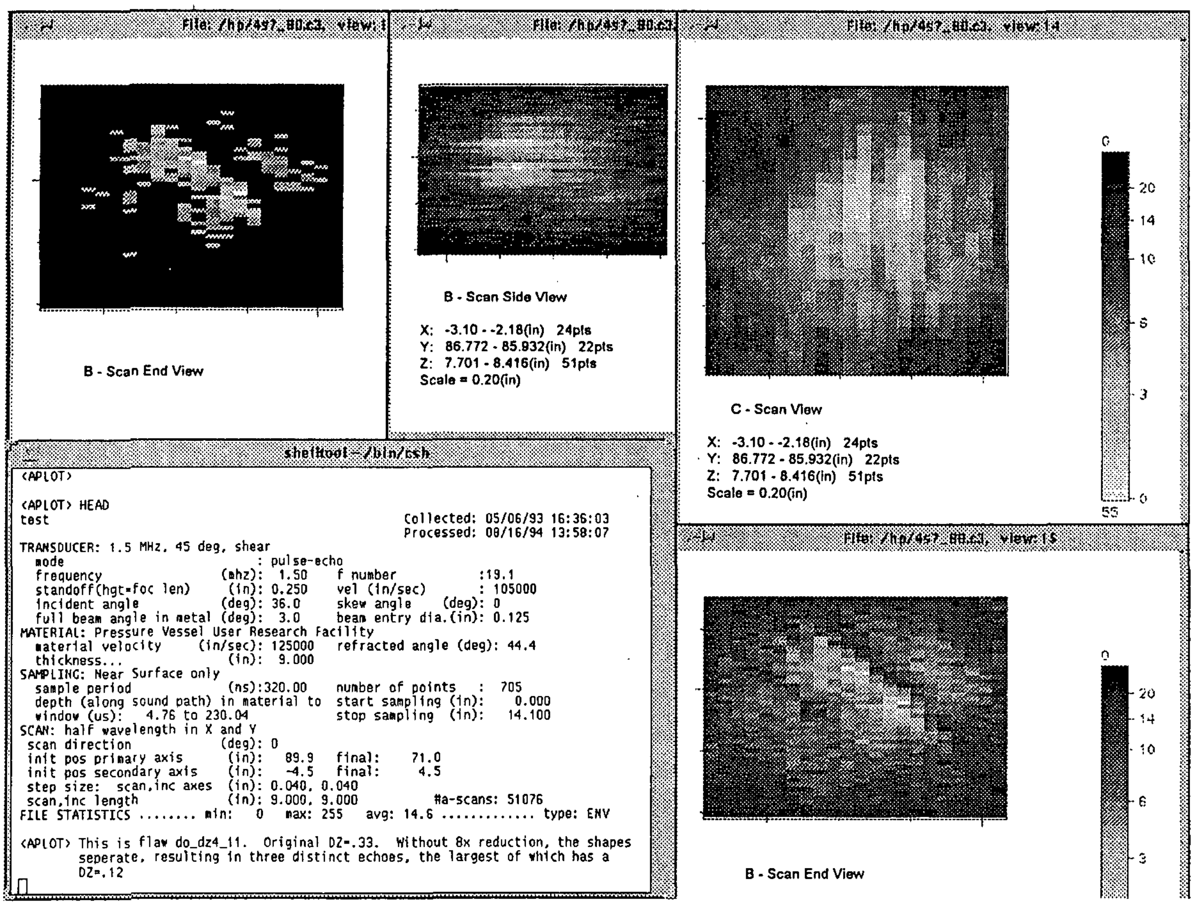


Figure A.98b - Planar indication #11 in the base metal below 25 mm: mode 7

Figures A.99a-b show planar indication #12 in the base metal below 25 mm. This planar indication has a through-wall extent of 6 mm based on tip signal pattern. The detection was made in mode 6 where it displayed a pair of TOF shapes at a depth of 118 mm. The shape quality is good for this indication. There was a confirmation in mode 8 at a depth of 119 mm. Based on LOS in a cloud like shape, the confirmation mode gave a through-wall extent estimate of 13 mm. The two Z values of 118 to 119 mm give an alternate depth size of 1 mm. The indication is characterized as planar based on the tip signal pattern. The length is 17 mm and was made to LOS in mode 6. The range of aspect ratios (length/depth) of this indication is 1.3 to 2.8. The maximum amplitude-to-noise ratio is of medium range at 50 to 15. The X coordinate of 25 mm shows that the indication is in the base metal, possibly in the HAZ. The Z coordinate of 118 mm shows that the indication is in the middle third of the vessel.

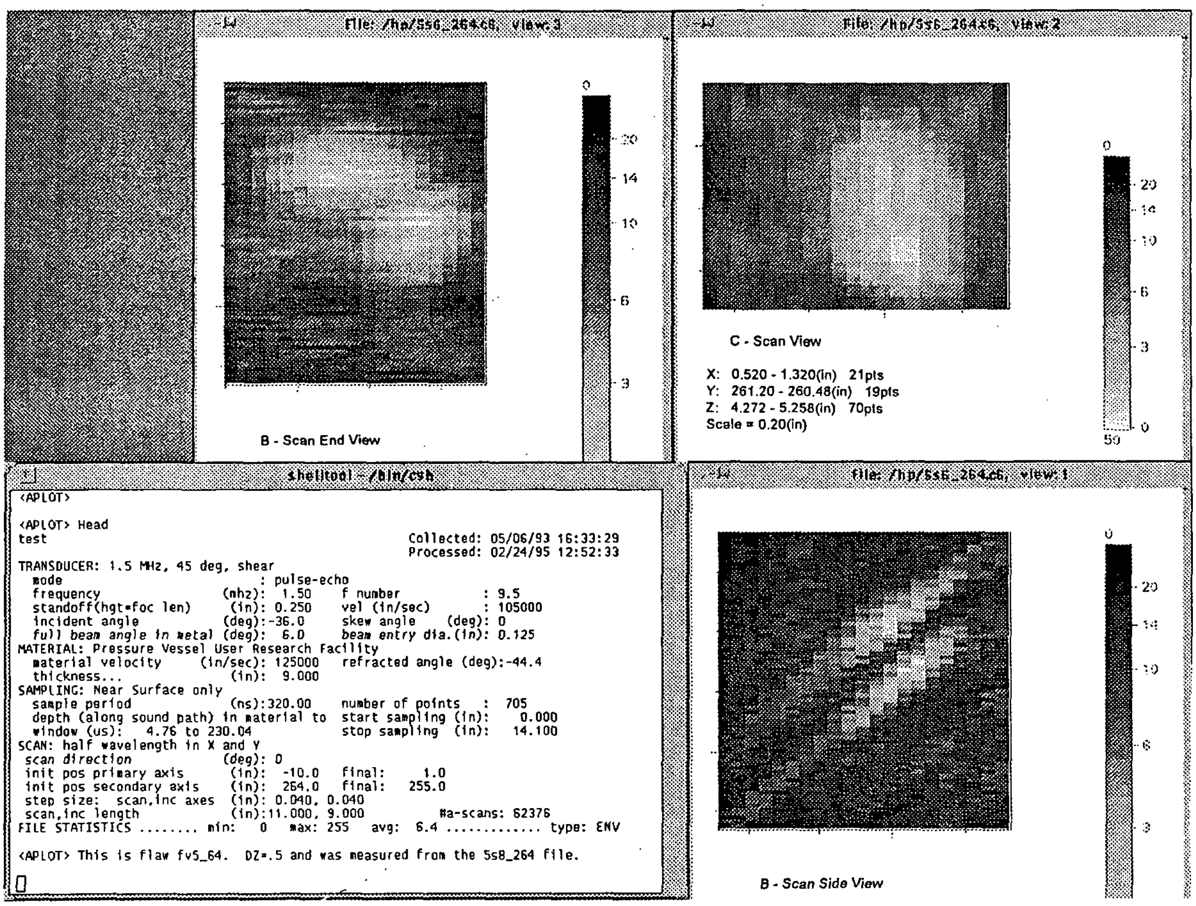


Figure A.99a - Planar indication #12 in the base metal below 24 mm: mode 6

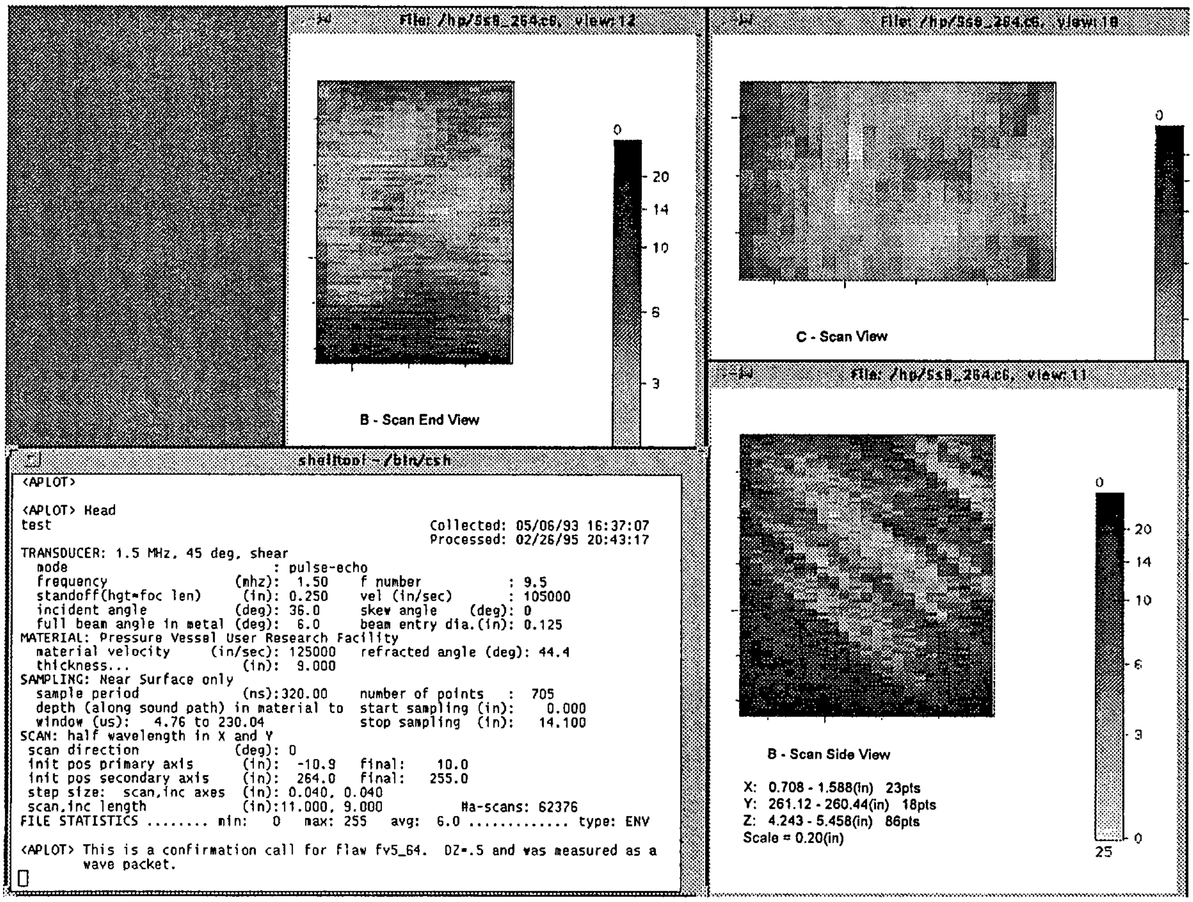


Figure A.99b - Planar indication #12 in the base metal below 25 mm: mode 8

Figure A.100 shows planar indication #13 in the base metal below 25 mm. Based on LOS in a cloud like pattern, this planar indication has a through-wall extent of 4 mm. The detection was made in mode 6 where the shape was cloud like in nature at a depth of 123 mm. The shape quality for this indication is good but broken up, implying that more than one small flaw may be present. There were no confirmations in other modes. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. The length is 30 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 8 which tends to confirm the large through-wall extent. The maximum amplitude-to-noise ratio is of medium range at 58 to 20. The X coordinate of 36 mm shows that the indication is clearly in the base metal. The Z coordinate of 123 mm shows that the indication is in the middle third of the vessel.

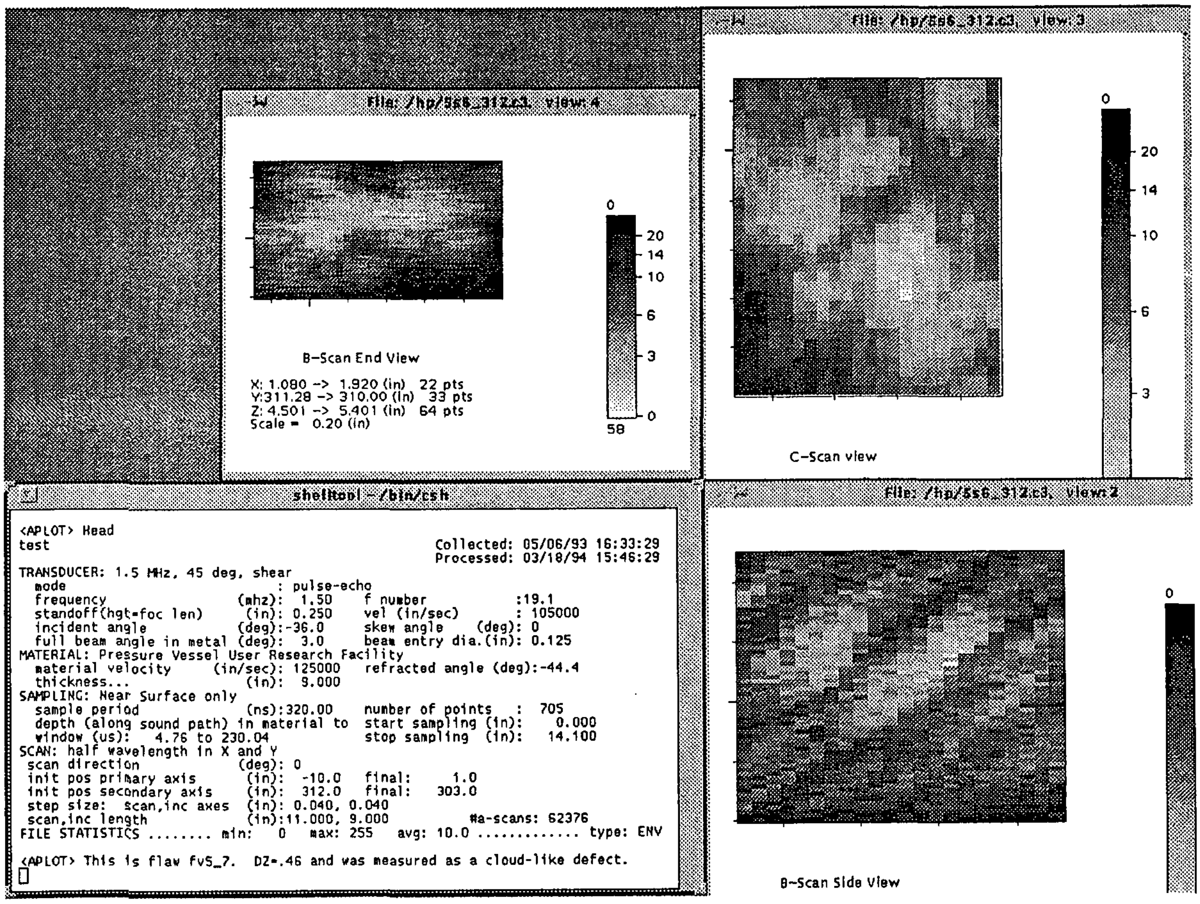


Figure A.100 - Planar indication #13 in the base metal below 25 mm: mode 6

Figures A.101a-b show planar indication #14 in the base metal below 25 mm. Based on LOS in a cloud like pattern, this planar indication has a through-wall extent of 4 mm. The detection was made in mode 8 where the shape was cloud like in nature at a depth of 192 mm. The shape quality for this indication is good but broken up, implying that more than one small flaw may be present. There was a confirmation in mode 6 at a depth of 195 mm which gave a through-wall extent estimate of 4 mm based on wave packet width. The two Z values of 192 to 195 mm give an alternate depth size of 3 mm. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. The length is 25 mm and was made to LOS in mode 8. The aspect ratio (length/depth) of this indication is 6 which tends to confirm the large through-wall extent. The maximum amplitude-to-noise ratio is of medium range at 38 to 10. The X coordinate of -49 mm shows that the indication is clearly in the base metal. The Z coordinate of 192 to 195 mm shows that the indication is in the outer third of the vessel.

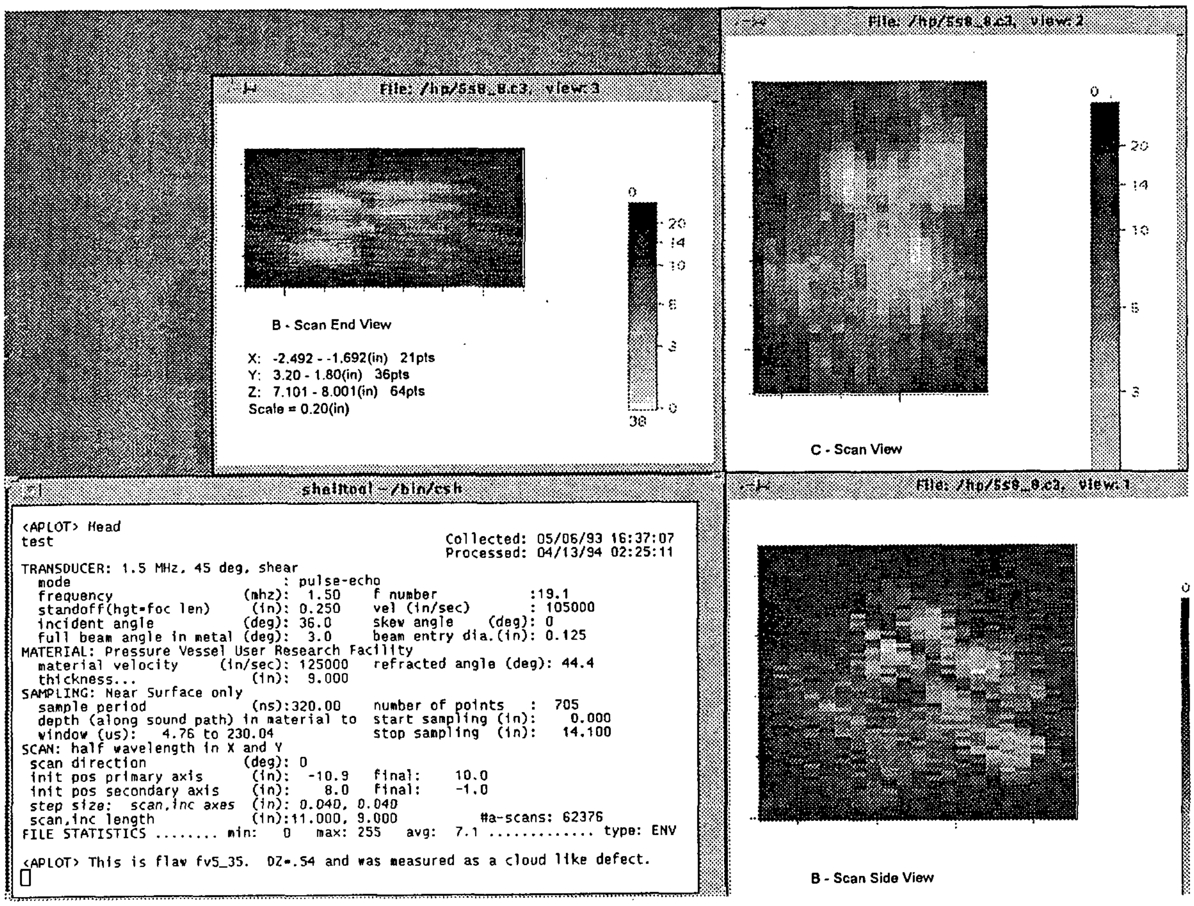


Figure A.101a - Planar indication #14 in the base metal below 25 mm: mode 8

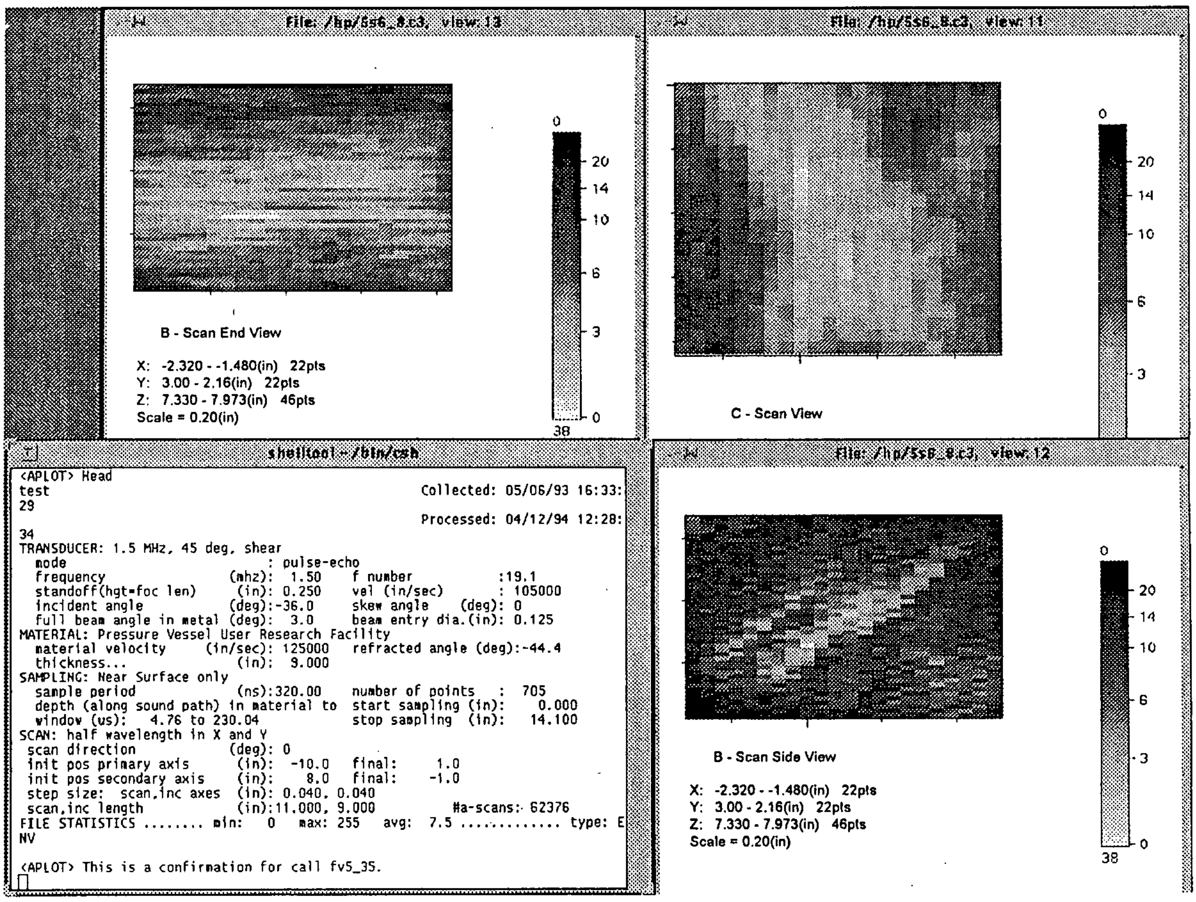


Figure A.101b - Planar indication #14 in the base metal below 25 mm: mode 6

Figure A.102 shows planar indication #15 in the base metal below 25 mm. Based on LOS in a cloud like pattern, this planar indication has a through-wall extent of 4 mm. The detection was made in mode 9 where the shape was cloud like in nature at a depth of 220 mm. The shape quality for this indication is good but broken up, implying that more than one small flaw may be present. There were no confirmations in other modes. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. The width is 18 mm and was made to LOS in mode 9. The aspect ratio (width/depth) of this indication is 4. The maximum amplitude-to-noise ratio is of medium range at 25 to 7. The X coordinate of 90 mm shows that the indication is clearly in the base metal. The Z coordinate of 220 mm shows that the indication is in the near the outer wall of the of the vessel.

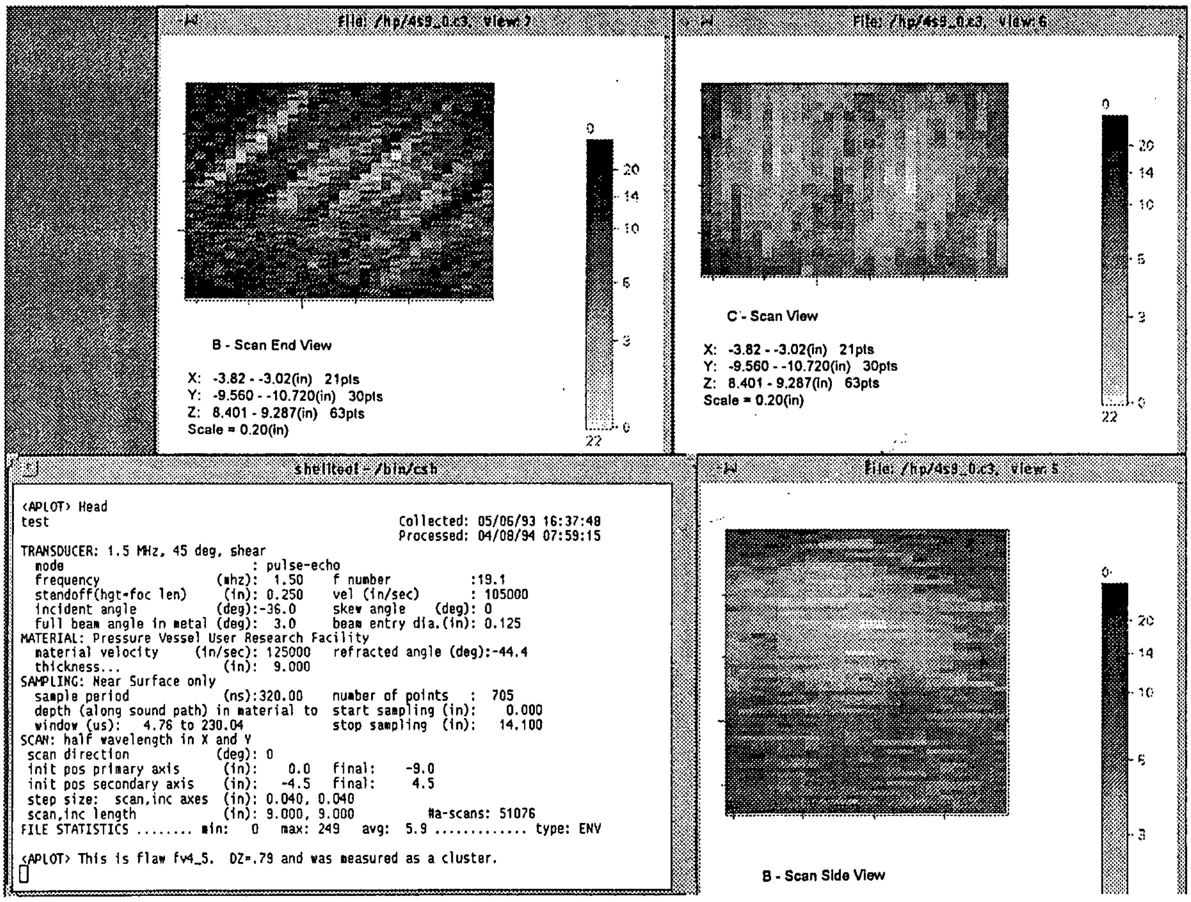


Figure A.102 - Planar indication #15 in the base metal below 25 mm: mode 9

Figure A.103 shows planar indication #16 in the base metal below 25 mm. Based on LOS in a cloud like pattern, this planar indication has a through-wall extent of 4 mm. The detection was made in mode 6 where the shape was cloud like in nature at a depth of 122 mm. The shape quality for this indication is good but broken up, implying that more than one small flaw may be present. There were no confirmations in other modes. The indication is characterized as planar based on lack of detection in normal beam or orthogonal modes. The length is 15 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 4. The maximum amplitude-to-noise ratio is of medium range at 52 to 14. The X coordinate of 36 mm shows that the indication is clearly in the base metal. The Z coordinate of 122 mm shows that the indication is in the middle third of the vessel.

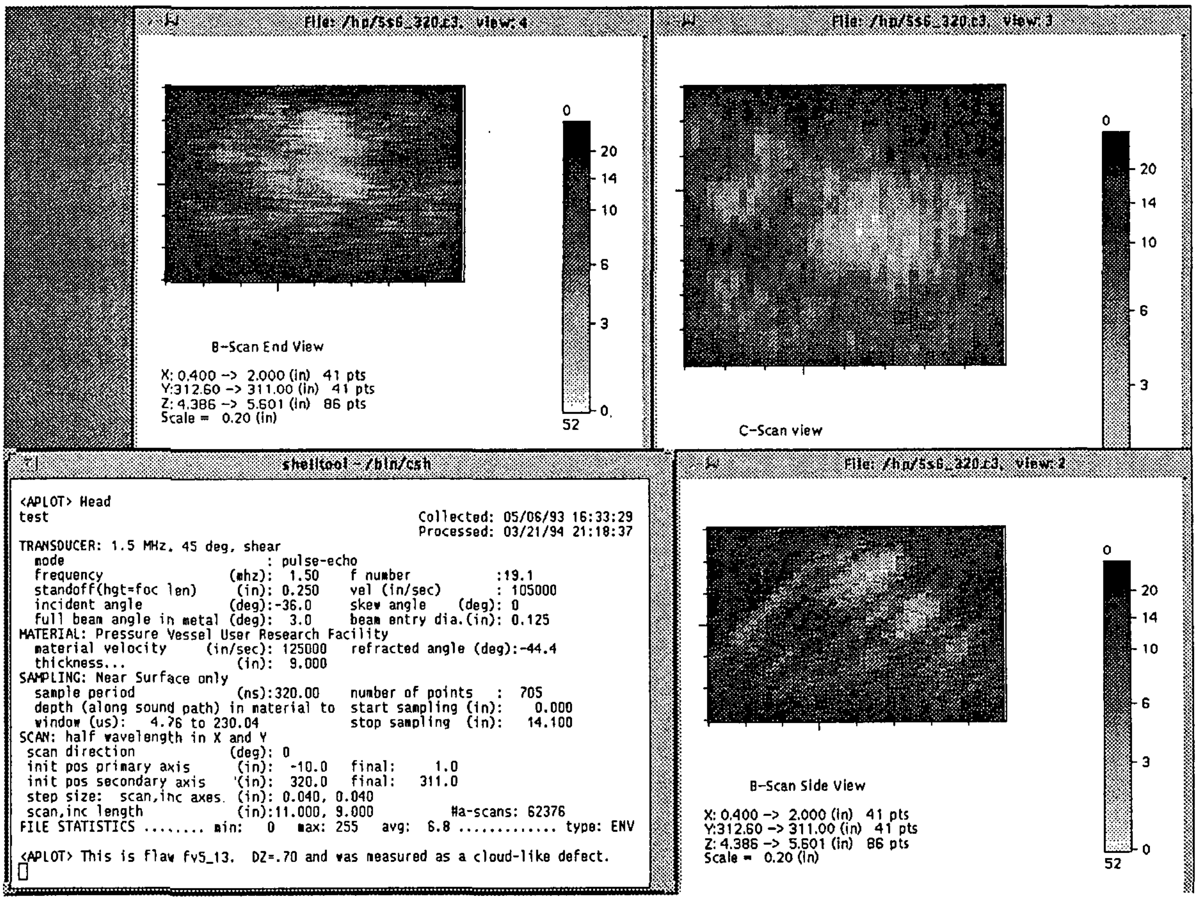


Figure A.103 - Planar indication #16 in the base metal below 25 mm: mode 6

Volumetric Indications in the Base Metal Below 25 mm

Figures A.104a-c show volumetric indication #1 in the base metal below 25 mm. Based on LOS in a cloud like pattern, this volumetric indication has a through-wall extent of 7 mm. The detection was made in modes 6 and 8. In mode 8 the shape was cloud like in nature at a depth of 108 mm. In mode 6 a through-wall extent estimate of 1 mm was obtained from a wave packet width. The shape quality is good for this indication. There was a confirmation in mode 10 at a depth of 115 mm. The two Z values of 108 to 115 mm give an alternate depth size of 7 mm. The indication is characterized as volumetric based on normal beam detection. The length is 19 mm and was made to LOS in mode 6. The width is 6 mm and was made to LOS in mode 10. The aspect ratio (length/depth) of this indication is 3. The maximum amplitude-to-noise ratio is high at 105 to 25. The X coordinate of 28 mm shows that the indication is in the base metal. The Z coordinate of 107 to 115 mm shows that the indication is in the middle third of the vessel.

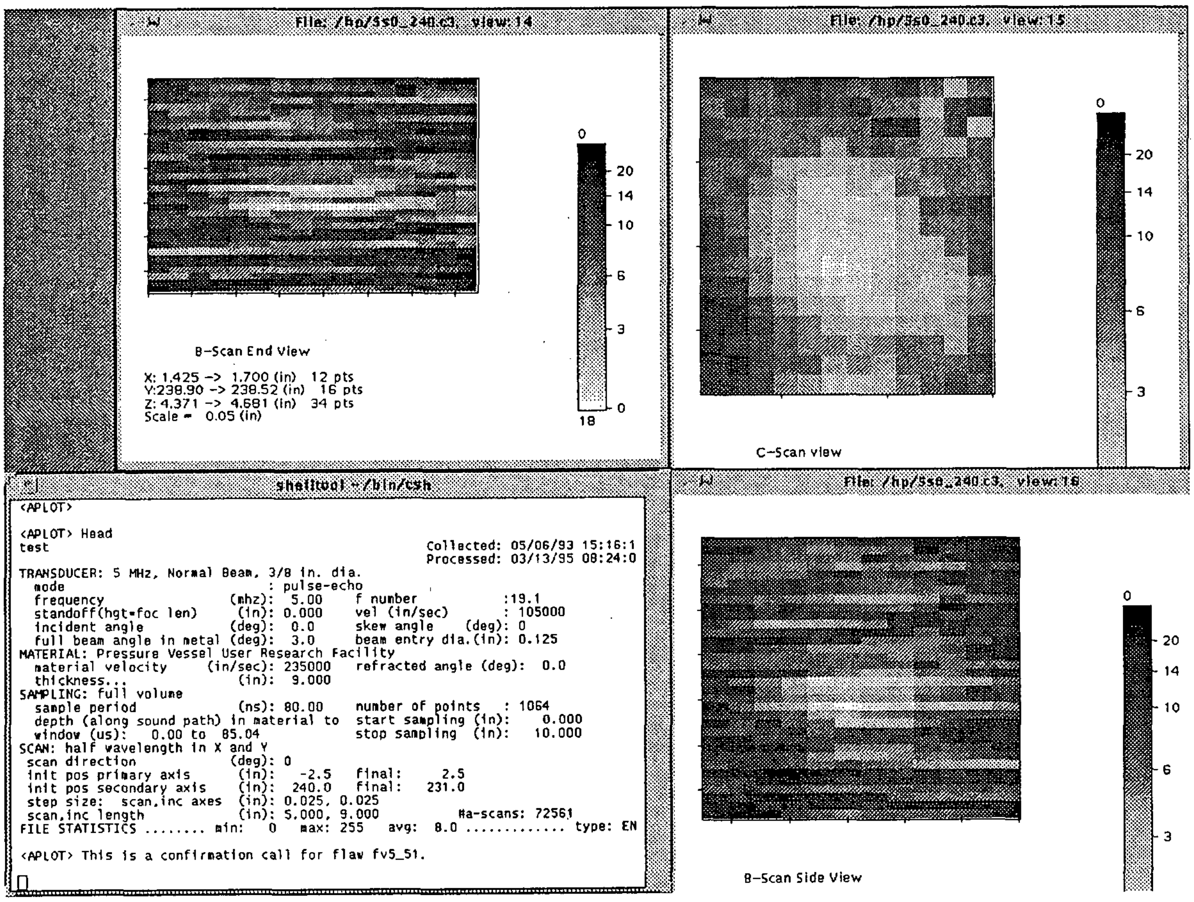


Figure A.104a - Volumetric indication #1 in the base metal below 25 mm: mode 10

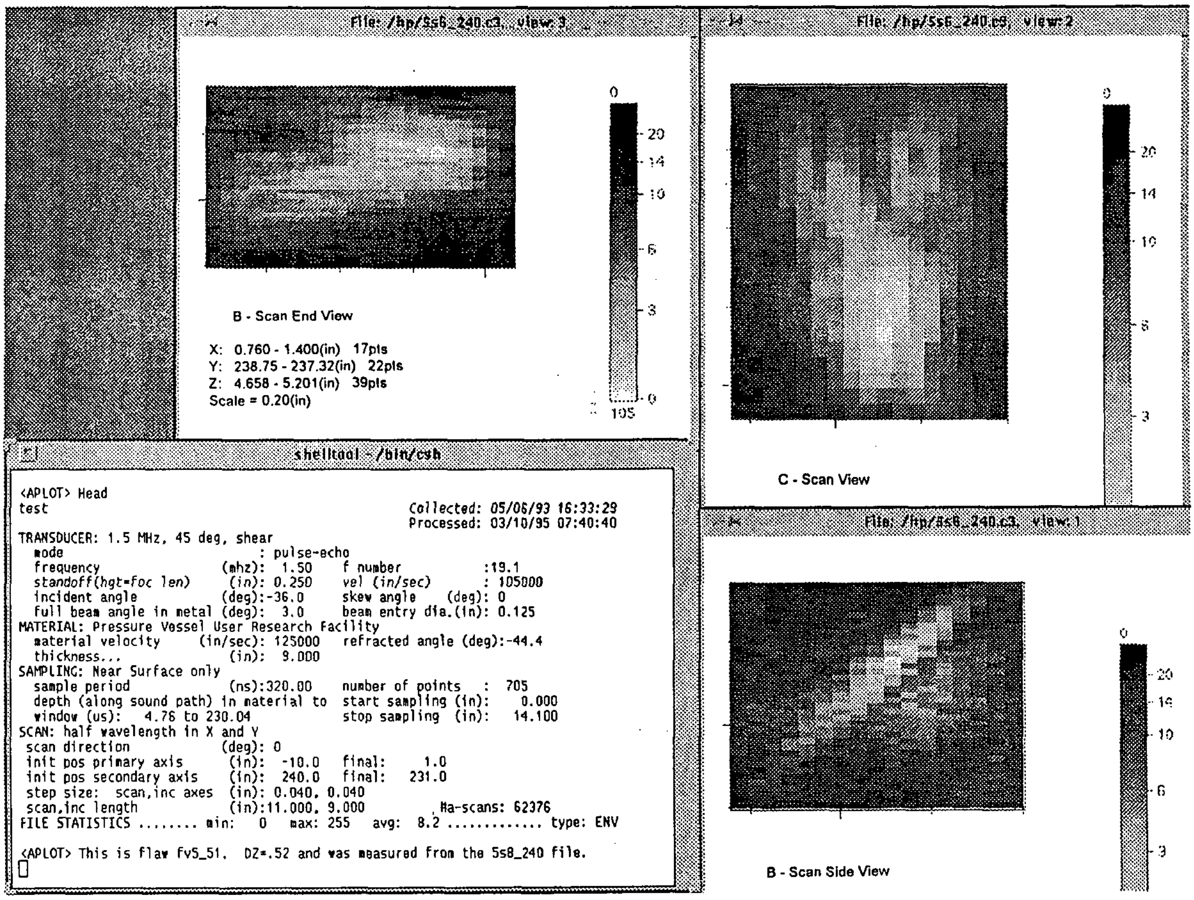


Figure A.104b - Volumetric indication #1 in the base metal below 25 mm: mode 6

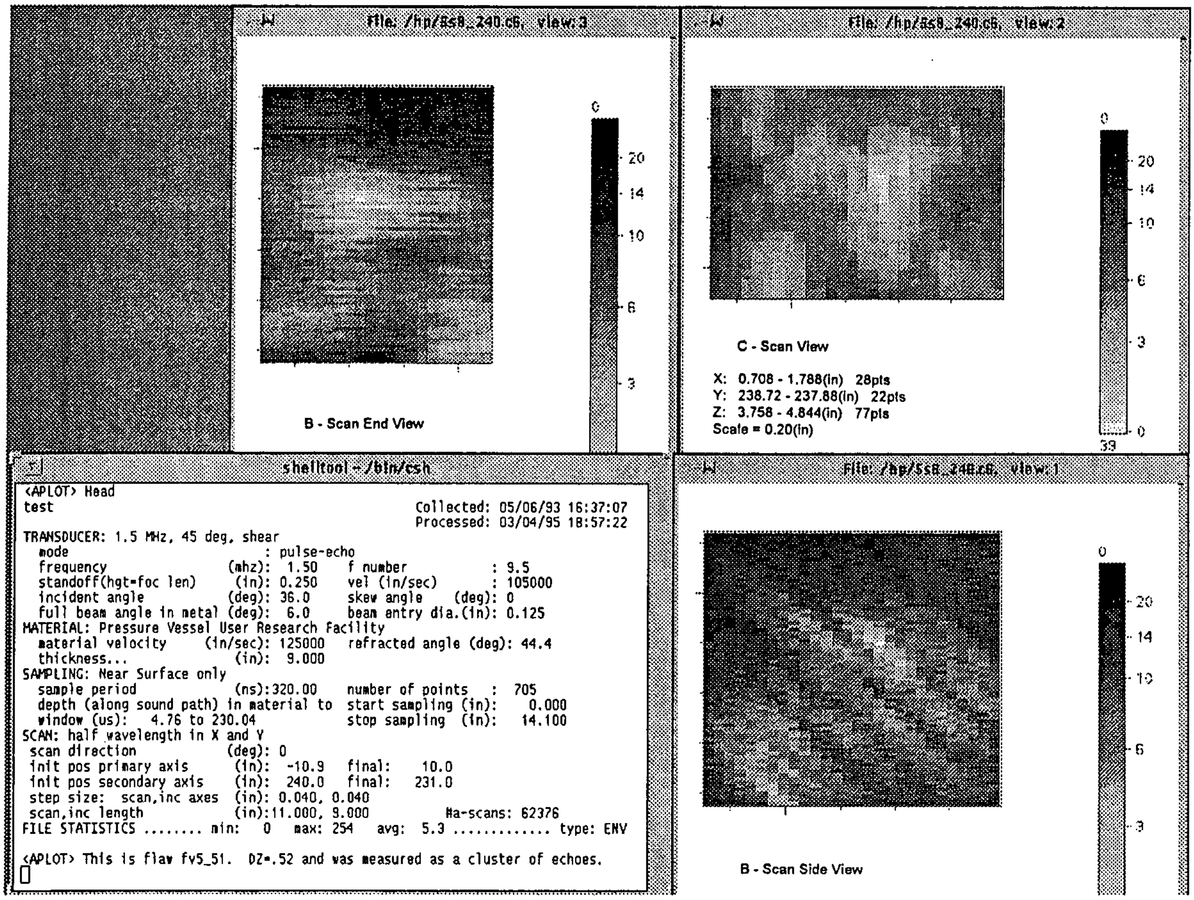


Figure A.104c - Volumetric indication #1 in the base metal below 25 mm: mode 8

Figures A.105a-c show volumetric indication #2 in the base metal below 25 mm. Based on wave packet width in mode 6, this volumetric indication has a through-wall extent of 5 mm. The detection was made in modes 6,7, and 10. In mode 6 it displayed TOF shape at a depth of 118 mm, while in mode 7 it displayed TOF shape at a depth of 113 mm and gave a through-wall extent of 3 mm based on wave packet width. The detection in mode found the indication at a depth of 117 mm. The different Z values of 113 to 118 mm give an alternate depth size of 5 mm. The indication is characterized as volumetric based on normal beam detection. The length is 19 mm and was made to LOS in mode 10. The width is 11 mm and was made to LOS in mode 10. The aspect ratio (length/depth) of this indication is 4 which tends to confirm the large through-wall extent. The maximum amplitude-to-noise ratio is high at 77 to 17. The X coordinate of 58 mm shows that the indication is clearly in the base metal. The Z coordinate of 113 to 118 mm shows that the indication is in the middle third of the vessel.

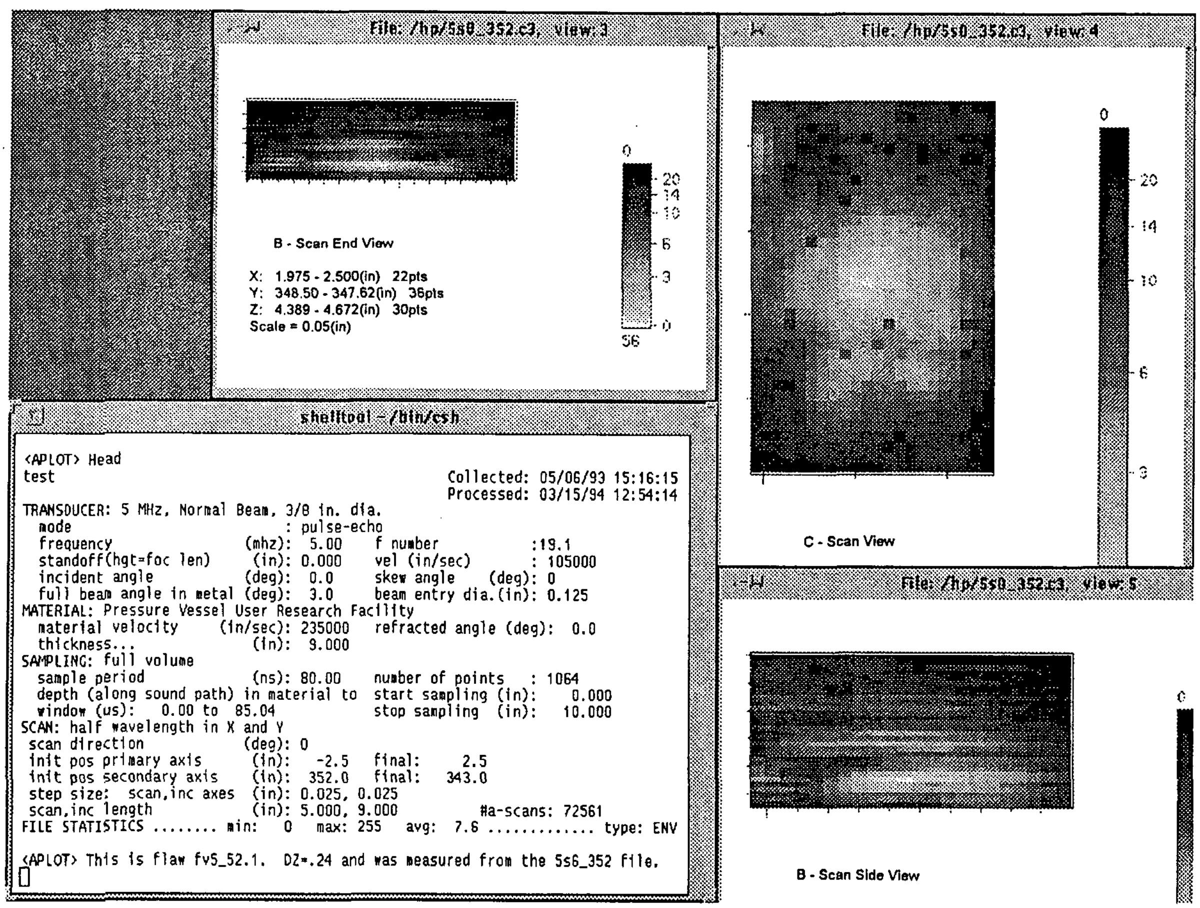


Figure A.105a - Volumetric indication #2 in the base metal below 25 mm: mode 10

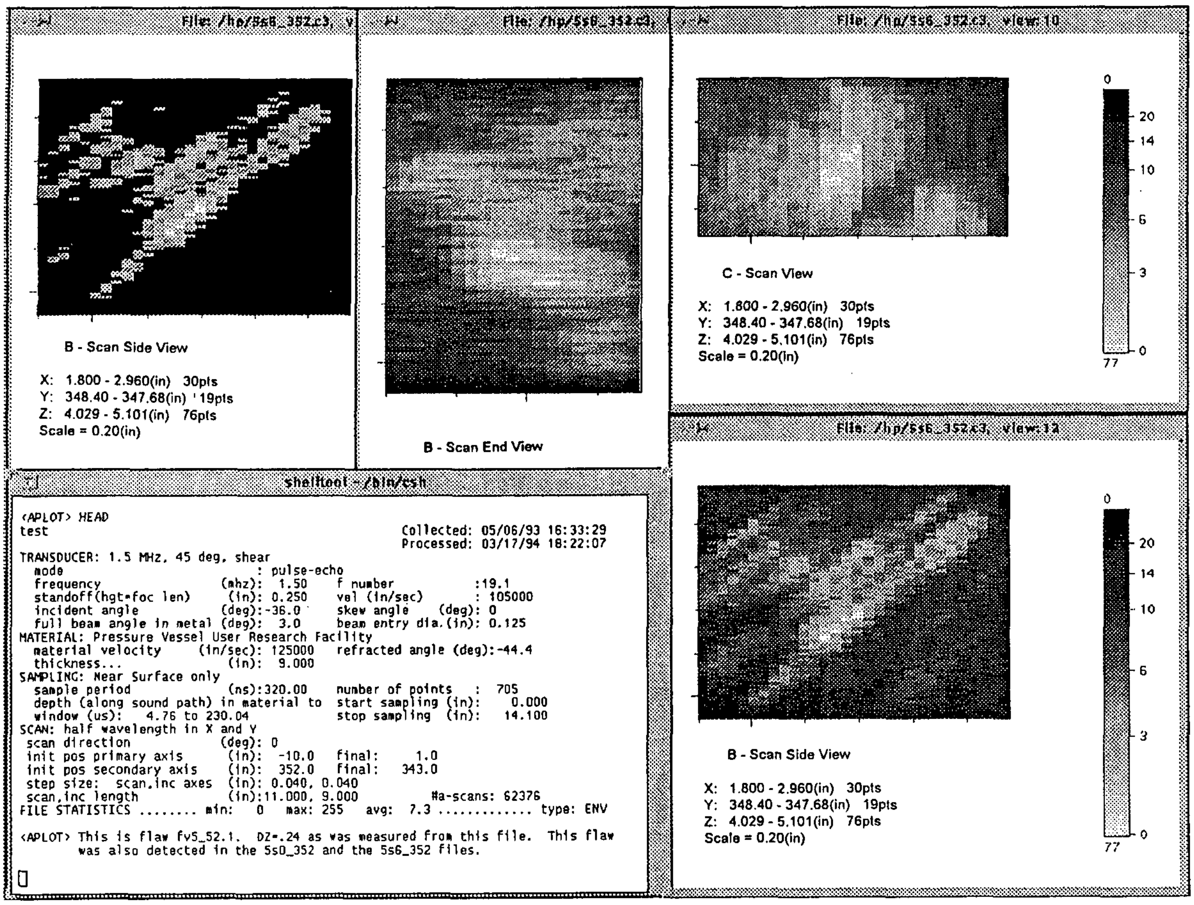


Figure A.105b - Volumetric indication #2 in the base metal below 25 mm: mode 6

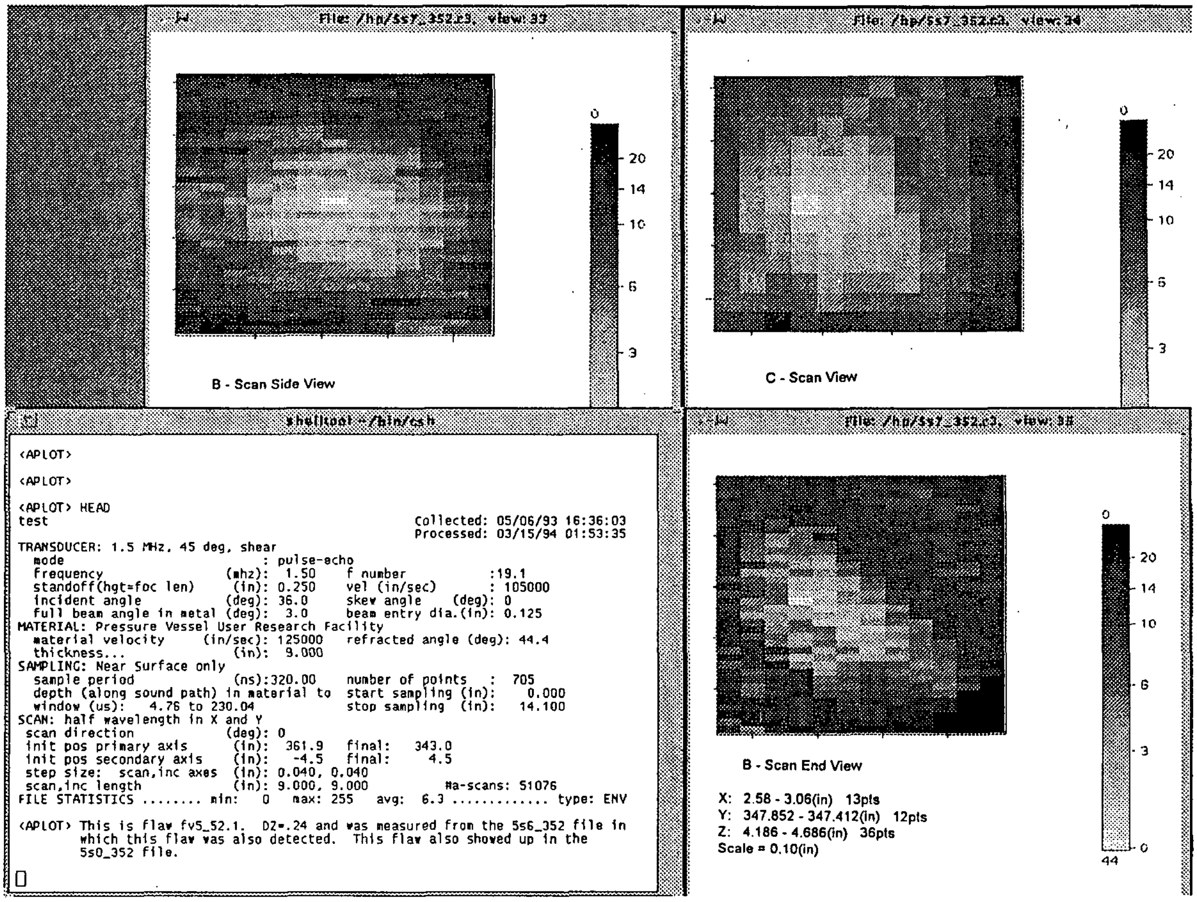


Figure A.105c - Volumetric indication #2 in the base metal below 25 mm: mode 7

Figures A.106a-e show volumetric indication #3 in the base metal below 25 mm. This volumetric indication has a through-wall extent of 5 mm based on wave packet width. The detection was made in mode 8 where it had isolated TOF shape at a depth of 91 mm. More than one TOF shape was present. The shape quality for this indication is good but broken up, implying that more than one small flaw may be present. There were confirmations in modes 6,7,9, and 10 at depths of 86 to 96 mm. The confirmation modes gave a through-wall extent estimate of 3 to 4 mm based on wave packet width. The different Z values of 86 to 96 mm give an alternate depth size of 10 mm. The indication is characterized as volumetric based on normal beam detection and detection in orthogonal modes. The length is 12 mm and was made to LOS in mode 6. The width is 48 mm and was made to LOS in mode 9. The aspect ratio (width/depth) of this indication is 10. The maximum amplitude-to-noise ratio is of medium range at 35 to 10. The X coordinate of 56 mm shows that the indication is clearly in the base metal. The Z coordinate of 86 to 96 mm shows that the indication is in the middle third of the vessel.

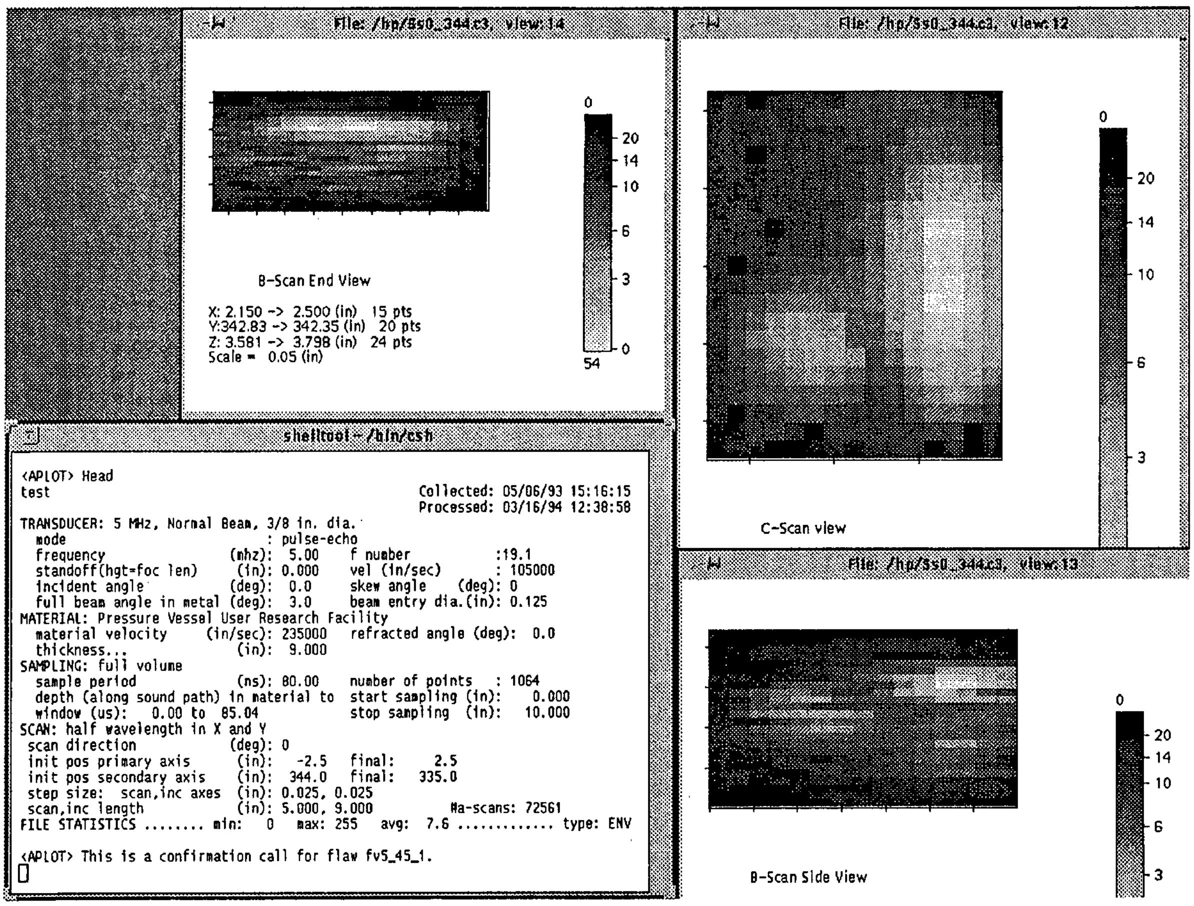


Figure A.106a - Volumetric indication #3 in the base metal below 25 mm: mode 10

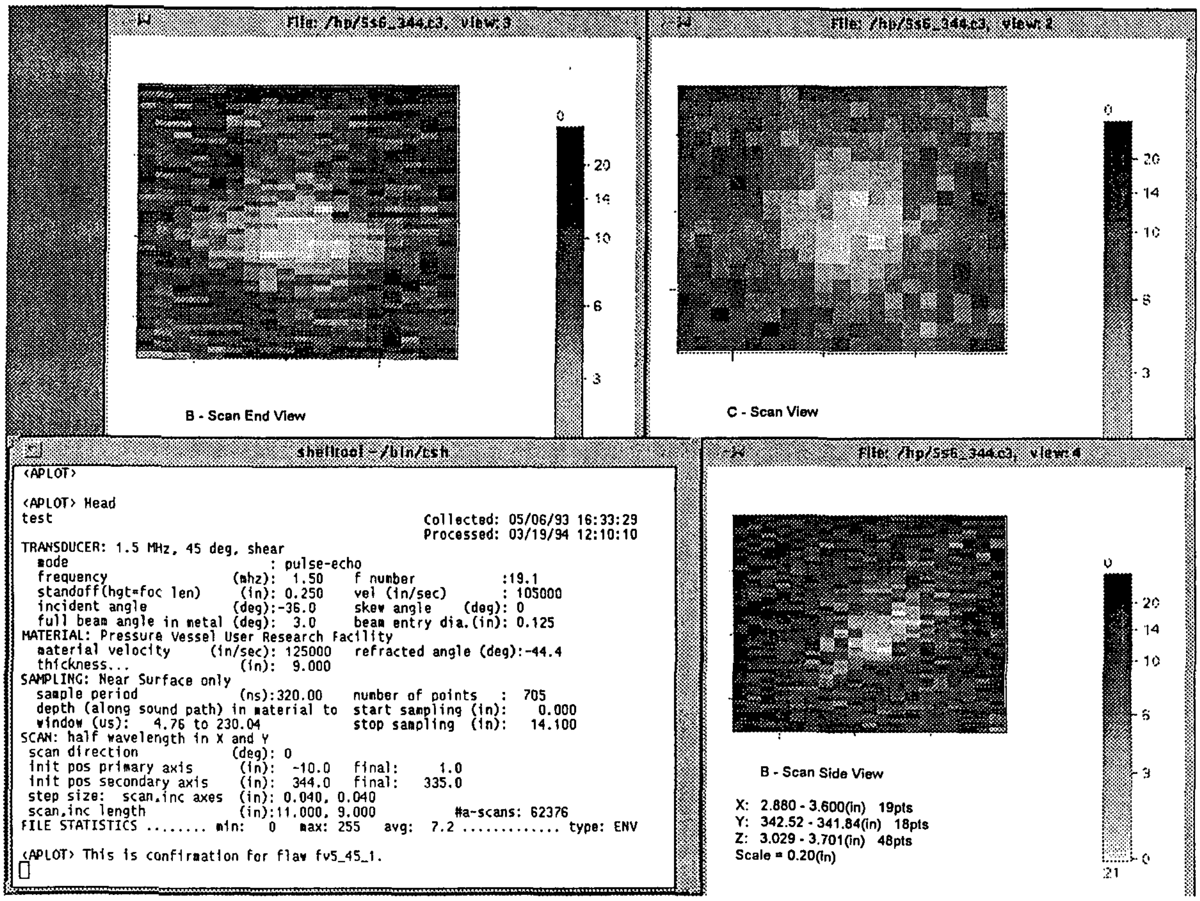


Figure A.106b - Volumetric indication #3 in the base metal below 25 mm: mode 6

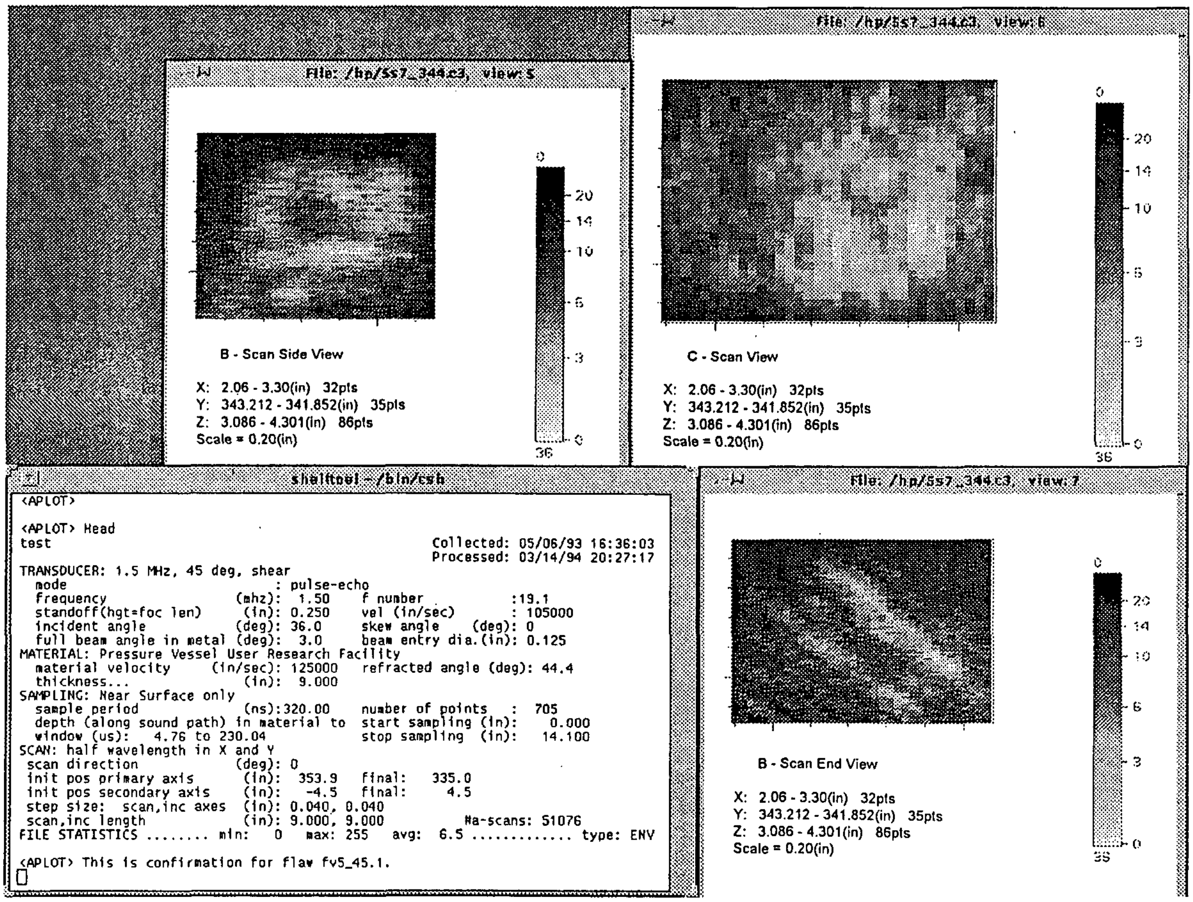


Figure A.106c - Volumetric indication #3 in the base metal below 25 mm: mode 7

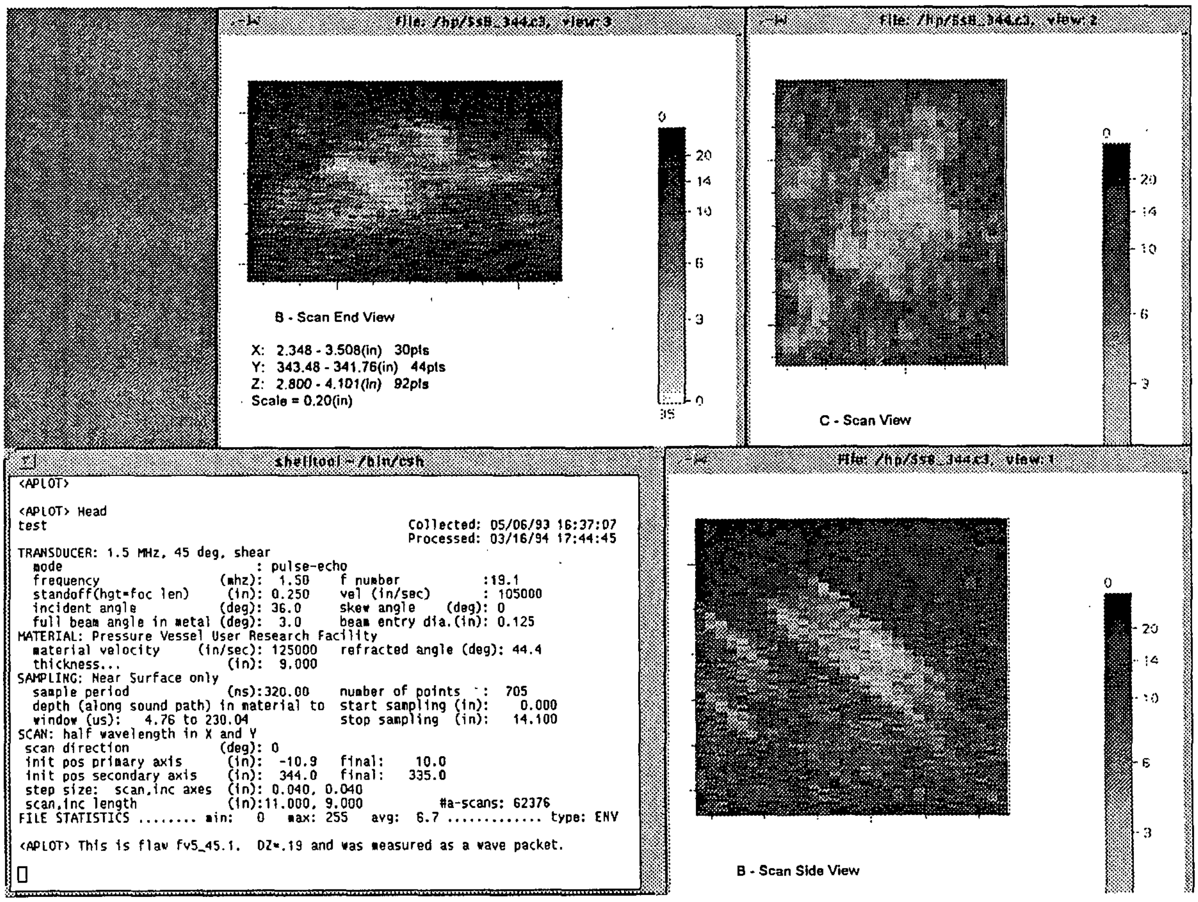


Figure A.106d - Volumetric indication #3 in the base metal below 25 mm: mode 8

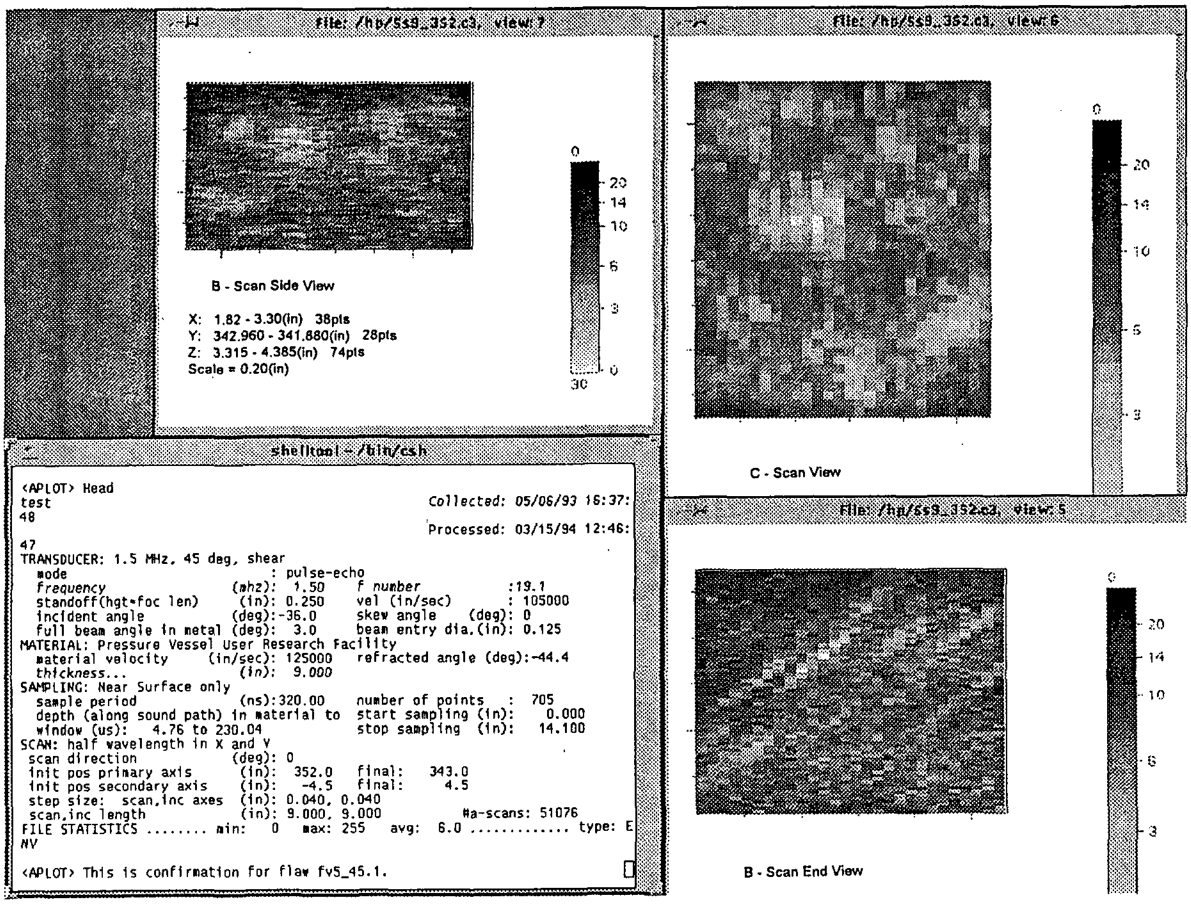


Figure A.106e - Volumetric indication #3 in the base metal below 25 mm: mode 9

Figure A.107 shows volumetric indication #4 in the base metal below 25 mm. This volumetric indication has a through-wall extent of 5 mm based on ring around pattern. The detection was made in mode 7 where it displayed a pair of TOF shapes at a depth of 106 mm. The shape quality is good for this indication. There were no confirmations in other modes. The indication is characterized as volumetric based on the detection of ring around shape. The width is 9 mm and was made to LOS in mode 7. The aspect ratio (width/depth) of this indication is 1.8. The maximum amplitude-to-noise ratio is high at 35 to 8. The X coordinate of 108 mm shows that the indication is clearly in the base metal. The Z coordinate of 106 mm shows that the indication is in the middle third of the vessel.

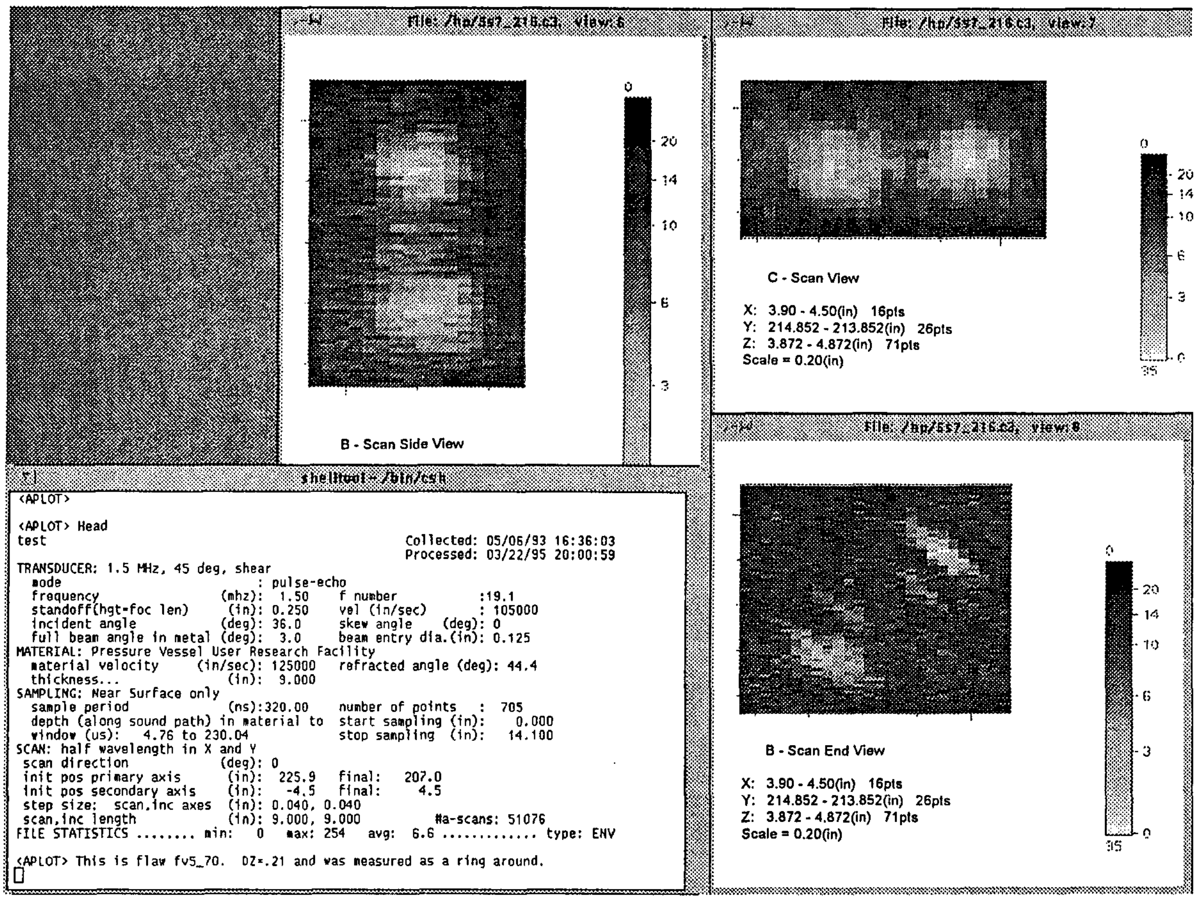


Figure A.107 - Volumetric indication #4 in the base metal below 25 mm: mode 7

Figures A.108a-b show volumetric indication #5 in the base metal below 25 mm. This volumetric indication has a through-wall extent of 5 mm based on wave packet width. The detection was made in mode 6 where it had isolated TOF shape at a depth of 85 mm. The shape quality is good for this indication. There were confirmations in modes 7 and 8 at depths of 81 and 82 mm. The confirmation mode gave a through-wall extent estimate of 1 mm based on wave packet width and 4 mm based on ring around pattern. The different Z values of 81 to 85 mm give an alternate depth size of 4 mm. The indication is characterized as volumetric based on detection in orthogonal modes and the detection of ring around shape. The length is 28 mm and was made to LOS in mode 6. The width is 14 mm and was made to LOS in mode 7. The range of aspect ratios (length/depth) of this indication is 6 to 7 which tends to confirm the large through-wall extent. The maximum amplitude-to-noise ratio is high at 63 to 13. The X coordinate of 29 mm shows that the indication is in the base metal, possibly in the HAZ. The Z coordinate of 81 to 85 mm shows that the indication is in the middle third of the vessel.

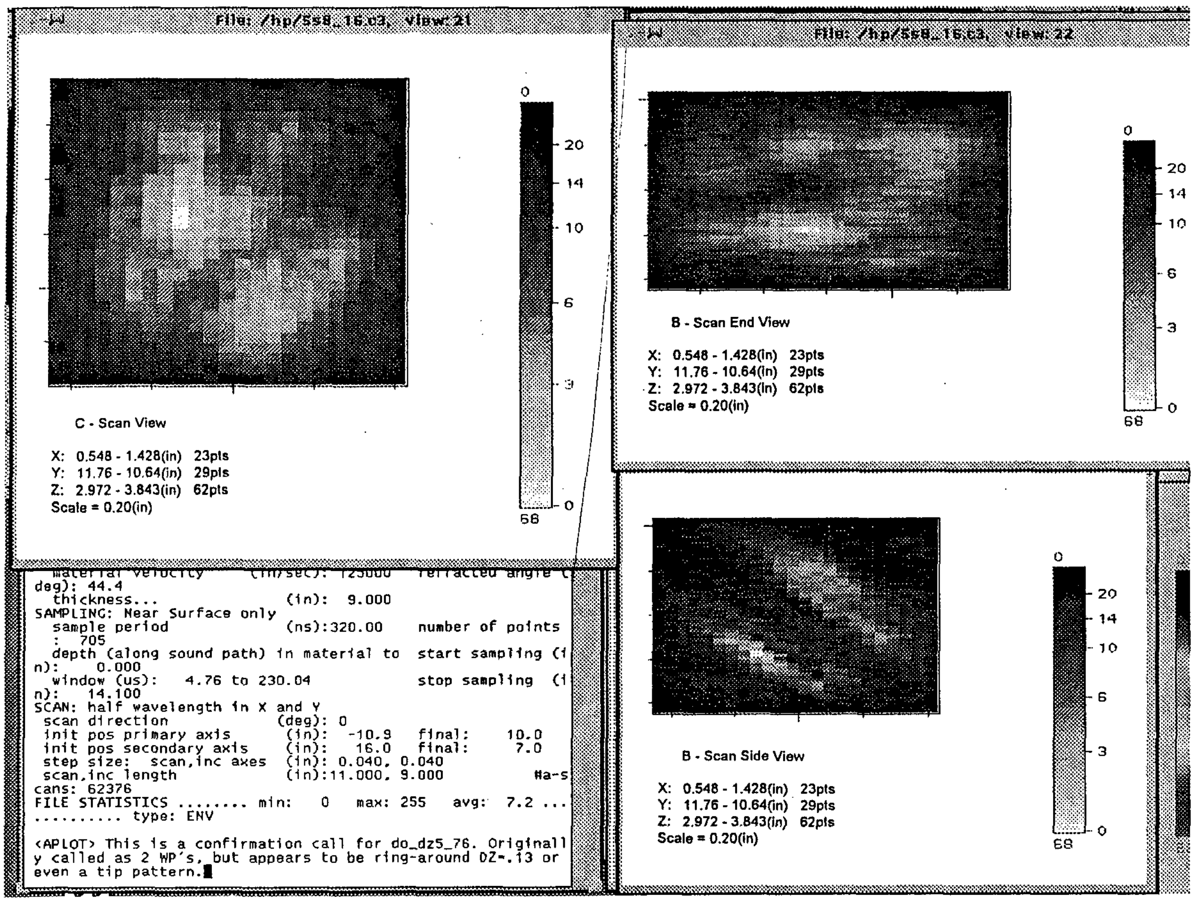
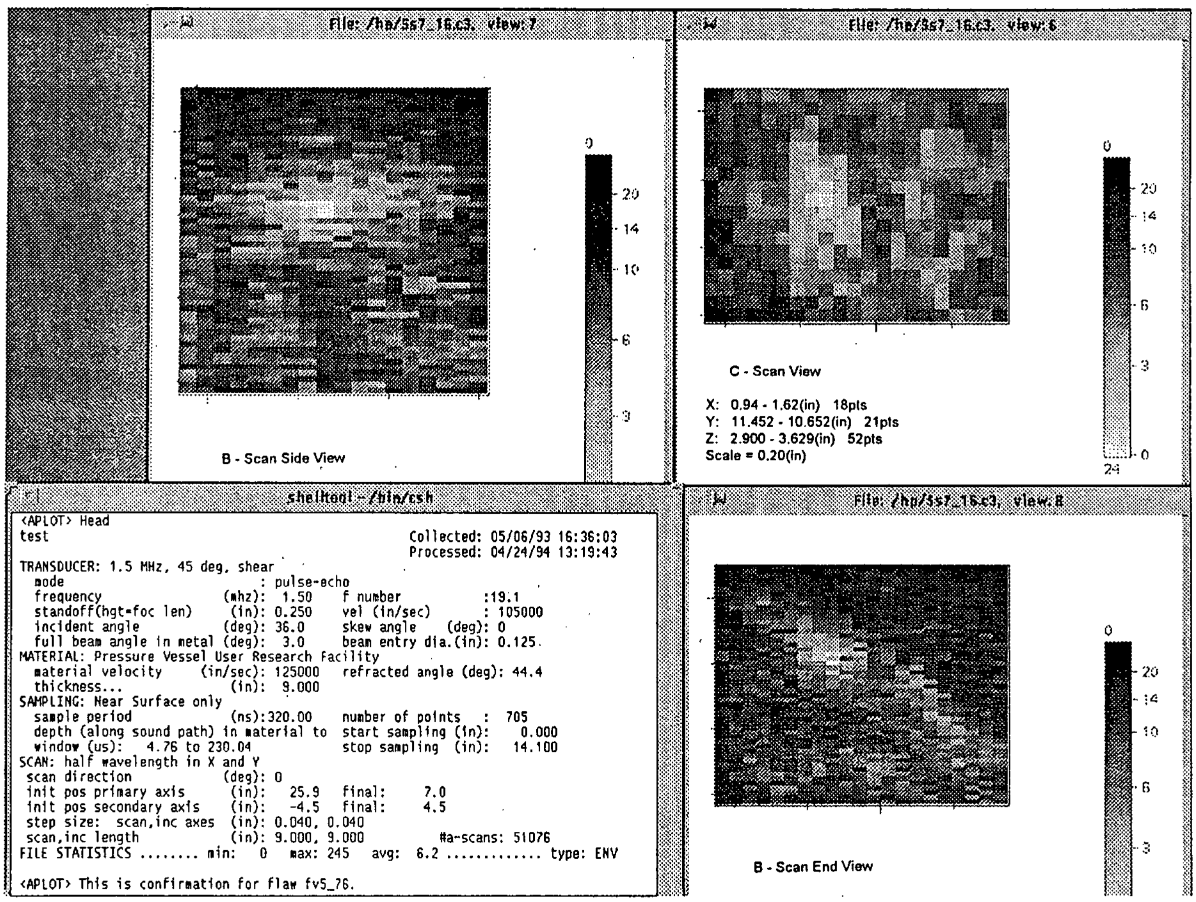


Figure A.108a - Volumetric indication #5 in the base metal below 25 mm: mode 8



-Figure A.108b - Volumetric indication #5 in the base metal below 25 mm: mode 7

Figures A.109a-b show volumetric indication #6 in the base metal below 25 mm. This volumetric indication has a through-wall extent of 5 mm based on wave packet width. The detection was made in mode 6 where it had isolated TOF shape at a depth of 130 mm. The shape quality for this indication is good but broken up, implying that more than one small flaw may be present. There was a confirmation in mode 10 at a depth of 128 mm. The two Z values of 128 to 130 mm give an alternate depth size of 2 mm. The indication is characterized as volumetric based on normal beam detection. The length is 20 mm and was made to LOS in mode 6. The width is 9 mm and was made to LOS in mode 10. The aspect ratio (length/depth) of this indication is 4 which tends to confirm the large through-wall extent. The maximum amplitude-to-noise ratio is of medium range at 86 to 24. The X coordinate of 31 mm shows that the indication is in the base metal, possibly in the HAZ. The Z coordinate of 128 to 130 mm shows that the indication is in the middle third of the vessel.

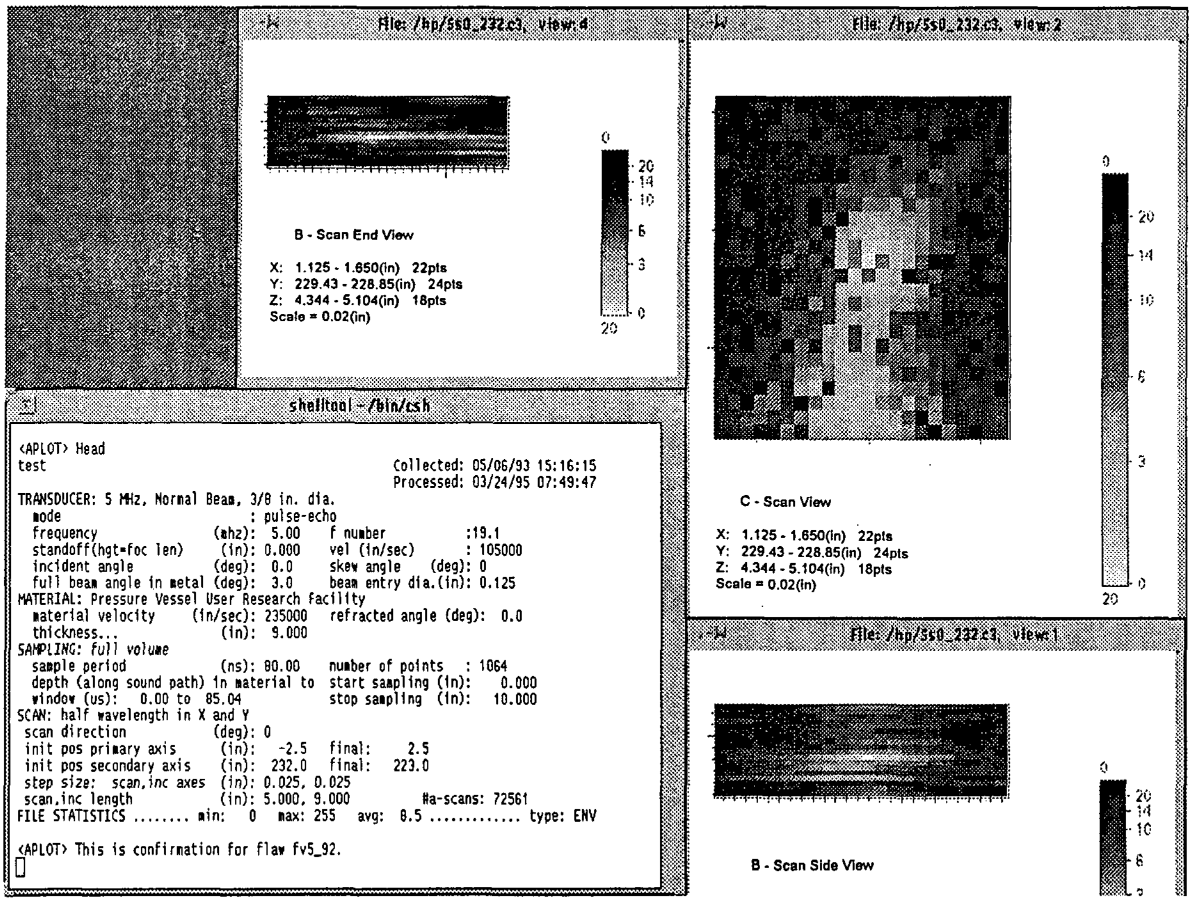


Figure A.109a - Volumetric indication #6 in the base metal below 25 mm: mode 10

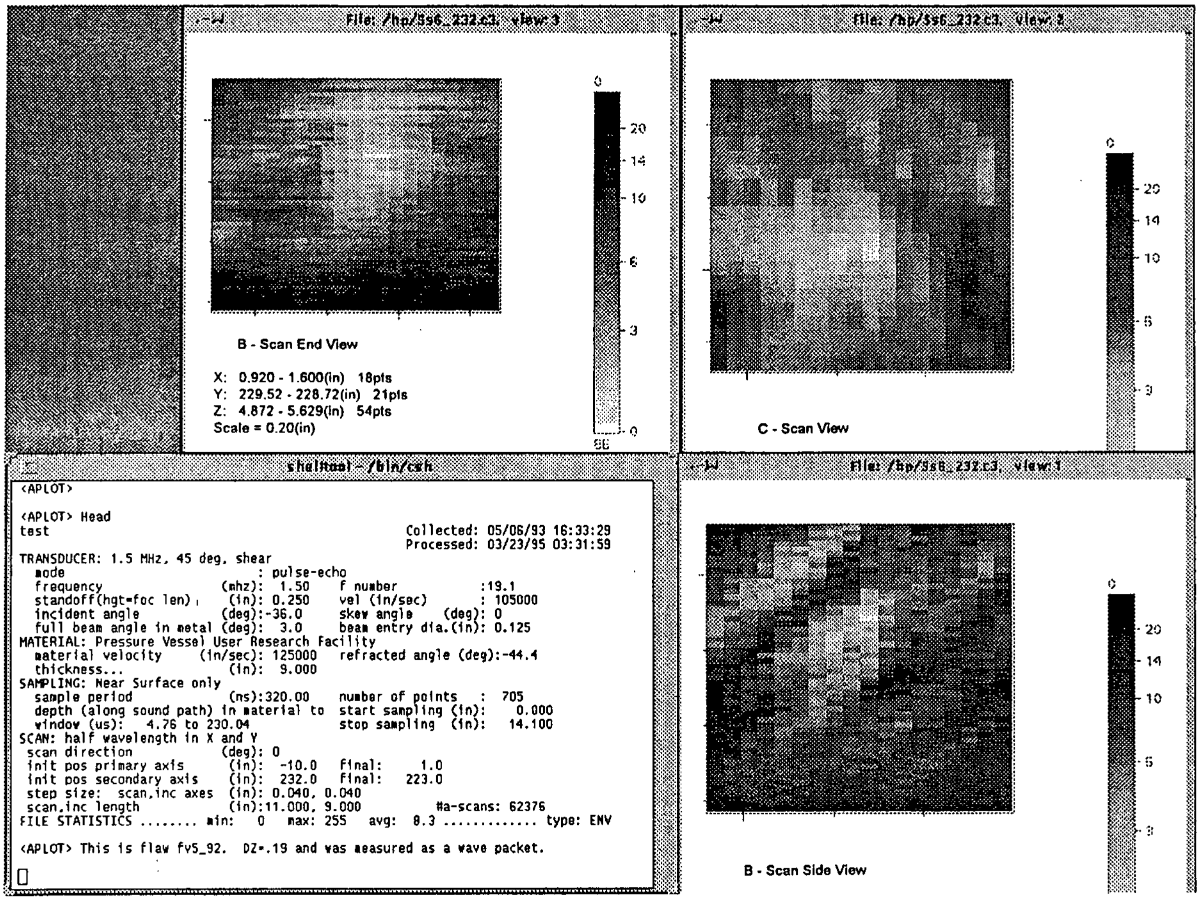


Figure A.109b - Volumetric indication #6 in the base metal below 25 mm: mode 6

Figures A.110a-b show volumetric indication #7 in the base metal below 25 mm. This volumetric indication has a through-wall extent of 5 mm based on ring around pattern. The detection was made in mode 6 where it displayed a pair of TOF shapes at a depth of 103 mm. The shape quality is good for this indication. There was a confirmation in mode 8 at depth of 104 mm. The confirmation mode gave a through-wall extent estimate of 2.5 mm based on wave packet width. The two Z values of 103 to 104 mm give an alternate depth size of 1 mm. The indication is characterized as volumetric based on the detection of ring around shape. The length is 46 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 9. The maximum amplitude-to-noise ratio is low at 13 to 6. The X coordinate of 48 mm shows that the indication is clearly in the base metal. The Z coordinate of 103 to 104 mm shows that the indication is in the middle third of the vessel.

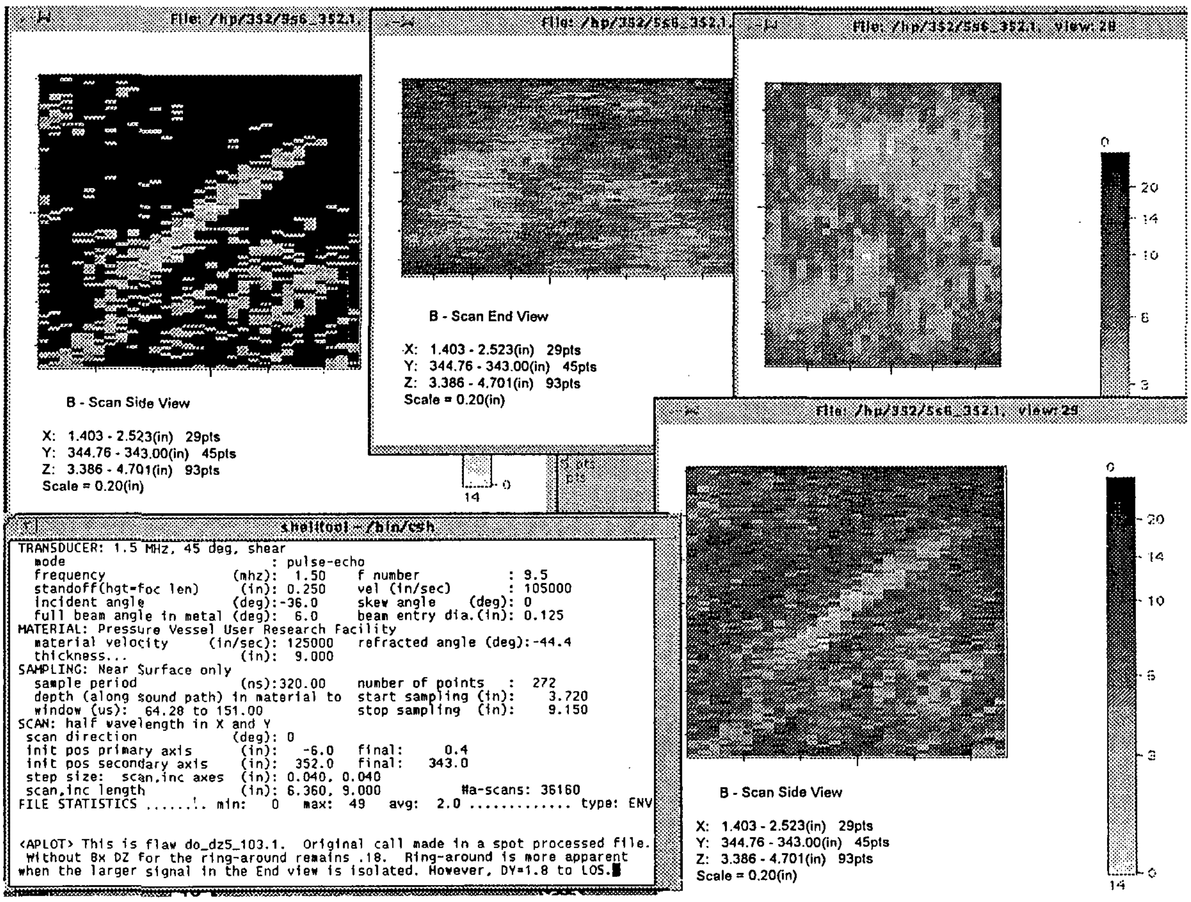


Figure A.110a - Volumetric indication #7 in the base metal below 25 mm: mode 6

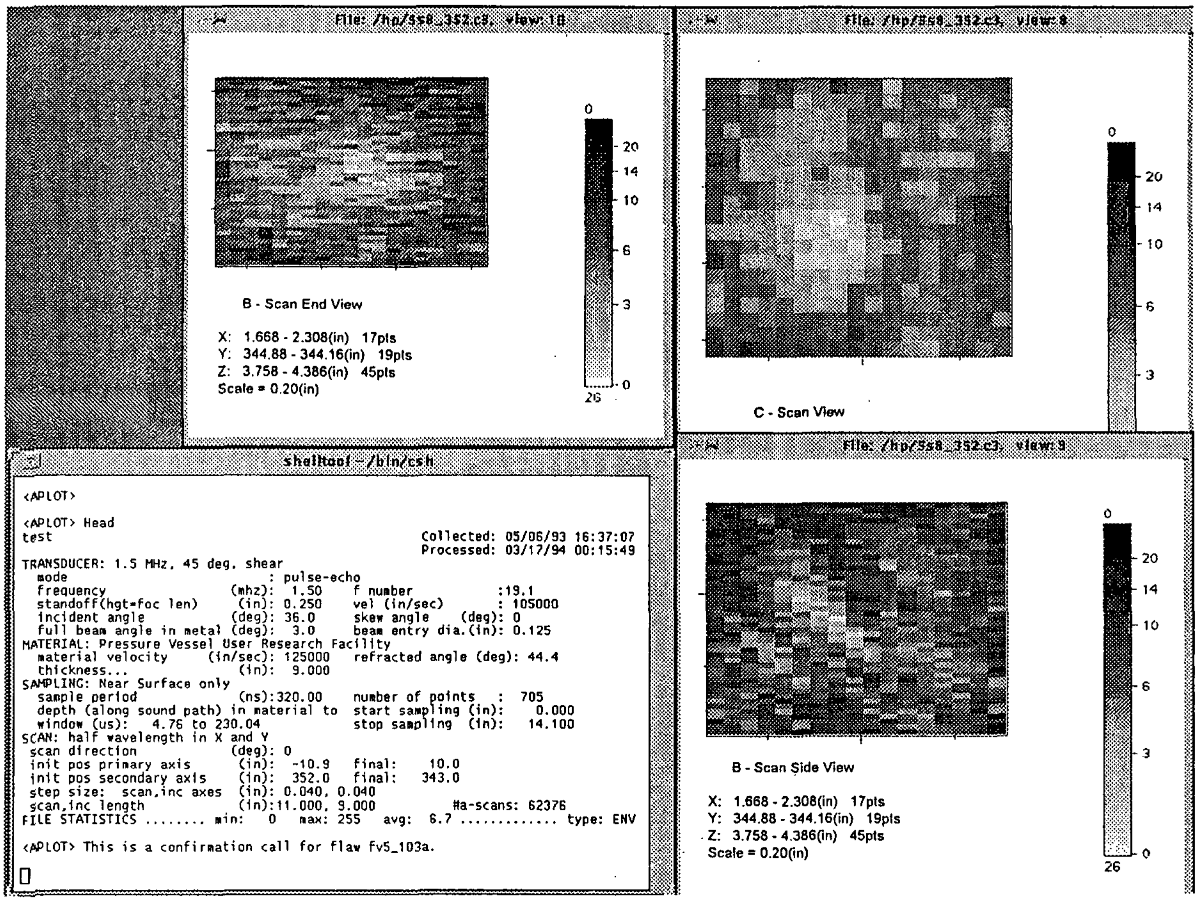


Figure A.110b - Volumetric indication #7 in the base metal below 25 mm: mode 8

Figure A.111 shows volumetric indication #8 in the base metal below 25 mm. This volumetric indication has a through-wall extent of 4 mm based on ring around pattern. The detection was made in mode 6 where it displayed a pair of TOF shapes at a depth of 119 mm. The shape quality for this indication is good but broken up, implying that more than one small flaw may be present. There were no confirmations in other modes. The indication is characterized as volumetric based on the detection of ring around shape. The length is 41 mm and was made to LOS in mode 6. The aspect ratio (length/depth) of this indication is 10 which tends to confirm the large through-wall extent. The maximum amplitude-to-noise ratio is of medium range at 79 to 24. The X coordinate of 26 mm shows that the indication is in the base metal, possibly in the HAZ. The Z coordinate of 119 mm shows that the indication is in the middle third of the vessel.

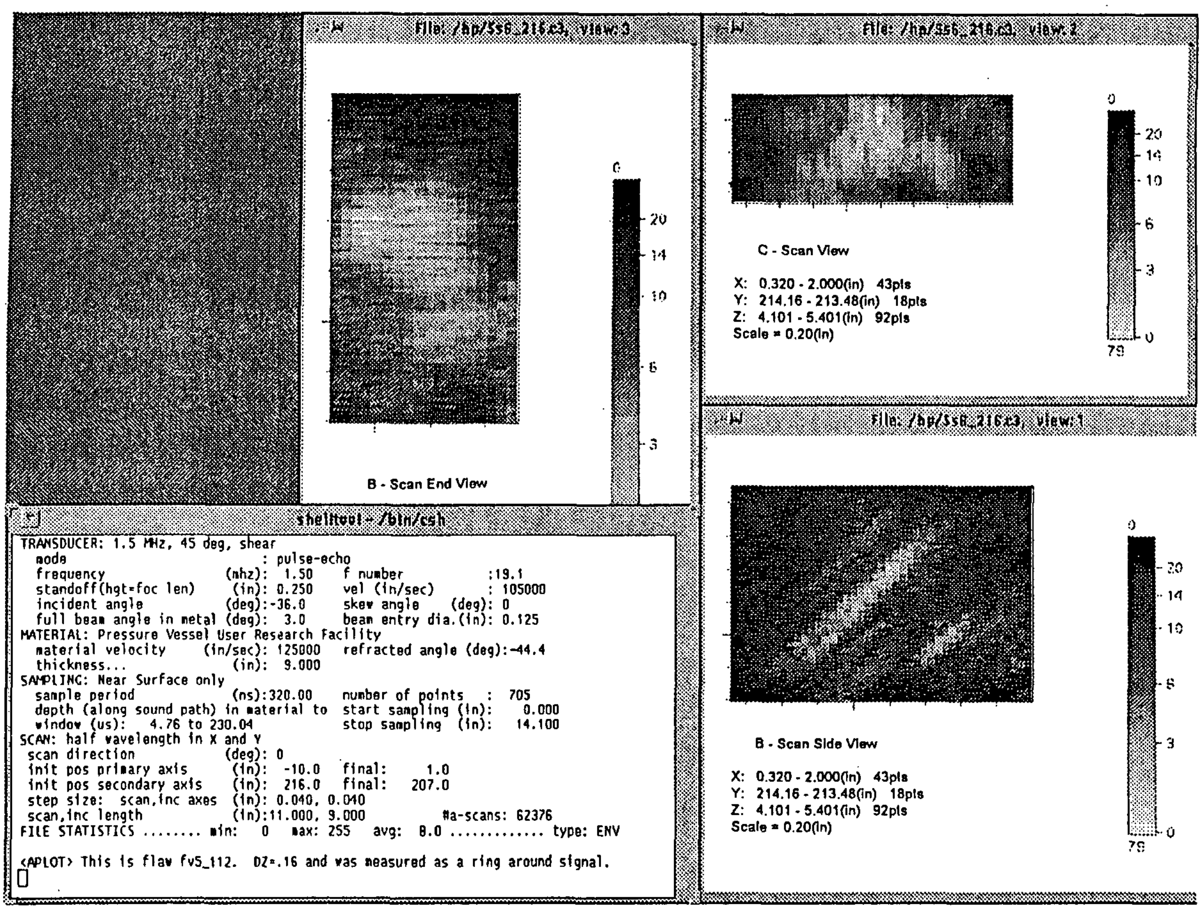


Figure A.111 - Volumetric indication #8 in the base metal below 25 mm: mode 6

Appendix B

Inspections of the Midland Vessel

Appendix B

Inspections of the Midland Vessel

This appendix contains the results of a nondestructive examination of nuclear reactor vessel weldment for the presence of fabrication defects. Sections of material, approximately 1219 mm (4 ft.) in length, were cut from an unused nuclear reactor vessel, the Midland Vessel, by Babcock and Wilcox (Booth 1998) and sent to the EPRI NDE Center. PNNL conducted a sequence of ispections using the Synthetic Aperture Focusing Technique for Ultrasonic Testing (SAFT-UT) on this vessel material under the sponsorship of the U.S. Nuclear Regulatory Commission for the purpose of detecting and characterizing the fabrication (preservice) defects. The results of these SAFT-UT inspections are the subject of this report.

Among the principle findings of this analysis is that the SAFT-UT data correlates with a destructive analysis of one block of the material. The results of this correlation demonstrate that the majority of the destructively analyzed flaws are ready apparent in the SAFT-UT data. The SAFT-UT inspections of approximately 1000 square inches of clad surface area show eight total defects at the clad to base metal interface. All of the eight defects are less than 2.2 mm in through-wall extent and in the range of 2 to 15 mm in lateral extent. In 164 linear inches of weld, 23 total defects were found in the weldment, heat-affected zone, and base metal. Of these 23 defects, 17 had a through-wall extent of 2 mm or less. The remaining 6 defects had a through-wall extent in the range of 5 to 18 mm. The lateral extent of the 23 base-metal defects was in the range of 5 to 36 mm. The size distribution of flaws as measured by SAFT-UT in the Midland blocks is estimated to be not measurably different in shape from that of the Marshall distribution; however, the overall density of flaws is estimated to be substantially larger than that of the Marshall distribution.

Recommendations are given in this appendix for gaining additional resolving power using SAFT-UT. The frequencies of transducers, scanning step sizes, and requisite data volumes for examining vessel material for fabrication defects are discussed. The use of material coordinates for inspection systems is recommended for efficiency in analysis and protecting the quality of the data.

Appendix B provides the reader with an understanding of the vessel material that was inspected and the kinds of inspections that were performed by SAFT-UT. A correlation of the SAFT-UT indications that were found in the data with a destructive analysis of a fraction of the material is also given. Finally, the detection methods, the sizes and types of the defects, and the distribution of those defects in important categories are documented in this Appendix.

1.0 Introduction

This report is part of a program, sponsored by the U.S. Nuclear Regulatory Commission (NRC), to develop a technical data base for fabrication flaws that exist in nuclear reactor pressure vessels (RPV). In this program, samples of RPV material are examined to detect and characterize the flaws introduced into the material when it was fabricated. The obtained flaw data can then be used to estimate rates of occurrences in a portion of the reactor population.

During the month of June 1989, the Midland blocks, consisting of material removed from the beltline region of the Midland reactor pressure vessel were examined using the Synthetic Aperture Focusing Technique for Ultrasonic Testing (SAFT-UT) developed by PNNL under sponsorship of the U.S. NRC. The SAFT-UT system provides very high-resolution images for use in reliably detecting flaws and accurately sizing the flaws detected. The SAFT-UT system was taken to the Electric Power Research Institute (EPRI) NDE Center in Charlotte, North Carolina, where the Midland blocks were sent after being cut from the reactor pressure vessel. Ultrasonic and radiographic test were performed by NDE Center staff and SAFT-UT examinations were performed by PNNL staff. The purpose of the SAFT-UT inspections was to obtain information on the population of fabrication flaws in the Midland vessel.

Data from a destructive analysis of a portion of the vessel material, obtained from the EPRI NDE Center, has been correlated with the SAFT-UT data. The destructively analyzed flaws have been used to confirm the sizing accuracy and adjust the detection and characterization method. The adjusted characterization method has been applied to all of the indications in the SAFT-UT data and a complete set of images are provided in the report. The distribution of flaws in important categories is provided in the report.

This report contains a description of the Midland blocks. The physical characteristics of the blocks, including the thickness of the cladding, are reported in Section 2. The details of the SAFT-UT inspections are given in Section 3. This section contains a description of what portion of each Midland block was inspected. It contains a specification for the transducers used. Section 4 contains the correlation of the SAFT-UT data with a destructive analysis of one of the Midland blocks. This section contains a description of the detection and sizing methods for SAFT-UT indications as supported by the destructive analysis. Section 5 contains a complete analysis of the indications of the fabrication defects found by SAFT-UT in the Midland blocks. The images of the indications are included in this section. Section 5 should be skipped by those who are not interested in the specifics of the SAFT-UT images. Section 6 contains the distribution of the fabrication flaws in important categories, and Section 7 describes the recommendations for use of SAFT-UT to conduct inspections of reactor pressure vessel material.

2.0 Description of Midland Blocks

Information obtained from Babcock and Wilcox indicated that this vessel was manufactured by piercing a large ingot of steel and then rolling it until a ring of the proper shape and size was obtained. The cladding was deposited using a multi-wire (either 3 or 6) process and then it was smoothed with a belt grinder. The cladding is nominally 6 mm (1/4-in.) thick with a minimum thickness of 4.8 mm (3/16 in.).

The blocks were nominally 224 mm (8.8 in.) thick and 762 mm (30 in.) wide. Block lengths varied but were about 1219 mm (48 in.) long. The reactor pressure vessel (RPV) circumferential weldment was centered in the blocks. Three of the blocks inspected by SAFT-UT were cut down in size so that they were only 305 mm (12 in.) wide, in preparation for subsequent machining into mechanical test specimens. The location, type, orientation, and size of all of the detected flaws were to be estimated. This information would provide guidance for machining the mechanical test specimens in order to avoid unintentionally including flawed material in the study of the mechanical properties of non-degraded and intentionally degraded reactor vessel material.

Blocks were removed from three circumferential welds as shown in Figure 2.1. The blocks were numbered with the weld number (1, 2, or 3) and then with the order of removal in the sequence as show in the figure. Block 1-8 is then the eighth block removed from weld number 1. Weld #1, sometimes referred to as the beltline weld, is the weld between the lower shell course and the intermediate shell course of the vessel.

A coordinate system was established for each of the blocks and fiducial marks were placed on the blocks for use in the NDE. The weld center line was marked and the distance along the weld was measured as either plus or minus a distance from a fiducial mark near the center of the block. Figure 2.2 shows the nominal cross section of the weld.

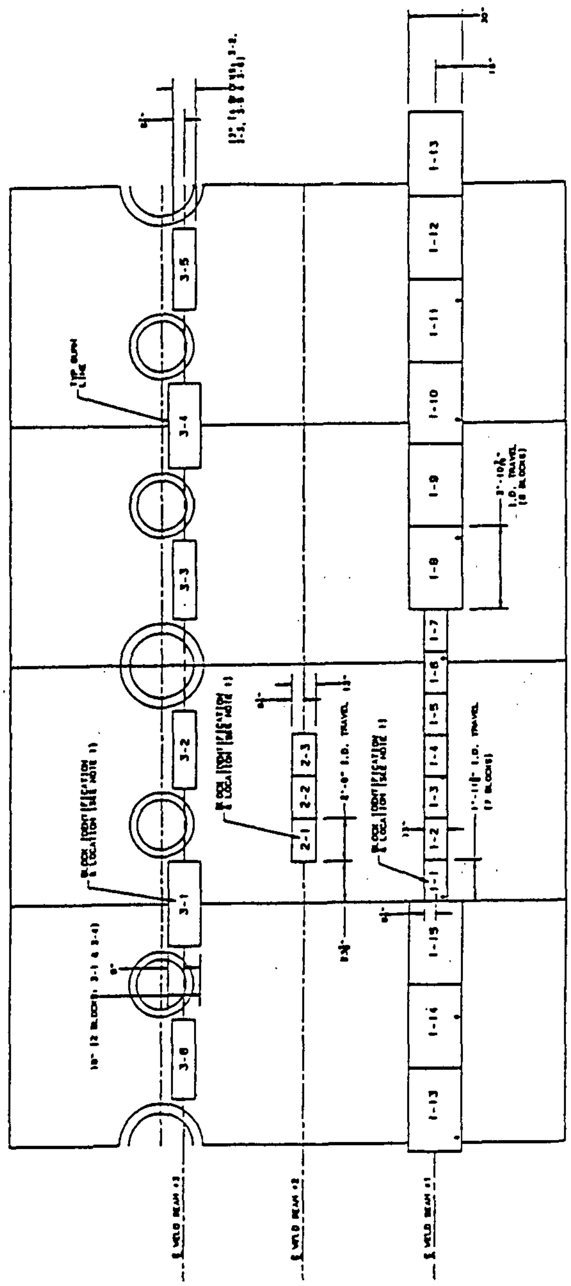


Figure 2.1 Diagram of Material Removed from the Midland Vessel
Source: Babcock & Wilcox Co. (1989)

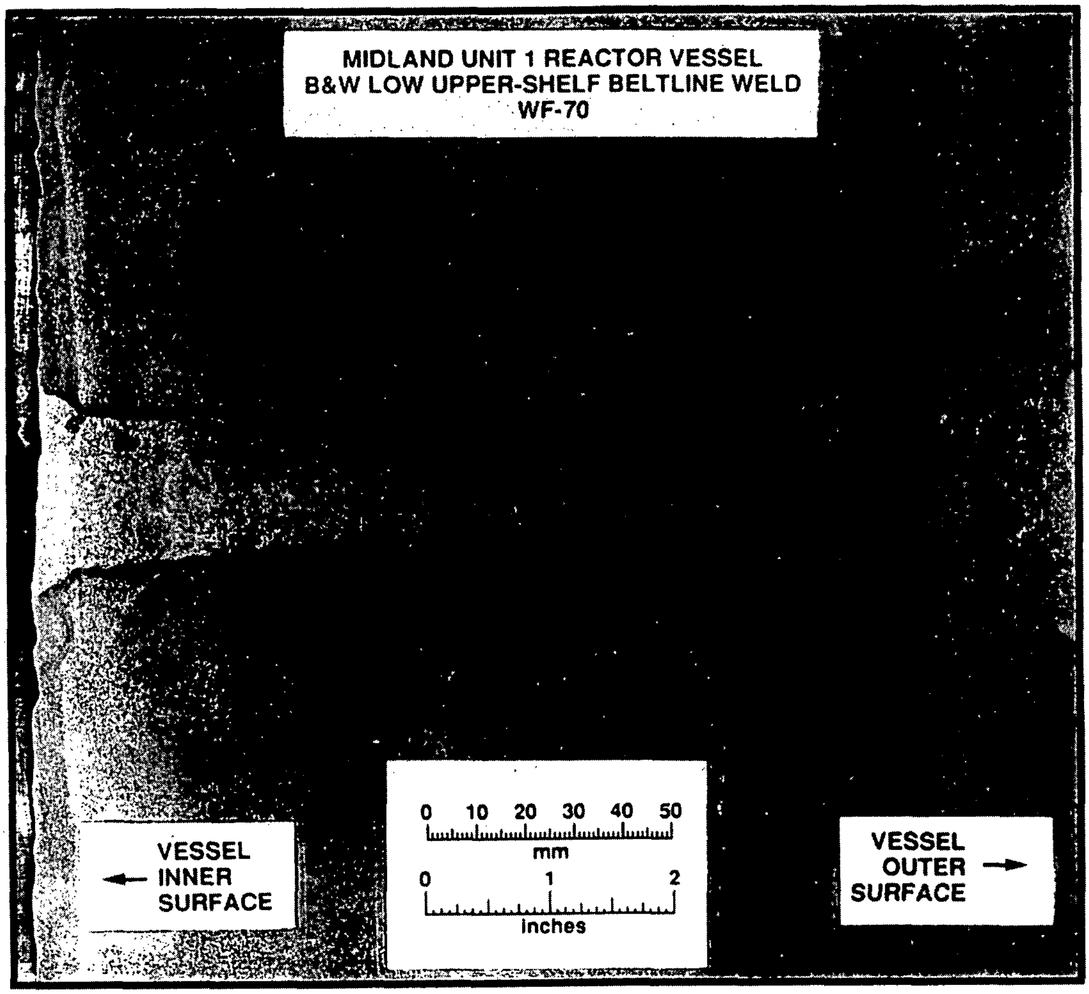


Figure 2.2 Photograph of Weld Cross Section
(Provided by Oak Ridge National Laboratory)

3.0 SAFT-UT Measurements

Four of the blocks that were cut from the beltline weld of the Midland vessel were inspected by SAFT-UT. The inspections covered a total of 4166 mm (164 in.) of circumferential weld length by collecting 155 files containing 650 Mbytes of data. Figure 3.1 shows some of the Midland blocks at the EPRI NDE Center when the SAFT-UT inspections were starting. Figure 3.2 shows the SAFT-UT system during the inspections. Figures 3.3 and 3.4 show the scanning configuration on Block 1-8.

As described in Section 2, a coordinate system was established for each block. The center line of the weld was marked and this line, replacing the circumferential axis of the vessel, is labeled the "Y" axis in this report. The distance across the weld, replacing the height axis of the vessel, is labeled the "X" axis in this report.

3.1 SAFT-UT Inspections of Midland Block 1-8

Block 1-8 was the first block inspected by SAFT-UT. This block was 224 mm (8.8 in.) thick, 1156 mm (45.5 in.) in circumferential length, and 722 mm (30.4 in.) high. Because of the scanner's geometry, a decision was made to scan the central 787 mm (31 in.) of the block and only return to the outer portions if time permitted.

Table 3.1 describes the inspections that were made on Block 1-8 by SAFT-UT. Block 1-8 received 45° shear wave inspections that were not made on the other three blocks. The other blocks received normal beam inspections from the top or bottom faces. These faces were not available on Block 1-8 when the SAFT-UT inspections were made.

Inspection #1 in the table was made with an RTD 88-255, L-wave, 2.0-MHz dual element normal beam probe on the clad surface. Inspection #2 was made with an RTD 1287-1156, L-wave, 2.0-MHz, dual element 45° probe from the clad surface. The direction of insonification was +X; that is, reflectors were illuminated from their -X side. Inspection #3 is a repeat of #2 where the insonification direction is -X. Inspections #4 and #5 were made from the clad side with an RTD 84-23, 70° L-wave, 2.0-MHz, dual element probe. Inspections #6 and #9 were full volume normal beam inspections using an Aerotech L07489, 2.25-MHz, 6.4 mm (0.25-in.) diameter, contact transducer on the clad surface. Inspections #7 and #8 were full volume 45° shear wave inspections from the clad side using a 1.0-MHz, 6.4 mm (0.25-in.) diameter transducer on a 45° wedge. Inspections #10 and #11 were full volume 45° shear wave inspections from the unclad side using an Aerotek K31358, 2.25-MHz, 6.4 mm (0.25-in.) diameter transducer on a 45° wedge.

3.2 SAFT-UT Inspections of Block 1-9

Table 3.2 describes the inspections that were made on Block 1-9 by SAFT-UT. This block was 305 mm (12 in.) wide and did not receive 45° shear wave inspections. Instead, normal beam inspections were made from the bottom face.

Inspection #1 was made with an RTD 84-23, 70° L-wave, 2.0-MHz, dual element probe where the direction of insonification was +X. Inspection #2 is a repeat of #1 where the insonification direction is -X. Inspections #3, #4, and #5 were full volume normal beam inspections using an Aerotech L07489, 2.25-MHz, 6.4 mm (0.25-in.) diameter, contact transducer.

3.3 SAFT-UT Inspections of Block 1-11

Table 3.3 describes the inspections that were made on Block 1-11 by SAFT-UT. This block was 305 mm (12 in.) wide and did not receive 45° shear wave inspections. Instead, normal beam inspections were made from top face.

Inspection #1 was made with an RTD 84-23, 70° L-wave, 2.0-MHz, dual element probe where the direction of insonification was +X. Inspection #2 is a repeat of #1 where the insonification direction is -X. Inspections #3, #4, and

#5 were full volume normal beam inspections using an Aerotech L07489, 2.25-MHz, 6.4 mm (0.25-in.) diameter, contact transducer.

Table 3.1 SAFT-UT Inspections on Block 1-8

Inspection No. / Type	Beam Direction	Frequency, MHz	Y Coverage, mm (in.)	X Coverage, mm (in.)
Near-Surface (Clad) Zone Inspections				
1 / Normal beam	N/A	2.0	-51 to 102 (-2.0 to 4.0)	-75 to 75 (-3.0 to 3.0)
2 / 45°L	+X	2.0	-51 to 102 (-2.0 to 4.0)	-75 to 75 (-3.0 to 3.0)
3 / 45°L	-X	2.0	-51 to 102 (-2.0 to 4.0)	-75 to 75 (-3.0 to 3.0)
4 / 70°L	+X	2.0	-560 to 535 (-22.0 to 21.0)	-152 to 152 (-6.0 to 6.0)
5 / 70°L	-X	2.0	-560 to 535 (-22.0 to 21.0)	-152 to 152 (-6.0 to 6.0)
Inspections of the Weld from the Clad Side				
6 / Normal beam	N/A	2.25	-432 to 381 (-17.0 to 15.0)	-317 to 330 (-12.5 to 13.0)
7 / 45°S	+X	1.0	-411 to 393 (-16.2 to 15.5)	-330 to 330 (-13.0 to 13.0)
8 / 45°S	+Y	1.0	-406 to 381 (-16.0 to 15.0)	-76 to 76 (-3.0 to 3.0)
Inspections of the Weld from the Unclad Side				
9 / Normal beam	N/A	2.25	-483 to 422 (-19.0 to 16.6)	-342 to 355 (-13.5 to 14.0)
10 / 45°S	+X	2.25	-483 to 406 (-19.0 to 16.0)	-356 to 229 (-14.0 to 9.0)
11 / 45°S	-X	2.25	-483 to 355 (-19.0 to 14.0)	-38 to 267 (-1.5 to 10.5)

Table 3.2 SAFT-UT Inspections on Block 1-9

Inspection No. / Type	Beam Direction	Frequency, MHz	Y Coverage, mm (in.)	X Coverage, mm (in.)
Near-Surface (Clad) Zone Inspections				
1 / 70°L	+X	2.0	-560 to 535 (-22.0 to 21.0)	-152 to 152 (-6.0 to 6.0)
2 / 70°L	-X	2.0	-560 to 535 (-22.0 to 21.0)	-152 to 152 (-6.0 to 6.0)
Inspections of the Weld from the Clad Side				
3 / Normal beam	N/A	2.25	-450 to 465 (-17.7 to 18.3)	-152 to 152 (-6.0 to 6.0)
Inspections of the Weld from the Unclad Side				
4 / Normal beam	N/A	2.25	-635 to 610 (-25.0 to 24.0)	-152 to 152 (-6.0 to 6.0)
Inspections of the Weld from Bottom Side				
5 / Normal beam	N/A	2.25	-457 to 400 (-18.0 to 15.7)	-152 to 152 (-6.0 to 6.0)

3.4 SAFT-UT Inspections of Block 1-12

Table 3.4 describes the inspections that were made on Block 1-12 by SAFT-UT. This block was 305 mm (12 in.) wide and did not receive 45° shear wave inspections. Instead, normal beam inspections were made from top face.

Inspection #1 was made with an RTD 84-23, 70° L-wave, 2.0-MHz, dual element probe where the direction of insonification was +X. Inspection #2 is a repeat of #1 where the insonification direction is -X. Inspections #3 and #4 were full-volume normal beam inspections using an Aerotech L07489, 2.25-MHz, 6.4 mm (0.25-in.) diameter, contact transducer.

Table 3.3 SAFT-UT Inspections on Block 1-11

Inspection No. / Type	Beam Direction	Frequency, MHz	Y Coverage, mm (in.)	X Coverage, mm (in.)
Near-Surface (Clad) Zone Inspections				
1 / 70°L	+X	2.0	-475 to 601 (-18.7 to 24.0)	-152 to 152 (-6.0 to 6.0)
2 / 70°L	-X	2.0	-475 to 601 (-18.7 to 24.0)	-152 to 152 (-6.0 to 6.0)
Inspections of the Weld from the Clad Side				
3 / Normal beam	N/A	2.25	-483 to 597 (-19.0 to 23.5)	-152 to 152 (-6.0 to 6.0)
Inspections of the Weld from the Unclad Side				
4 / Normal beam	N/A	2.25	-584 to 635 (-23.0 to 25.0)	-152 to 152 (-6.0 to 6.0)
Inspections of the from Top Side				
5 / Normal beam	N/A	2.25	-356 to 587 (-14.0 to 23.0)	-152 to 152 (-6.0 to 6.0)

Table 3.4 SAFT-UT Inspections on Block 1-12

Inspection No. / Type	Beam Direction	Frequency, MHz	Y Coverage, mm (in.)	X Coverage, mm (in.)
Near-Surface (Clad) Zone Inspections				
1 / 70°L	+X	2.0	-508 to 584 (-20.0 to 23.0)	-152 to 152 (-6.0 to 6.0)
2 / 70°L	-X	2.0	-508 to 584 (-20.0 to 23.0)	-152 to 152 (-6.0 to 6.0)
Inspections of the Weld from the Unclad Side				
3 / Normal beam	N/A	2.25	-584 to 610 (-23.0 to 24.0)	-152 to 152 (-6.0 to 6.0)
Inspections of the Weld from Top Side				
4 / Normal beam	N/A	2.25	-508 to 584 (-20.0 to 23.0)	-152 to 152 (-6.0 to 6.0)

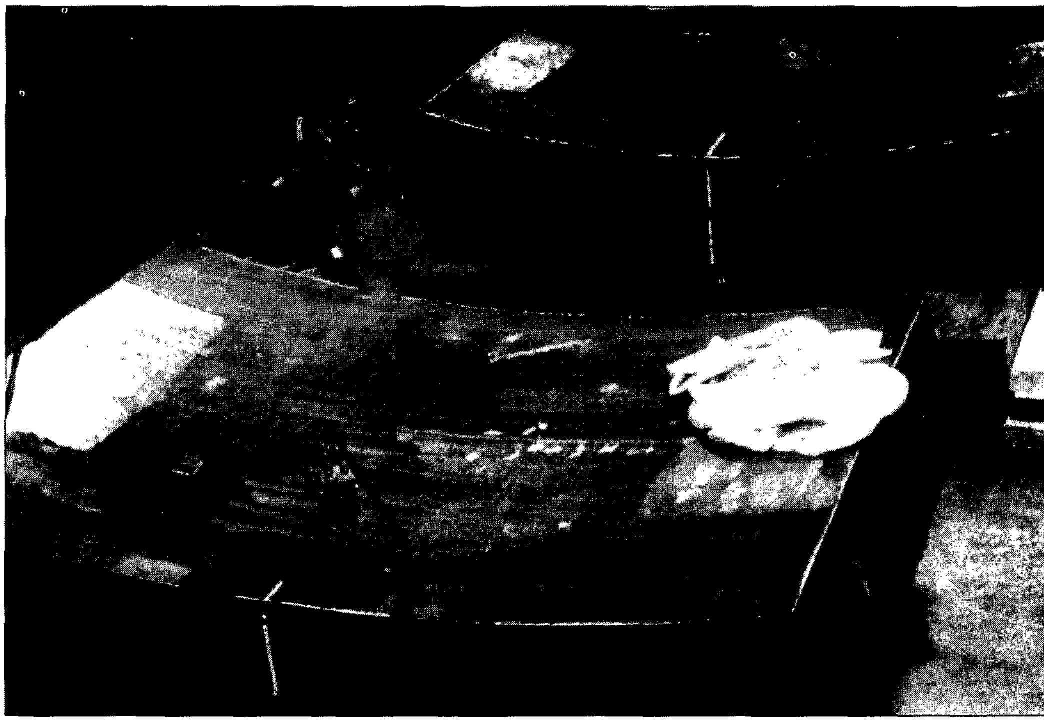


Figure 3.1 Photo of Material Removed from the Midland Vessel

Figure 3.2 Photo of SAFT-UT System as Configured for Inspection of Midland Blocks

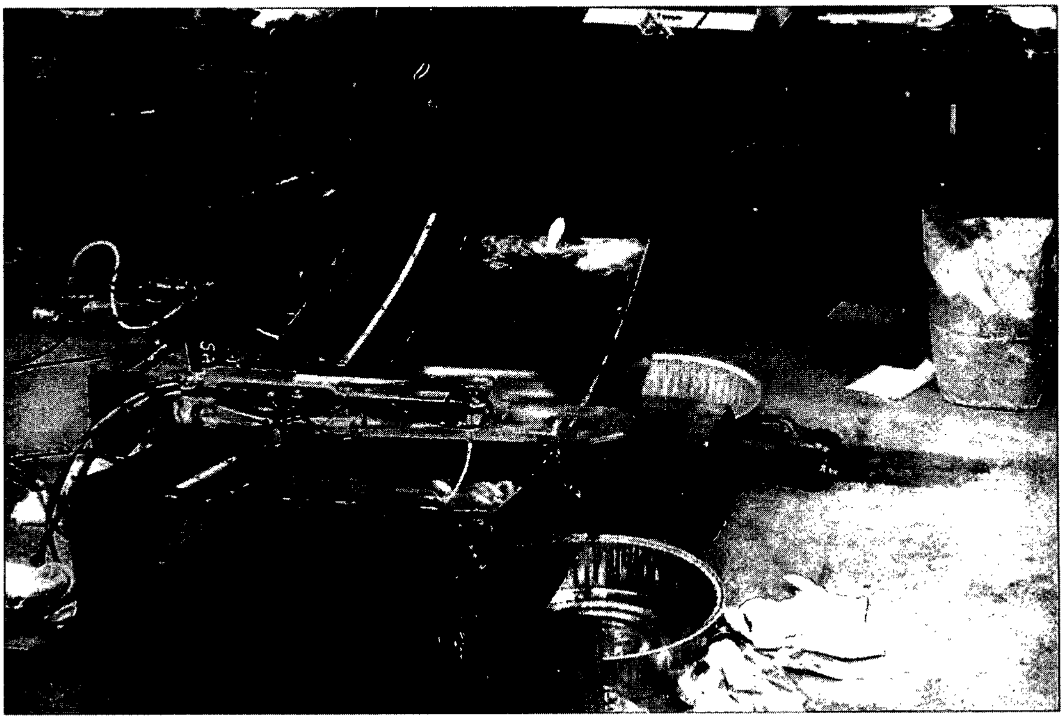


Figure 3.3 Photo of SAFT-UT Scanner Performing Inspections on the Clad Side of a Midland Block

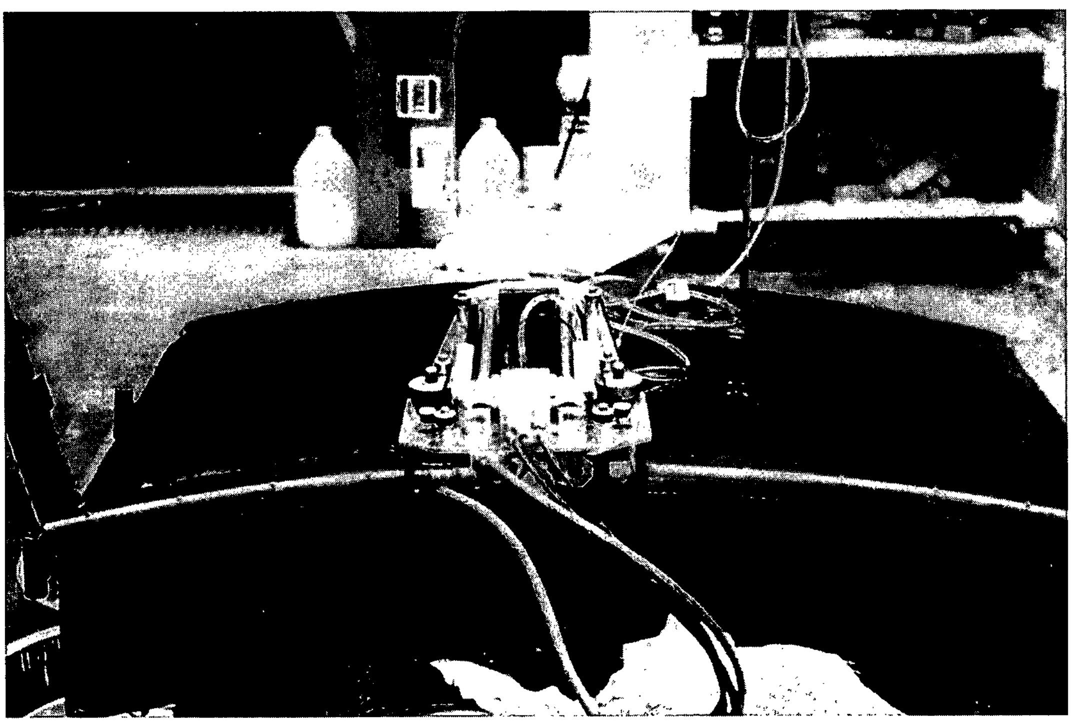


Figure 3.4 Photo of SAFT-UT Scanner Performing Inspections on the Unclad Side of a Midland Block

4.0 Correlation of SAFT-UT Data with Destructive Analysis of Block 1-8

In this section a comparison is made of SAFT-UT inspection results with a destructive analysis performed by the EPRI NDE Center on Block 1-8. The destructive analysis reported sizes for defects at the weld root and at the clad-to-base metal interface. The detection results for SAFT-UT are given for the weld root followed by the detection results for the clad-to-base metal interface.

4.1 Destructive Analysis of Indications

Tables 4.1 and 4.2 describe the results from the destructive analysis of 13 indications found by the (non-SAFT) ultrasonic testing (UT) performed by the staff at the EPRI NDE Center. Indications were found near the root of the weld and near the clad-to-base metal interface.

For the six indications in the base metal (Table 4.1), "Y" refers to the circumferential position (along the weld center line) for the indication as reported by the UT. "DY" is the extent of a flaw in circumferential direction as measured by the destructive analysis. If the indication was not found in the destructive analysis, then no value is given for "DY." "X" and "DX" are not given but the defects are reported to be in the weld root which inplies "X" = 0.0 $\pm$ 12 mm. "Z" refers tothedepth from the clad side of the block (inside of the vessel) as reported by the UT. "DZ" is the extent in the depth dimension as measured by the destructive analysis. The characteristics of the defects that were found in the destructive analysis are also given in Tables 4.1 and 4.2 along with a reference to the individual photographs of the defects.

For the seven indications near the clad-to-base metal interface (Table 4.2), "DY" is not reported by the destructive analysis. If the indication was not found in the destructive analysis, then no value is given for "DX."

Defects were not determined by the destructive analysis for indications 1, 4, 9, 12, and 13. Two defects were found for indications 3, 6, and 10. Figures 4.1 through 4.11 were provided by the Electric Power Research Institute's NDE Center, Charlotte, North Carolina.

4.2 Defects Found in the Weld Root

Table 4.3 shows the results of the analysis of SAFT-UT data for the detection of the weld root defects from the destructive test. The detection result is shown for each of the six different SAFT-UT inspections performed on Block 1-8. Two of the defects, #5 and #6, were readily apparent in the SAFT-UT data. One of the defects, #2, was not detected. It should be noted that none of the six defects were in the central 610 mm (24 in.) of the block. As a consequence of this, all of the defects were missed by at least one SAFT-UT inspection and one of the defects, #3, was not covered by any of the SAFT-UT inspections because this defect was located near the end of the block.

4.2.1 Description of Detection Method

The defects were small slag, typically 1-2 mm in diameter, and were located at the weld root, about 89 mm (3.5 in.) below the clad surface. In order to successfully detect the weak signals from these reflectors, the SAFT-UT data was analyzed by looking for the presence of distinguishing shapes amidst the surrounding background noise. The typical shape for a reflector in the 45° shear inspections is shown in Figure 4.12. This shape can be found only in the side view (B-scan) of the 45° shear data. The typical shape for a reflector in the normal beam data is shown in Figure 4.13.

This detection method leads to the identification of additional reflectors in the SAFT-UT data. These additional reflectors fall into two general categories. The first category are those that are found near the weld root, between 80 mm and 95 mm (3.25 and 3.75 in.) from the clad surface. There are two indications in this category and they are found by both 45° shear and normal beam inspections. The second category of additional base-metal indications found by

SAFT-UT are not found near the weld root. There are seven of these indications and most of these are only found by the normal beam inspections. All of the SAFT-UT data have been analyzed by this detection method. The data are reported in Section 5.0. All the summary results are covered in Section 6.0.

Table 4.1 Results from the Destructive Analysis of Indications in Block 1-8 (Weld Root Indications)

Indication No.	Y, mm (in.)	DY, mm (in.)	X, mm (in.)	DX, mm (in.)	Z, mm (in.)	DZ, mm (in.)	Characterization
1	-465 (-18.3)	-	-	-	100 (3.9)	-	Presence not determined by destructive test.
2	-445 (-17.5)	1 (0.04)	-	-	98 (3.8)	2 (0.08)	Slag. See destructive test results in Figure 4.1.
3t	470 (18.5)	0.75 (0.03)	-	-	74 (2.9)	1.25 (0.05)	Destructive test found 2 defects. Both were slag. See destructive test results of 3b in Figure 4.2.
3b	-	3 (0.12)	-	-		1.25 (0.05)	
4	420 (16.5)	-	-	-	91 (3.6)	-	Presence not confirmed by destructive test. See destructive test results in Figure 4.3.
5	380 (15.0)	5 (0.2)	-	-	89 (3.5)	2 (0.08)	Slag. See destructive test results in Figure 4.4.
6t	350 13.8	2 (0.08)	-	-	99 (3.9)	1.5 (0.06)	Destructive test found 2 defects, both slag. See destructive test results in Figures 4.5 and 4.6.
6b		3.5 (0.14)	-	-		2.5 (0.10)	

4.3 Defects Found Near the Clad-to-Base Metal Interface

Table 4.4 shows the results of the analysis of SAFT-UT data for the detection of the four clad-to-base metal defects from the destructive test. Only the four locations where the destructive analysis reported defects are considered in the table. One of the defects, #8, was readily apparent in the SAFT-UT data in that it had the proper shape in side-view B-scan and had considerable amplitude in both inspections. One of the defects, #7, was detected and had the proper shape from one inspection only. One of the defects, #11, was detected at a high amplitude, but shapeless spot. One of the defects, #10, was not detected by SAFT-UT.

4.3.1 Description of Detection Method

The five defects were small slag, typically 1-2 mm in depth and 2-5 mm in length, and were located at the interface between the clad and the base metal. In order to successfully detect the signals from these reflectors, the SAFT-UT data was analyzed in two steps. The first step was to look for the presence of distinguishing shapes. The second step was to look for high-amplitude signals that have some bulk, not just one hot pixel, where the amplitude is considerably above the background reflections from the clad-to-base metal interface. The typical shape for a reflector in the 70°L-wave inspections is shown in Figure 4.14. This shape can be found only in the side view (B-scan) of the 70° L-wave data. The typical image for a reflector that is included based on amplitude alone is shown in Figure 4.15.

It is important to consider the number of additional flaws that this detection method leads to in the SAFT-UT data from Block 1-8. These additional reflectors fall into two general categories. The first category are those that have a distinguishing shape. There were no reflectors in this category in the data from Block 1-8. The second category are the reflectors that qualify based on amplitude. There are three reflectors in this category in the SAFT-UT data from Block 1-8. All of the SAFT-UT data have been analyzed by this detection method. The results are reported in Section 5.0.

Table 4.2 Results from the Destructive Analysis of Indications in Block 1-8 (Near-Surface Zone Indications)

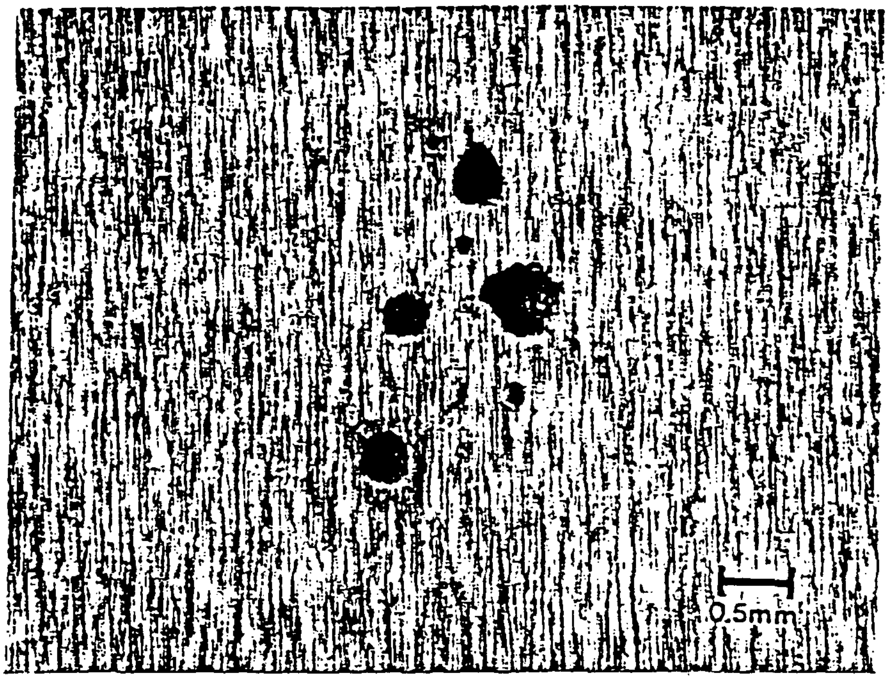
Indication No.	Y, mm (in.)	DY, mm (in.)	X, mm (in.)	DX, mm (in.)	Z, mm (in.)	DZ, mm (in.)	Characterization
7	81 (3.2)	-	-22 (-0.8)	4 (0.16)	-	1 (0.04)	Clad-to-base metal interface slag. See destructive test results in Figure 4.7.
8	112 (4.4)	-	33 (1.3)	5 (0.2)	-	2 (0.08)	Clad-to-base metal interface slag. See destructive test results in Figure 4.8.
9	112 (4.4)	-	0 (0.0)	-	-	-	Presence not determined by destructive test.
10a	204 (8.0)	-	15 (0.6)	5 (0.2)	-	1 (0.04)	Clad-to-base metal interface. See destructive test results in Figure 4.9.
10b	-	-	-	2 (0.08)	-	1 (0.04)	1 mm below interface. See destructive test results in Figure 4.10.
11	235 (9.2)	-	-15 (-0.6)	1.5 (0.06)	-	0.5 (0.02)	Clad-to-base metal interface. See destructive test results in Figure 4.11.
12	235 (9.2)	-	12 (0.5)	-	-	-	Presence not determined by destructive test.
13	288 (15.3)	-	-11 (-0.4)	-	-	-	Presence not determined by destructive test.

Table 4.3 Detection by SAFT-UT of the Weld-Root Defects found in the Destructive Analysis of Midland Block 1-8

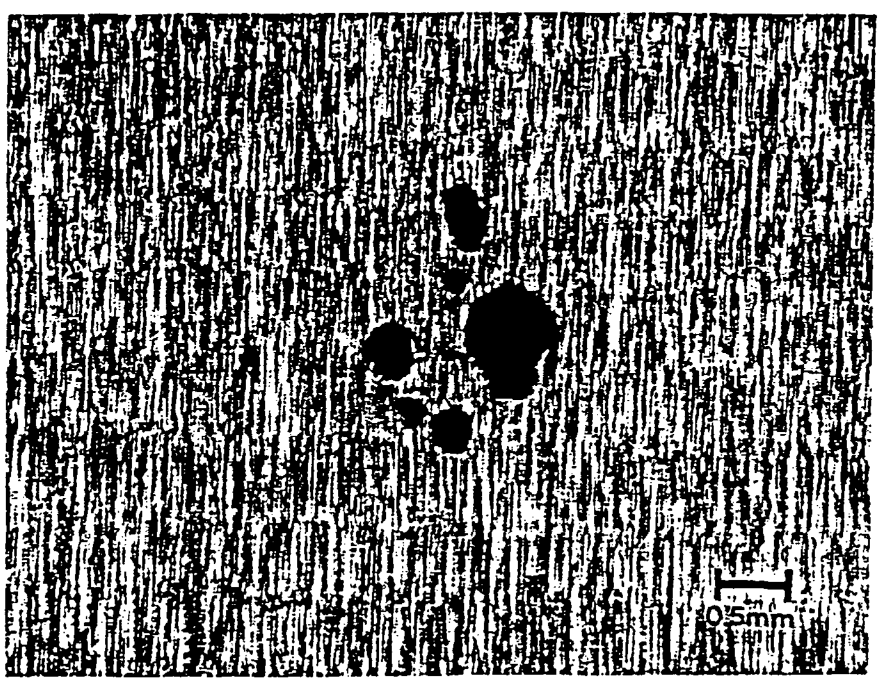
	#2	#6
Normal beam, clad side Normal beam, unclad side 45° shear, clad, dir = 0 45° shear, clad, dir = 90 45° shear, unclad, dir = 0 45° shear, unclad, dir = 180	No coverage No detection No coverage No detection No detection No detection	No detection No detection No detection No coverage Detection Detection
Detection Results	Not detected	Detected (high S/N)
	#5	#3
Normal beam, clad side Normal beam, unclad side 45° shear, clad, dir = 0 45° shear, clad, dir = 90 45° shear, unclad, dir = 0 45° shear, unclad, dir = 180	Detection No detection No coverage No detection Detection Detection	No coverage No coverage No coverage No coverage No coverage No coverage
Detection Result	Detected (high S/N)	No coverage

Table 4.4 Detection by SAFT-UT of the Clad-to-Base Metal Defects found in the Destructive Analysis of Midland Block 1-8

	#7	#8	#10	#11
70°, L-wave, dir = +X 70°, L wave, dir = -X	Detection No detection	Detection Detection	No detection No detection	No detection Detection
Detection Result	Detection	Detection	No detection	Detection

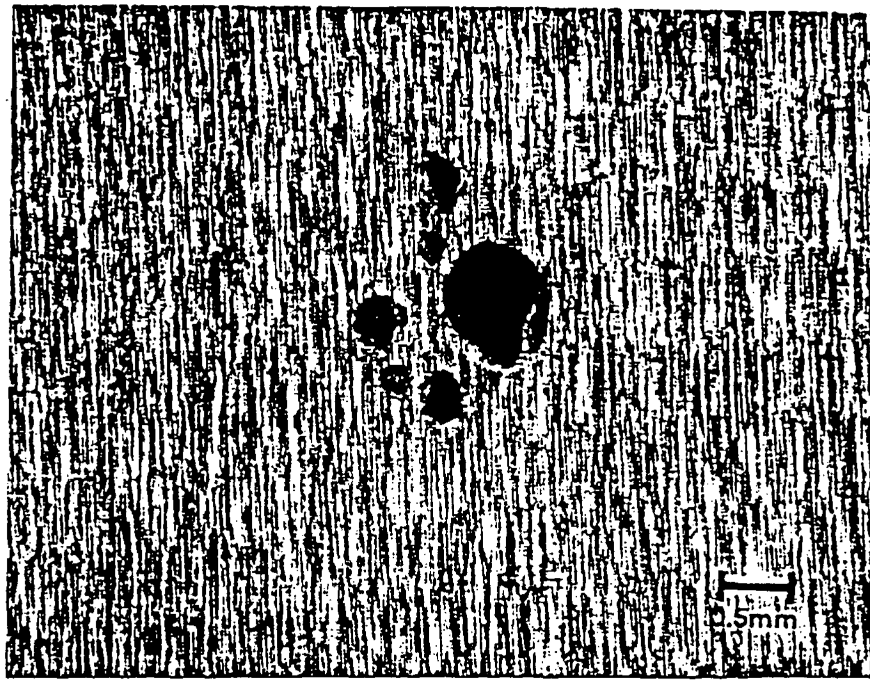


(a) Depth: 14.25 mm (0.561 in.), as machined

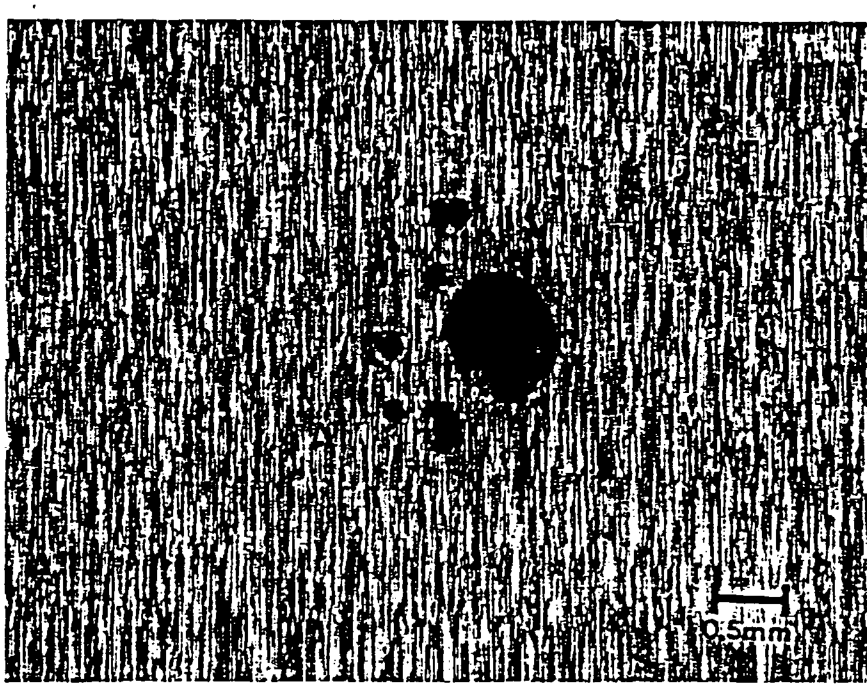


(b) Depth: 14.15 mm (0.557 in.), as machined

Figure 4.1 DA Photograph of Midland Flaw 1-8 #2
Photographs provided by the EPRI NDE Center

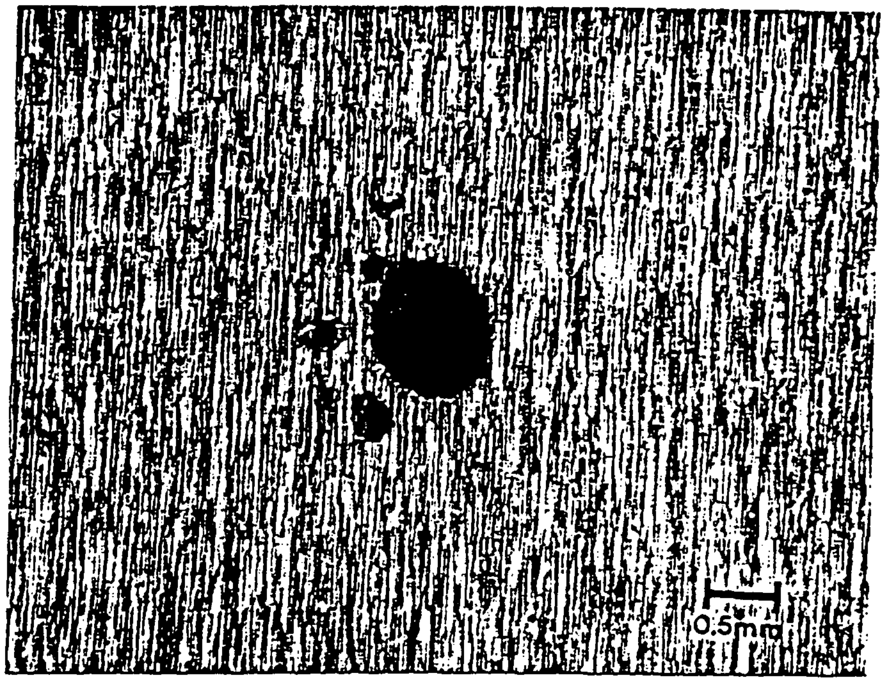


(c) Depth: 14.1 mm (0.555 in.), as machined

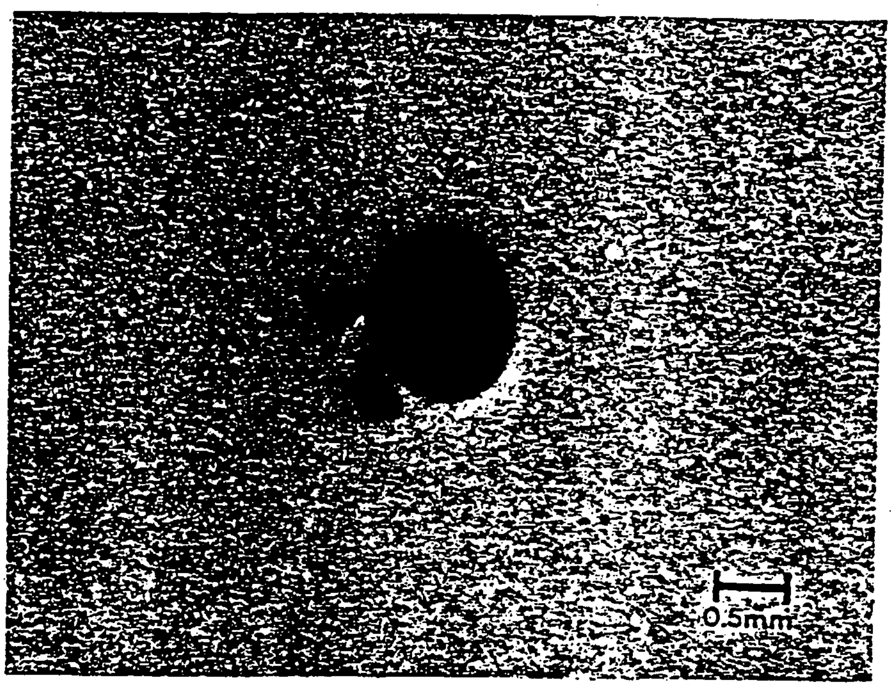


(d) Depth: 14.05 mm (0.553 in.), as machined

Figure 4.1 (cont'd)
Photographs provided by the EPRI NDE Center

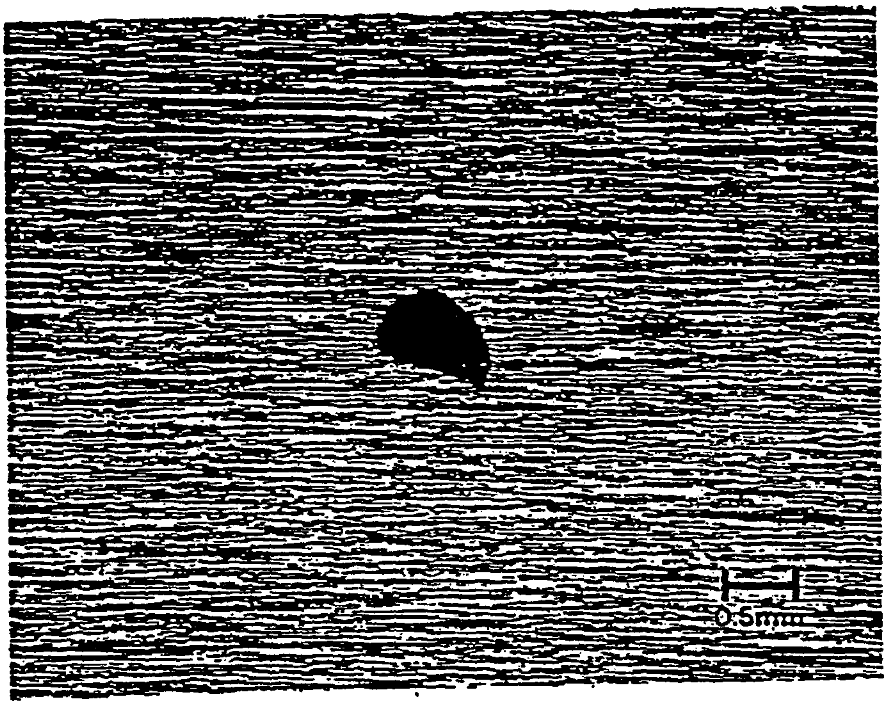


(e) Depth: 14.02 mm (0.552 in.), as machined

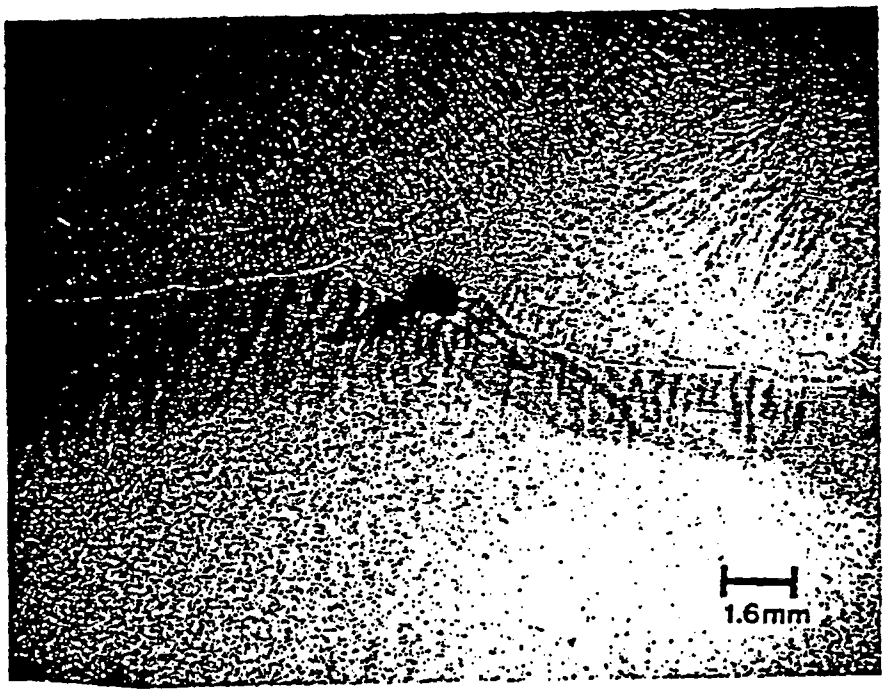


(f) Depth: 14.97 mm (0.550 in.), as polished and etched

Figure 4.1 (cont'd)
Photographs provided by the EPRI NDE Center



(a) As machined



(b) Polished and etched

Figure 4.2 DA Photograph of Midland Flaw 1-8 #3b
Photographs provided by the EPRI NDE Center

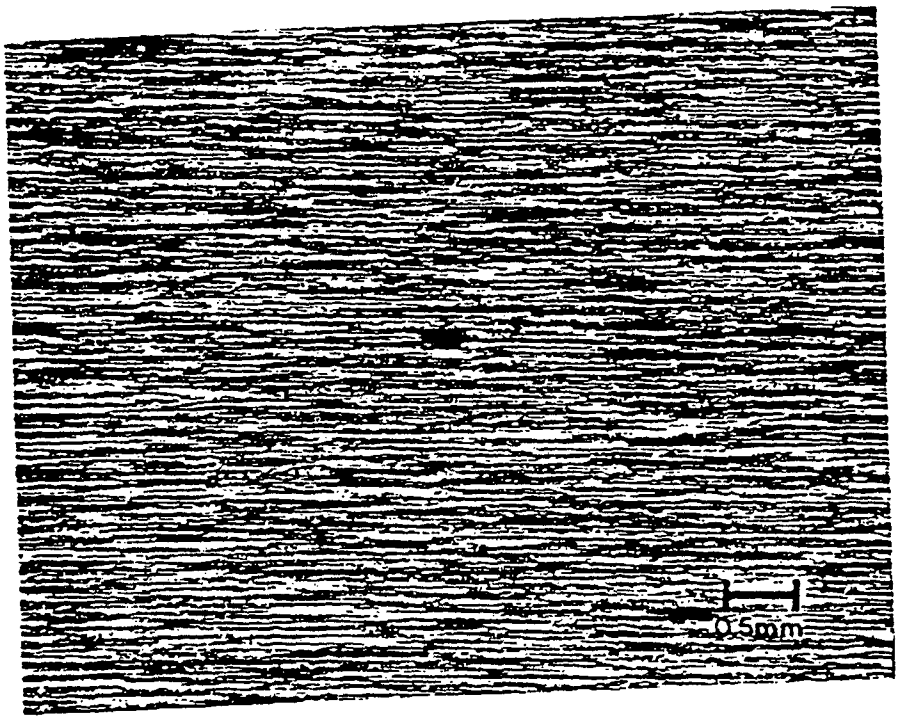
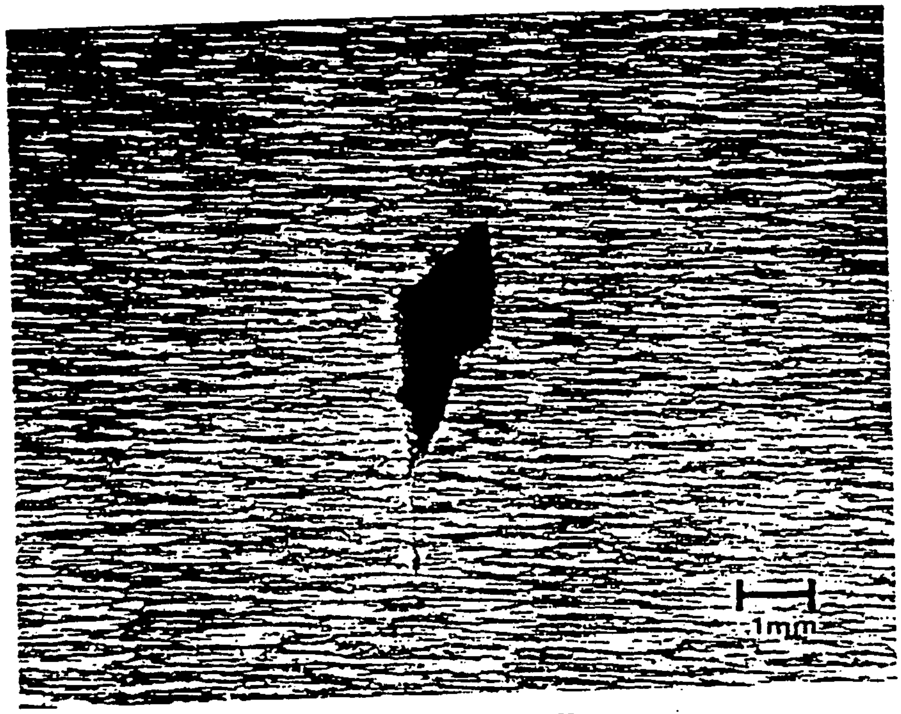
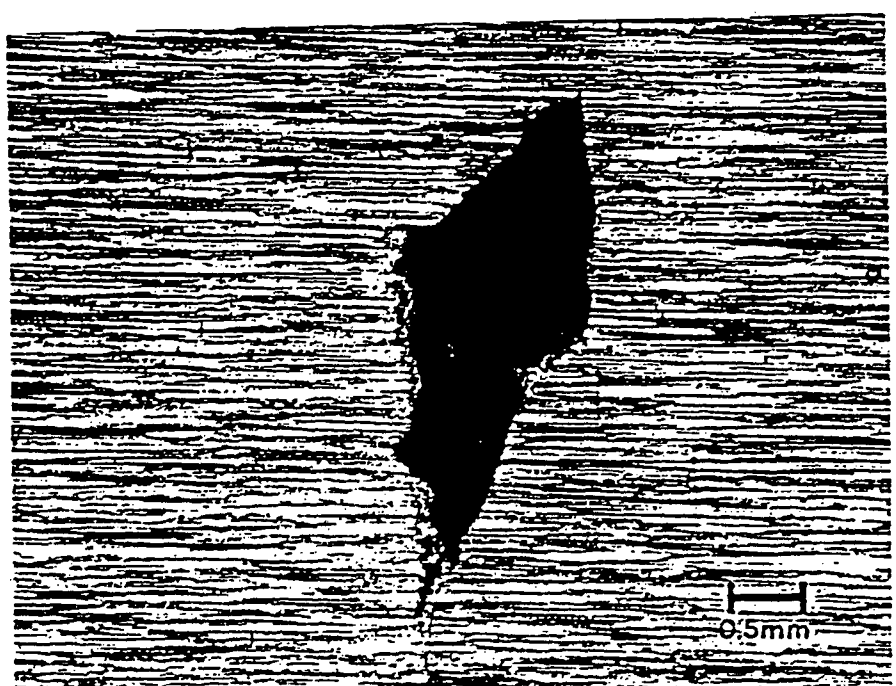


Figure 4.3 DA Photograph of Midland Flaw 1-8 #4b, as machined.
Photograph provided by the EPRI NDE Center

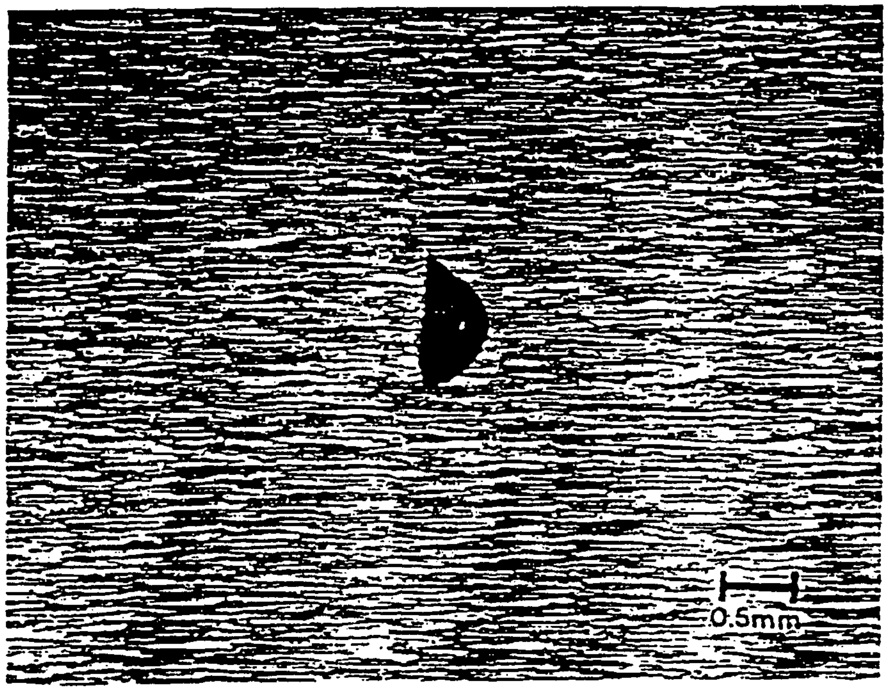


(a) Magnification: 10X

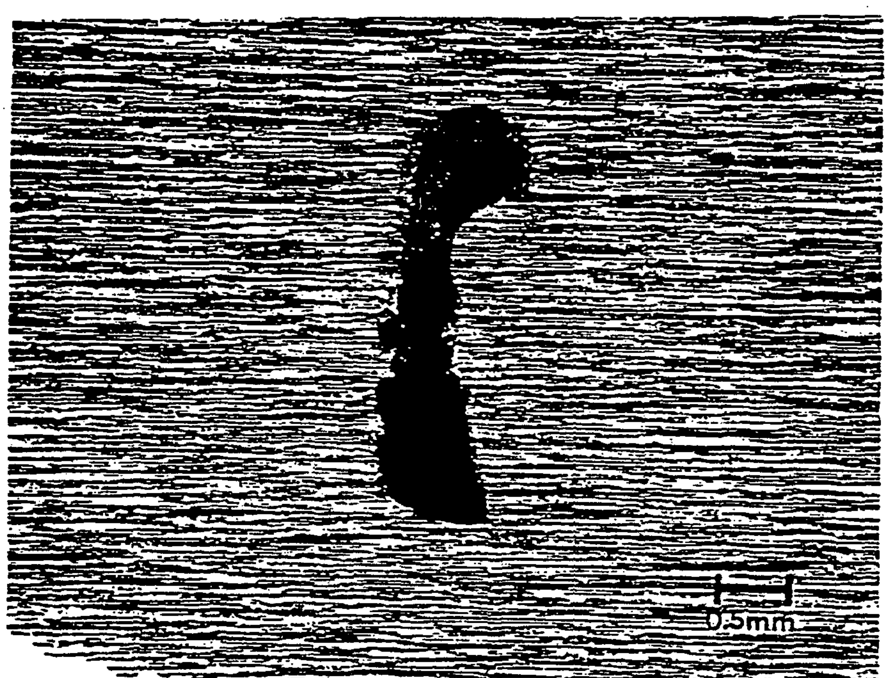


(b) Magnification: 20X

Figure 4.4 DA Photograph of Midland Flaw 1-8 #5t
Photographs provided by the EPRI NDE Center

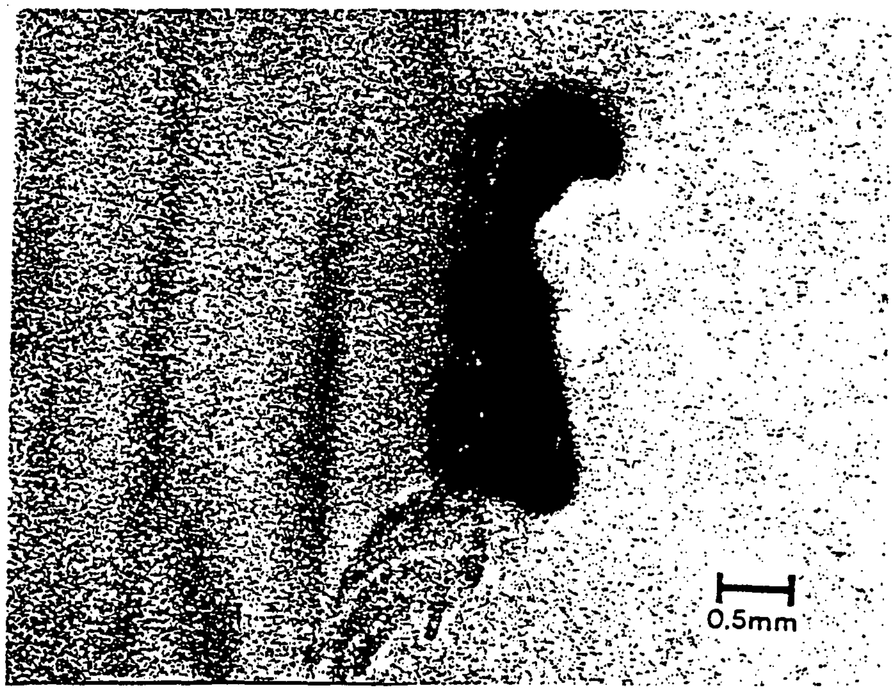


(a) Depth: 6.32 mm (0.249 in.), as machined

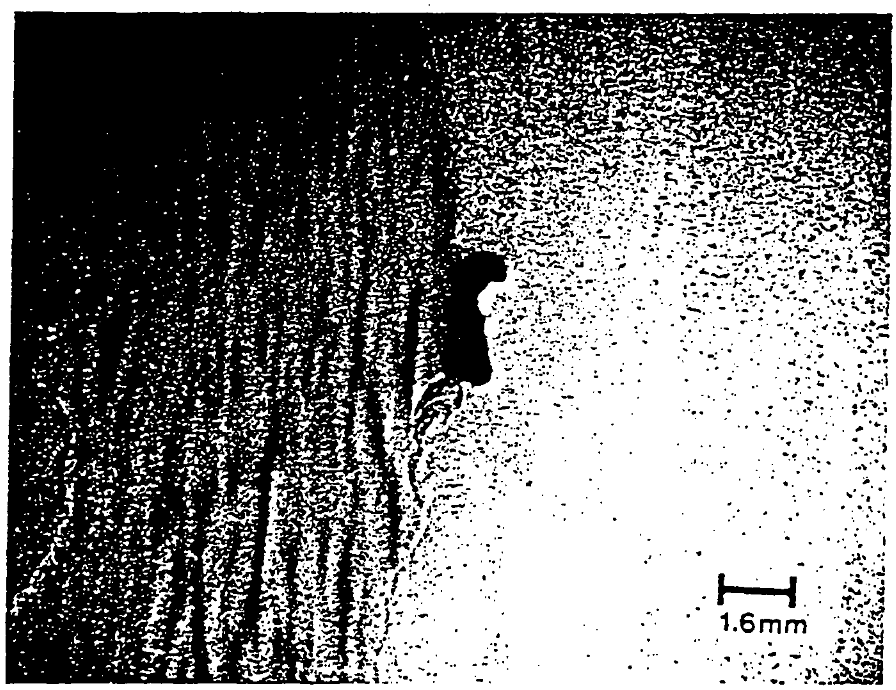


(b) Depth: 5.82 mm (0.229 in.), as machined

Figure 4.5 DA Photograph of Midland Flaw 1-8 #6b
Photographs provided by the EPRI NDE Center

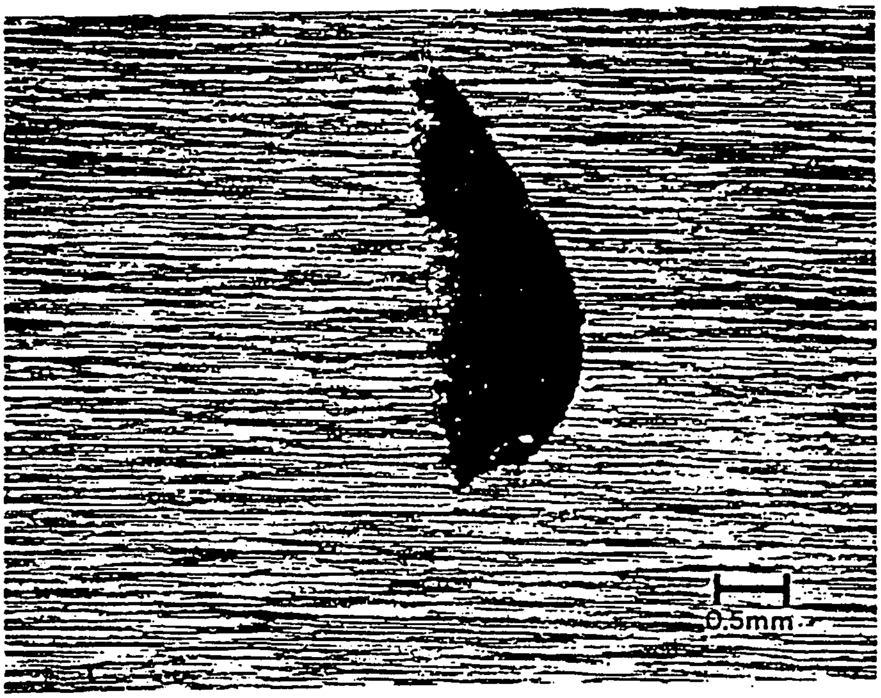


(c) As polished and etched, magnification: 20X

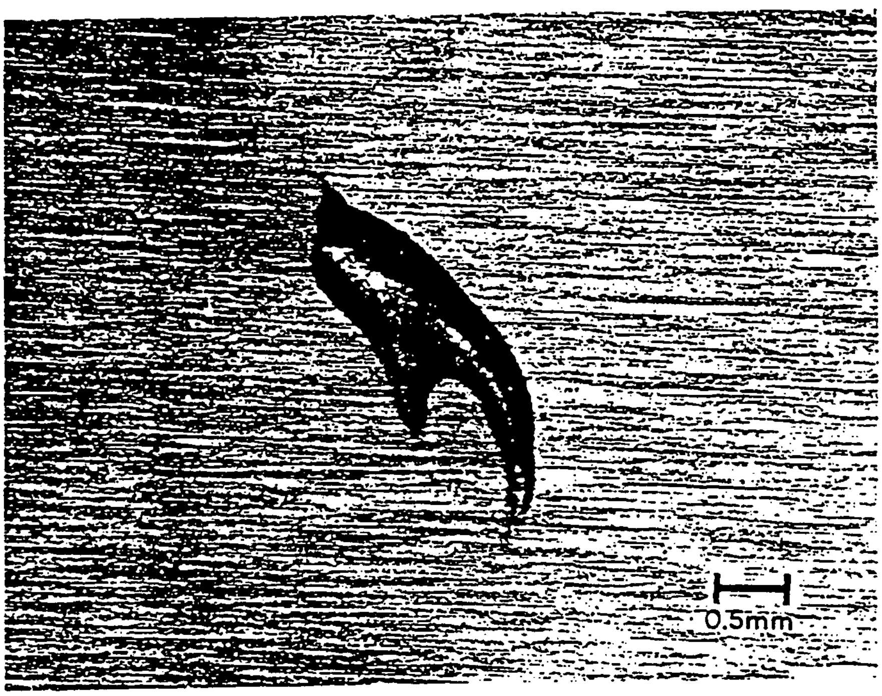


(d) As polished and etched, magnification: 6.3X

Figure 4.5 (cont'd)
Photographs provided by the EPRI NDE Center

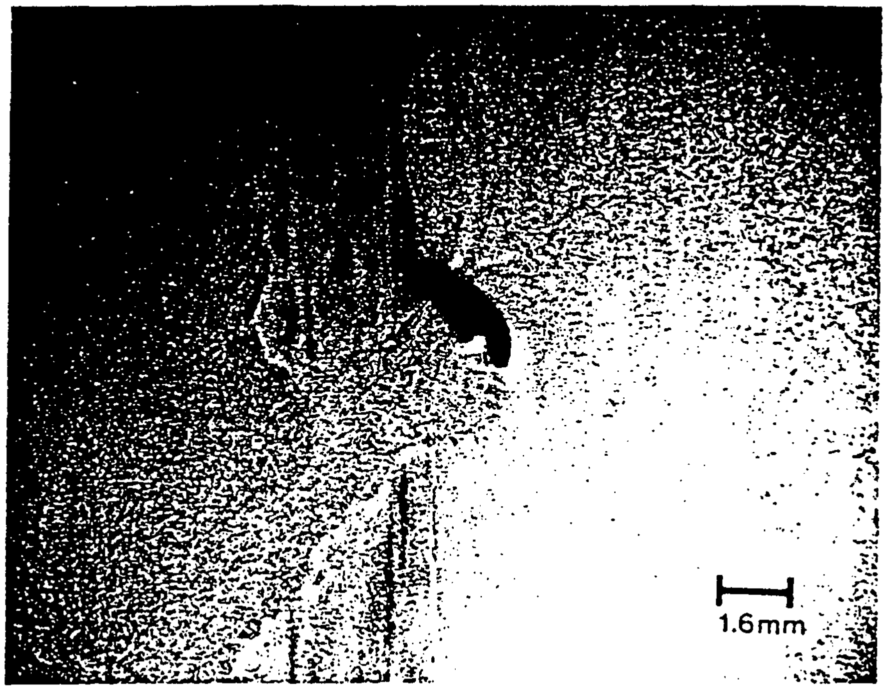


(a) Depth: 6.45 mm (0.254 in.), as machined

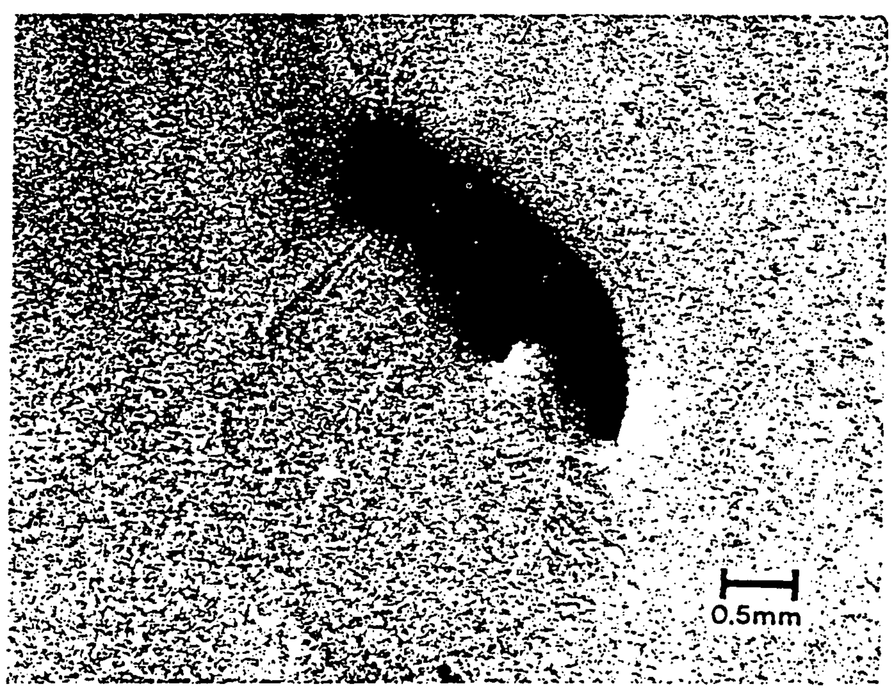


(b) Depth: 6.2 mm (0.244 in.), as machined

Figure 4.6 DA Photograph of Midland Flaw 1-8 #6t
Photographs provided by the EPRI NDE Center

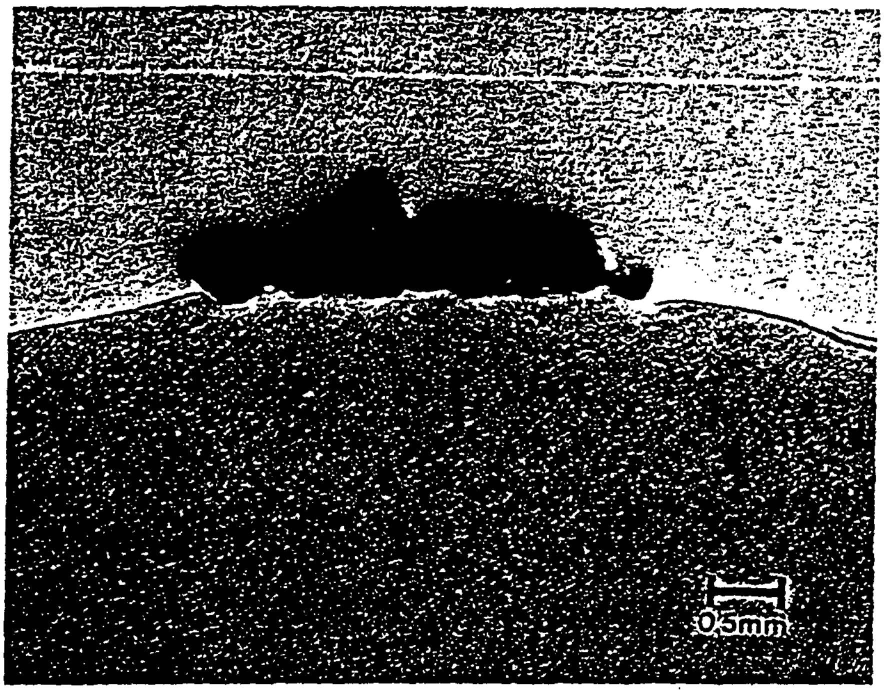


(c) As polished and etched, magnification: 6.3X

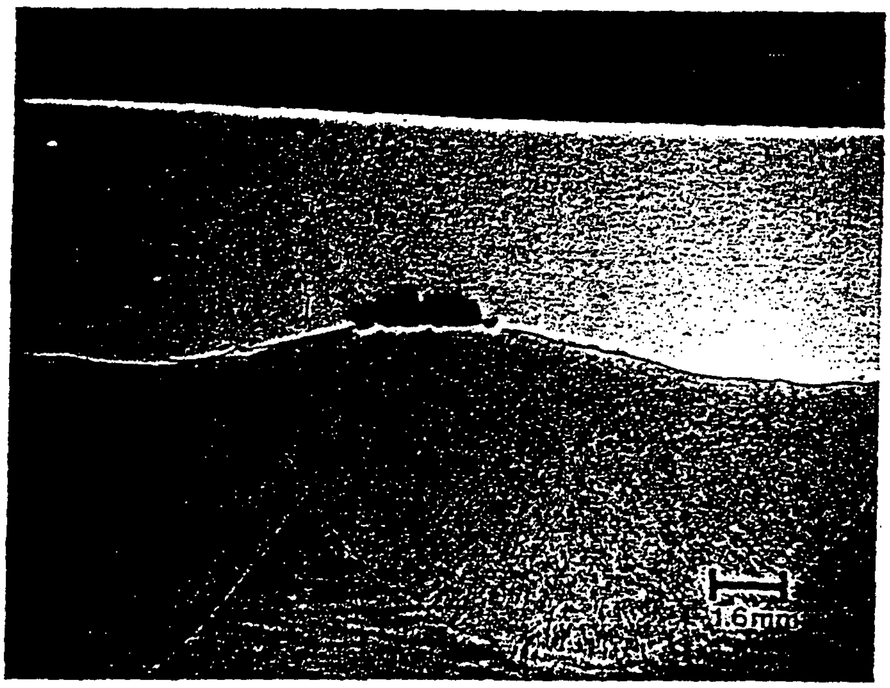


(d) As polished and etched, magnification: 20X

Figure 4.6 (cont'd)
Photographs provided by the EPRI NDE Center

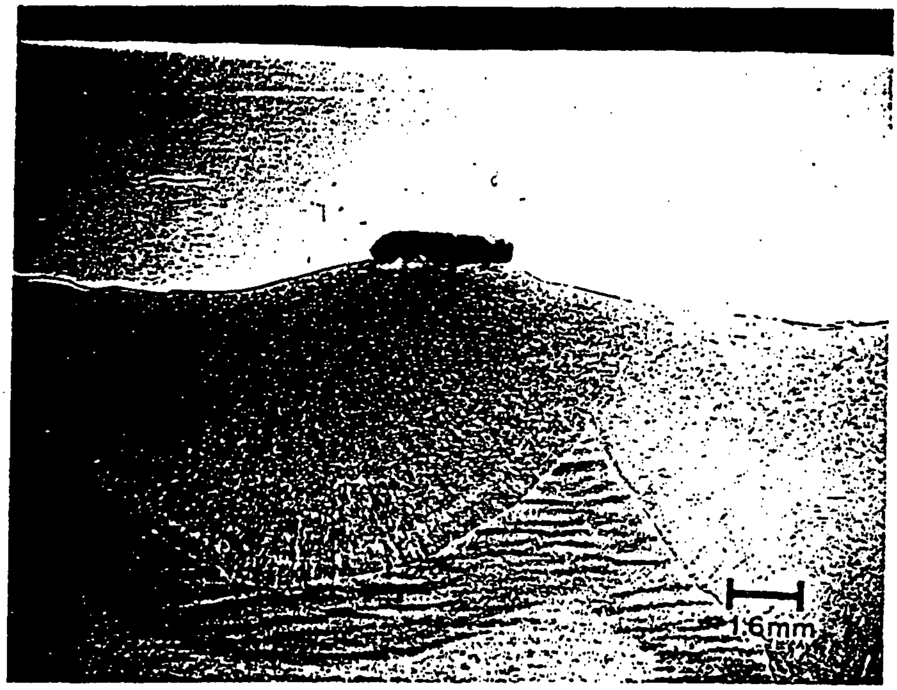


(a) As polished and etched, magnification: 20X

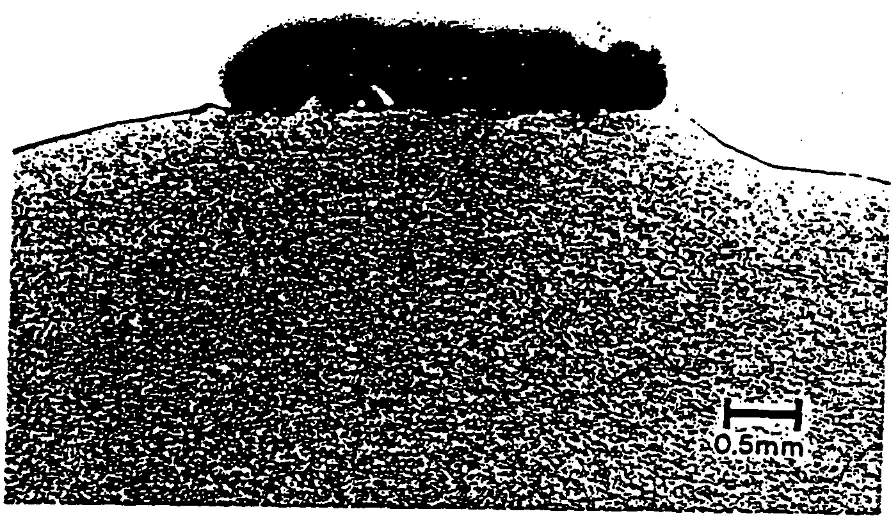


(b) As polished and etched, magnification: 6.3X

Figure 4.7 DA Photograph of Midland Flaw 1-8 #7b
Photographs provided by the EPRI NDE Center

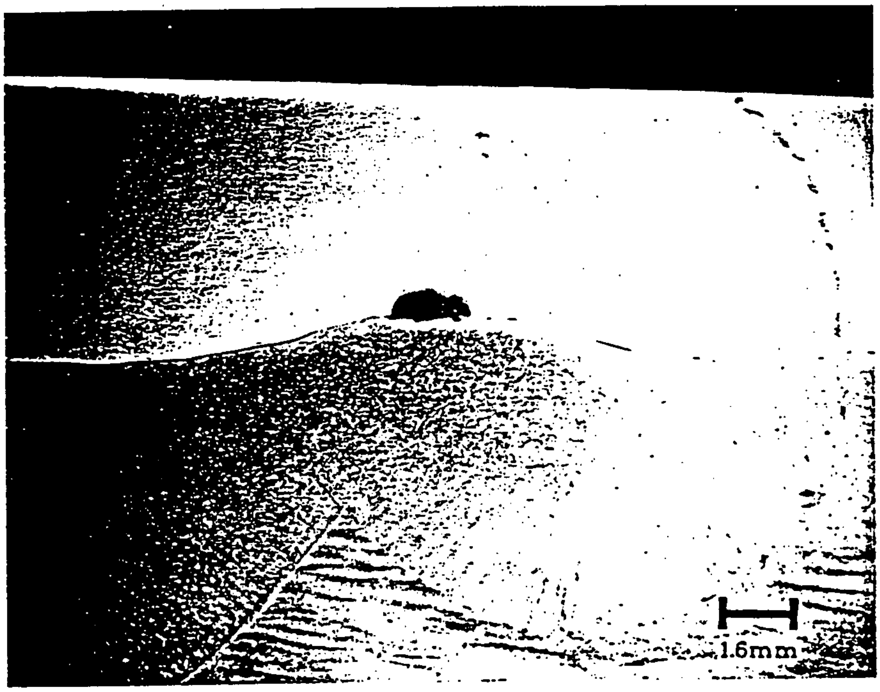


(a) As polished and etched, magnification: 6.3X

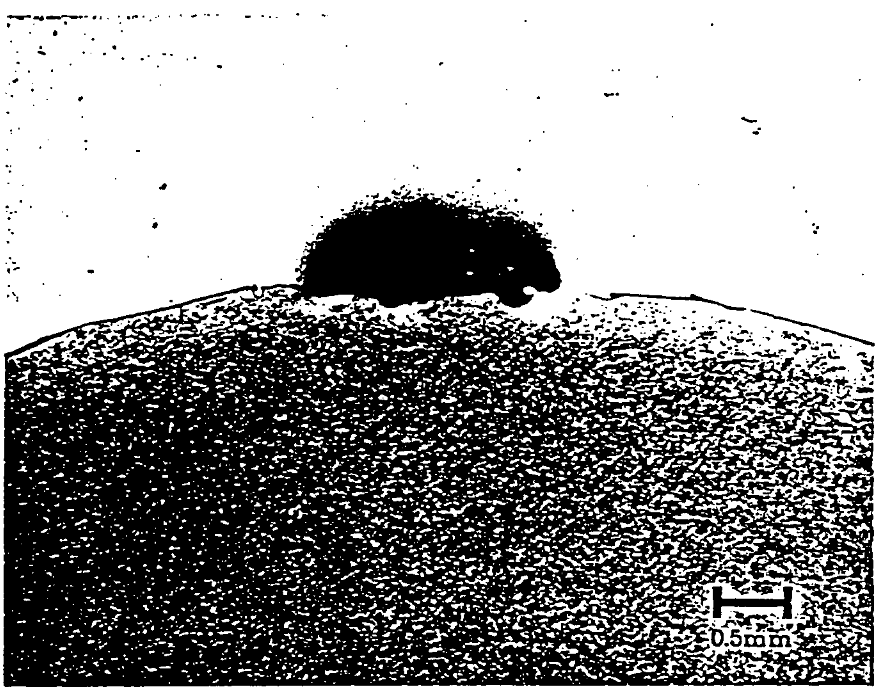


(b) As polished and etched, magnification: 20X

Figure 4.8 DA Photograph of Midland Flaw 1-8 #8
Photographs provided by the EPRI NDE Center

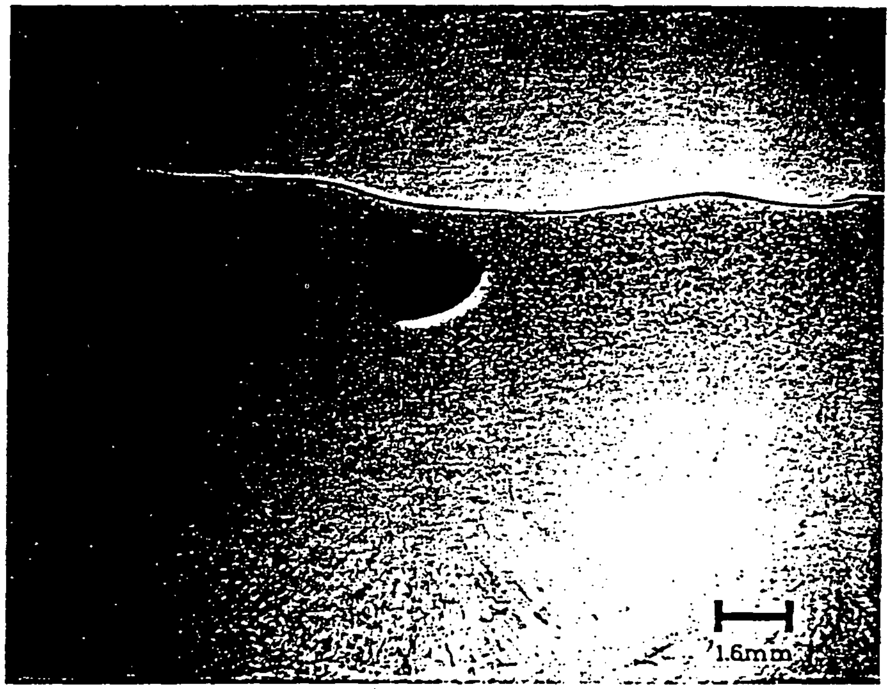


(a) As polished and etched, magnification: 6.3X

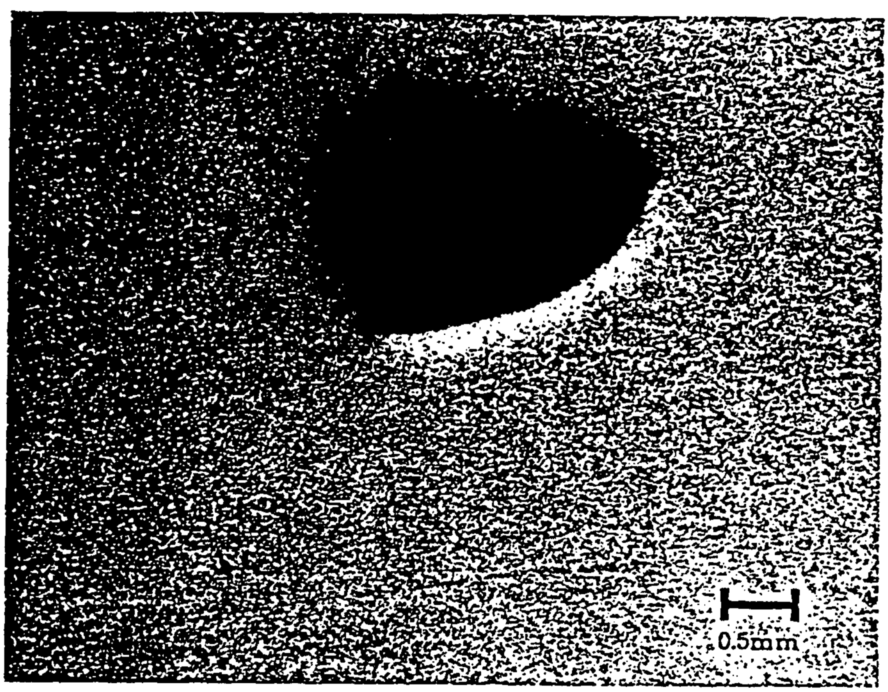


(b) As polished and etched, magnification: 20X

Figure 4.9 DA Photograph of Midland Flaw 1-8 #10a
Photographs provided by the EPRI NDE Center

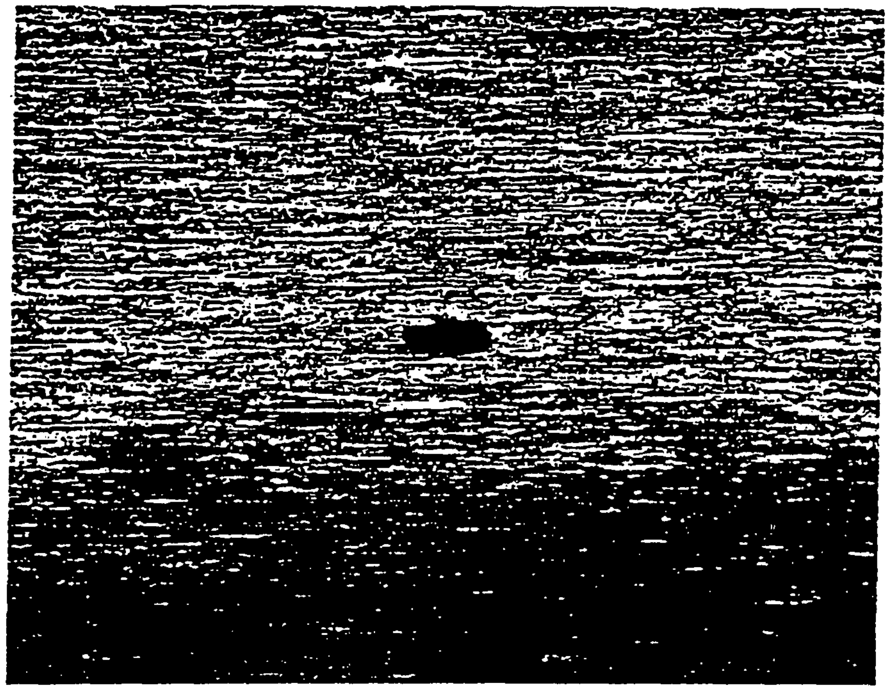


(a) As polished and etched, magnification: 6.3X

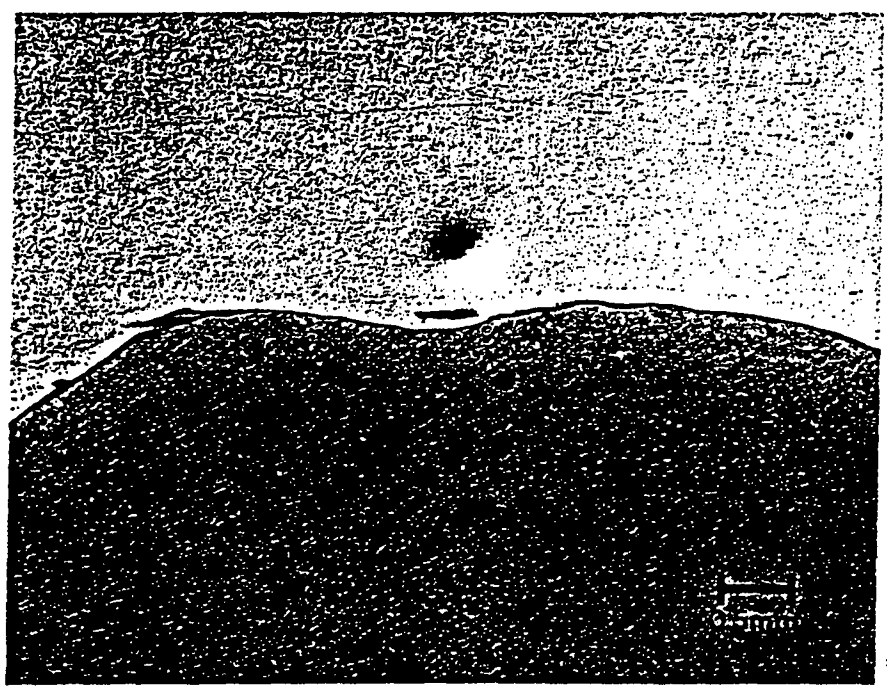


(b) As polished and etched, magnification: 20X

Figure 4.10 DA Photograph of Midland Flaw 1-8 #10b
Photographs provided by the EPRI NDE Center



(a) As machined



(b) As polished and etched

Figure 4.11 DA Photograph of Midland Flaw 1-8 #11
Photographs provided by EPRI NDE Center

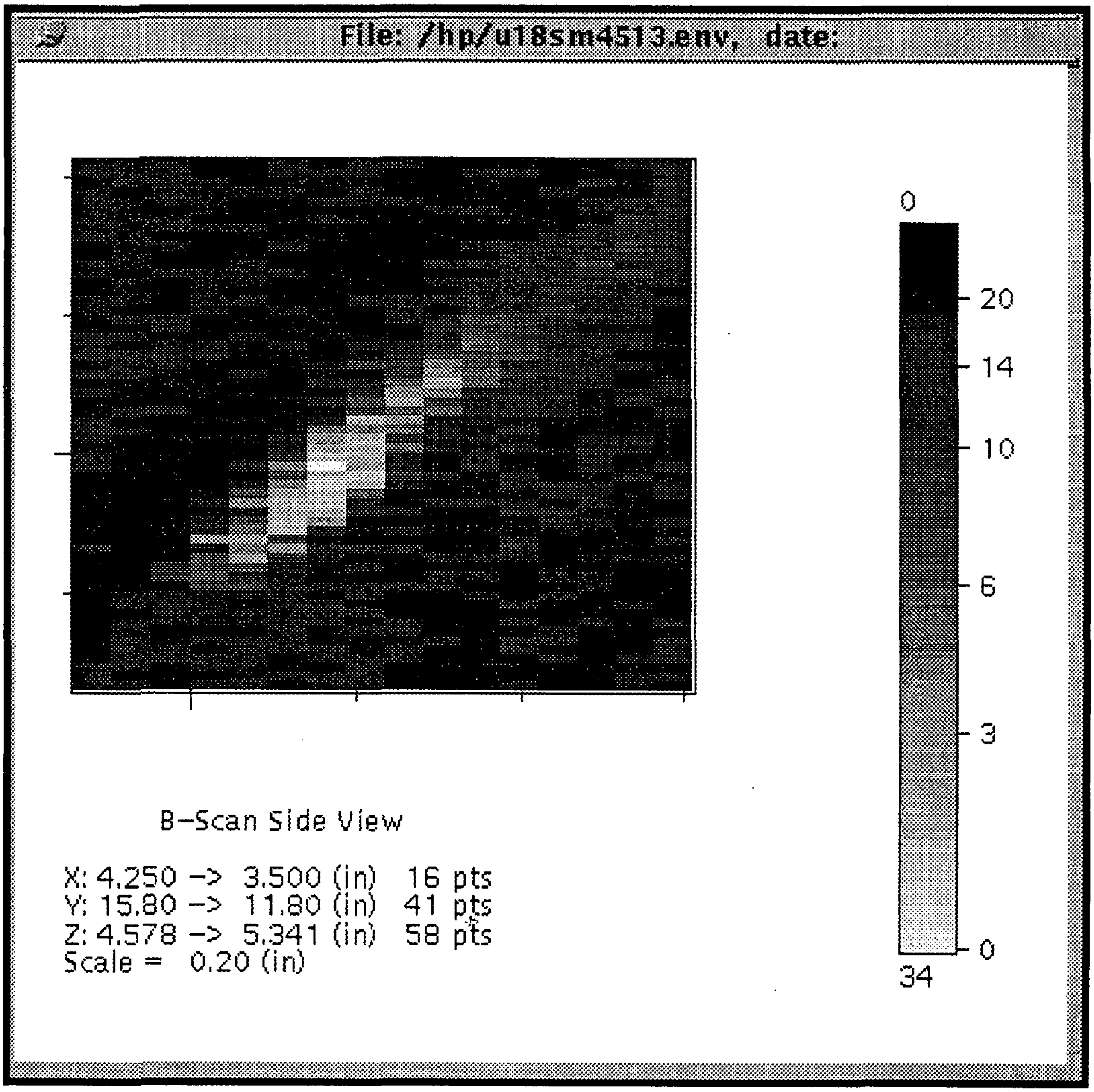


Figure 4.12 Typical Shape for a Reflector in the 45° Shear Inspections. Side View (XZ) of Base-Metal Indication in Block 1-8 at Y = 350 mm. 45° shear inspection from the unclad side. Beam direction is +X. Z values in the figure are measured from the unclad side.

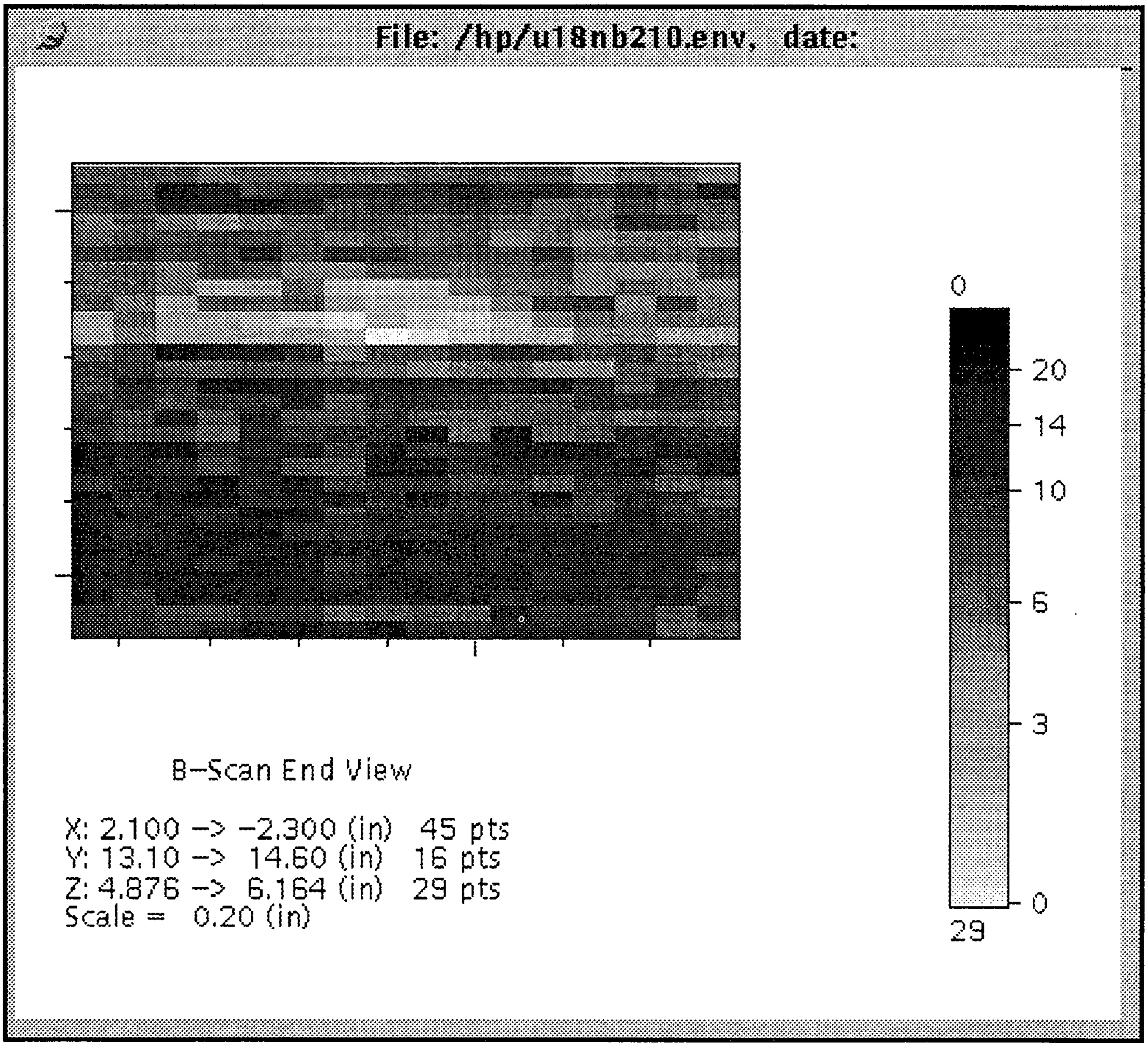


Figure 4.13 Typical Shape for a Reflector in the Normal Beam Data. Side View (XZ) of Base-Metal Indication in Block 1-8 at Y = 350 mm. Normal beam inspection from the unclad side. Z values in the figure are measured from the unclad side.

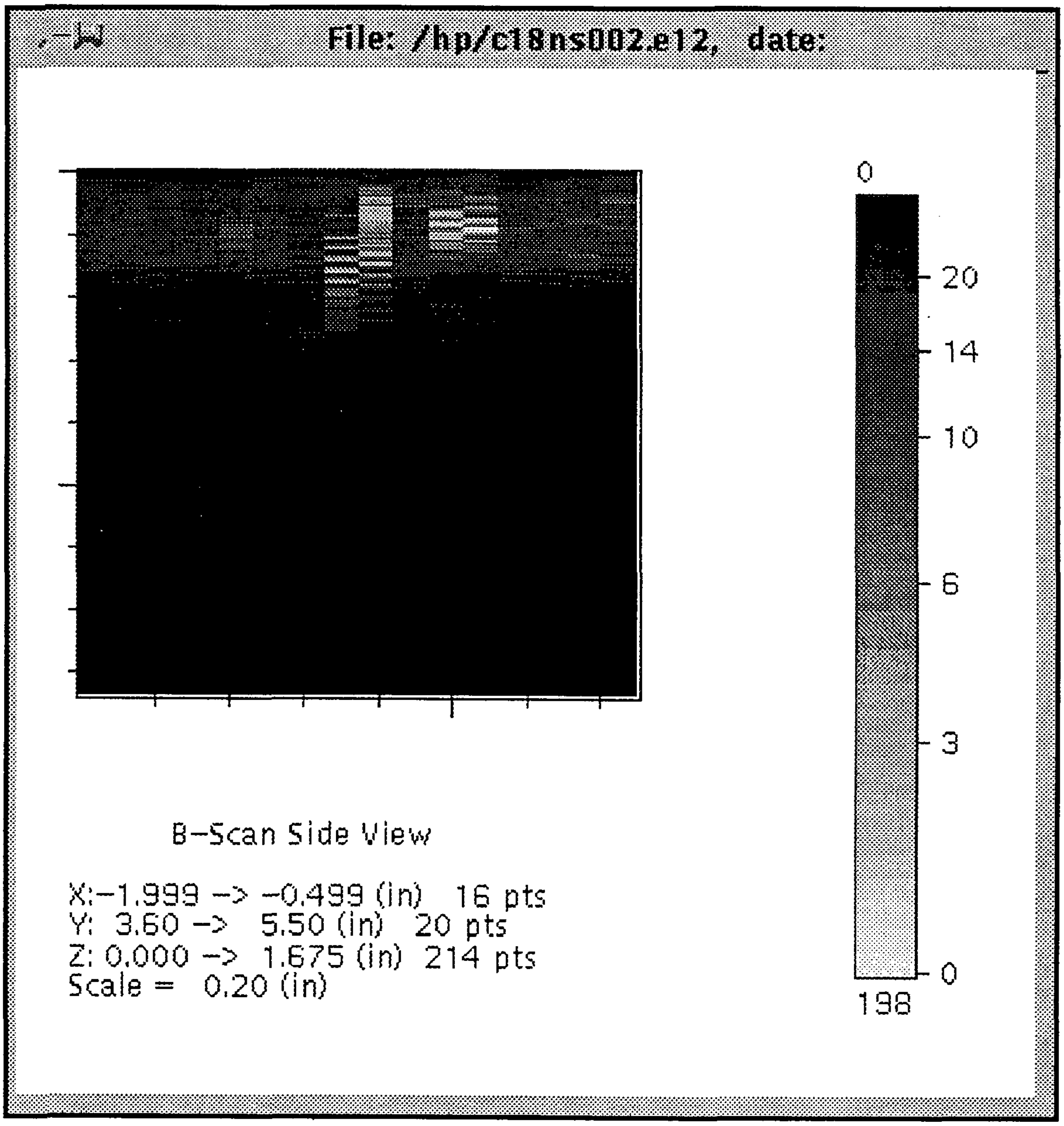


Figure 4.14 Typical Shape for a Reflector in the 70° L-Wave Inspections. Side View (XZ) of Clad to Base-Metal Indication in Block 1-8 at Y = 112 mm. 70° L-wave inspection with beam direction of +X.

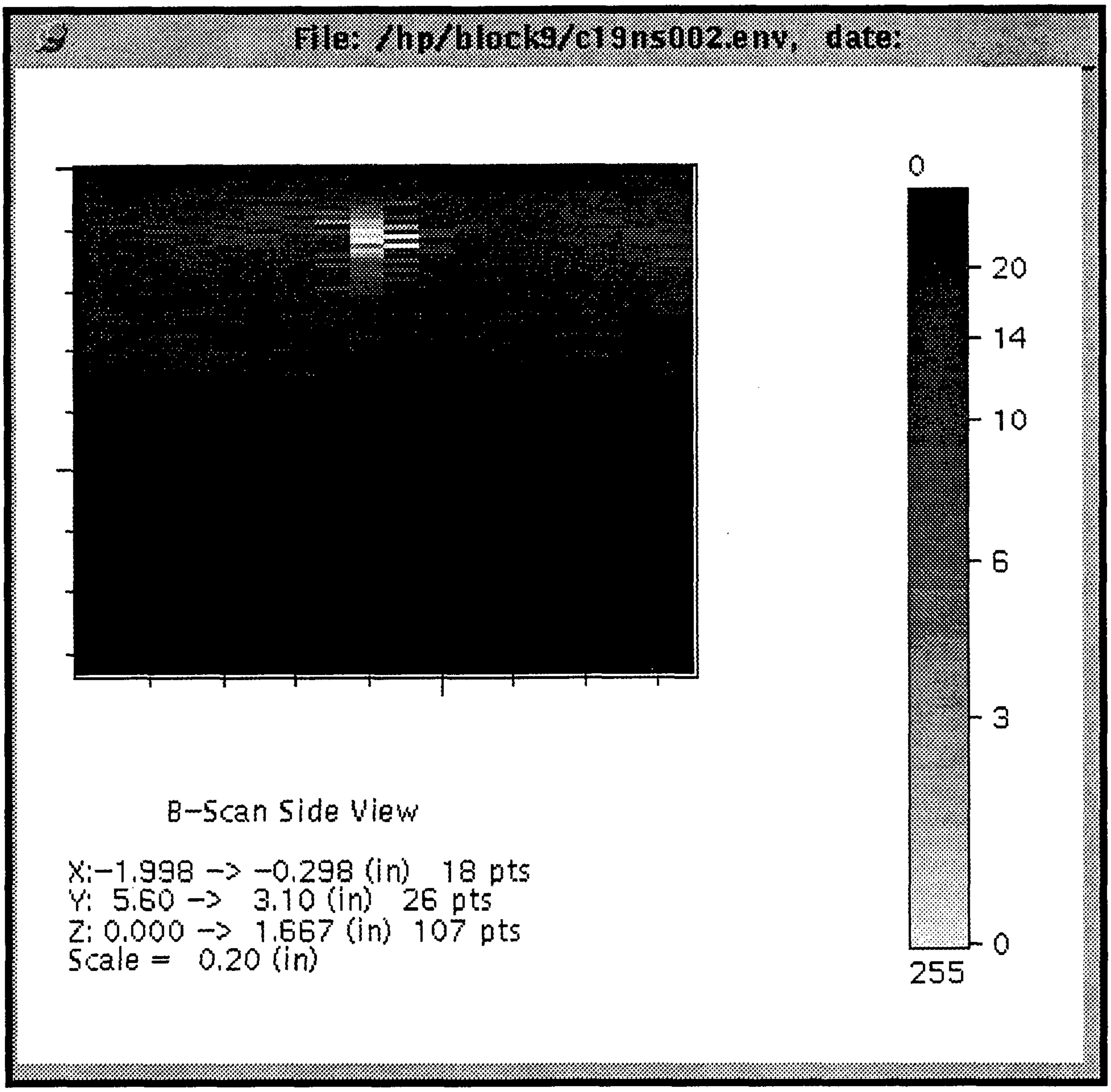


Figure 4.15 Typical Shapeless Image for a Bright Reflection in the 70° L-Wave Inspections. Side View (XZ) of Clad to Base-Metal Indication in Block 1-9 at Y = 117 mm. 70° L-wave inspection with beam direction of +X.

5.0 Analysis of SAFT-UT Data

In this section, the indications detected in the SAFT-UT data are characterized according to location, size, and flaw type. Images are presented in this section for all of the indications. Tables are provided for listing and describing the important attributes of the indications.

SAFT-UT images are presented in three engineering views: side view, end view, and C-scan view. The axes displayed in the images are the scanner's axes and the coordinates are scanner coordinates, not material coordinates. When the scanner axes differs from the material axis, an explanation is given in the figure caption.

The first of the three views in the figures is always the B-scan side view. In this view, the vertical axis is "Z" in scanner coordinates, with axis label given in the form of "Z: X.XXX → Y.YYY" where X.XXX is the coordinate at the top of the vertical axis and Y.YYY is the coordinate at the bottom of the axis. The horizontal axis is "X" in scanner coordinates, and the "Y" axis is perpendicular to the view. The scale given is the distance between the tick marks (minor tick marks included).

The second of the three views is always the B-scan end view. In this view, the vertical axis is "Z" and the horizontal axis is "Y." The third view is always the C-scan end view where the vertical axis is "Y" and the horizontal axis is "X."

The units in the images are given in inches, as determined by the software, and displays in metric units are not available at this time. Metric units are given in the text wherever possible. The tables give material coordinates for the location of the reflectors. Sizing in the tables uses the best available information from the inspections in which a reflector was detected.

For large flaws, a doublet set of time-of-flight (TOF) curves is expected. However, in analyzing the data, there were no cases where a doublet set of TOF curves was detected. The search for doublet TOF curves included exhaustive examination down to the background noise level of the data. Since no doublet TOF curves could be detected, it was postulated that the flaws were very small (no measurable extent along the line of insonification) and that the second TOF curve was merged with the first one.

Using this explanation, it then becomes important to be able to place an upper bound on the extent of a flaw that will cause the two TOF curves to collapse. There are a number of ways that this upper bound can be estimated. Two time-of-flight curves are said to be resolved when there is a 6-dB drop in amplitude between the two curves. This method yields a conservative result. A smaller amplitude drop, 3 dB, can be used to distinguish when a single TOF curve has greater effective ringdown due to the presence of a second curve. Flaws that have extent causing this broadening of the TOF curve can be sized to some degree and an effort should be made to do so.

The SAFT-UT data from the Midland blocks permits recognition that a TOF curve has increased in ringdown size. For the 45° shear inspections at 2.25 MHz, this criterion produces an upper bound flaw size of less than 1.3 mm (0.050 in.). In viewing the images of the responses from some of the indications, the responses tended to be tight packets. For indications imaged with the 70° probe, the upper bound flaw size was larger. For the 3 dB criterion, the upper bound flaw size was determined to be 2.24 mm (0.088 in.).

The lateral resolution of the system determines the minimum size in the plane perpendicular to the insonification direction for small reflectors. The resolution in this plane is on the order of 5.1 mm to 8.13 mm (0.2 in. to 0.32 in.) depending on the spatial sampling used for the various transducers and scans performed.

Since the indications in the Midland vessel had little measurable through-wall extent, it is difficult to characterize the indications as planar or volumetric. Still, it is important to use what features the data provides, and the following rules have been used in characterizing each reflector in the SAFT-UT data. For a reflector to be characterized as a planar flaw, it must be detected in an angle beam inspection or in normal beam from the bottom or top machined surfaces. And in addition, the reflector must be not detected in a normal beam inspection from the clad or unclad surfaces where adequate coverage is provided by at least one such inspection. All remaining reflectors are considered to be volumetric flaws.

5.1 Indications In and Near the Weld

There were a total of 23 indications that were detected in the SAFT-UT data from the weld and base metal in the four Midland blocks. None of the 23 showed a doublet TOF curve but nine of them had measurable through-wall extent.

5.1.1 Estimation of Weld and Base-Metal Defects in Block 1-8

Twelve indications were found in the weld and base metal in Block 1-8 but none showed measurable broadening of the TOF curve. Table 5.1 shows a direct comparison of the sizes and locations of reflectors in the SAFT-UT data that correspond with flaws found in the destructive analysis. Table 5.2 shows the location and characterization of all indications in the weld and base metal of Block 1-8 that were detected and characterized by SAFT-UT.

Table 5.1. Comparison of SAFT-UT Results with the Destructive Analysis of Weld Root Indications in Block 1-8

Flaw #5	Y, mm (in.)	DY, mm (in.)	X, mm (in.)	DX, mm (in.)	Z, mm (in.)	DZ, mm (in.)	Notes
Destructive Data	380 (15.0)	5 (0.2)	--	--	89 (3.5)	2 (0.1)	X and DX not given but flaw is in the weldment so X is 0 ± 12.7 mm (0.5 in.). See Figure 4.4.
SAFT-UT	380 (15.0)	5 (0.2)	-5 (-0.2)	13 (0.5)	89 (3.5)	1.3 (0.05)	DZ is determined from 45°S inspection from the unclad side. See Figure 5.1d.
Flaw #6t & 6b	**Y, mm (in.)**	**DY, mm (in.)**	**X, mm (in.)**	**DX, mm (in.)**	**Z, mm (in.)**	**DZ, mm (in.)**	**Notes**
Destructive Data	350 (13.8)	2.0 (0.08) 3.5 (0.14)	--	--	99 (3.9)	1.5 (0.06) 2.5 (0.10)	See Figures 4.5 and 4.6.
SAFT-UT	350 (13.8)	10 (0.4)	-10 (-0.4)	18 (0.7)	91 (3.6)	1.3 (0.05)	DZ is determined from 45°S inspection from the unclad side. See Figure 5.2g.

Table 5.2. SAFT-UT Results from Weld and Base Metal of Block 1-8

Y, mm (in.)	DY, mm (in.)	X, mm (in.)	DX, mm (in.)	Z, mm (in.)	DZ, mm (in.)	Characterization
380 (15.0)	5 (0.2)	-5 (-0.2)	13 (0.5)	89 (3.5)	1.3 (0.05)	Detected by SAFT-UT in normal beam from the clad side and in two different 45°S files from the unclad side. See Figure 5.1. DZ is determined from data shown in Figure 5.1d. This is one or more small volumetric defects. Destructive analysis shows one defect labeled 5T. See Table 4.1 and Figure 4.4 for DA results.
351 (13.8)	20 (0.8)	-10 (-0.4)	18 (0.7)	91 (3.6)	1.3 (0.05)	Detected by SAFT-UT in 45°S files from the unclad side. See Figure 5.2. DZ is determined from data shown in Figure 5.2g. This is one or more small planar defects. Destructive analysis shows two small defects label 6t and 6b. See Table 4.1 and Figure 4.5 for DA results.
318 (12.5)	15 (0.6)	-10 (-0.4)	13 (0.5)	91 (3.6)	1.3 (0.05)	Detected by SAFT-UT in normal beam from the clad side and in a 45°S inspection from the clad side. See Figure 5.3. This is a volumetric defect. DZ is estimated from Figure 5.3d.
249 (9.8)	5 (0.2)	0.0 (0.0)	20 (0.8)	109 (4.3)	1.3 (0.05)	Detected by SAFT-UT in normal beam from clad and unclad side. Also detected in 45°S files from the clad side. See Figure 5.4. This is a small volumetric defect. DZ is estimated from Figures 5.4k and 5.4g. DX is estimated from Figure 5.4h, and DY is estimated from Figure 5.4e.
-127 (-5.0)	10 (0.4)	0.00 (0.0)	15 (0.6)	112 (4.4)	-	Detected by SAFT-UT in normal beam from the clad side. See Figure 5.5. No estimate is made for DZ since this reflector is only detected in normal beam from the clad side. This is one or more small volumetric defects.
-249 (-9.8)	10 (0.4)	13 (0.5)	8 (0.3)	79 (3.1)	-	Detected by SAFT-UT in normal beam from the clad side. See Figure 5.6. No estimate is made for DZ since this reflector is only detected in normal beam from the clad side. This is a small volumetric defect.
-391 (-15.4)	10 (0.4)	5 (0.2)	8 (0.3)	86 (3.4)	-	Detected by SAFT-UT in normal beam from the clad side. See Figure 5.7. No estimate is made for DZ since this reflector is only detected in normal beam from the clad side. This is a small volumetric defect.
-465 (-18.3)	15 (0.6)	20 (0.8)	-	109 (4.3)	1.3 (0.05)	Detected by SAFT-UT in 45°S from the unclad side. See Figure 5.8. DZ is estimated from Figure 5.8a. No estimate is made for DX. DY is estimated from Figure 5.8b. This is a small defect, possibly planar since it was not detected in normal beam. But, confidence is

Y, mm (in.)	DY, mm (in.)	X, mm (in.)	DX, mm (in.)	Z, mm (in.)	DZ, mm (in.)	Characterization
						limited by the lack of coverage from the clad side. An indication was reported at this location by NDE center UT. Destructive analysis did not find a defect.
-71 (-2.8)	15 (0.6)	-15 (-0.6)	10 (0.4)	183 (7.2)	-	Detected by SAFT-UT in normal beam from the clad side. See Figure 5.9. No estimate is made for DZ since this reflector is only detected in normal beam from the clad side. This is a small volumetric defect.
-185 (-7.3)	25 (1.0)	2.5 (0.1)	51 (2.0)	155 (6.1)	-	Detected by SAFT-UT in normal beam from the clad side. See Figure 5.10. No estimate is made for DZ since this reflector is only detected in normal beam from the clad side. This is probably multiple volumetric defects.
-254 (-10.0)	20 (0.8)	-13 (-0.5)	13 (0.5)	183 (7.2)	-	Detected by SAFT-UT in normal beam from the clad side. See Figure 5.11. No estimate is made for DZ since this reflector is only detected in normal beam from the clad side. This is probably multiple small volumetric defects.
-325 (-12.8)	19 (0.75)	38 (1.5)	13 (0.5)	208 (8.2)	-	Detected by SAFT-UT in normal beam from the clad side. See Figure 5.12. No estimate is made for DZ since this reflector is only detected in normal beam from the clad side. This is probably multiple small volumetric defects.

5.1.2 Indications of Weld and Base-Metal Defects in Block 1-9

Eight indications were found in the weld and base metal in Block 1-9. Four of the eight are within ±1 in. of the weld center line and are considered to be associated with the weld. The other four are outside this zone and are considered to be indications from the parent material. Seven of the eight showed measurable depth extent. Table 5.3 shows the location and characterization of all indications in the base metal of Block 1-9 that were detected and characterized by SAFT-UT.

Table 5.3. SAFT-UT Results from Weld and Base Metal of Block 1-9

Y, mm (in.)	DY, mm (in.)	X, mm (in.)	DX, mm (in.)	Z, mm (in.)	DZ, mm (in.)	Characterization
Indications in and near the Weld of the Base Metal						
-582 (-22.9)	36 (1.4)	18 (-0.7)	-	178 (7.0)	18 (0.7)	Detected by SAFT-UT in normal beam from the bottom side. See Figure 5.13. This is probably multiple planar defects separated by 36 mm (1.4 in.) in Y.
-584 (-23.0)	23 (0.9)	-43 (-1.7)	-	145 (5.7)	<5 (<0.2)	Detected by SAFT-UT in normal beam from the bottom side. See Figure 5.14. This is either small planar defects separated by 23 mm (0.9 in.) in Y or a single planar defect of the size noted.
-597 (-23.5)	-	-66 (-2.6)	-	178 (7.0)	10 (0.4)	Detected by SAFT-UT in normal beam from bottom side. See Figure 5.15. Only part of the defect was insonified by SAFT-UT. This is probably a small planar defect of the size noted.
-221 (-8.7)	13 (0.5)	-30 (-1.2)	-	64 (2.5)	5 (0.2)	Detected by SAFT-UT in normal beam from the bottom side. See Figure 5.16. This is probably a single planar defect of the size noted.
-69 (-2.7)	13 (0.5)	2 (0.1)	-	114 (4.5)	5 (0.2)	Detected by SAFT-UT in normal beam from the bottom side. See Figure 5.17. This is a small planar defect.
183 (7.2)	25 (1.0)	-2 (-0.1)	-	121 (4.8)	8 (0.3)	Detected by SAFT-UT in normal beam from the bottom side. See Figure 5.18. This is a small planar defect.
203 (8.0)	10 (0.4)	0 (0.0)	5 (0.2)	119 (4.7)	-	Detected by SAFT-UT in normal beam from the clad side. See Figure 5.19. No estimate is made for DZ since this reflector is only detected in normal beam from the clad side. This is a small volumetric defect.
185 (7.3)	23 (0.9)	76 (3.0)	5 (0.2)	206 (8.1)	-	Detected by SAFT-UT in normal beam from the clad side. See Figure 5.20. No estimate is made for DZ since this reflector is only detected in normal beam from the clad side. This is a small volumetric defect.

5.1.3 Indications of Weld and Base-Metal Defects in Block 1-11

Two indications were found in the weld and base metal in Block 1-11. Both of the indications showed measurable depth extent. Table 5.4 shows the location and characterization of the two indications in the base metal that were detected and characterized by SAFT-UT.

Table 5.4. SAFT-UT Results from Block 1-11

Y, mm (in.)	DY, mm (in.)	X, mm (in.)	DX, mm (in.)	Z, mm (in.)	DZ, mm (in.)	Characterization
-152 (-6.0)	10 (0.4)	8 (0.3)	-	132 (5.2)	2 (0.1)	Detected by SAFT-UT in normal beam from the top side. See Figure 5.21. This is a small planar defect.
-140 (-5.5)	20 (0.8)	-13 (-0.5)	-	150 (5.9)	2 (0.1)	Detected by SAFT-UT in normal beam from the top side. See Figure 5.22. This is either small planar defects separated by 20 mm or a single planar defect of the size noted.

5.1.4 Indications of Weld and Base-Metal Defects in Block 1-12

One indications was found in the base metal in block 1-12. Table 5.5 shows the location and characterization of the indication.

Table 5.5. SAFT-UT Results from Block 1-12

Y, mm (in.)	DY, mm (in.)	X, mm (in.)	DX, mm (in.)	Z, mm (in.)	DZ, mm (in.)	Characterization
-96 (-3.8)	10 (0.4)	-13 (-0.5)	-	119 (4.7)	2 (0.1)	Detected by SAFT-UT in normal beam from the top side. See Figure 5.23. This is a small planar defect.

5.2 Indications Near the Clad-to-Base Metal Interface

Table 5.6 shows a direct comparison of the sizes and locations of the reflectors in the SAFT-UT data that correspond with flaws found in the destructive analysis. There were a total of eight indications that were detected in the SAFT-UT data from the clad-to-base metal interface in four Midland blocks. All of the SAFT-UT data were analyzed using the method described in Section 4.2.1.

Table 5.6. Comparison of SAFT-UT Results with the Destructive Analysis of Block 1-8 (Near-Surface Zone Indications)

Flaw #7	Y, mm (in.)	DY, mm (in.)	X, mm (in.)	DX, mm (in.)	Z, mm (in.)	DZ, mm (in.)	Notes
Destructive Data	81 (3.2)	--	-22 (-0.8)	4 (0.16)	7 (0.27)	1 (0.04)	See Figure 4.7.
SAFT-UT	89 (3.5)	5 (0.2)	8 (0.3)	5 (0.2)	8 (0.3)	<2.2 (<0.09)	See Figure 5.26. There is a sign difference between the destructive analysis and the SAFT-UT data for X. The origin of this difference is not known.
Flaw #8	**Y, mm (in.)**	**DY, mm (in.)**	**X, mm (in.)**	**DX, mm (in.)**	**Z, mm (in.)**	**DZ, mm (in.)**	**Notes**
Destructive Data	112 (4.4)	--	33 (1.3)	5 (0.2)	10 (0.4)	2 (0.08)	See Figure 4.8.
SAFT-UT	112 (4.4)	5 (0.2)	-33 (-1.3)	5 (0.2)	10 (0.4)	<2.2 (<0.09)	See Figure 5.27. There is a sign difference between the destructive analysis and the SAFT-UT data for X. The origin of this difference is not known.
Flaw #11	**Y, mm (in.)**	**DY, mm (in.)**	**X, mm (in.)**	**DX, mm (in.)**	**Z, mm (in.)**	**DZ, mm (in.)**	**Notes**
Destructive Data	235 (9.2)	--	-15 (-0.6)	1.5 (0.06)	6 (0.24)	0.5 (0.02)	See Figure 4.11.
SAFT-UT	236 (9.3)	5 (0.2)	18 (0.7)	5 (0.2)	5 (0.2)	<2.2 (<0.09)	See Figure 5.28. There is a sign difference between the destructive analysis and the SAFT-UT data for X. The origin of this difference is not known.

5.2.1 Estimation of Defects at the Clad-to-Base Metal Interface in Block 1-8

Six indications were found at the clad-to-base metal interface in Block 1-8. Table 5.7 shows the location and characterization of all indications in Block 1-8 that were detected and characterized by SAFT-UT.

Table 5.7. SAFT-UT Results from the Clad-to-Base Metal Interface of Block 1-8

Y, mm (in.)	DY, mm (in.)	X, mm (in.)	DX, mm (in.)	Z, mm (in.)	DZ, mm (in.)	Characterization
-526 (-20.7)	5 (0.2)	-20 (-0.8)	5 (0.2)	5 (0.2)	<2.2 (<0.09)	Detected by SAFT-UT in 70° L-wave inspection in the +X direction only. See Figure 5.24. This is a volumetric defect.
-211 (-8.3)	2 (0.1)	-20 (-0.8)	5 (0.2)	5 (0.2)	<2.2 (<0.09)	Detected by SAFT-UT in 70° L-wave inspection in the +X direction only. See Figure 5.25. This is a volumetric defect.
89 (3.5)	5 (0.2)	8 (0.3)	5 (0.2)	8 (0.3)	<2.2 (<0.09)	Detected by SAFT-UT in 70° L-wave inspection in the +X direction only. See Figure 5.26. This is a volumetric defect. Destructive analysis shows one small defect labeled #7. See Table 4.1 and Figure 4.6 for DA results.
112 (4.4)	5 (0.2)	-33 (-1.3)	5 (0.2)	10 (0.4)	<2.2 (<0.09)	Detected by SAFT-UT in 70° L-wave inspections in the +X and -X directions. See Figure 5.27. This is a volumetric defect. Destructive analysis shows one defect labeled #8. See Table 4.1 and Figure 4.7 for DA results. This indication had been conservatively called planar in Doctor (1991). DA confirms volumetric.
236 (9.3)	5 (0.2)	18 (0.7)	5 (0.2)	5 (0.2)	<2.2 (<0.09)	Detected by SAFT-UT in 70° L-wave inspection in the -X direction only. See Figure 5.28. This is a volumetric defect. Destructive analysis shows one small defect labeled #11. See Table 4.1 and Figure 4.10 for DA results.
442 (17.4)	15 (0.6)	-23 (-0.9)	5 (0.2)	5 (0.2)	<2.2 (<0.09)	Detected by SAFT-UT in 70° L-wave inspection in the +X direction. See Figure 5.29. This is a volumetric defect.

5.2.2 Estimation of Defects at the Clad-to-Base Metal Interface in Block 1-9

One indication was found at the clad-to-base metal interface in Block 1-9. Table 5.8 shows the location and characterization of the one indication found by SAFT-UT in Block 1-9 at the clad-to-base metal interface.

Table 5.8. SAFT-UT Results from the Clad-to-Base Metal Interface of Block 1-9

Y, mm (in.)	DY, mm (in.)	X, mmm (in.)	DX, mm (in.)	Z, mm (in.)	DZ, mm (in.)	Characterization
117 (4.6)	15 (0.6)	-30 (-1.2)	5 (0.2)	5 (0.2)	<2.2 (<0.09)	Detected by SAFT-UT in 70° L-wave inspection in the +X direction. See Figure 5.30. This is either two small volumetric defects or a larger defect of the size noted.

5.2.3 Estimation of Defects at the Clad-to-Base Metal Interface in Block 1-11

One indication was found at the clad-to-base metal interface in Block 1-11. Table 5.9 shows the location and characterization of one indications found by SAFT-UT in Block 1-11.

Table 5.9. SAFT-UT Results from the Clad-to-Base Metal Interface of Block 1-11

Y, mm (in.)	DY, Mm (in.)	X, mm (in.)	DX, mm (in.)	Z, mm (in.)	DZ, mm (in.)	Characterization
387 (15.3)	23 (0.9)	8 (0.3)	5 (0.2)	11 (0.45)	<2.2 (<0.09)	Detected by SAFT-UT in 70° L-wave inspection in the -X direction only. See Figure 5.31. This is the deepest of the 8 indications found in the near-surface zone. Because no destructive data exists to prove otherwise, this indication is conservatively assumed to be planar.

5.2.4 Estimation of Defects at the Clad-to-Base Metal Interface in Block 1-12

No indications were found at the clad-to-base metal interface in Block 1-12.

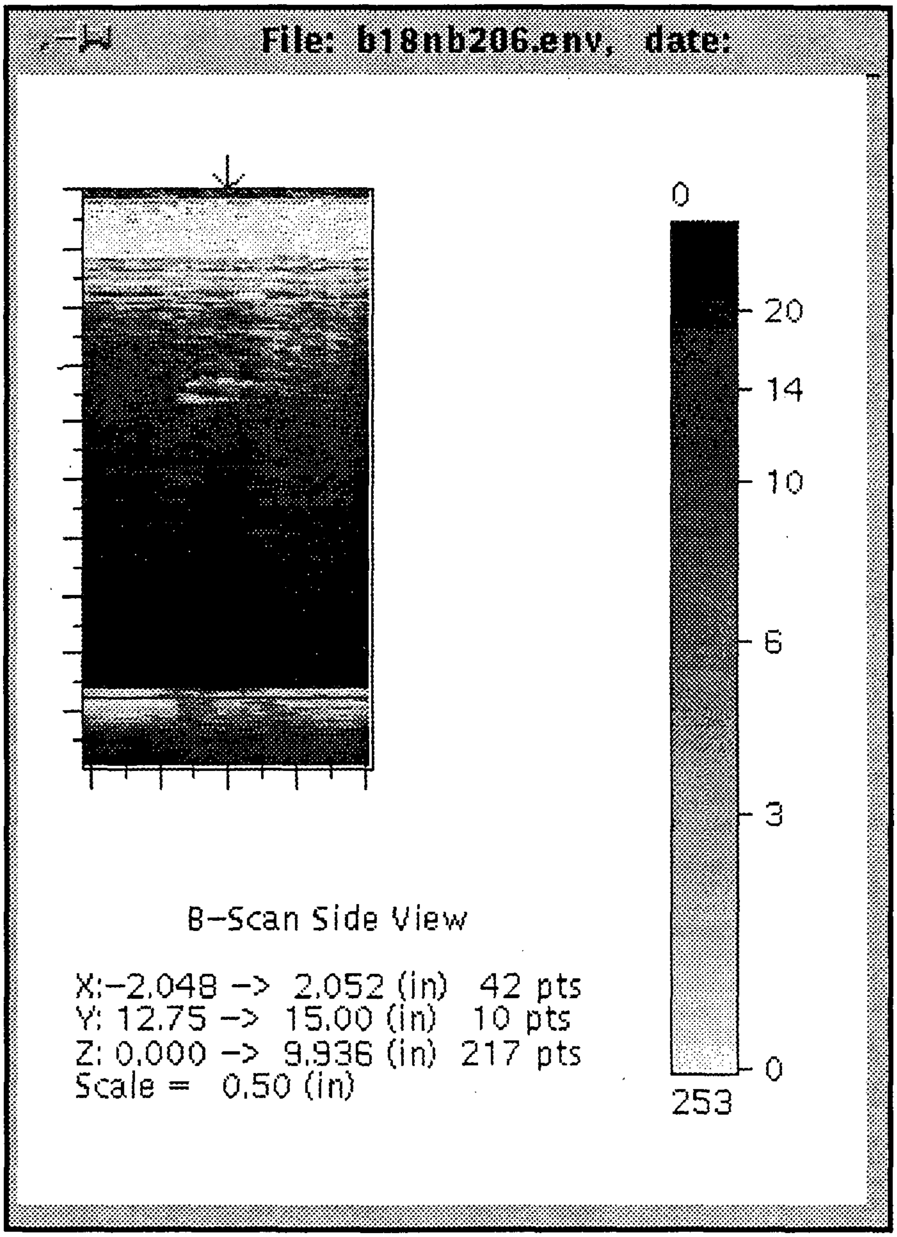


Figure 5.1a Side View (XZ) of Base-Metal Indication in Block 1-8 at Y = 381 mm (15.0 in.). Normal beam inspection from the clad side. This indication corresponds to flaw #5 in the destructive analysis.

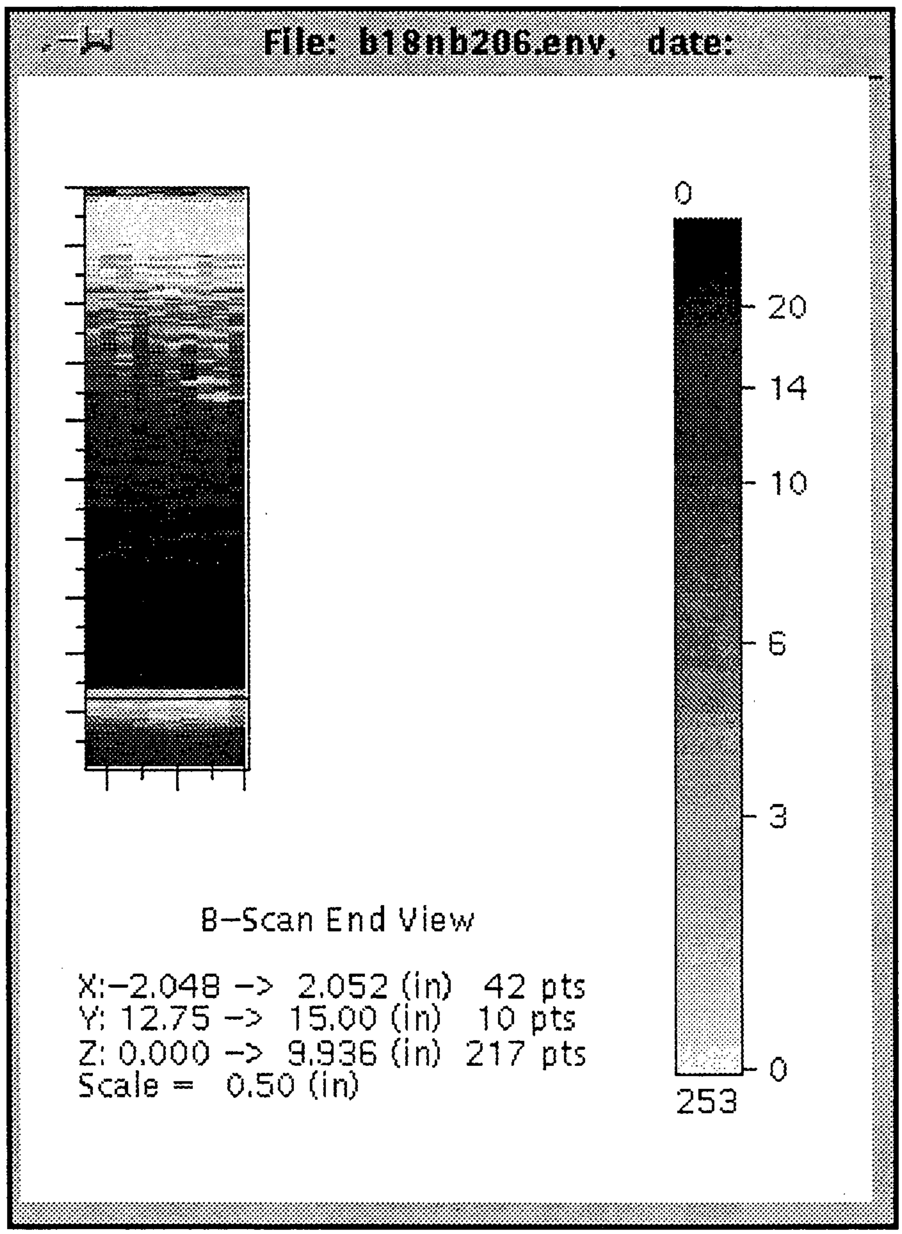


Figure 5.1b End View (YZ) of Base-Metal Indication in Block 1-8 at Y = 381 mm (15.0 in.). Normal beam inspection from the clad side. This indication corresponds to flaw #5 in the destructive analysis.

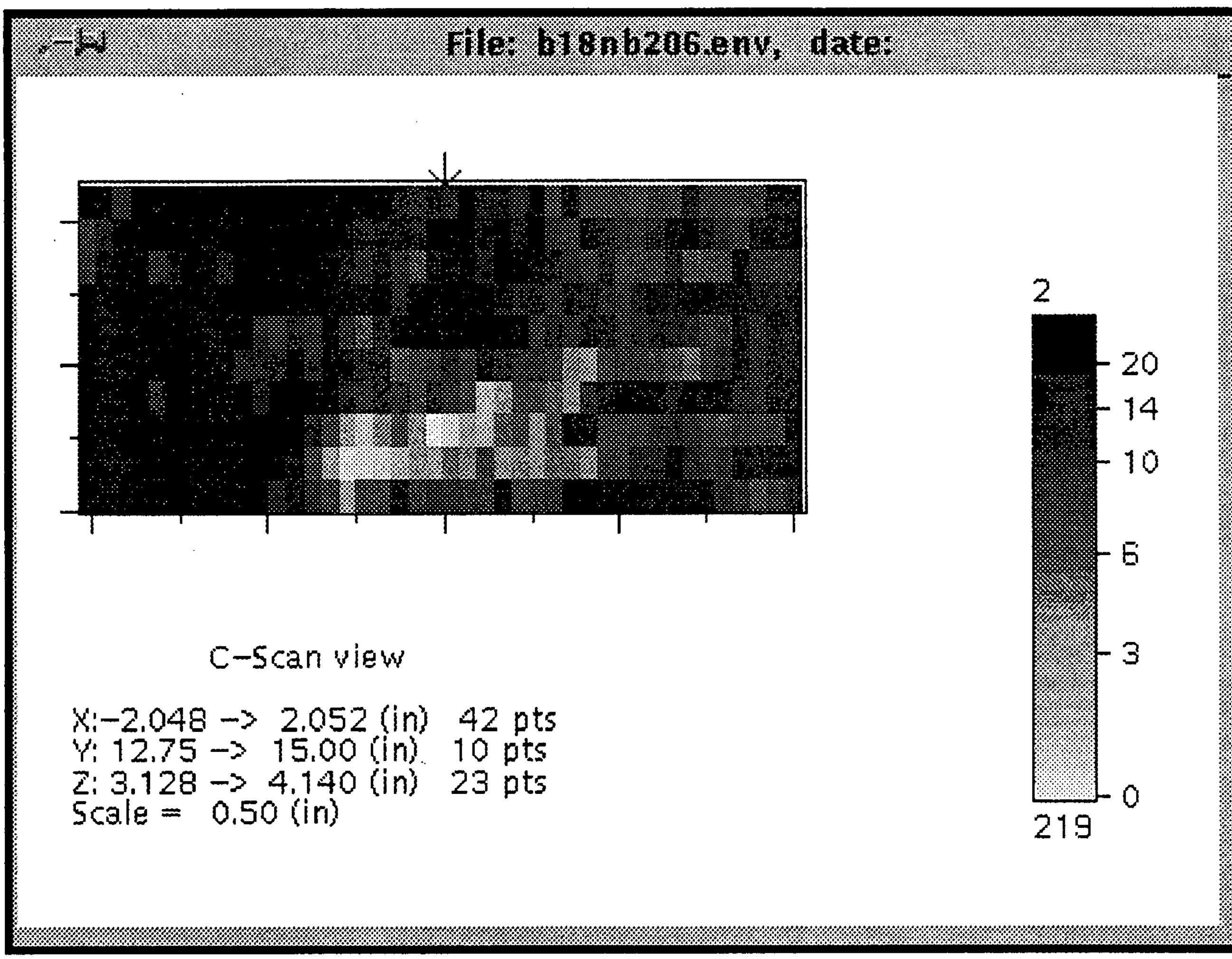


Figure 5.1c C-scan View (XY) of Base-Metal Indication in Block 1-8 at Y = 381 mm (15.0 in.). Normal beam inspection from the clad side. This indication corresponds to flaw #5 in the destructive analysis.

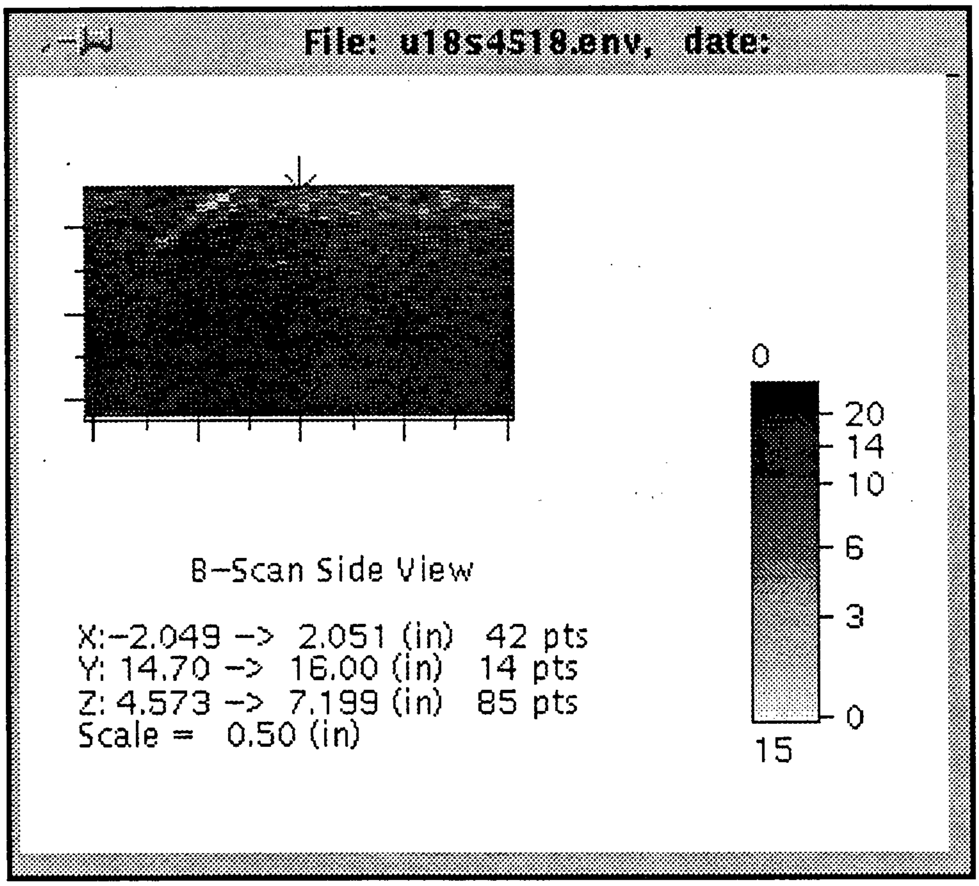


Figure 5.1d Side View (XZ) of Base-Metal Indication in Block 1-8 at Y = 381 mm (15.0 in.). 45° shear inspection from the unclad side. Beam direction is +X. Z values in the figure are measured from the unclad side. This indication corresponds to flaw #5 in the destructive analysis.

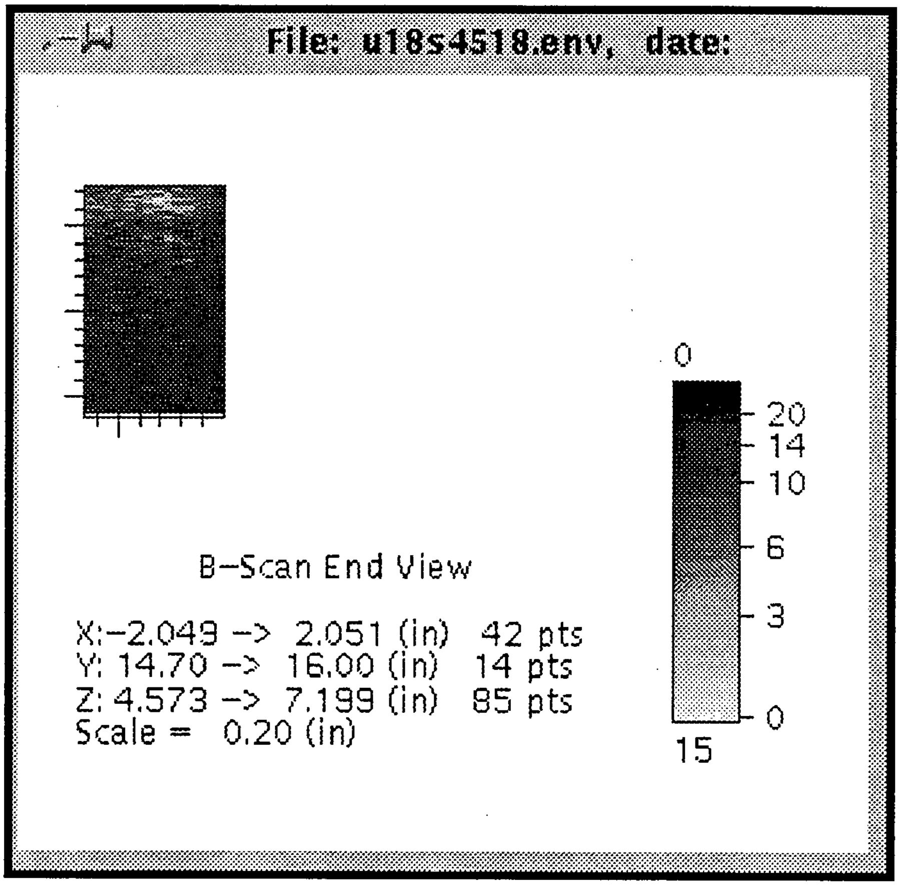


Figure 5.1e End View (YZ) of Base-Metal Indication in Block 1-8 at Y = 381 mm (15.0 in.). 45° shear inspection from the unclad side. Beam direction is +X. Z values in the figure are measured from the unclad side. This indication corresponds to flaw #5 in the destructive analysis.

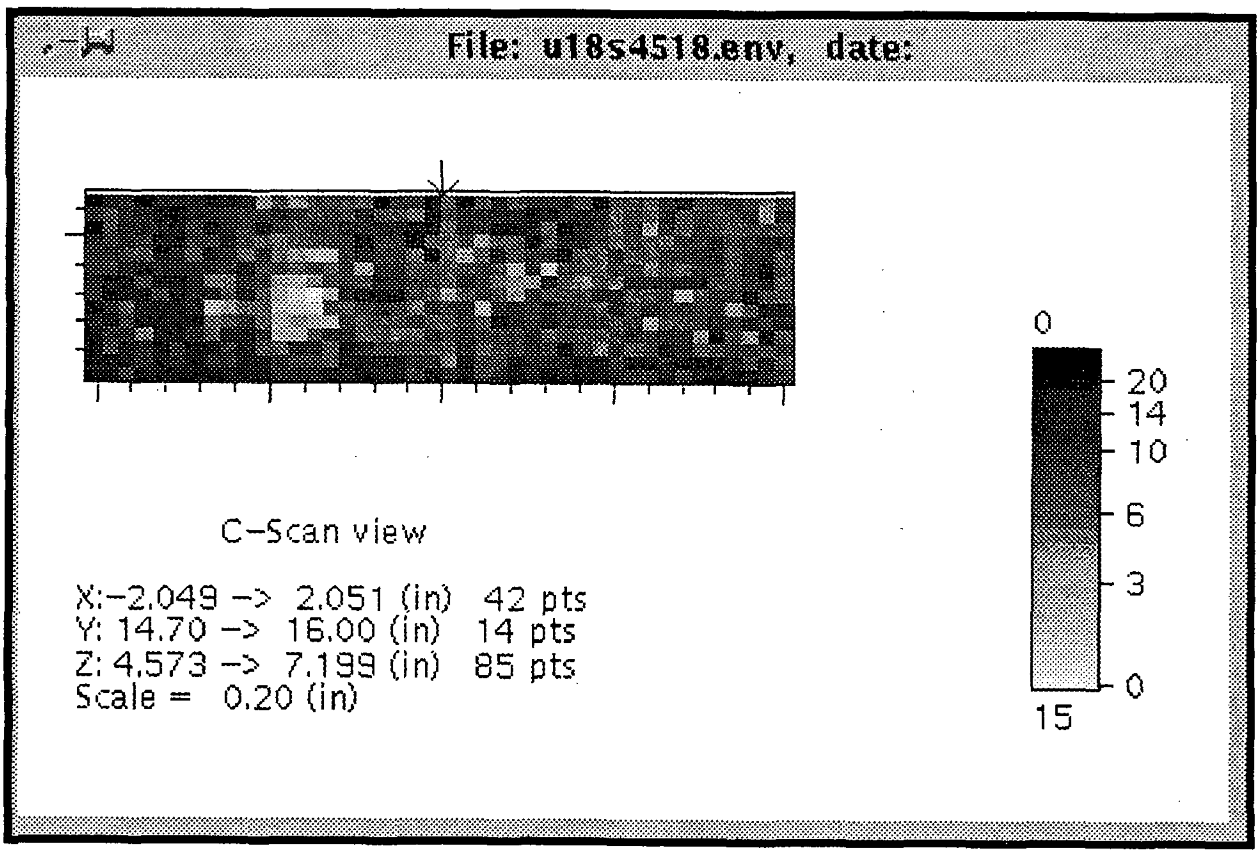


Figure 5.1f C-scan View (XY) of Base-Metal Indication in Block 1-8 at Y = 381 mm (15.0 in.). 45° shear inspection from the unclad side. Beam direction is +X. Z values in the figure are measured from the unclad side. This indication corresponds to flaw #5 in the destructive analysis.

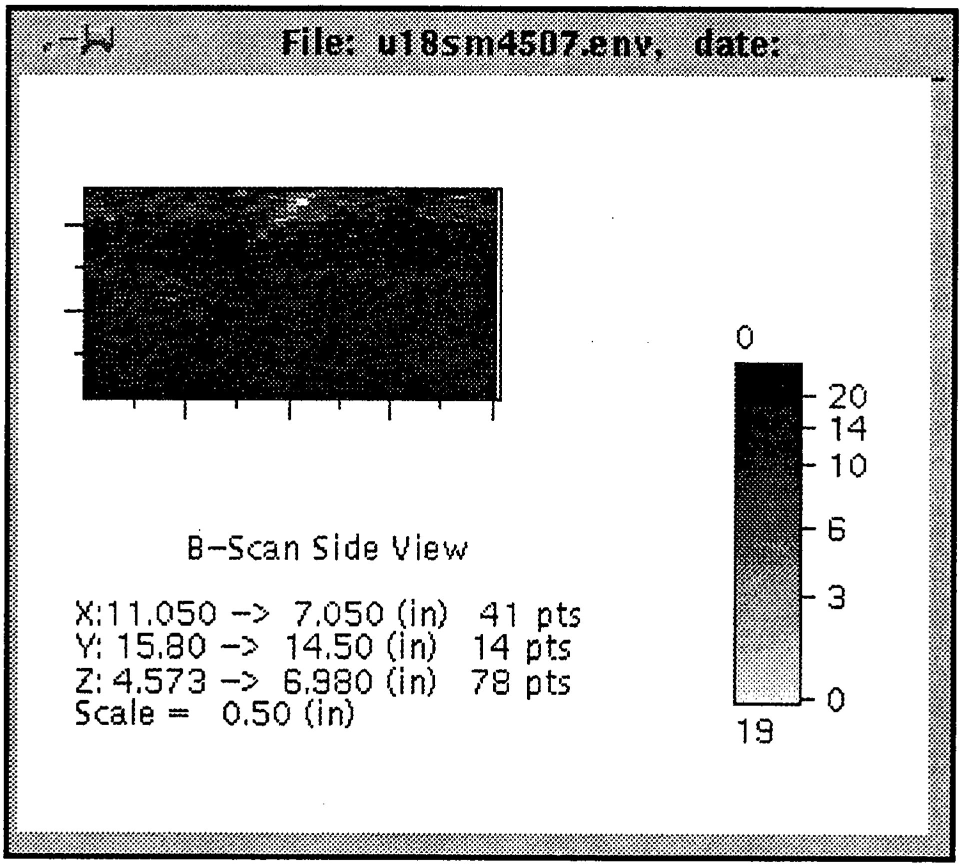


Figure 5.1g Side View (XZ) of Base-Metal Indication in Block 1-8 at Y = 381 mm (15.0 in.). 45° shear inspection from the unclad side. Beam direction is -X. Z values in the figure are measured from the unclad side. X values in the figure are +2 to -2 inches in material coordinates. This indication corresponds to flaw #5 in the destructive analysis.

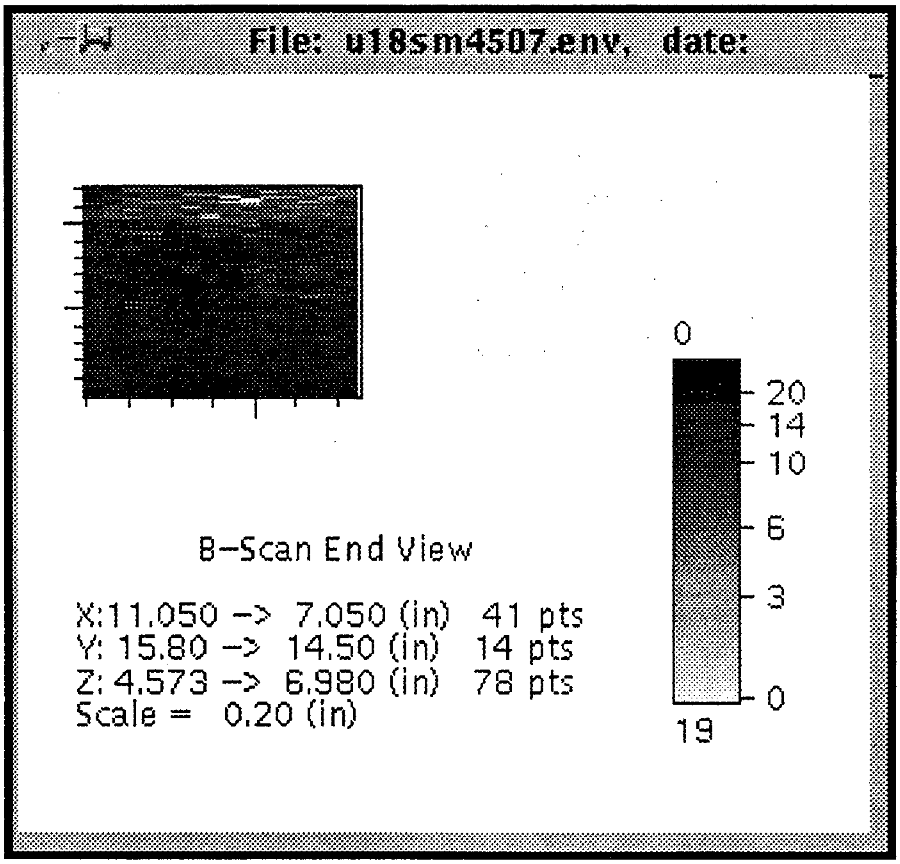


Figure 5.1h Side View (YZ) of Base-Metal Indication in Block 1-8 at Y = 381 mm (15.0 in.). 45° shear inspection from the unclad side. Beam direction is -X. Z values in the figure are measured from the unclad side. X values in the figure are +2 to -2 inches in material coordinates. This indication corresponds to flaw #5 in the destructive analysis.

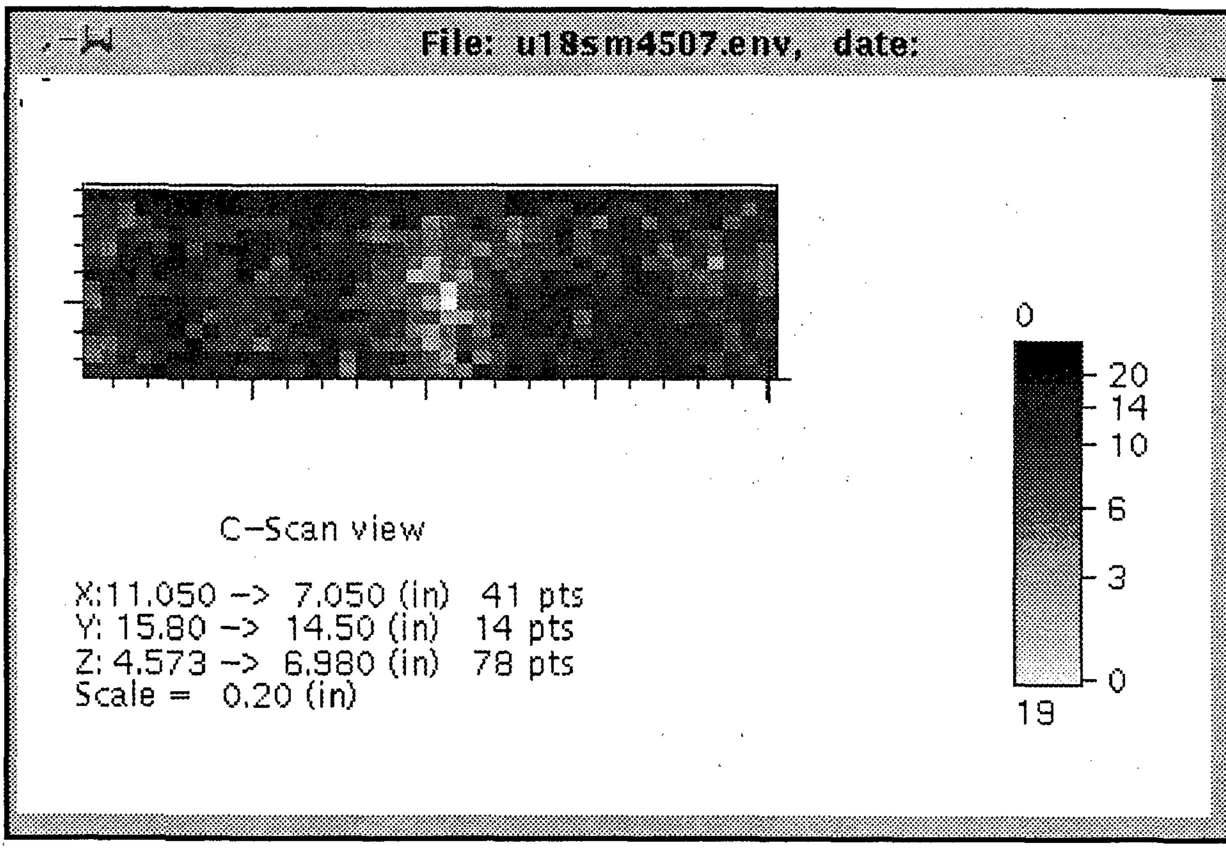


Figure 5.1i C-scan View (XY) of Base-Metal Indication in Block 1-8 at Y = 381 mm (15.0 in.). 45° shear inspection from the unclad side. Beam direction is -X. Z values in the figure are measured from the unclad side. X values in the figure are +2 to -2 inches in material coordinates. This indication corresponds to flaw #5 in the destructive analysis.

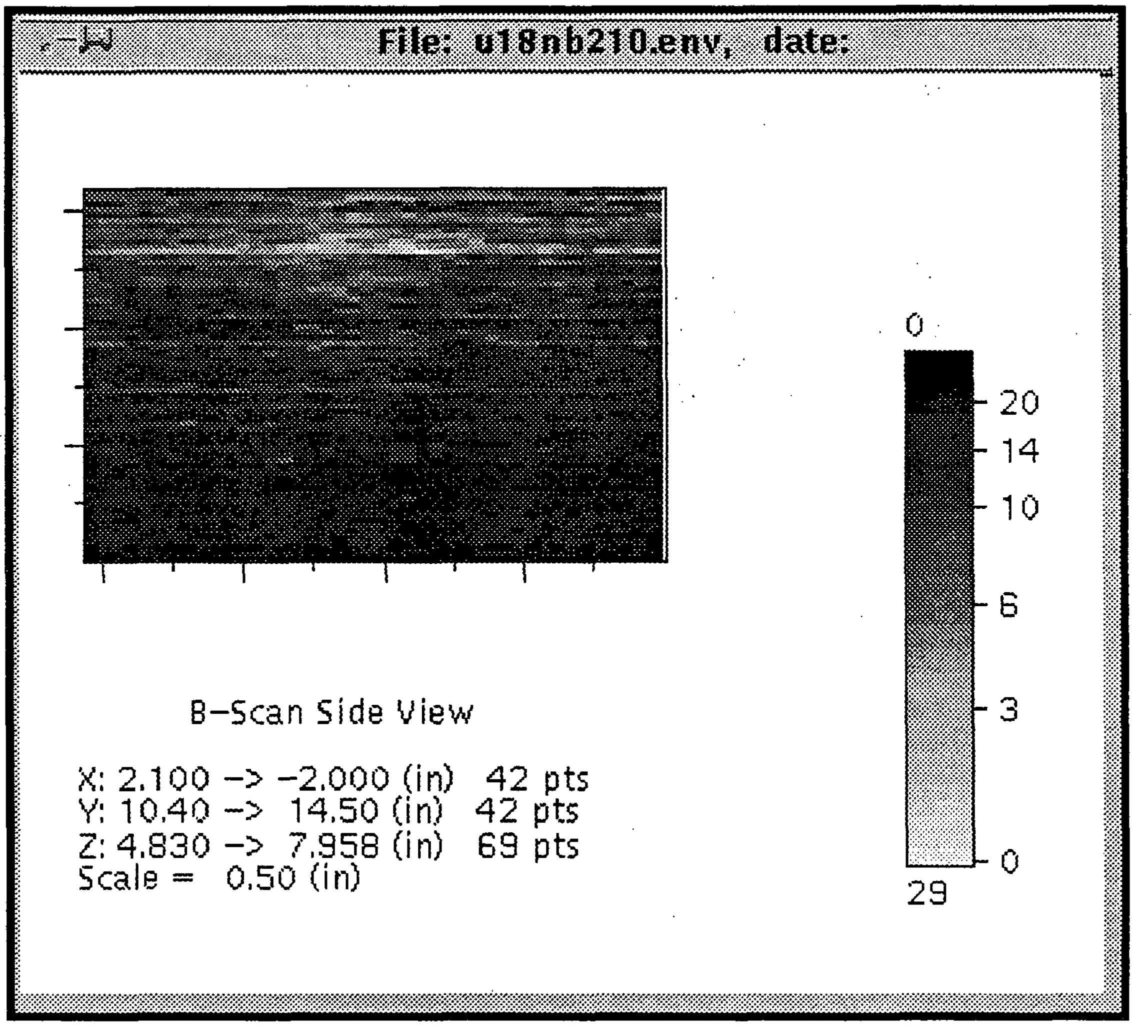


Figure 5.2a Side View (XZ) of Base-Metal Indication in Block 1-8 at Y = 351 mm (13.8 in.). Normal beam inspection from the unclad side. Z values in the figure are measured from the unclad side. This indication corresponds to flaw #6 in the destructive analysis.

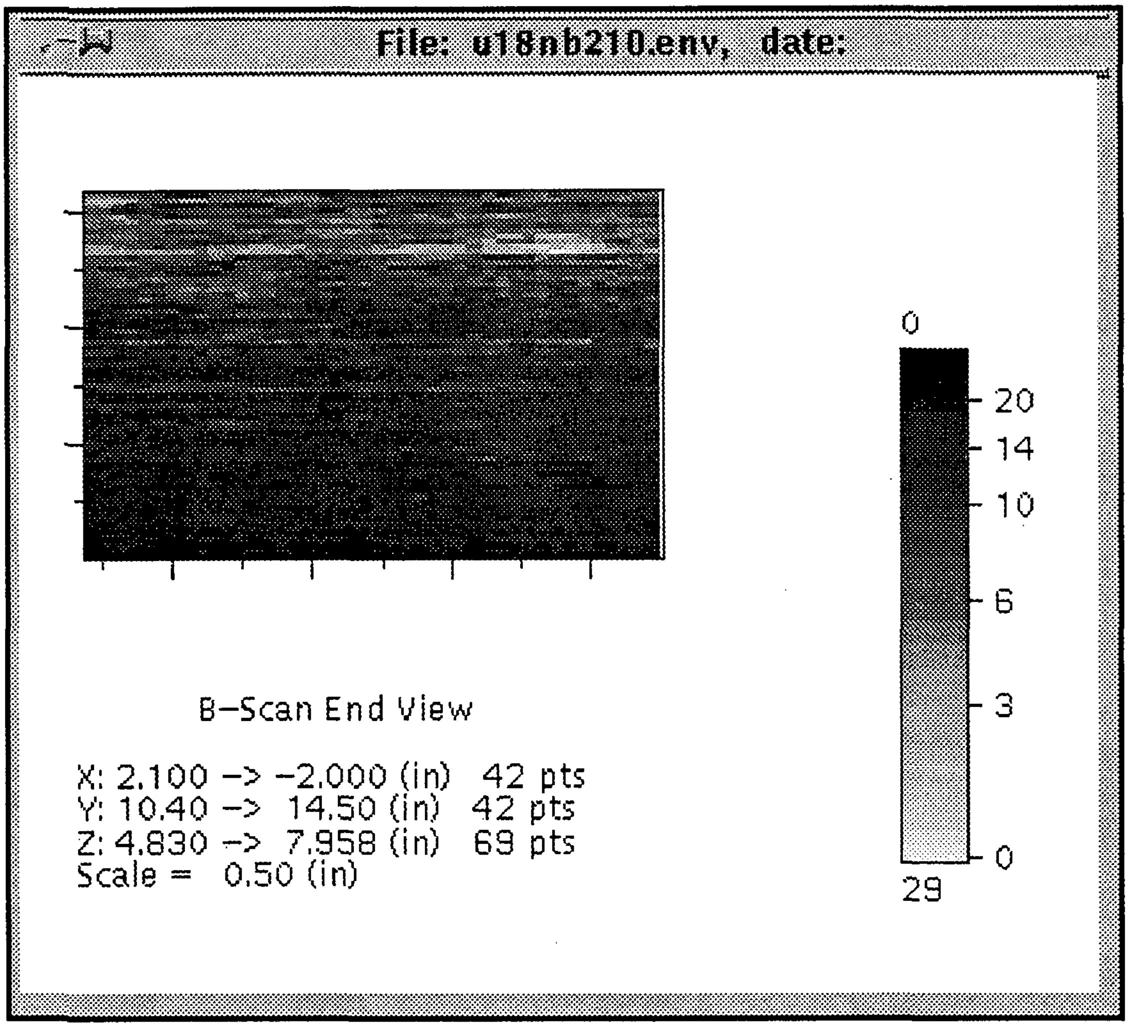


Figure 5.2b End View (YZ) of Base-Metal Indication in Block 1-8 at Y = 351 mm (13.8 in.). Normal beam inspection from the unclad side. Z values in the figure are measured from the unclad side. This indication corresponds to flaw #6 in the destructive analysis.

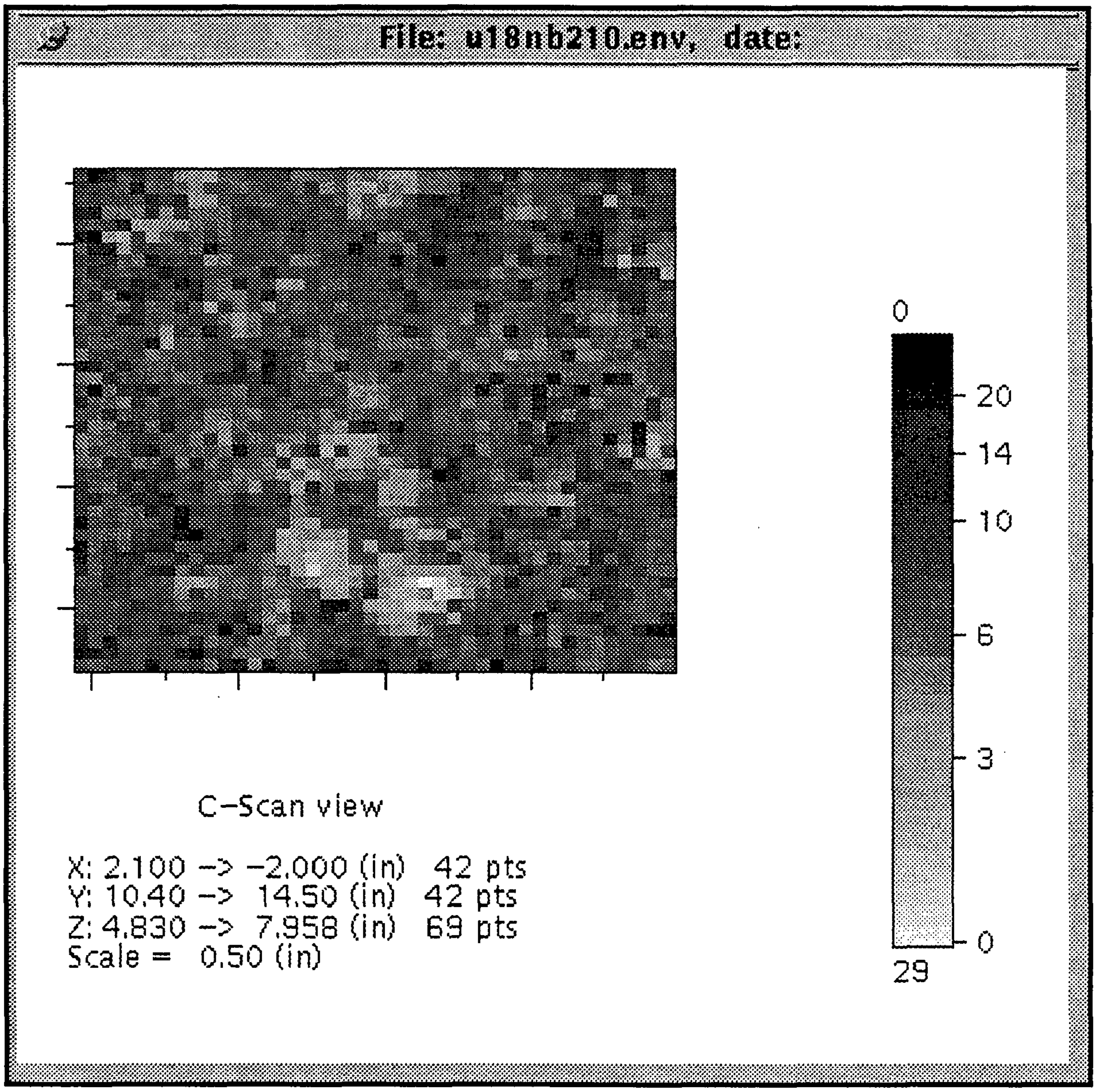


Figure 5.2c C-scan View (XY) of Base-Metal Indication in Block 1-8 at Y = 351 mm (13.8 in.). Normal beam inspection from the unclad side. Z values in the figure are measured from the unclad side. This indication corresponds to flaw #6 in the destructive analysis.

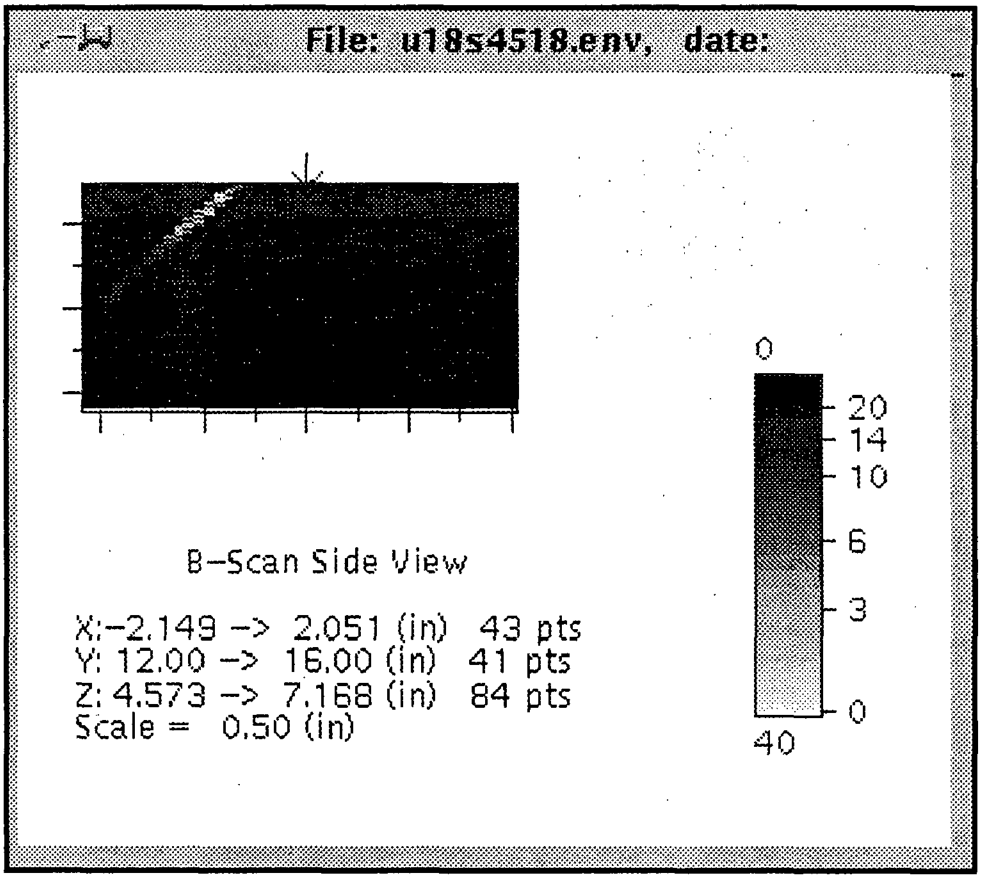


Figure 5.2d Side View (XZ) of Base-Metal Indication in Block 1-8 at Y = 351 mm (13.8 in.). 45° shear inspection from the unclad side. Beam direction is +X. Z values in the figure are measured from the unclad side. This indication corresponds to flaw #6 in the destructive analysis.

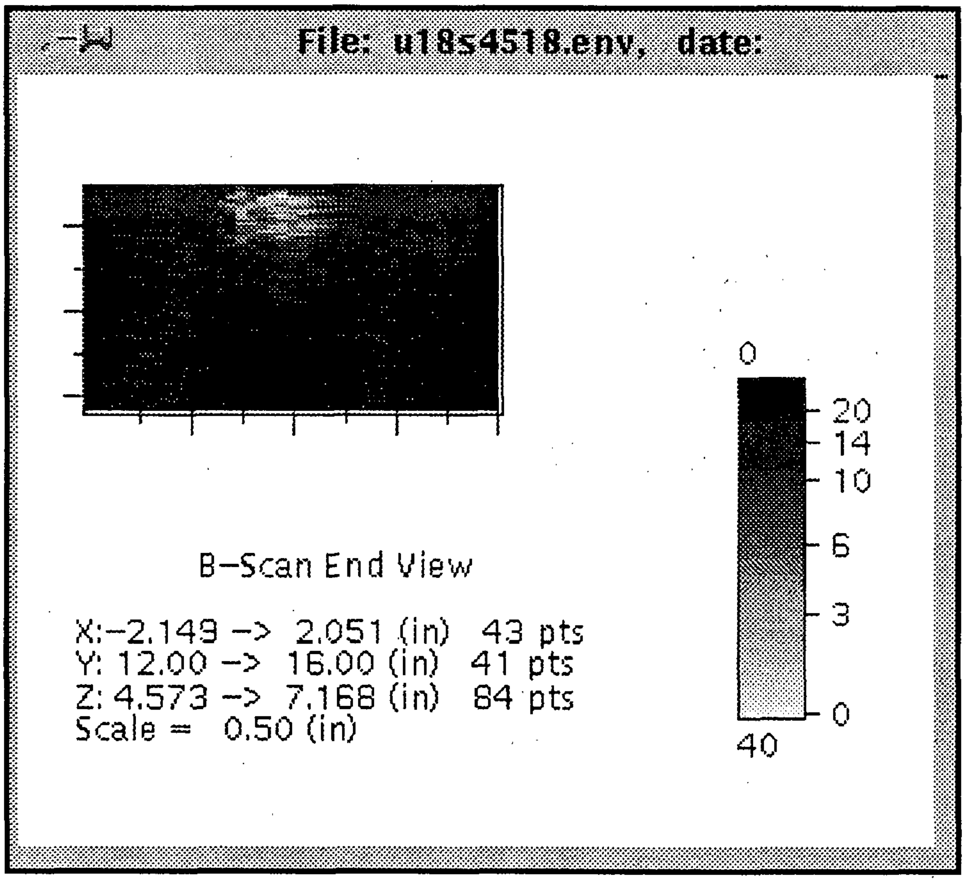


Figure 5.2e End View (YZ) of Base-Metal Indication in Block 1-8 at Y = 13.8 45° shear inspection from the unclad side. Beam direction is +X. Z values in the figure are measured from the unclad side. This indication corresponds to flaw #6 in the destructive analysis.

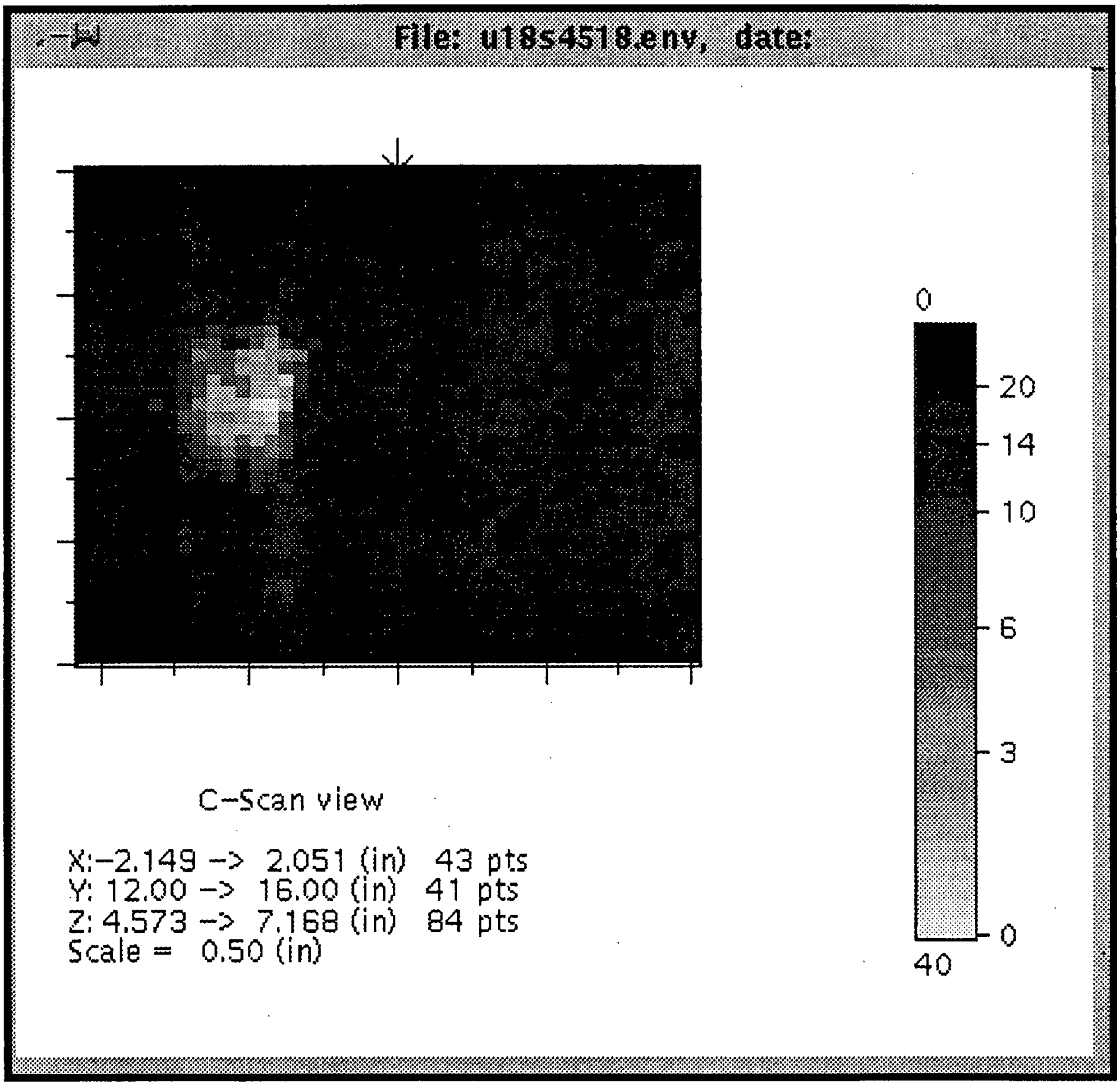


Figure 5.2f C-scan View (XY) of Base-Metal Indication in Block 1-8 at Y = 351 mm (13.8 in.). 45° shear inspection from the unclad side. Beam direction is +X. Z values in the figure are measured from the unclad side. This indication corresponds to flaw #6 in the destructive analysis.

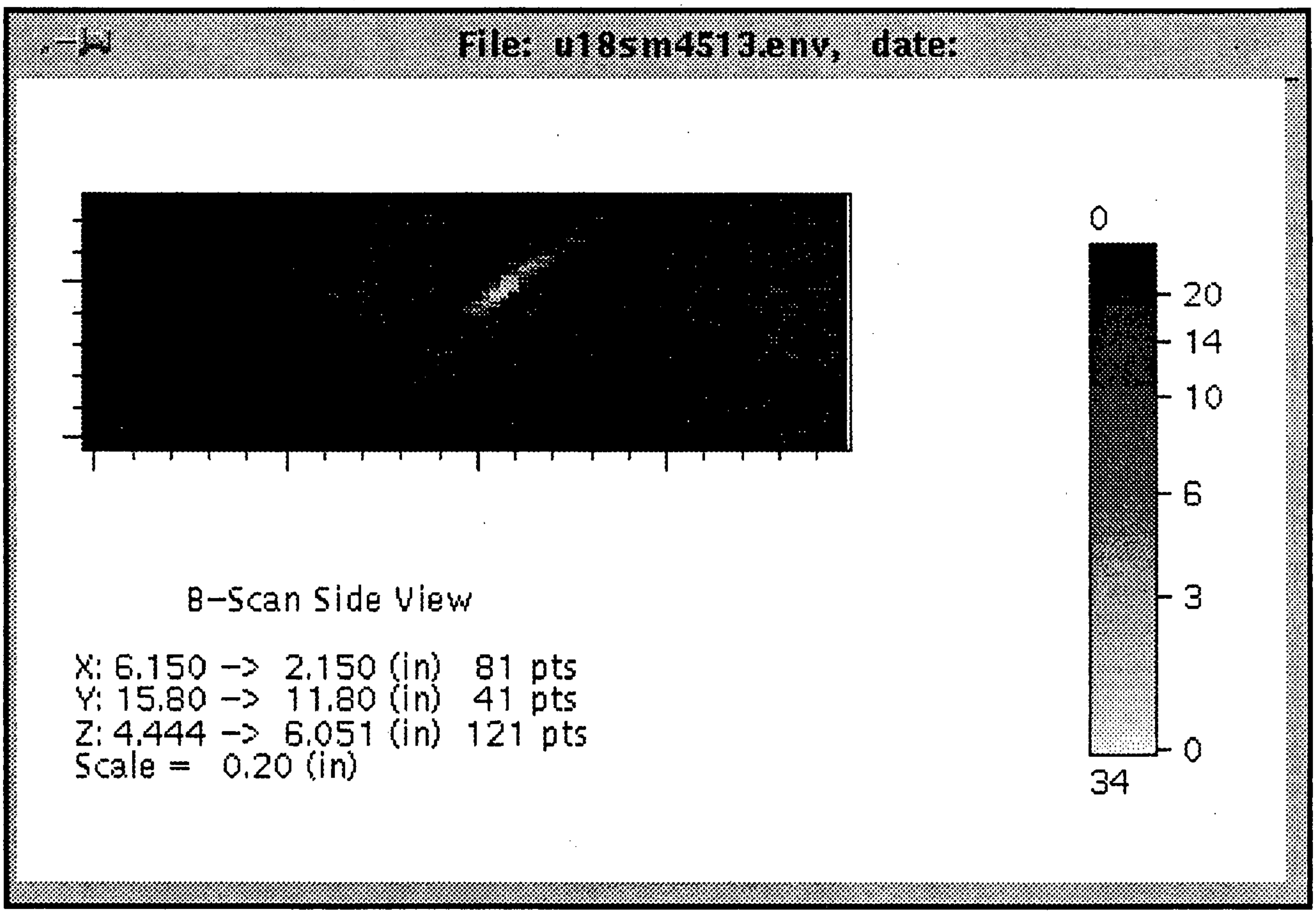


Figure 5.2g Side View (XZ) of Base-Metal Indication in Block 1-8 at Y = 351 mm (13.8 in.). 45° shear inspection from the unclad side. Beam direction is -X. Z values in the figure are measured from the unclad side. X values in the figure are +2 to -2 inches in material coordinates. This indication corresponds to flaw #6 in the destructive analysis.

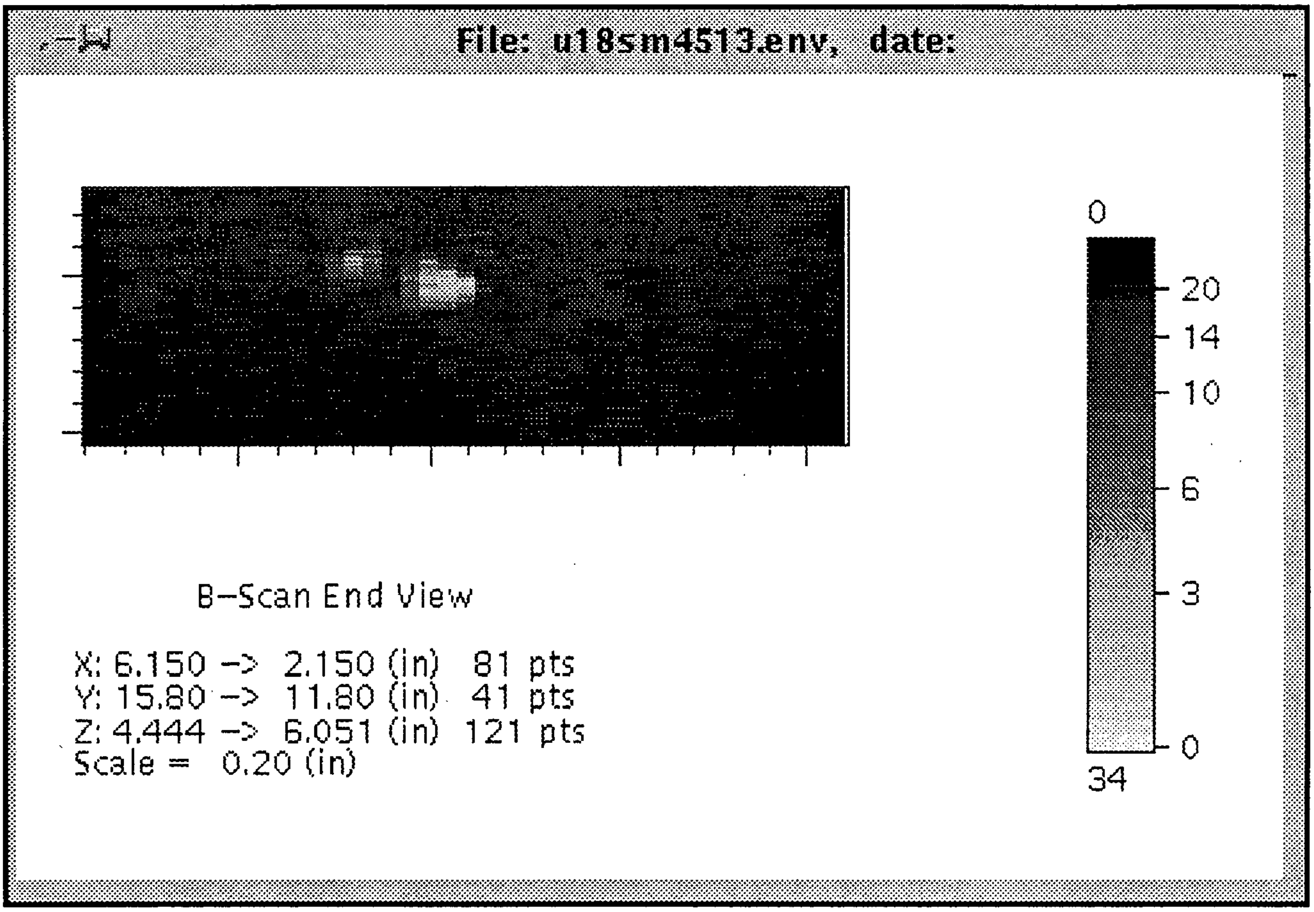


Figure 5.2h Side View (YZ) of Base-Metal Indication in Block 1-8 at Y = 351 mm (13.8 in.). 45° shear inspection from the unclad side. Beam direction is -X. Z values in the figure are measured from the unclad side. X values in the figure are +2 to -2 inches in material coordinates. This indication corresponds to flaw #6 in the destructive analysis.

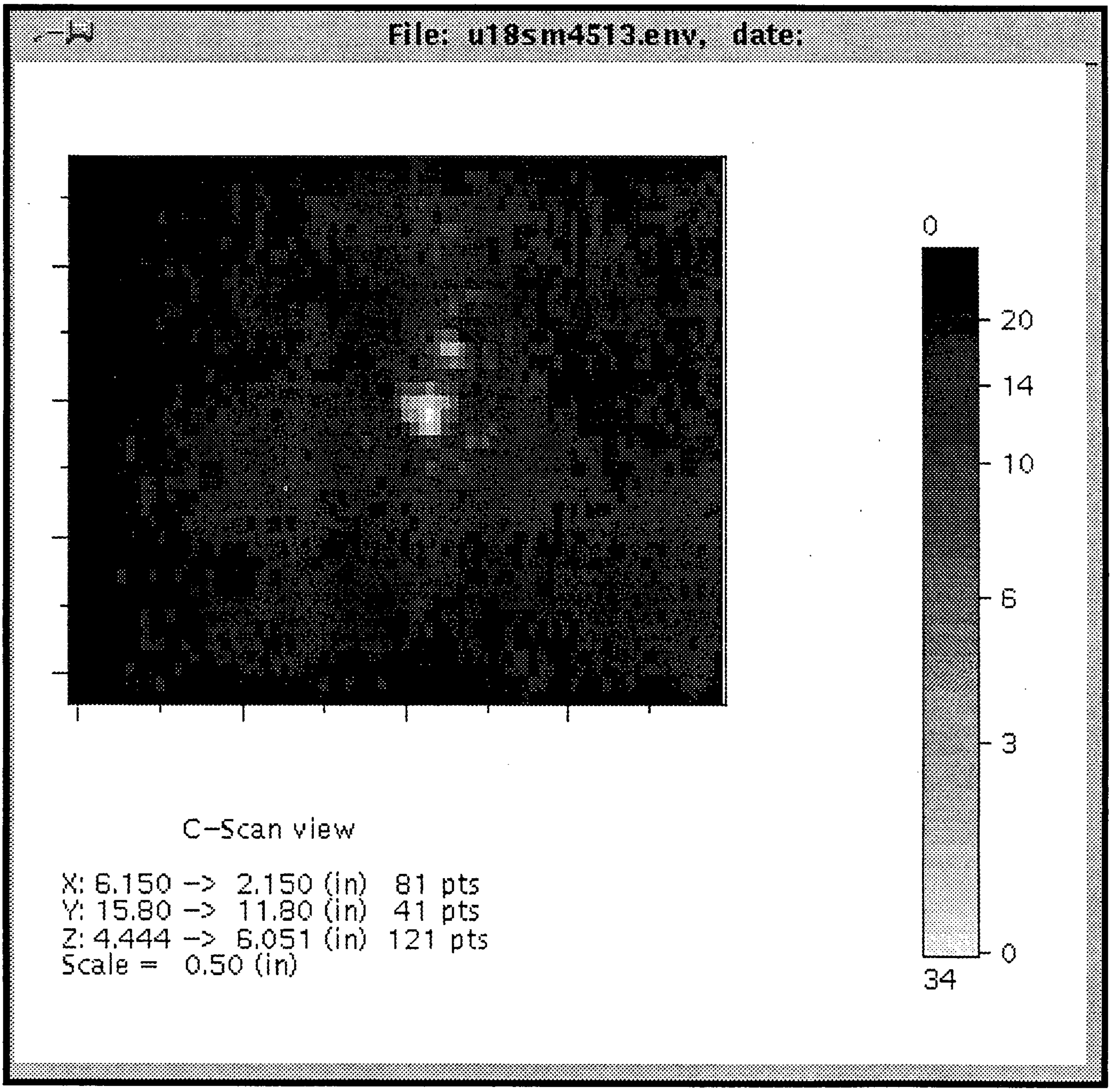


Figure 5.2i C-scan View (XY) of Base-Metal Indication in Block 1-8 at Y = 351 mm (13.8 in.). 45° shear inspection from the unclad side. Beam direction is -X. Z values in the figure are measured from the unclad side. X values in the figure are +2 to -2 inches in material coordinates. This indication corresponds to flaw #6 in the destructive analysis.

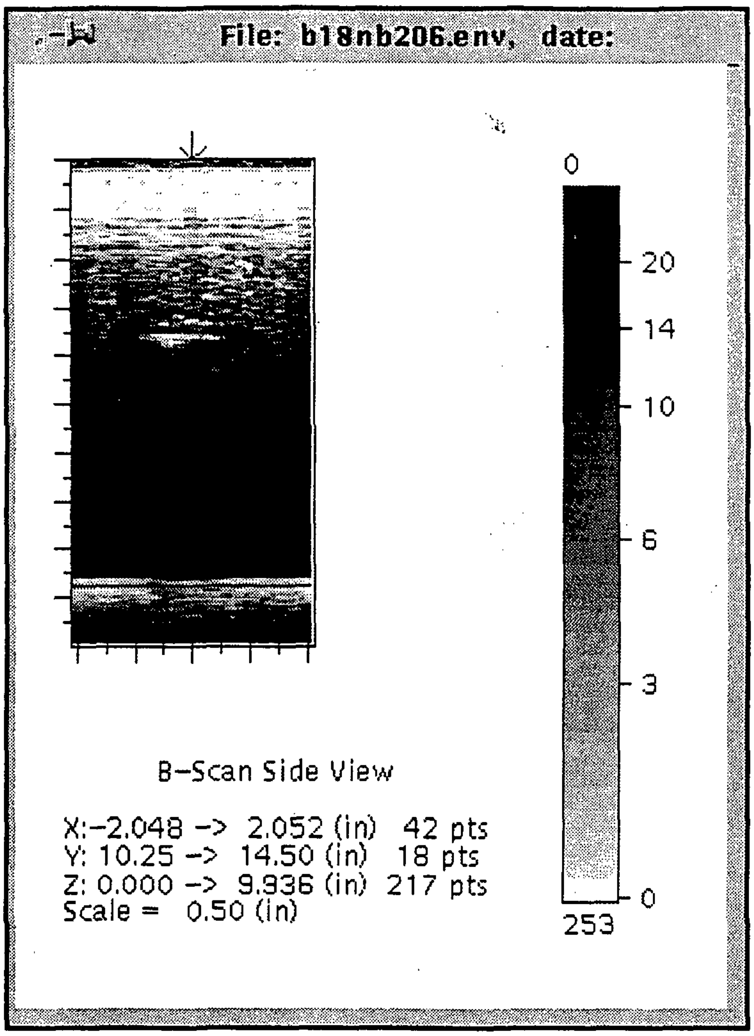


Figure 5.3a Side View (XZ) of Base-Metal Indication in Block 1-8 at Y = 318 mm (12.5 in.). Normal beam inspection from the clad side.

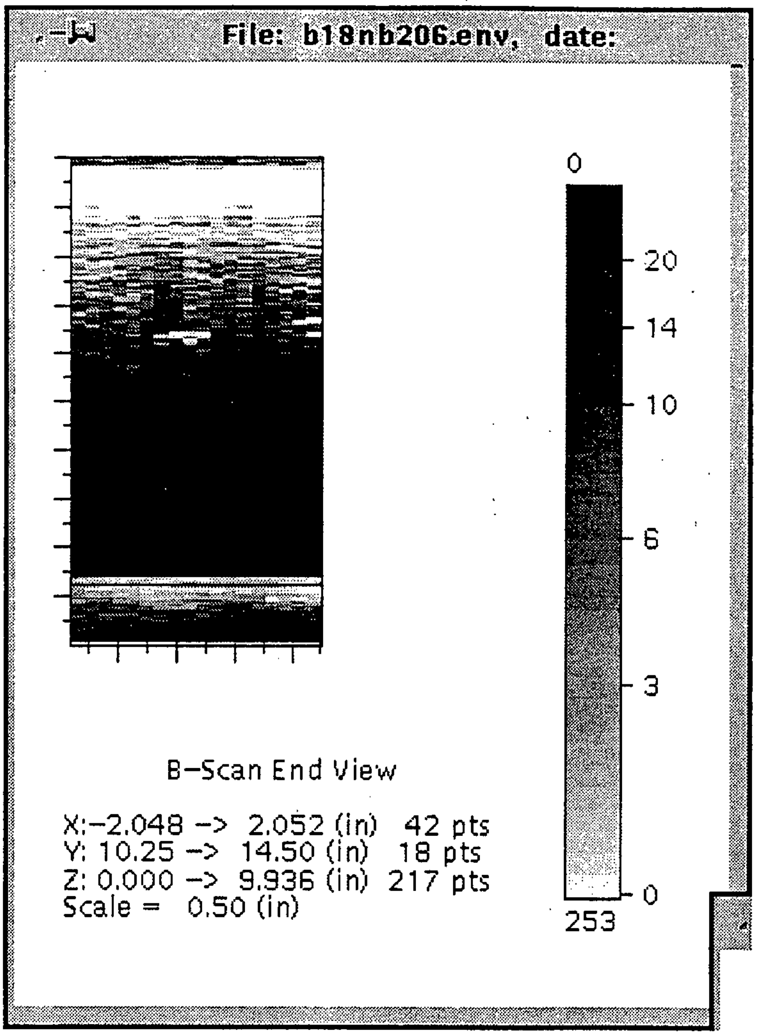


Figure 5.3b End View (YZ) of Base-Metal Indication in Block 1-8 at Y = 318 mm (12.5 in.). Normal beam inspection from the clad side.

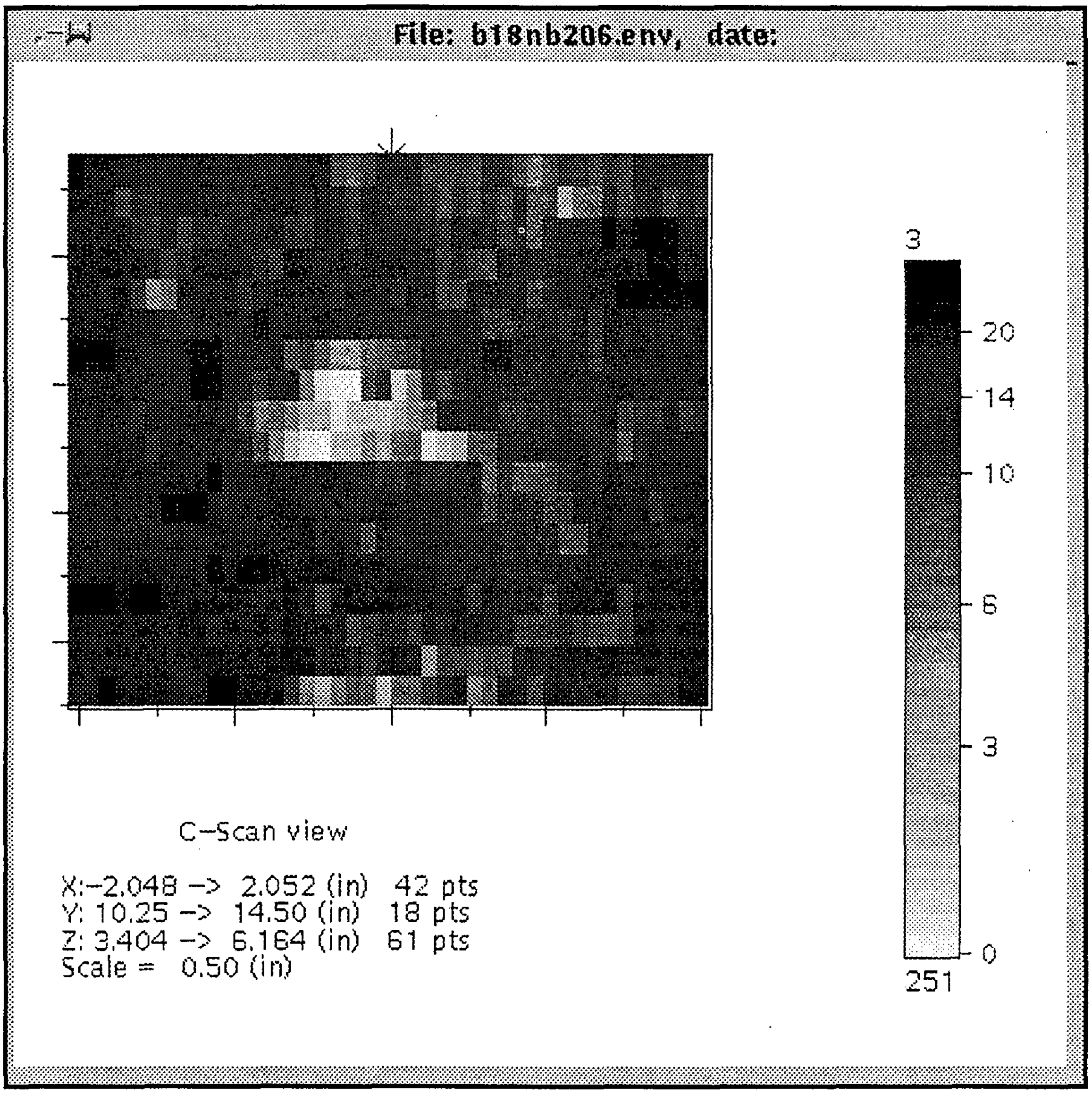


Figure 5.3c C-scan View (XY) of Base-Metal Indication in Block 1-8 at Y = 318 mm (12.5 in.). Normal beam inspection from the clad side.

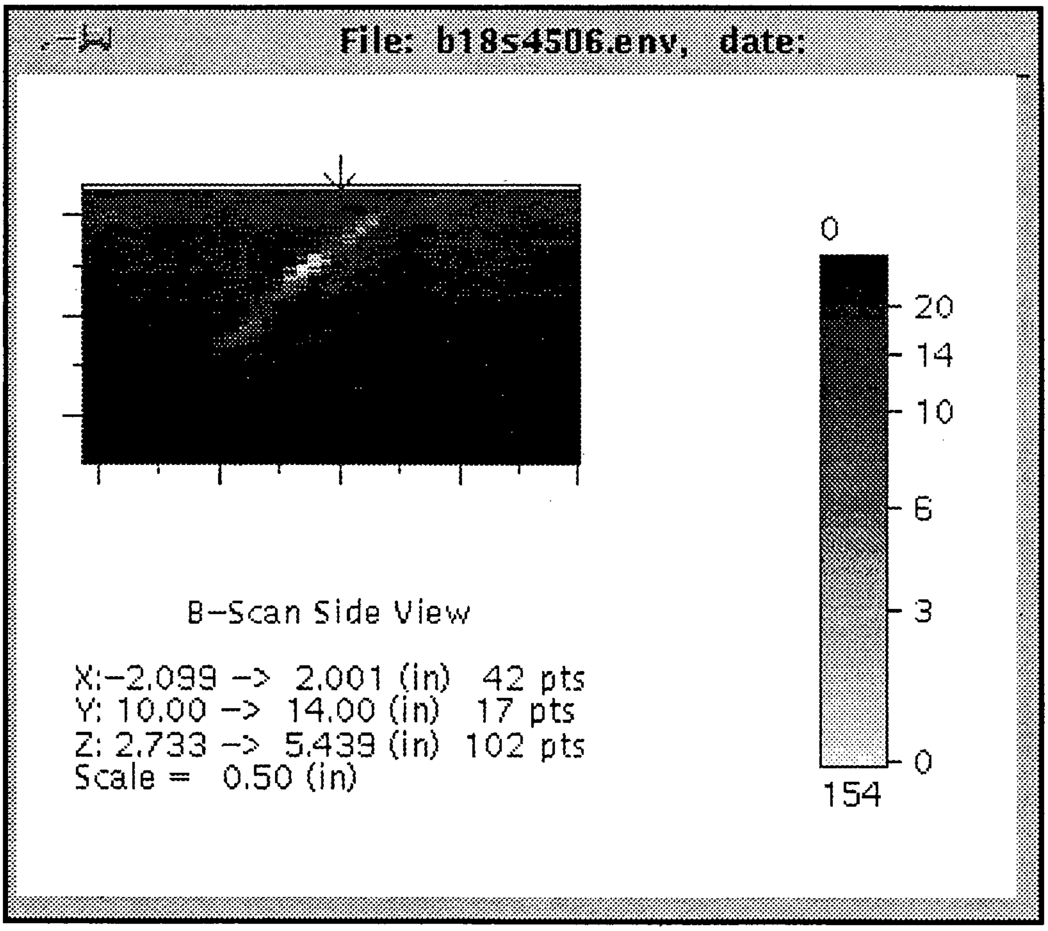


Figure 5.3d Side View (XZ) of Base-Metal Indication in Block 1-8 at Y = 318 mm (12.5 in.). 45° shear inspection from the clad side.

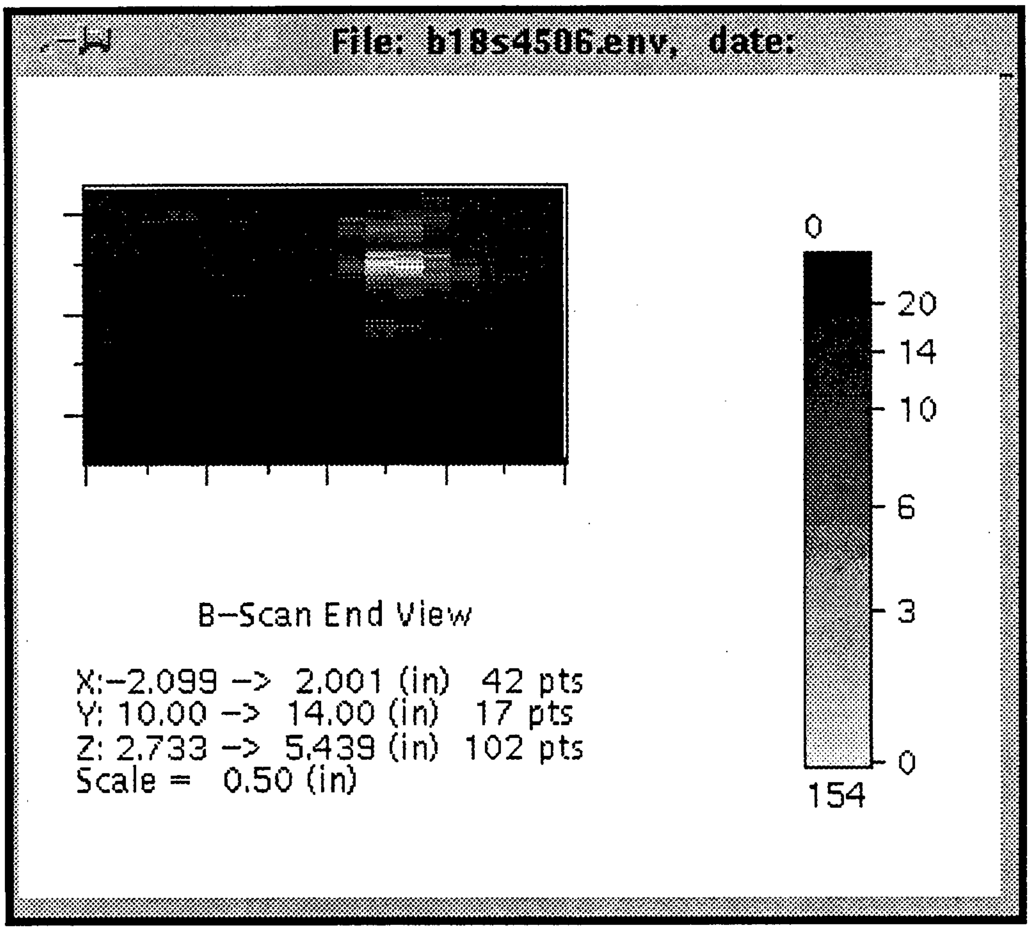


Figure 5.3e End View (YZ) of Base-Metal Indication in Block 1-8 at Y = 318 mm (12.5 in.). 45° shear inspection from the clad side.

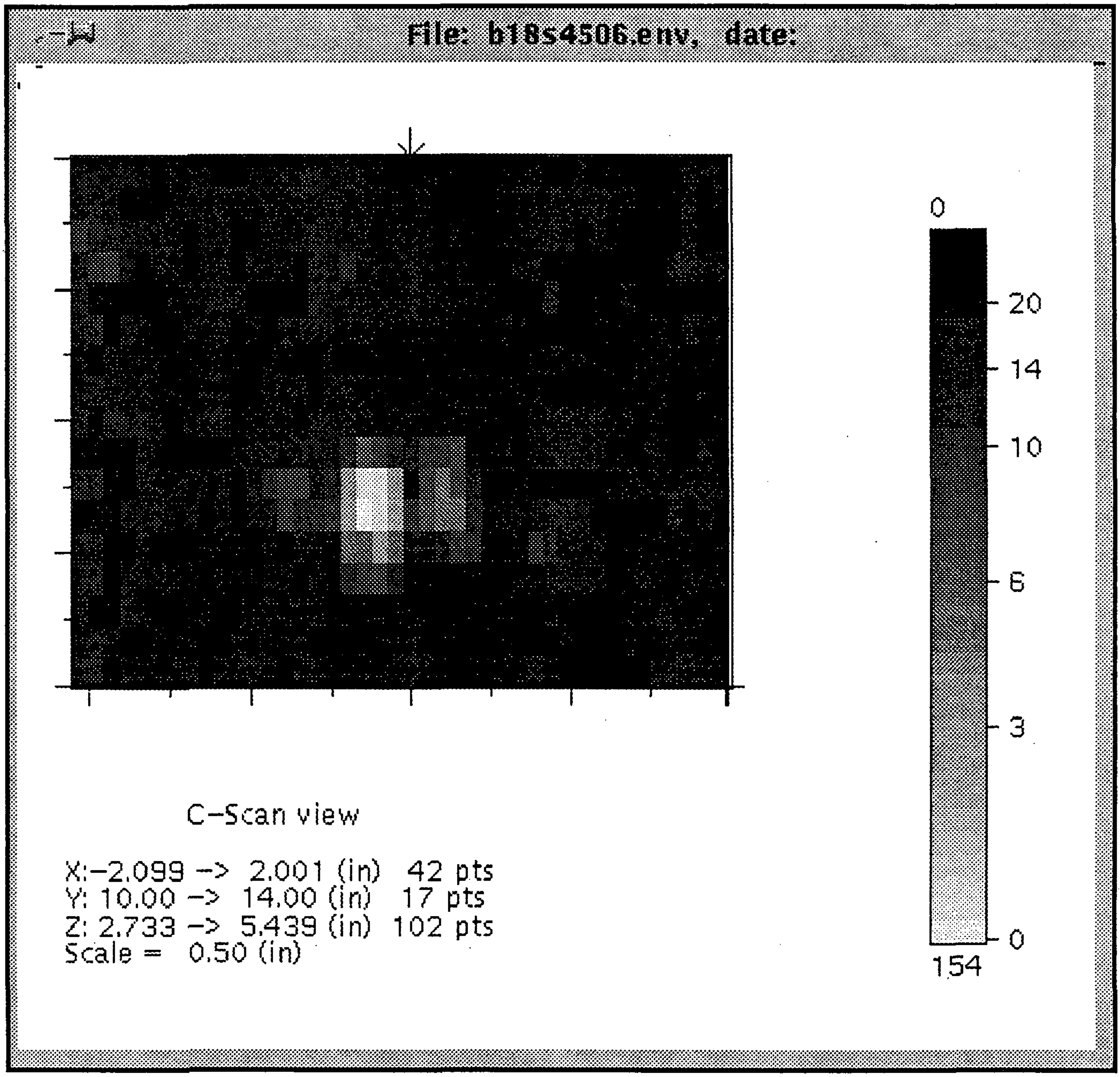


Figure 5.3f C-scan View (XY) of Base-Metal Indication in Block 1-8 at Y = 318 mm (12.5 in.). 45° shear inspection from the clad side.

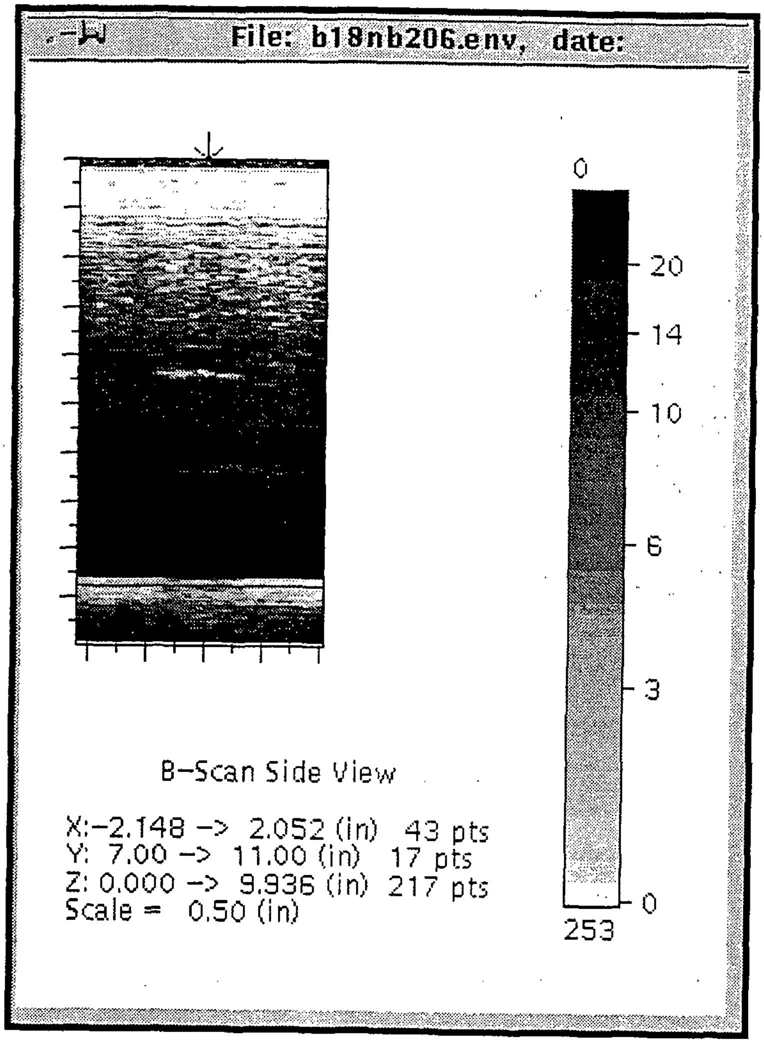


Figure 5.4a Side View (XZ) of Base-Metal Indication in Block 1-8 at Y = 249 mm (9.8 in.). Normal beam inspection from the clad side.

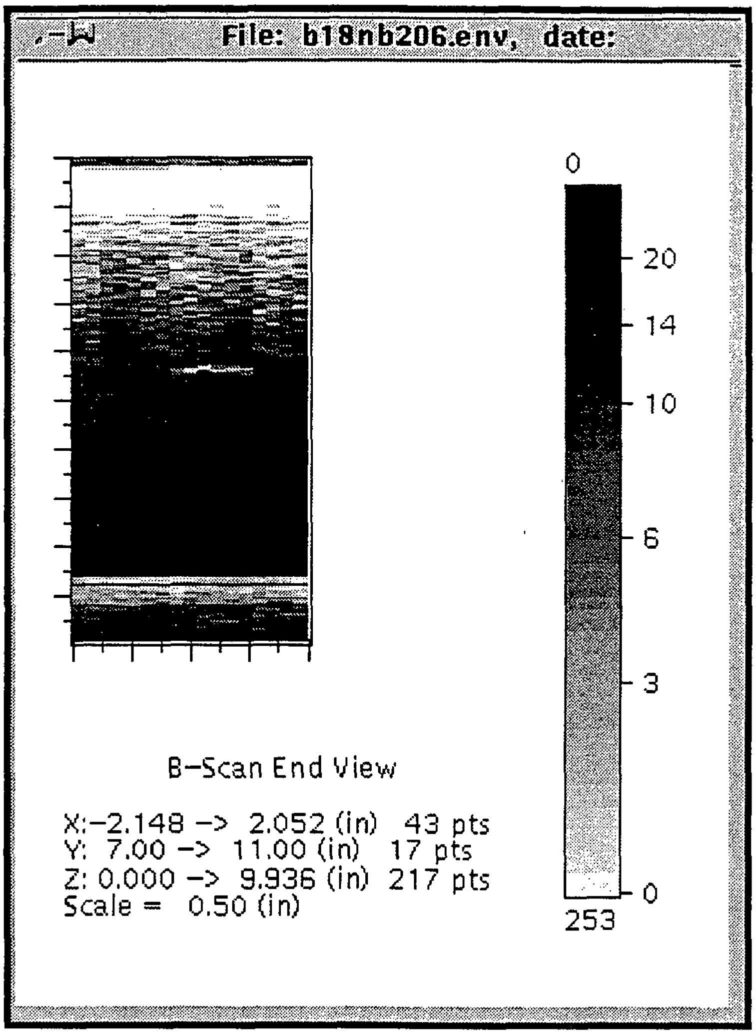


Figure 5.4b End View (YZ) of Base-Metal Indication in Block 1-8 at Y = 249 mm (9.8 in.). Normal beam inspection from the clad side.

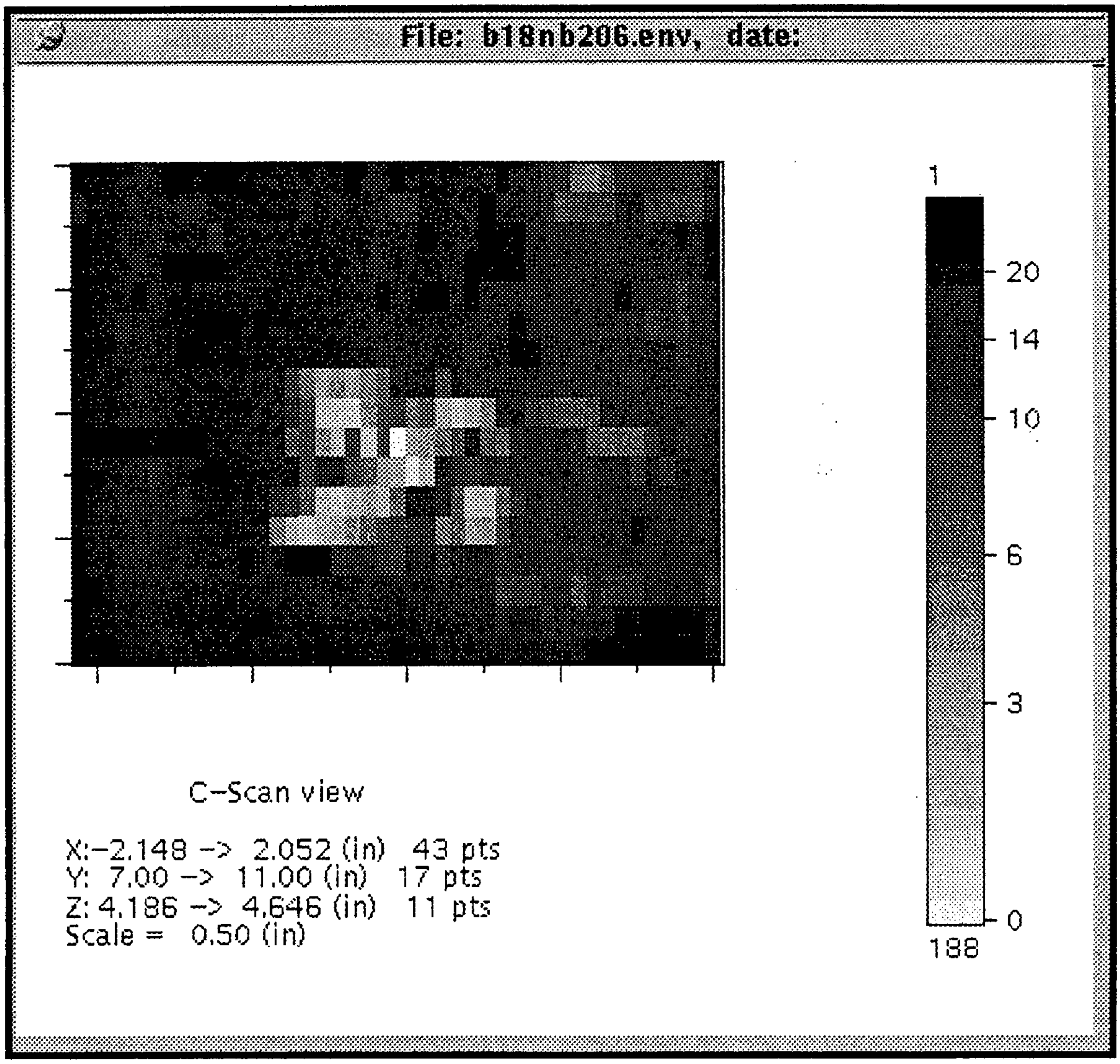


Figure 5.4c C-scan View (XY) of Base-Metal Indication in Block 1-8 at Y = 249 mm (9.8 in.). Normal beam inspection from the clad side.

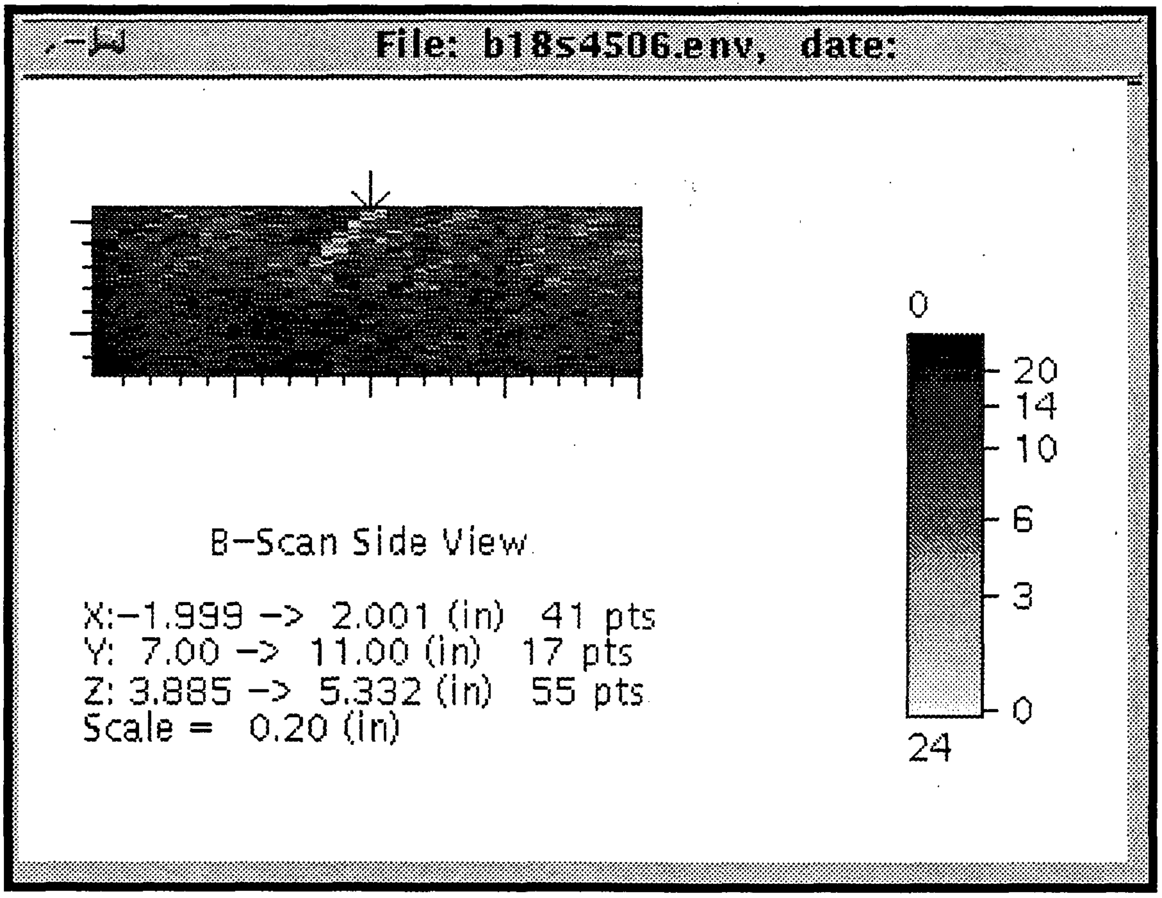


Figure 5.4d Side View (XZ) of Base-Metal Indication in Block 1-8 at Y = 249 mm (9.8 in.). 45° shear inspection from the clad side. Beam direction is +X.

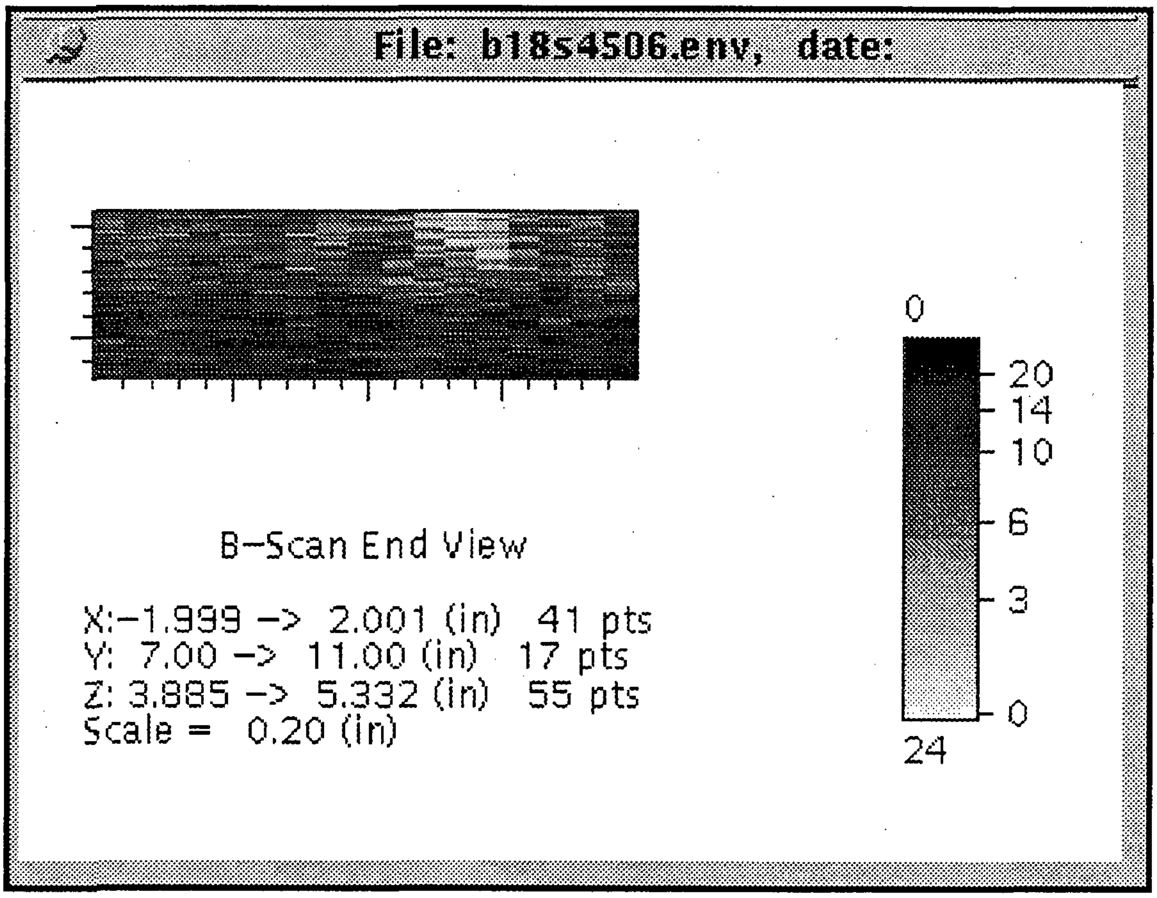


Figure 5.4e End View (YZ) of Base-Metal Indication in Block 1-8 at Y = 249 mm (9.8 in.). 45° shear inspection from the clad side. Beam direction is +X.

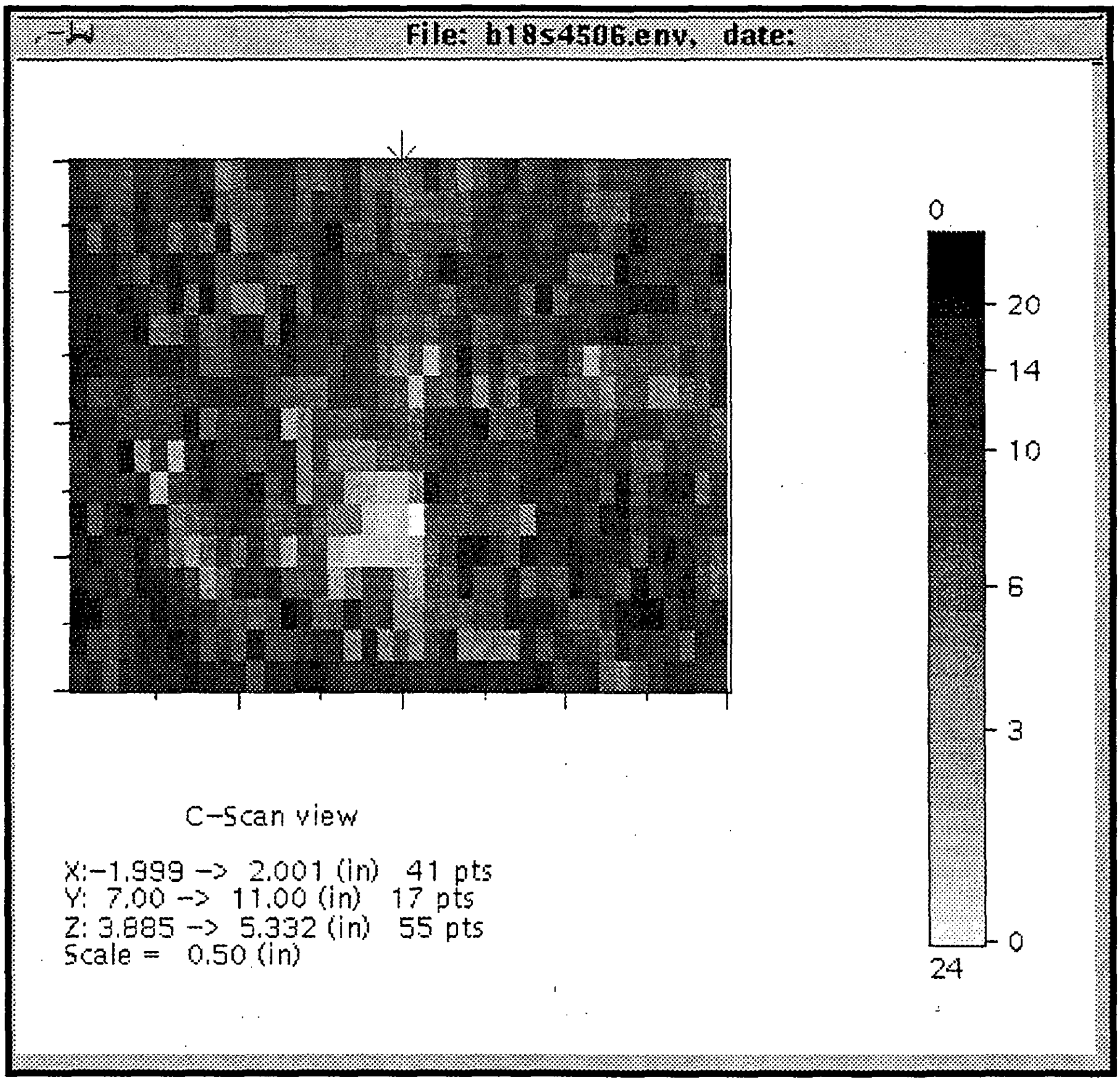


Figure 5.4f C-scan View (XY) of Base-Metal Indication in Block 1-8 at Y = 249 mm (9.8 in.). 45° shear inspection from the clad side. Beam direction is +X.

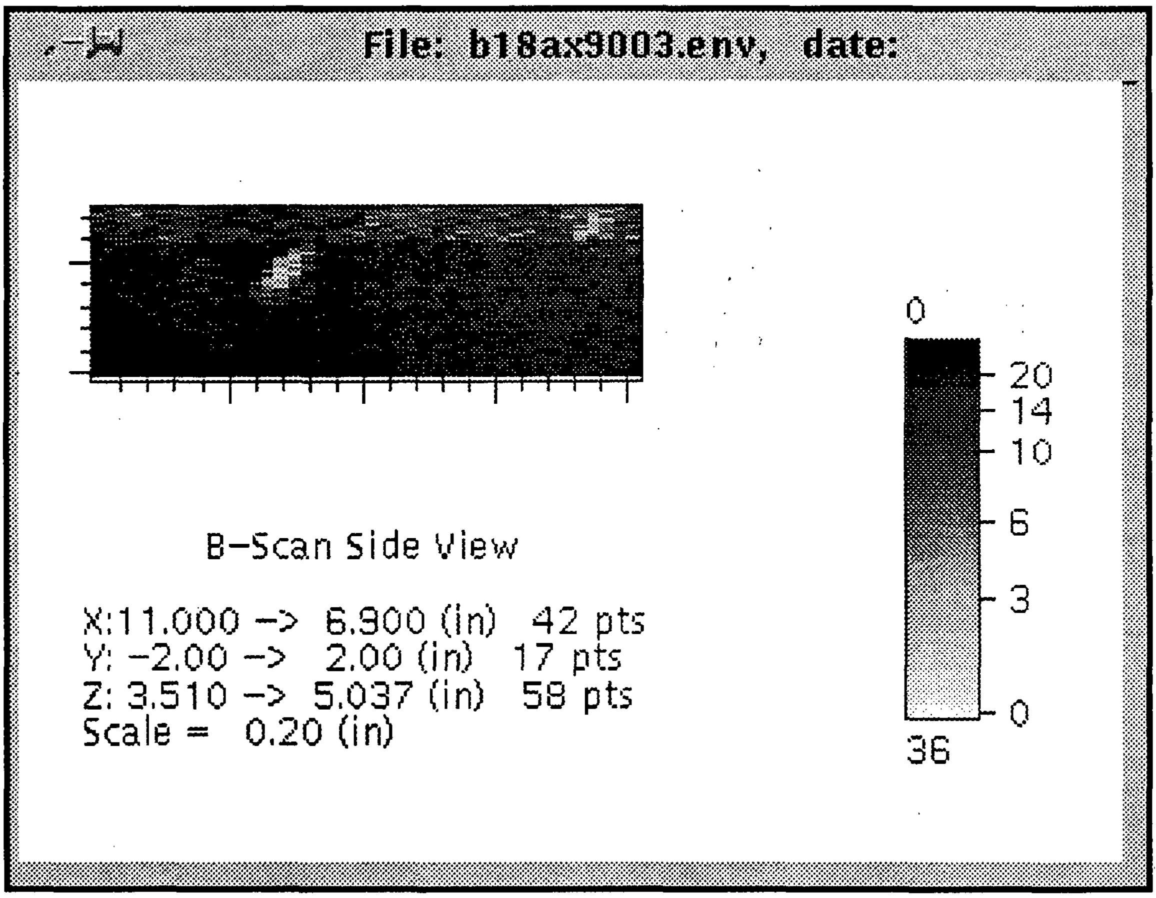


Figure 5.4g Side View (in scanner coordinates) of Base-Metal Indication in Block 1-8 at Y = 249 mm (9.8 in.). 45° shear inspection from the clad side. Beam direction is -Y. X coordinates shown in the figure correspond to Y material coordinates.

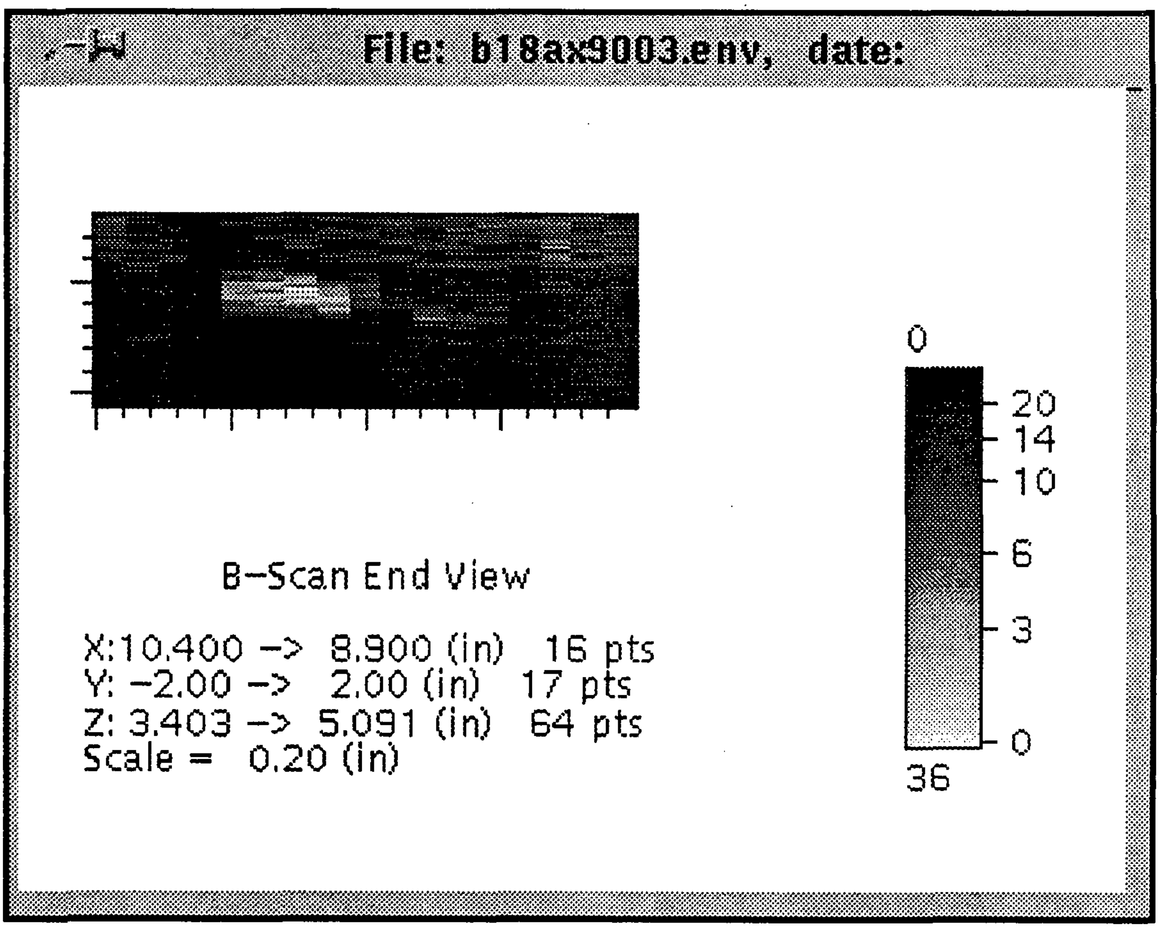


Figure 5.4h End View (in scanner coordinates) of Base-Metal Indication in Block 1-8 at Y = 249 mm (9.8 in.). 45° shear inspection from the clad side. Beam direction is -Y. Y coordinates shown in the figure correspond to X material coordinates.

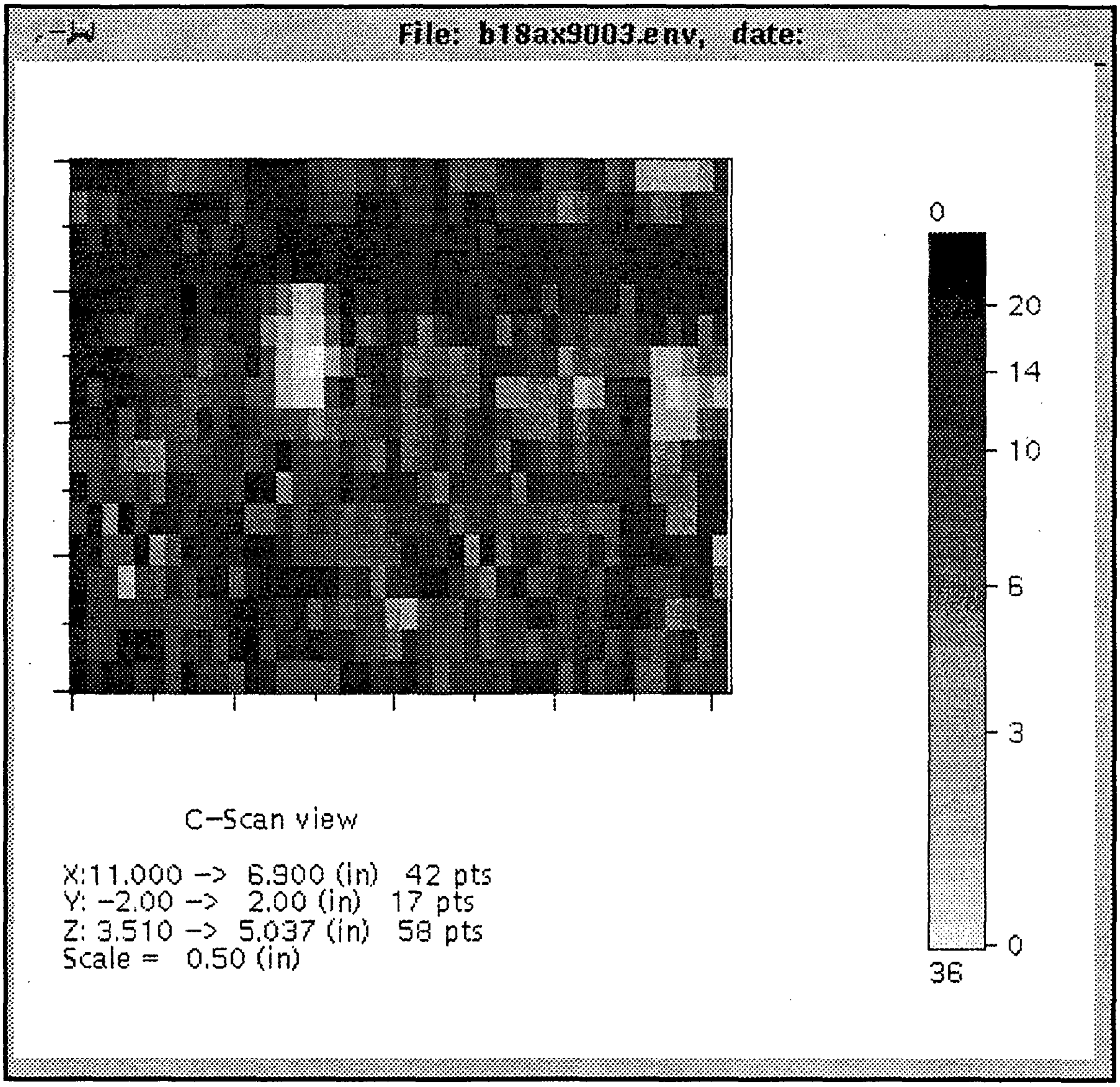


Figure 5.4i C-scan View (in scanner coordinates) of Base-Metal Indication in Block 1-8 at Y = 249 mm (9.8 in.). 45° shear inspection from the clad side. Beam direction is -Y. Y coordinates shown in the figure correspond to X material coordinates.

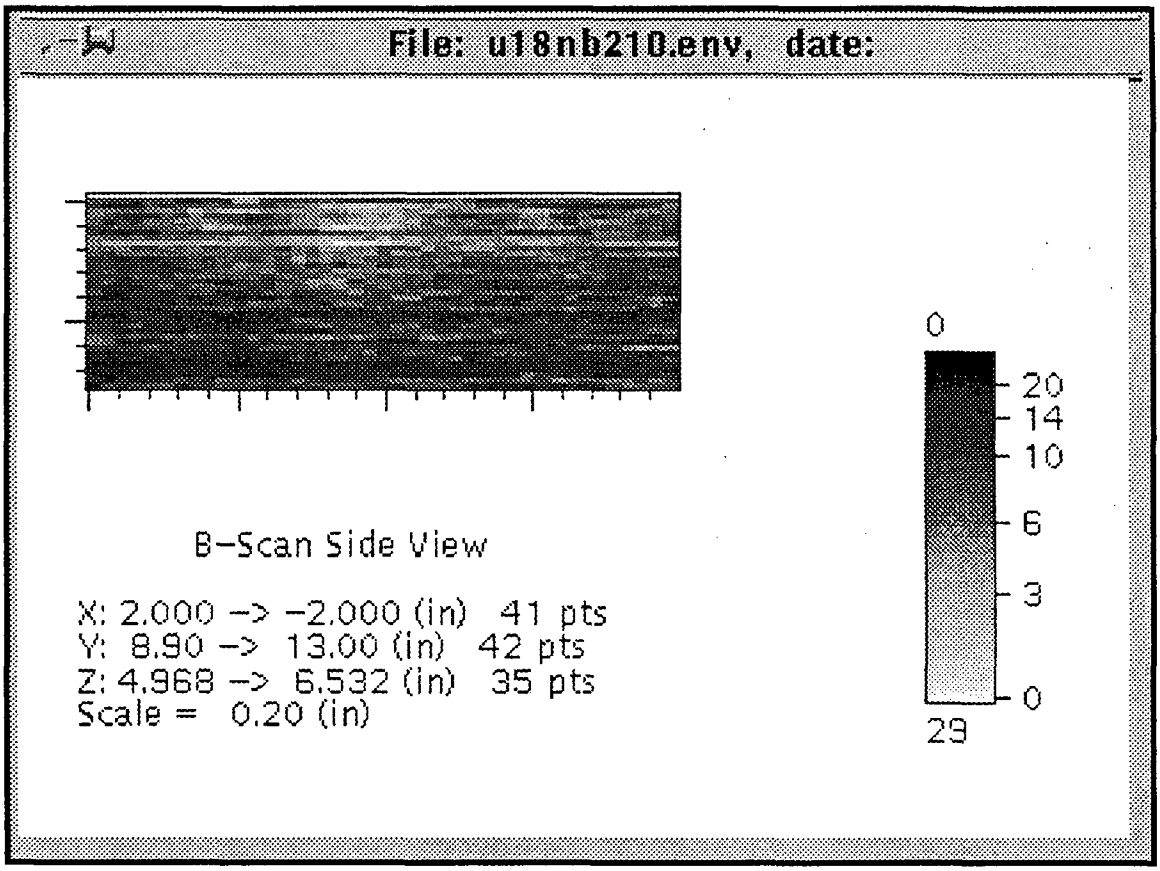


Figure 5.4j Side View (XZ) of Base-Metal Indication in Block 1-8 at Y = 249 mm (9.8 in.). Normal beam inspection from the unclad side. Z values shown in figure are measured from the unclad side.

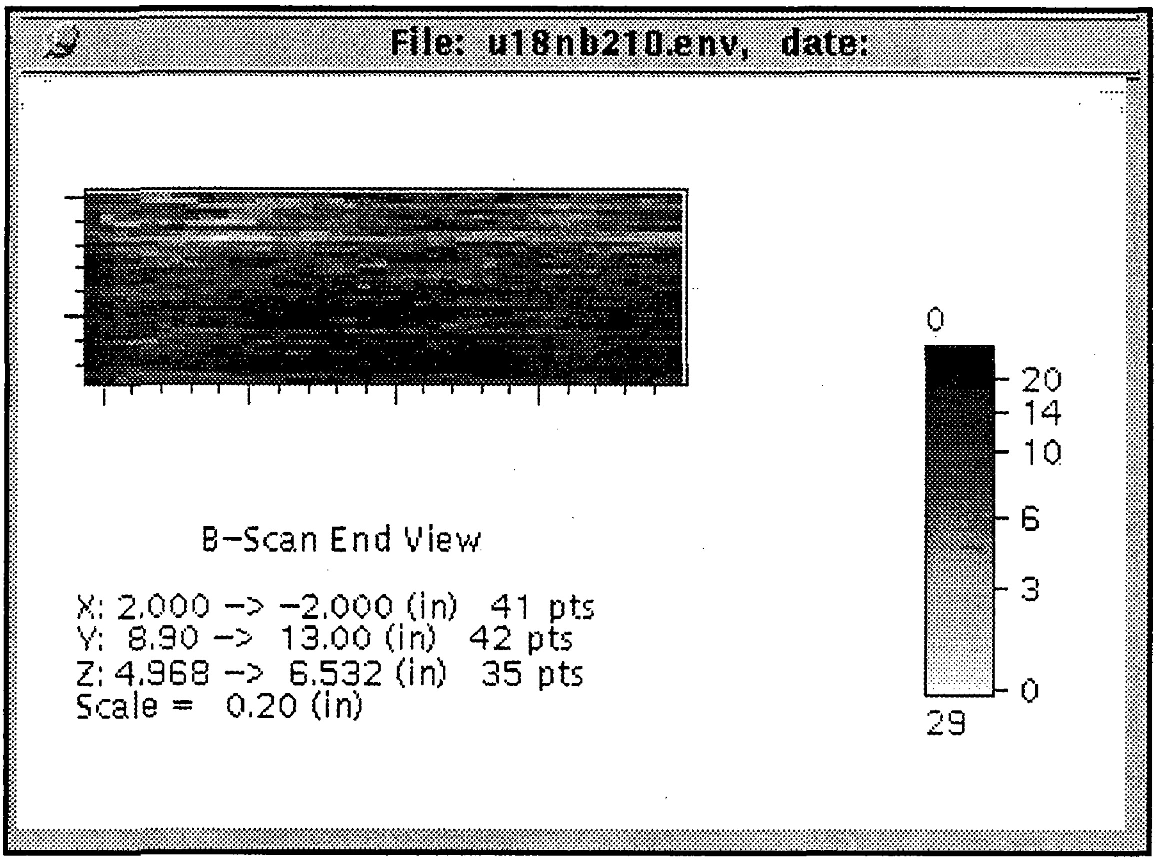


Figure 5.4k End View (YZ) of Base-Metal Indication in Block 1-8 at Y = 249 mm (9.8 in.). Normal beam inspection from the unclad side. Z values shown in figure are measured from the unclad side.

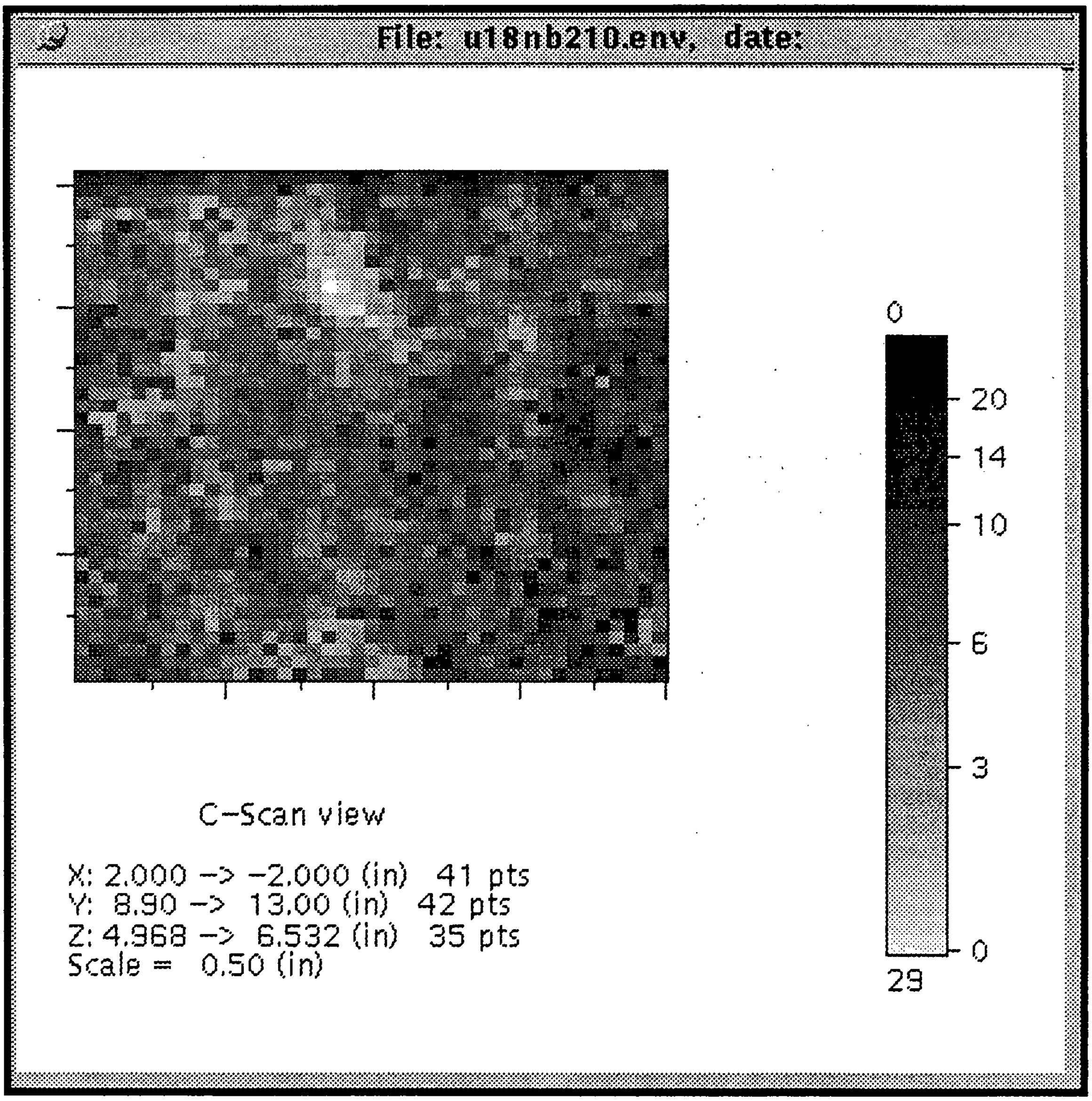


Figure 5.4l C-scan View (XY) of Base-Metal Indication in Block 1-8 at Y = 249 mm (9.8 in.). Normal beam inspection from the unclad side. Z values shown in figure are measured from the unclad side.

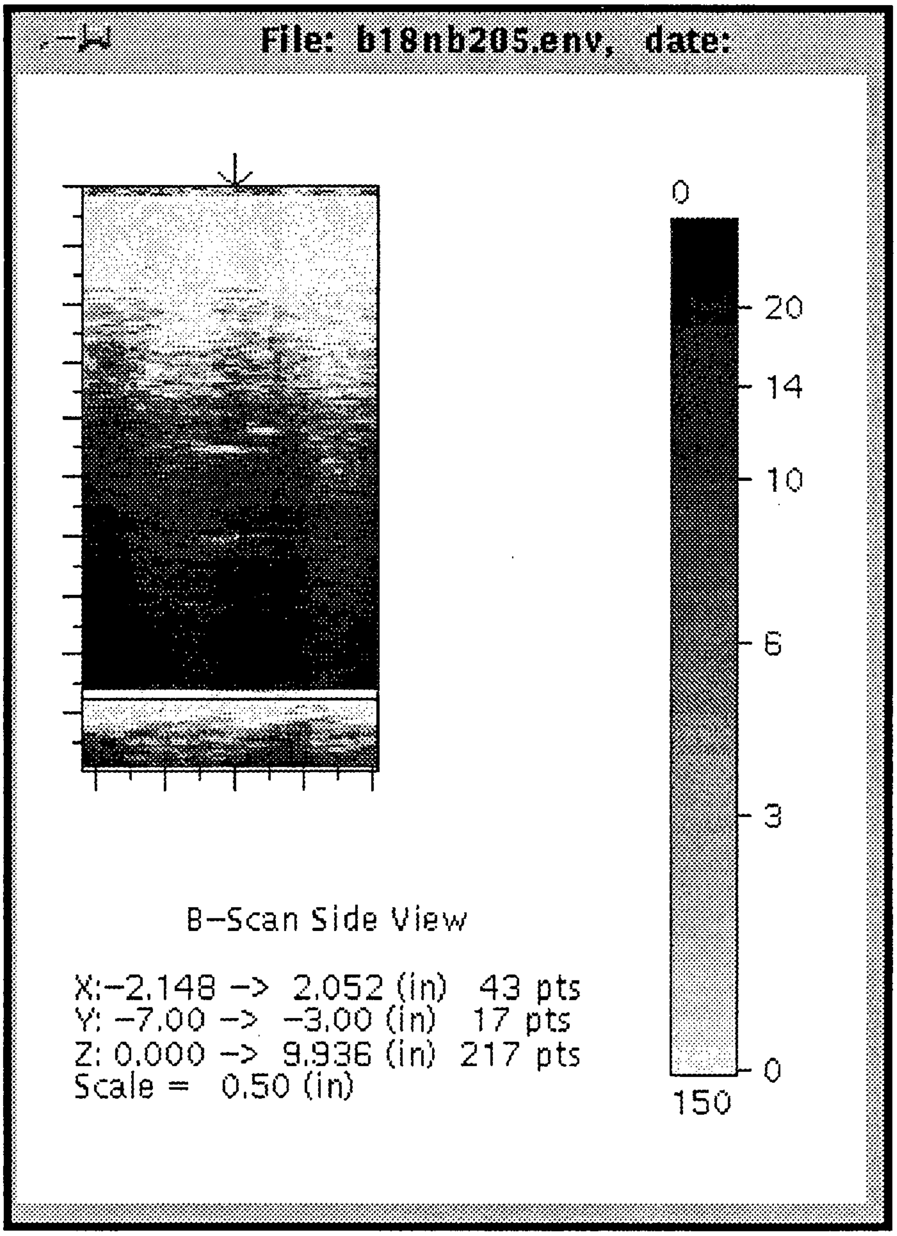


Figure 5.5a Side View (XZ) of Base-Metal Indication in Block 1-8 at Y = -127 mm (-5.0 in.). Normal beam inspection from the clad side.

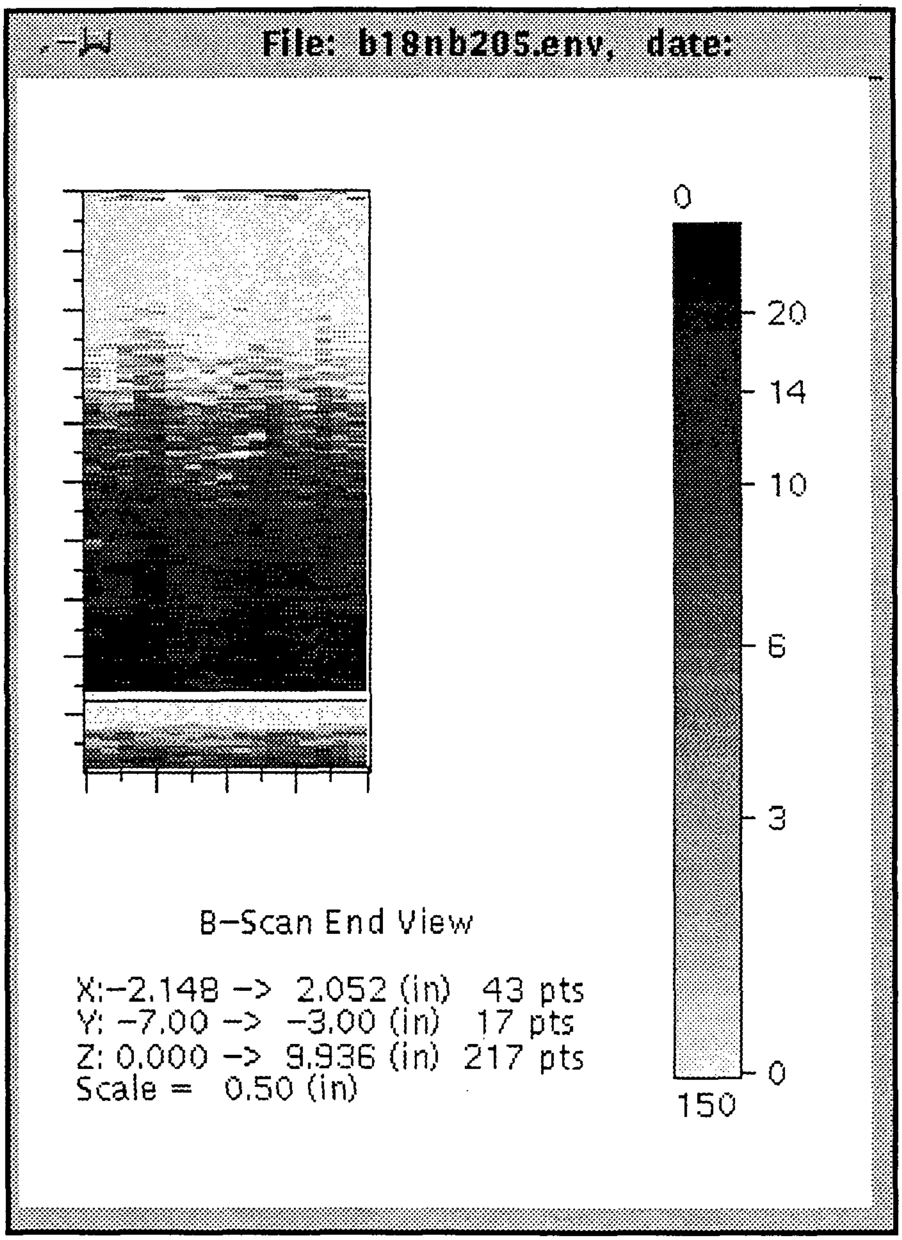


Figure 5.5b End View (YZ) of Base-Metal Indication in Block 1-8 at Y = -127 mm (-5.0 in.). Normal beam inspection from the clad side.

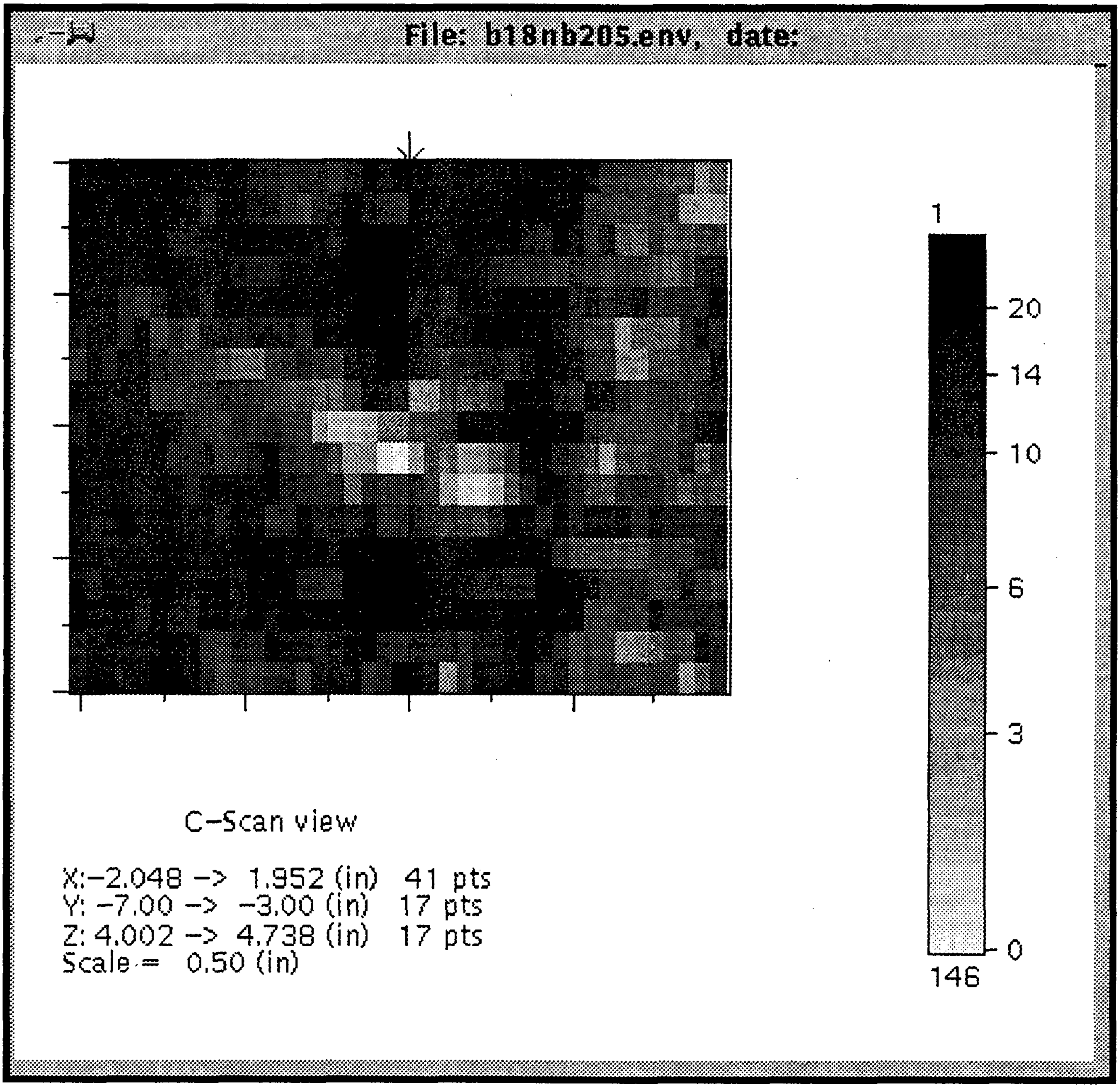


Figure 5.5c C-scan View (XY) of Base-Metal Indication in Block 1-8 at Y = -127 mm (-5.0 in.). Normal beam inspection from the clad side.

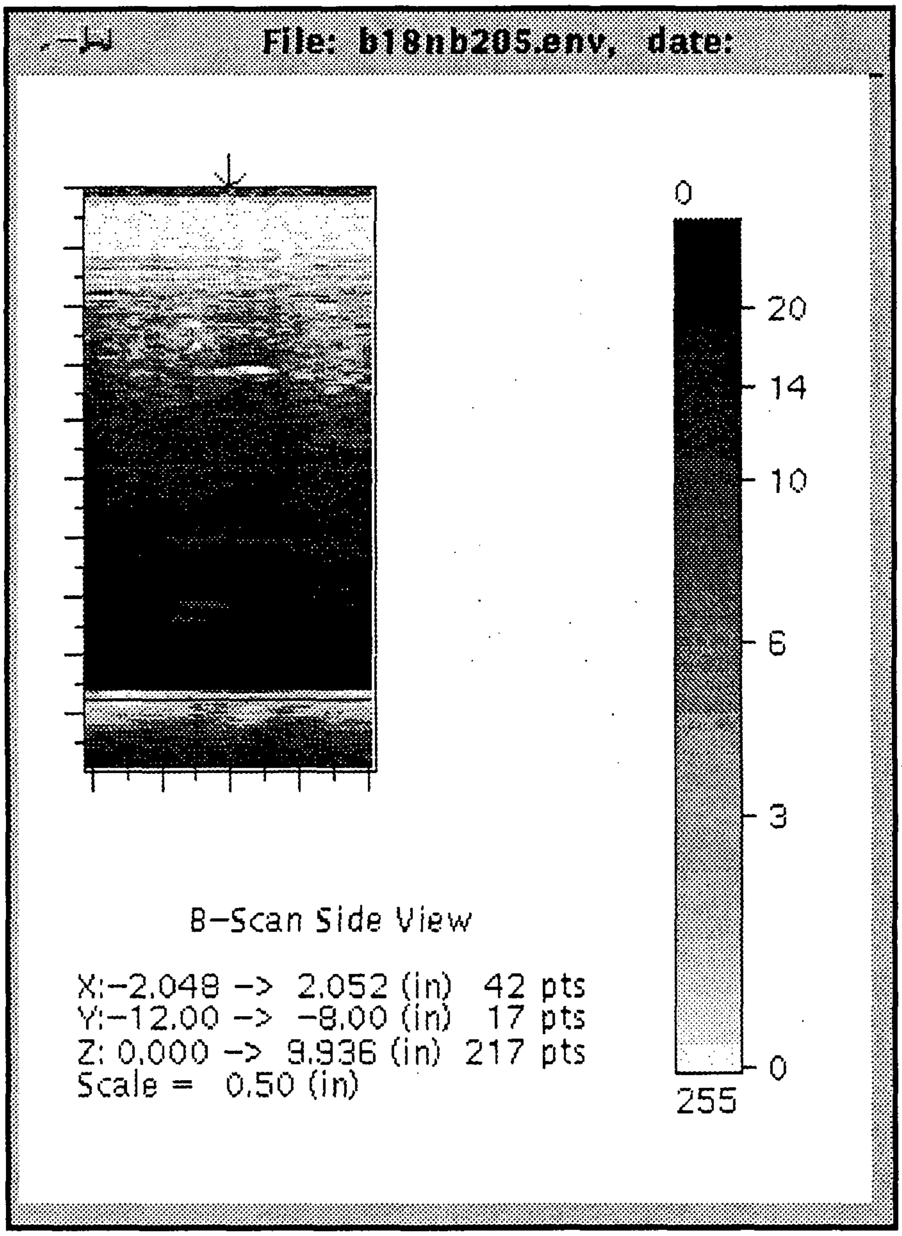


Figure 5.6a Side View (XZ) of Base-Metal Indication in Block 1-8 at Y = -249 mm (-9.8 in.). Normal beam inspection from the clad side.

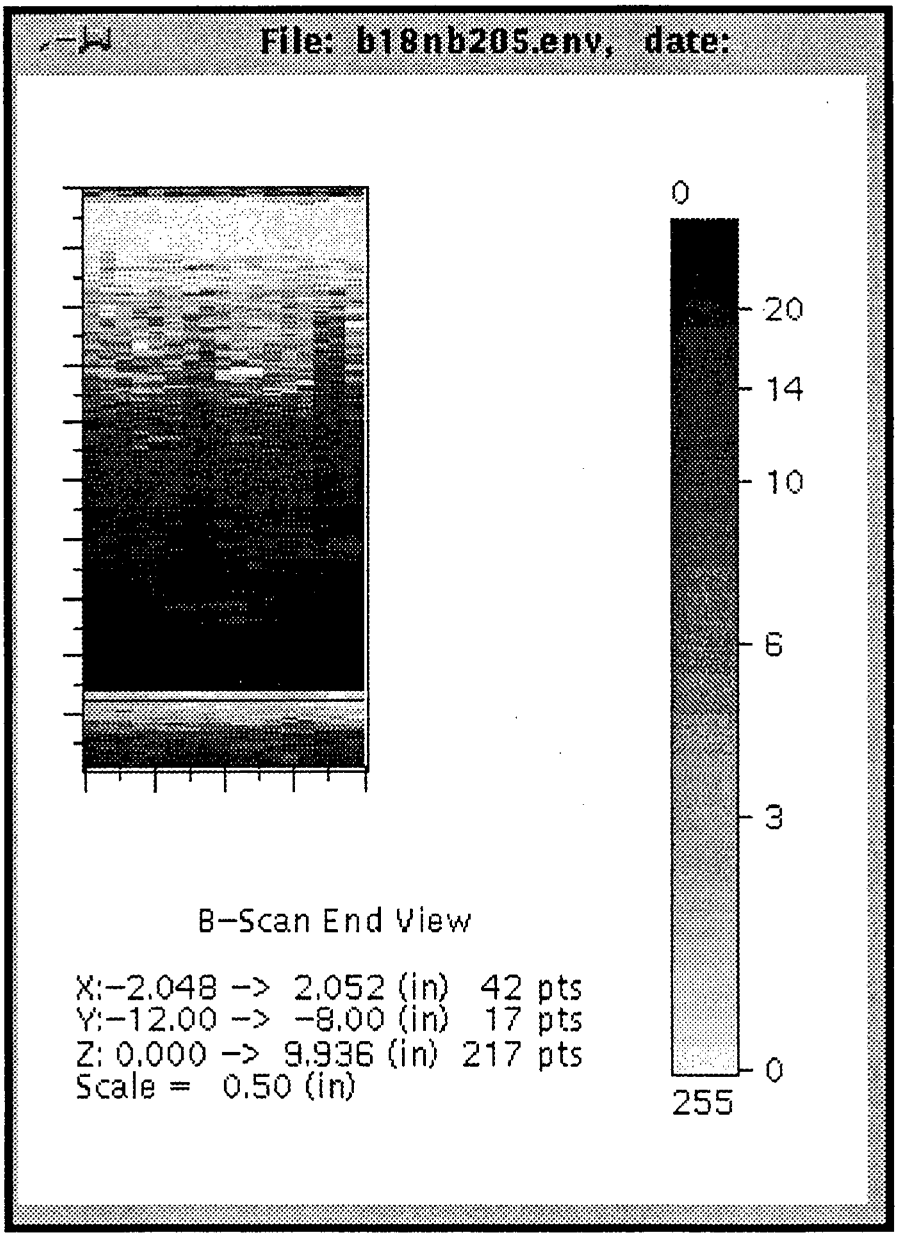


Figure 5.6b End View (YZ) of Base-Metal Indication in Block 1-8 at Y = -249 mm (-9.8 in.). Normal beam inspection from the clad side.

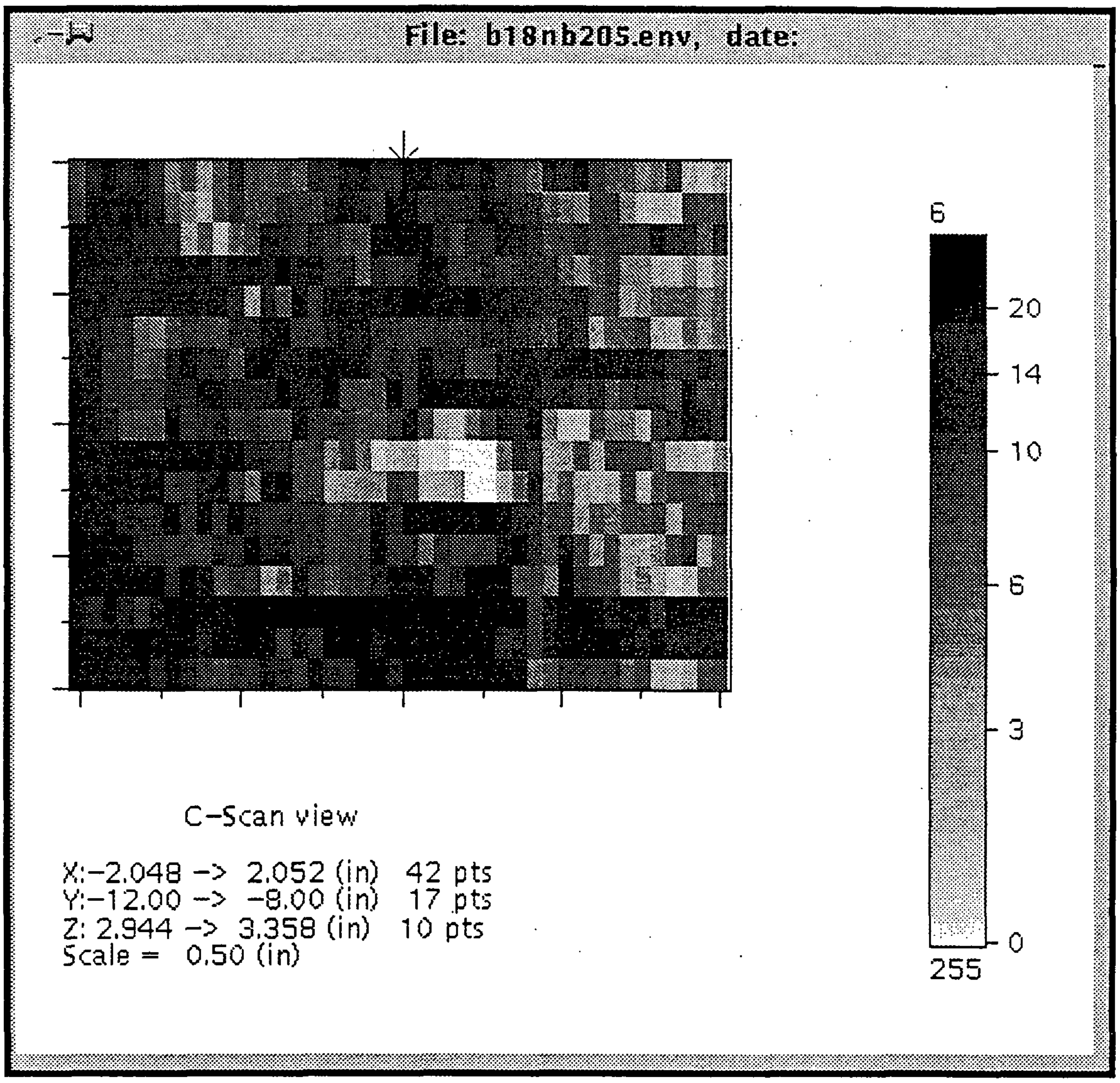


Figure 5.6c C-scan View (XY) of Base-Metal Indication in Block 1-8 at Y = -249 mm (-9.8 in.). Normal beam inspection from the clad side.

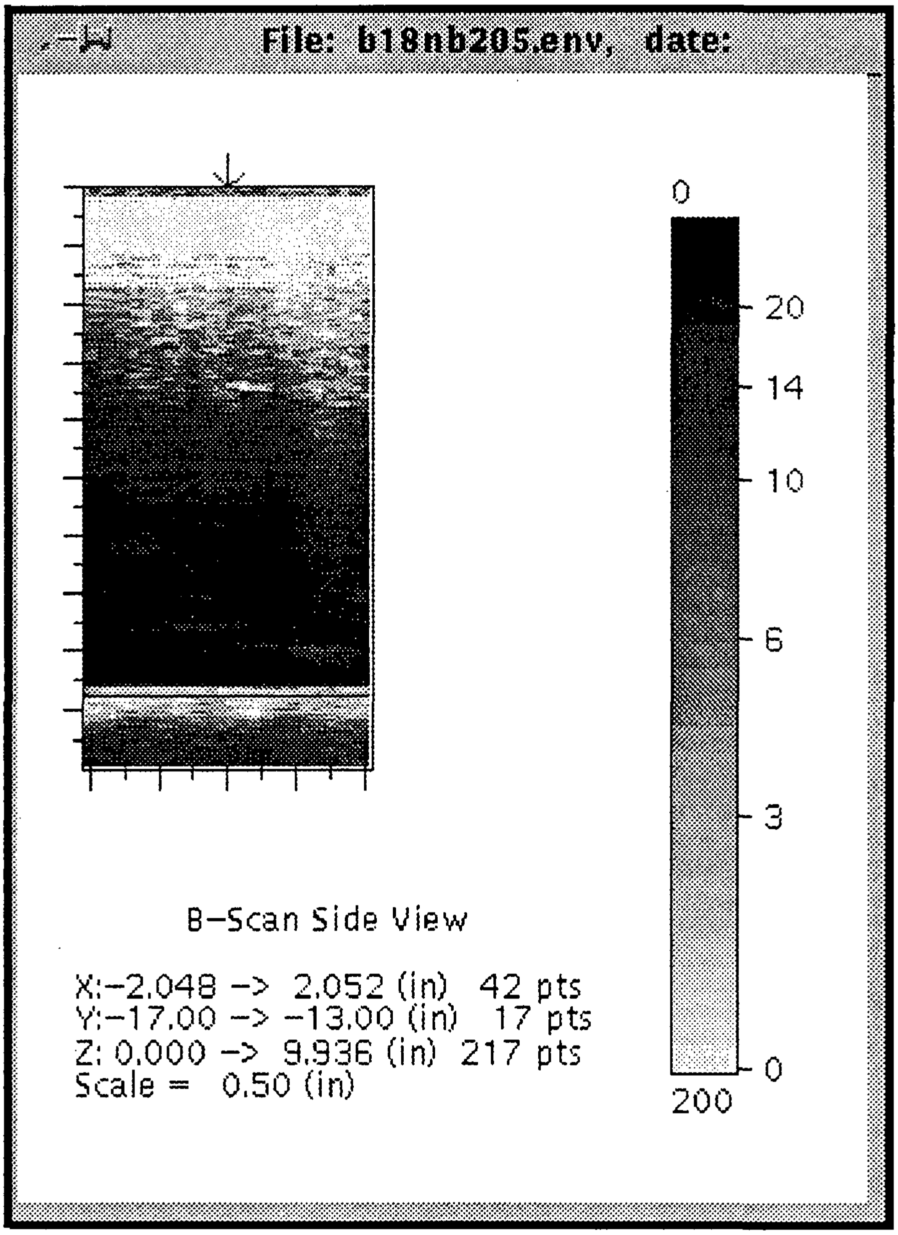


Figure 5.7a Side View (XZ) of Base-Metal Indication in Block 1-8 at Y = -391 mm (-15.4 in.). Normal beam inspection from the clad side.

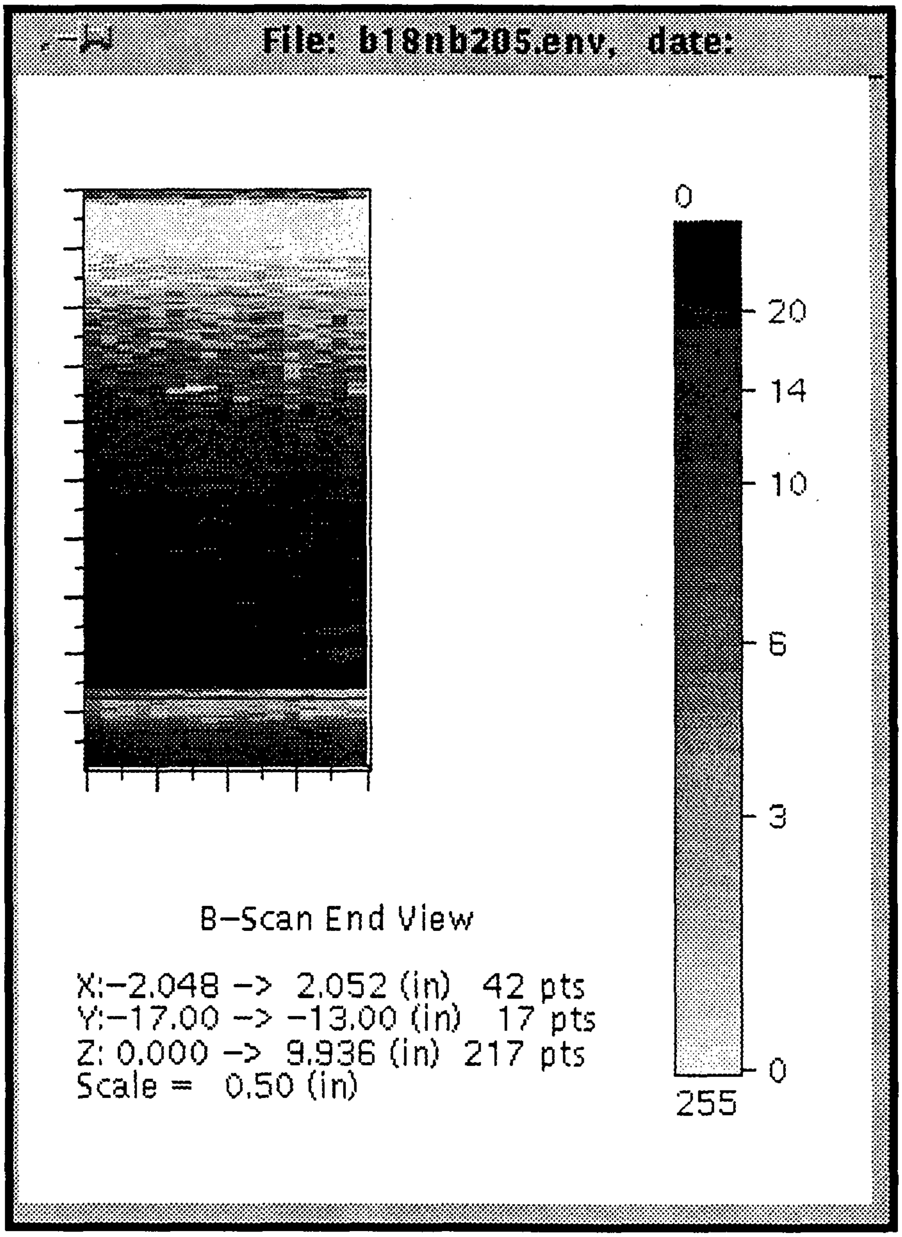


Figure 5.7b End View (YZ) of Base-Metal Indication in Block 1-8 at Y = -391 mm (-15.4 in.). Normal beam inspection from the clad side.

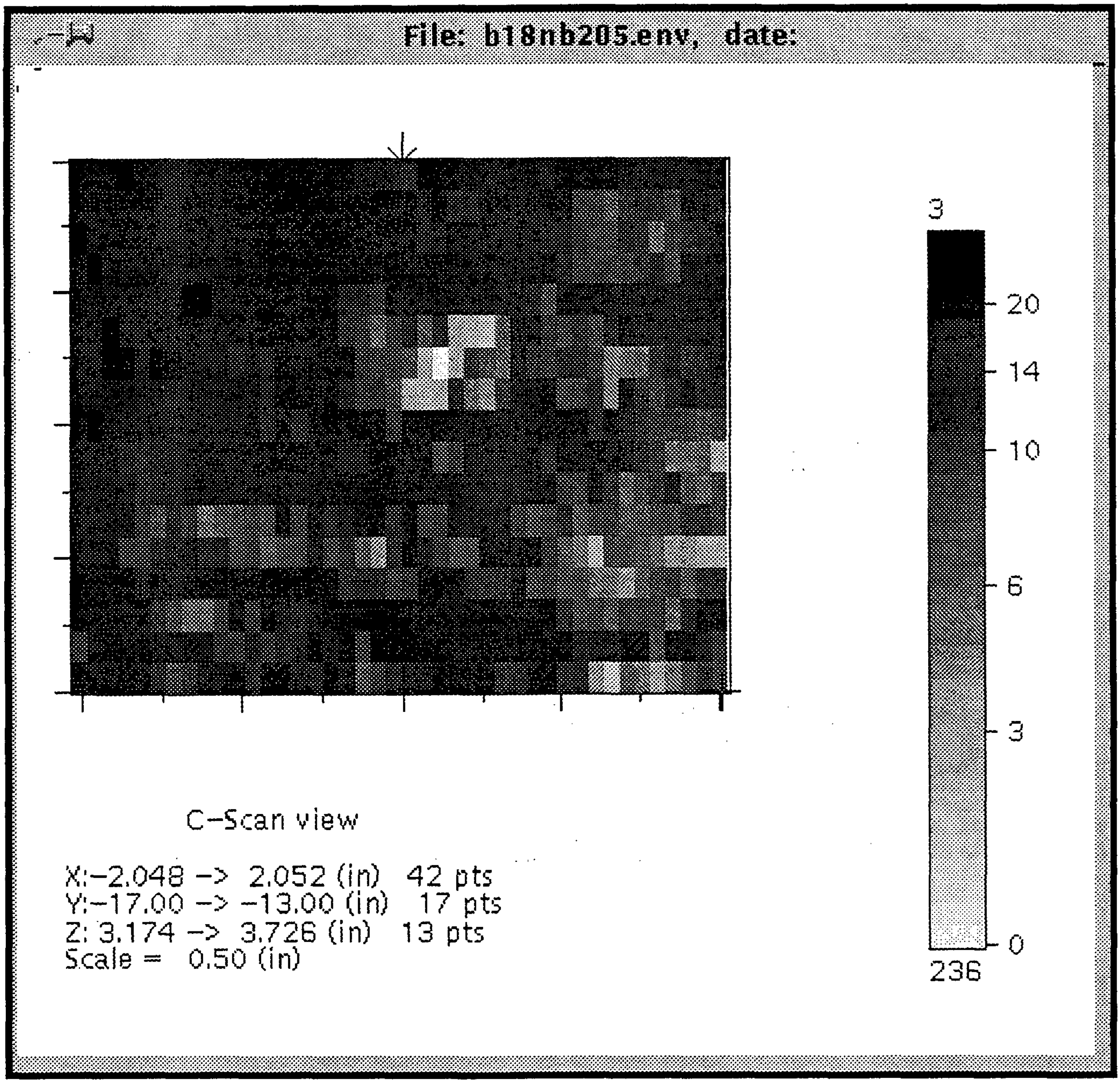


Figure 5.7c C-scan View (XY) of Base-Metal Indication in Block 1-8 at Y = -391 mm (-15.4 in.). Normal beam inspection from the clad side.

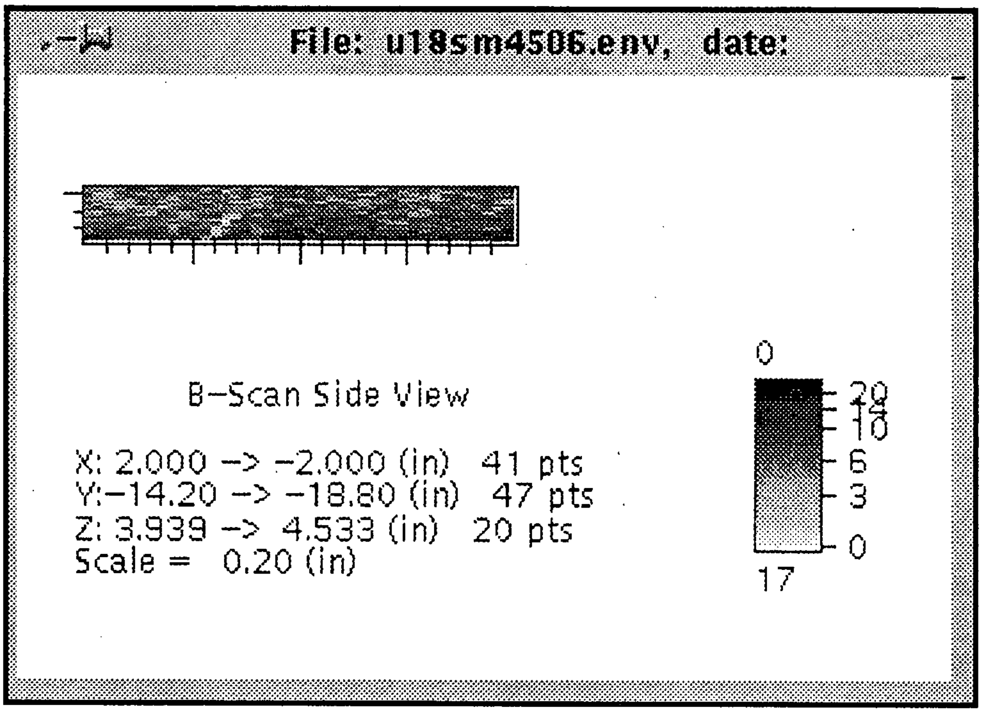


Figure 5.8a Side View (XZ) of Base-Metal Indication in Block 1-8 at Y = -465 mm (-18.3 in.). 45° shear inspection from the unclad side. Beam direction is -X. Z values in the figure are measured from the unclad side.

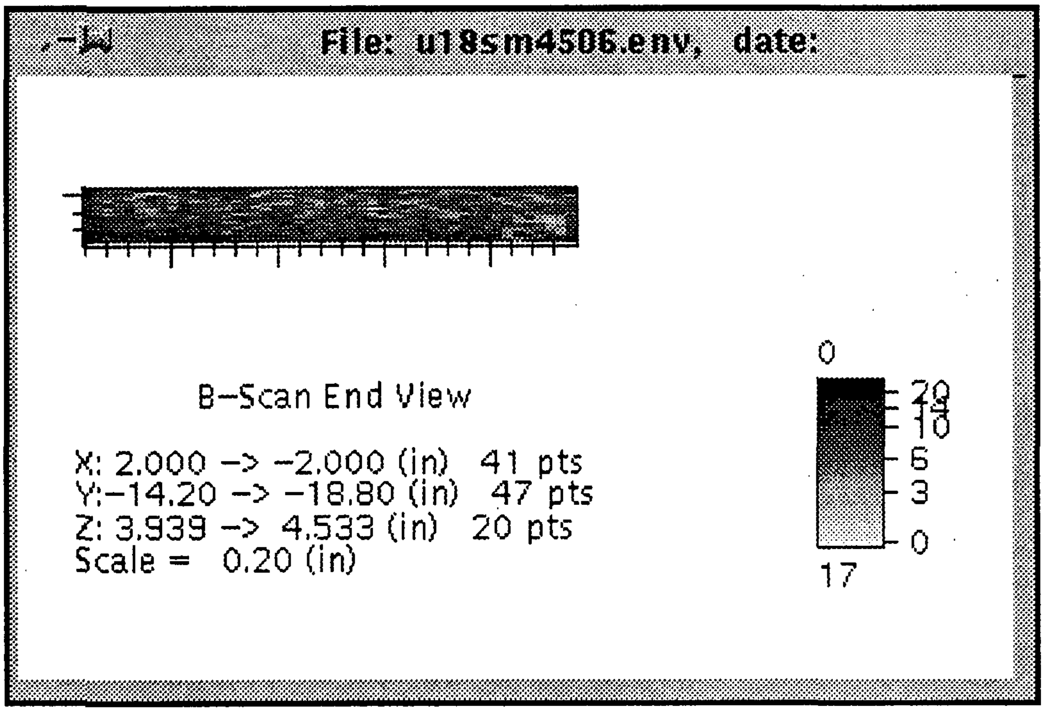


Figure 5.8b End View (YZ) of Base-Metal Indication in Block 1-8 at Y = -465 mm (-18.3 in.). 45° shear inspection from the unclad side. Beam direction is -X. Z values in the figure are measured from the unclad side.

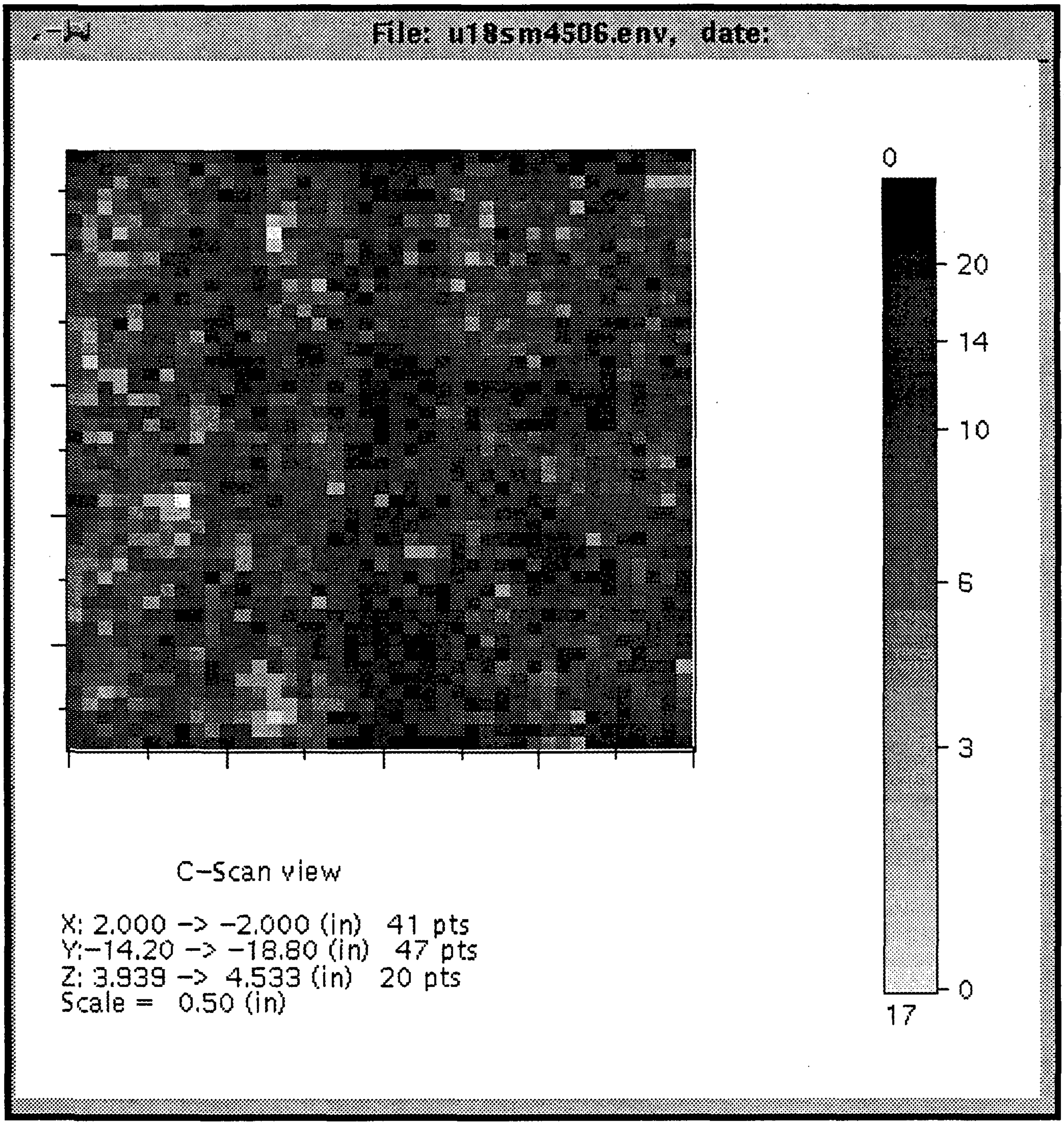


Figure 5.8c C-scan View (XY) of Base-Metal Indication in Block 1-8 at Y = -465 mm (-18.3 in.). 45° shear inspection from the unclad side. Beam direction is -X. Z values in the figure are measured from the unclad side.

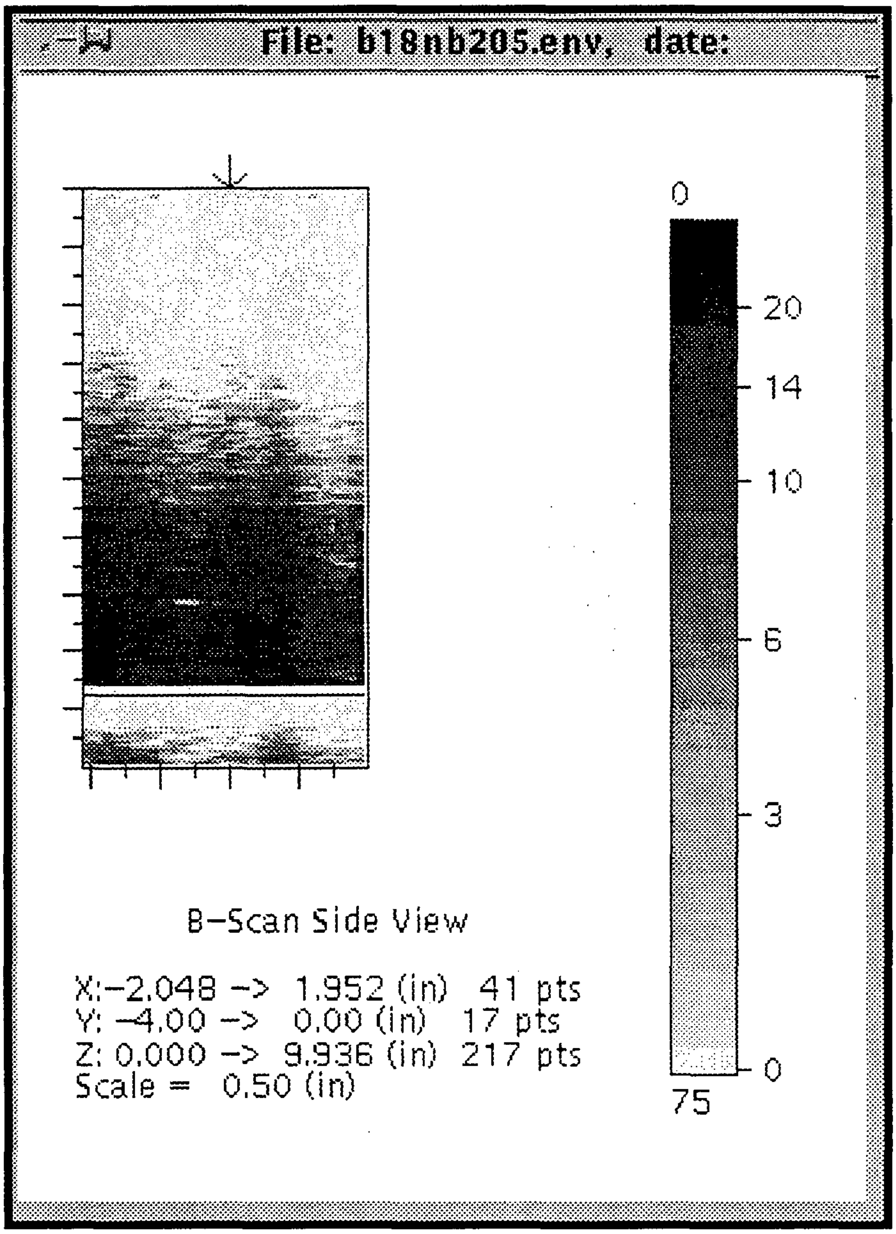


Figure 5.9a Side View (XZ) of Base-Metal Indication in Block 1-8 at Y = -71 mm (-2.8 in.). Normal beam inspection from the clad side.

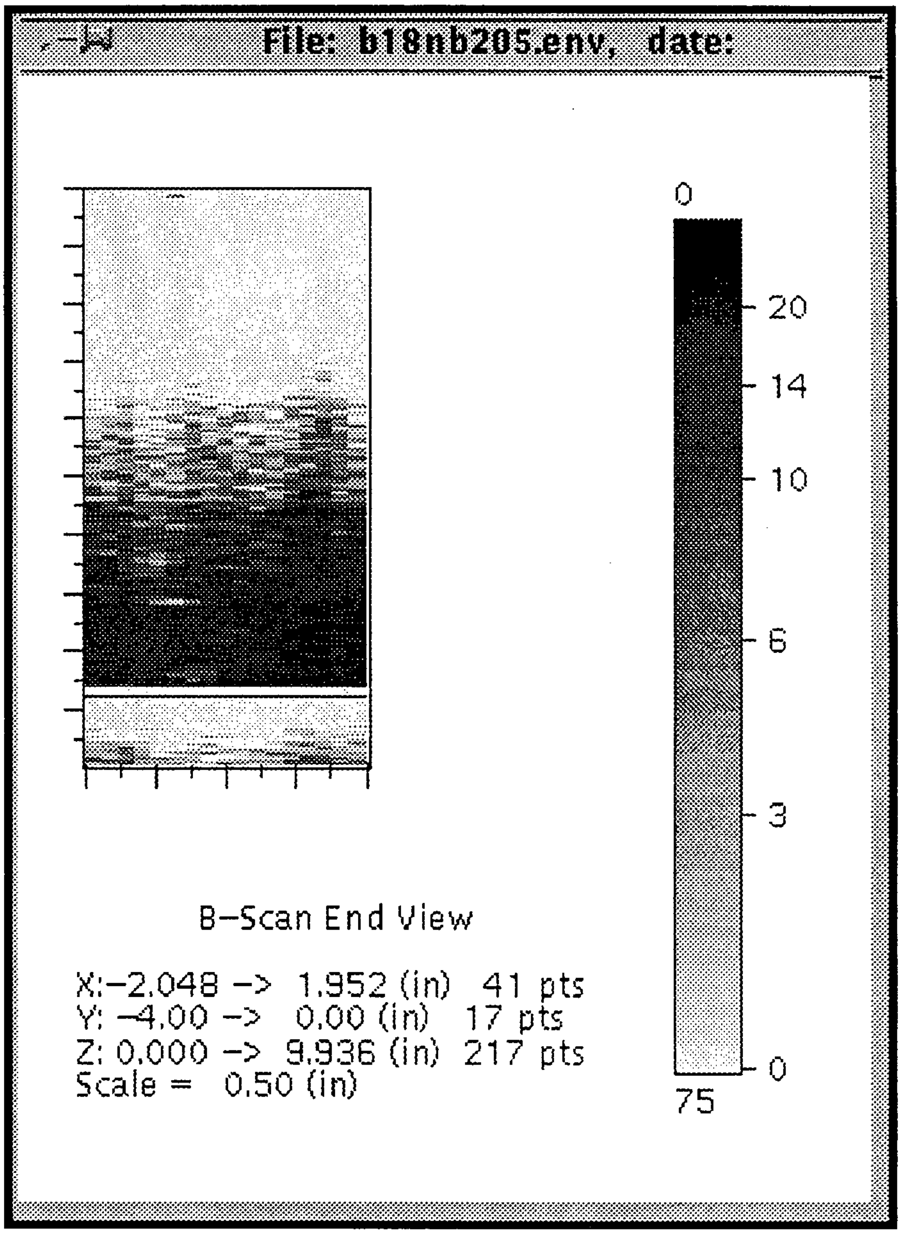


Figure 5.9b End View (YZ) of Base-Metal Indication in Block 1-8 at Y = -71 mm (-2.8 in.). Normal beam inspection from the clad side.

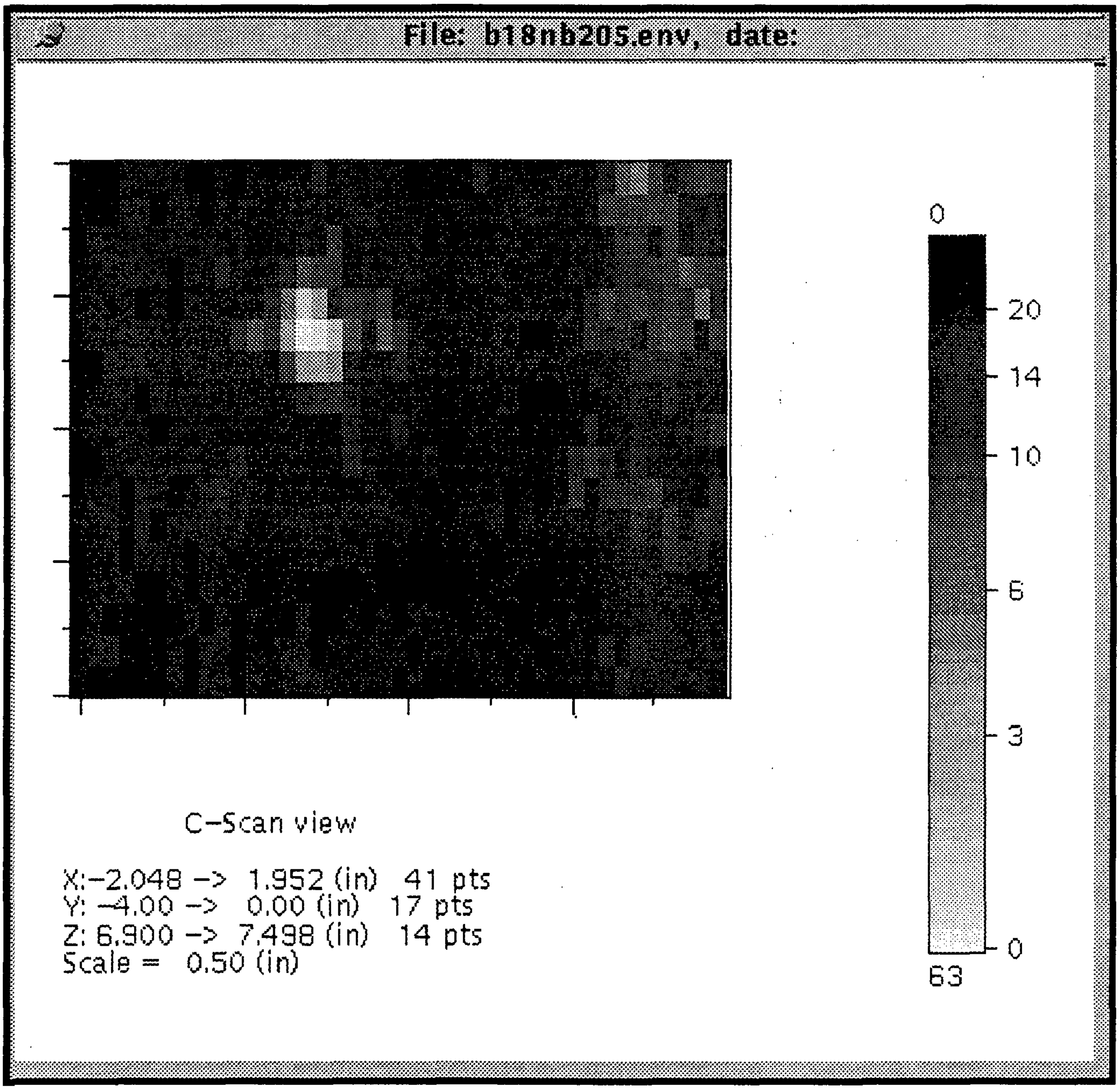


Figure 5.9c C-scan View (XY) of Base-Metal Indication in Block 1-8 at Y = -71 mm (-2.8 in.). Normal beam inspection from the clad side.

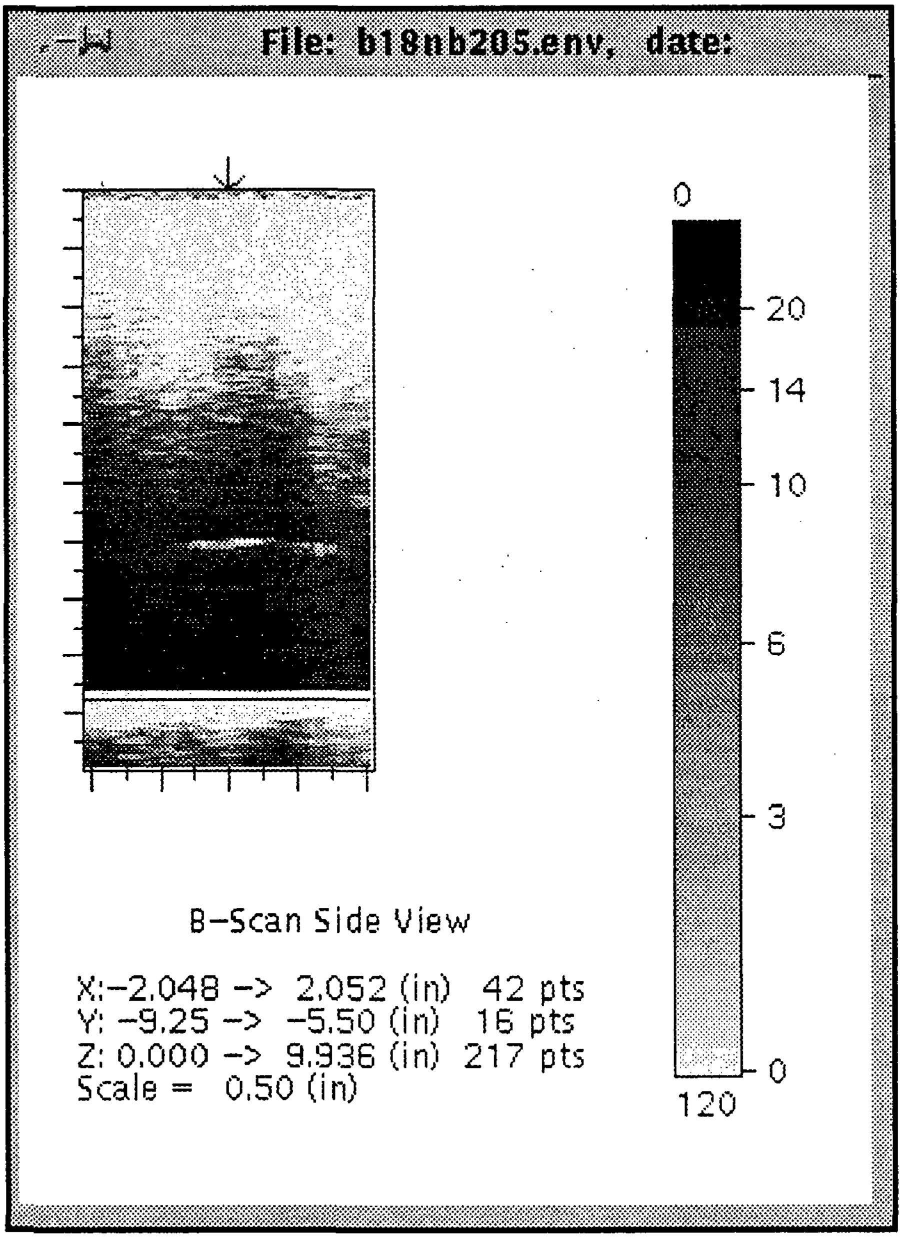


Figure 5.10a Side View (XZ) of Base-Metal Indication in Block 1-8 at Y = -185.4 mm (-7.3 in.). Normal beam inspection from the clad side.

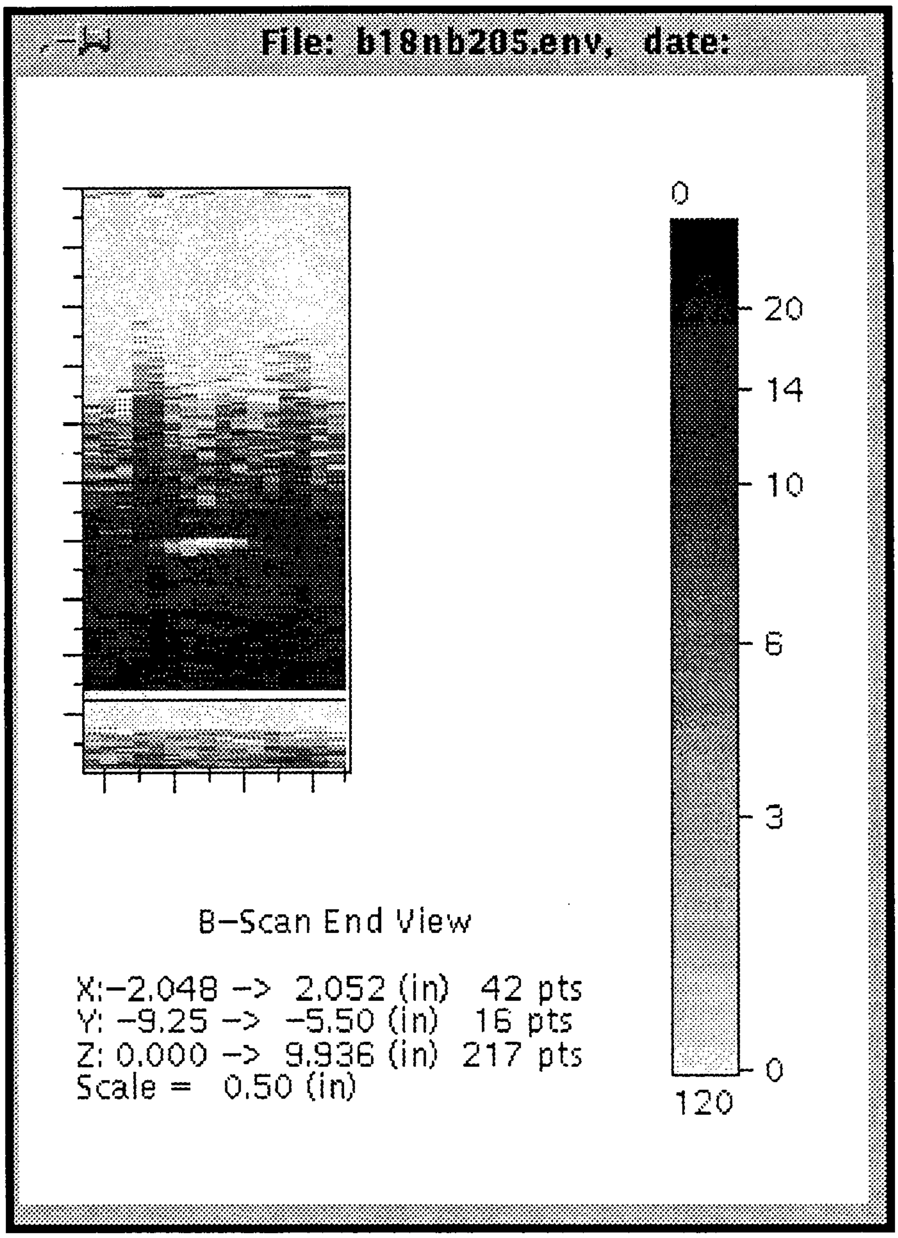


Figure 5.10b End View (YZ) of Base-Metal Indication in Block 1-8 at Y = -185.4 mm (-7.3 in.). Normal beam inspection from the clad side.

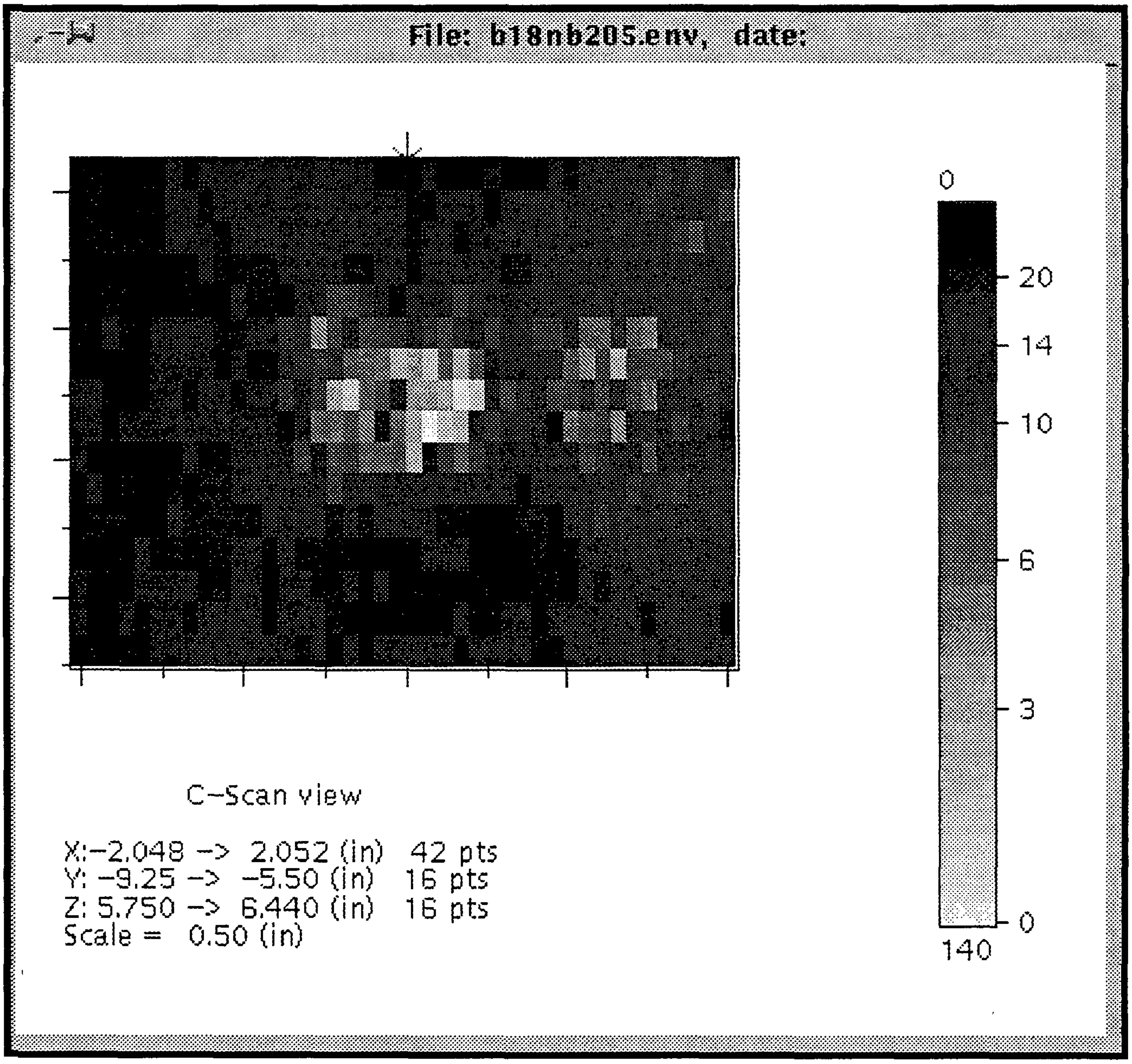


Figure 5.10c C-scan View (XY) of Base-Metal Indication in Block 1-8 at Y = -185.4 mm (-7.3 in.). Normal beam inspection from the clad side.

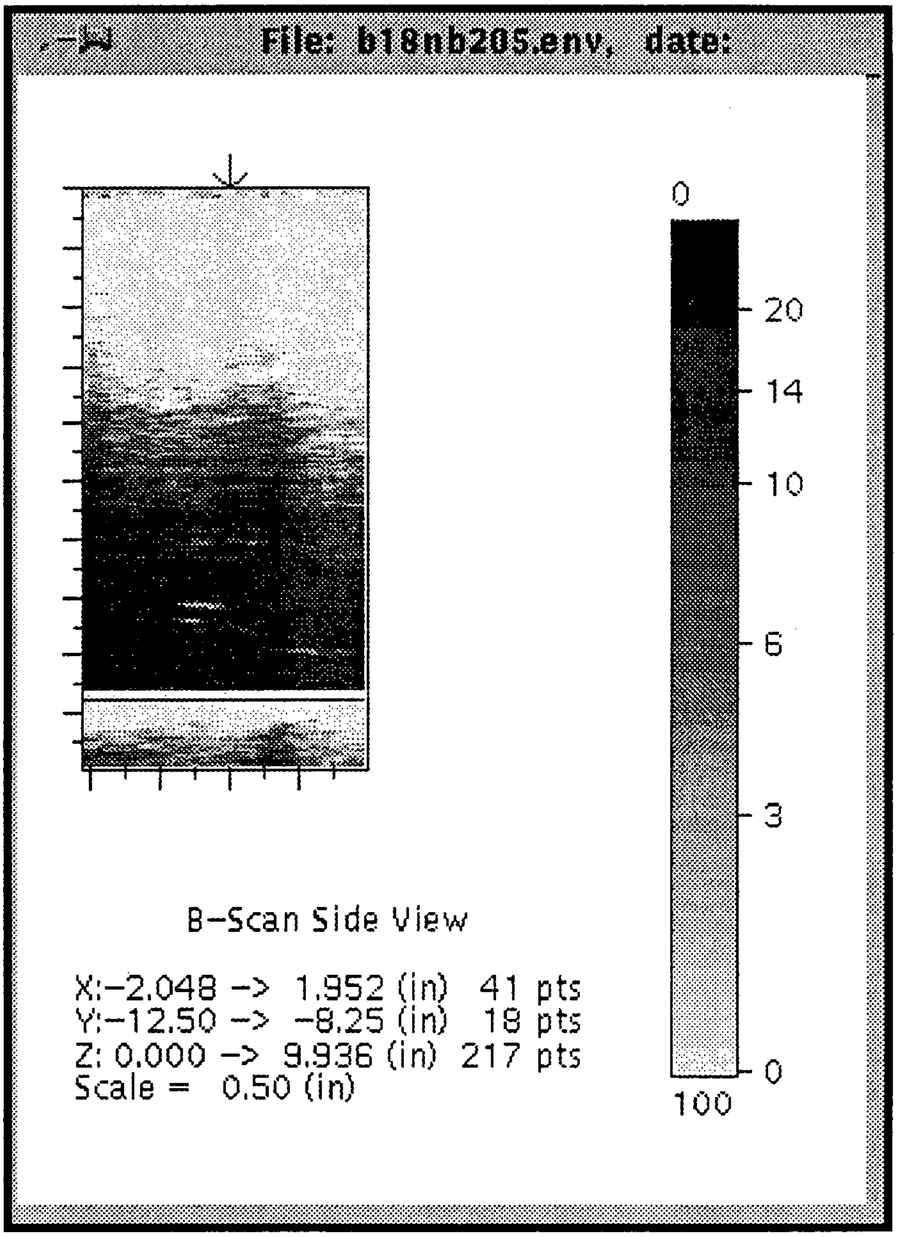


Figure 5.11a Side View (XZ) of Base-Metal Indication in Block 1-8 at Y = -254 mm (-10.0 in.). Normal beam inspection from the clad side.

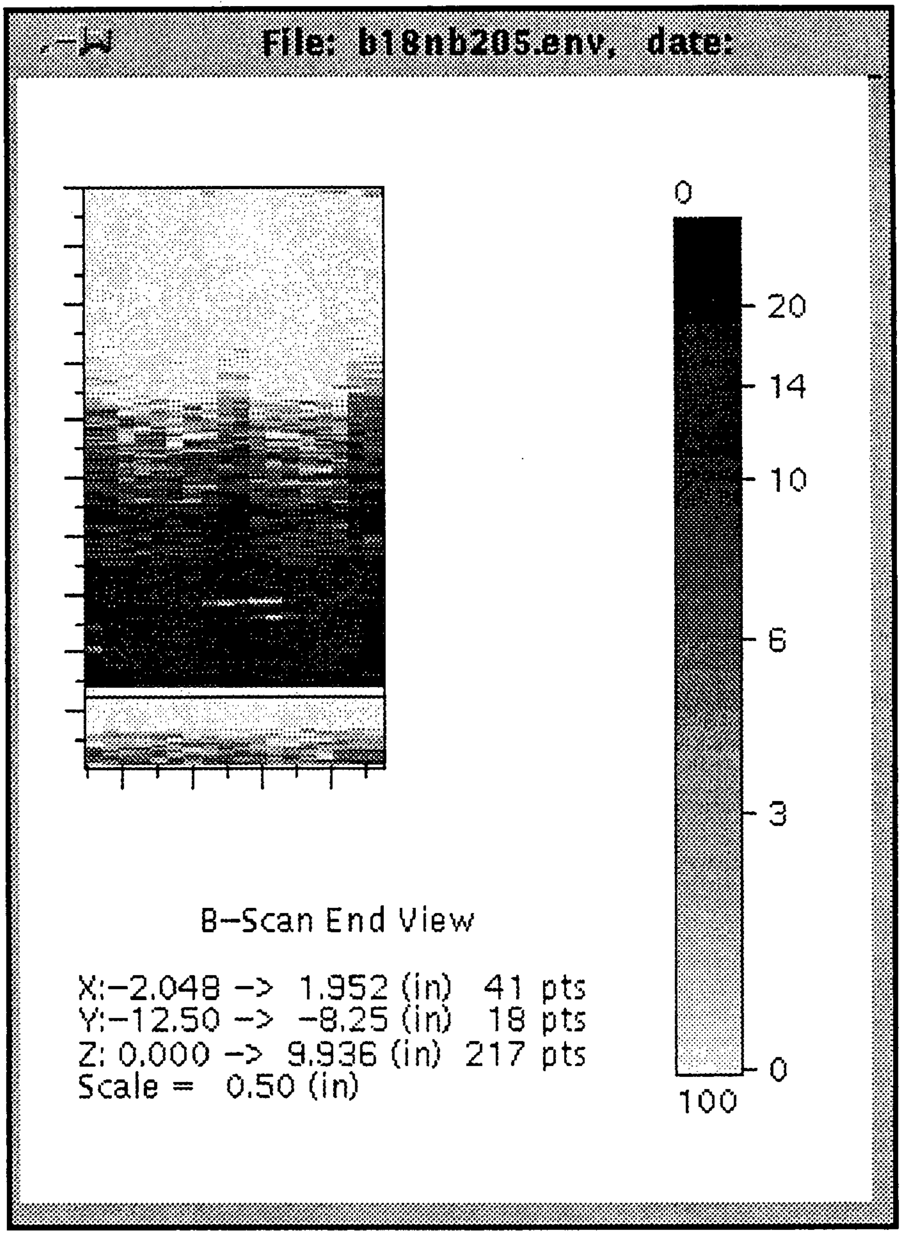


Figure 5.11b End View (YZ) of Base-Metal Indication in Block 1-8 at Y = -254 mm (-10.0 in.). Normal beam inspection from the clad side.

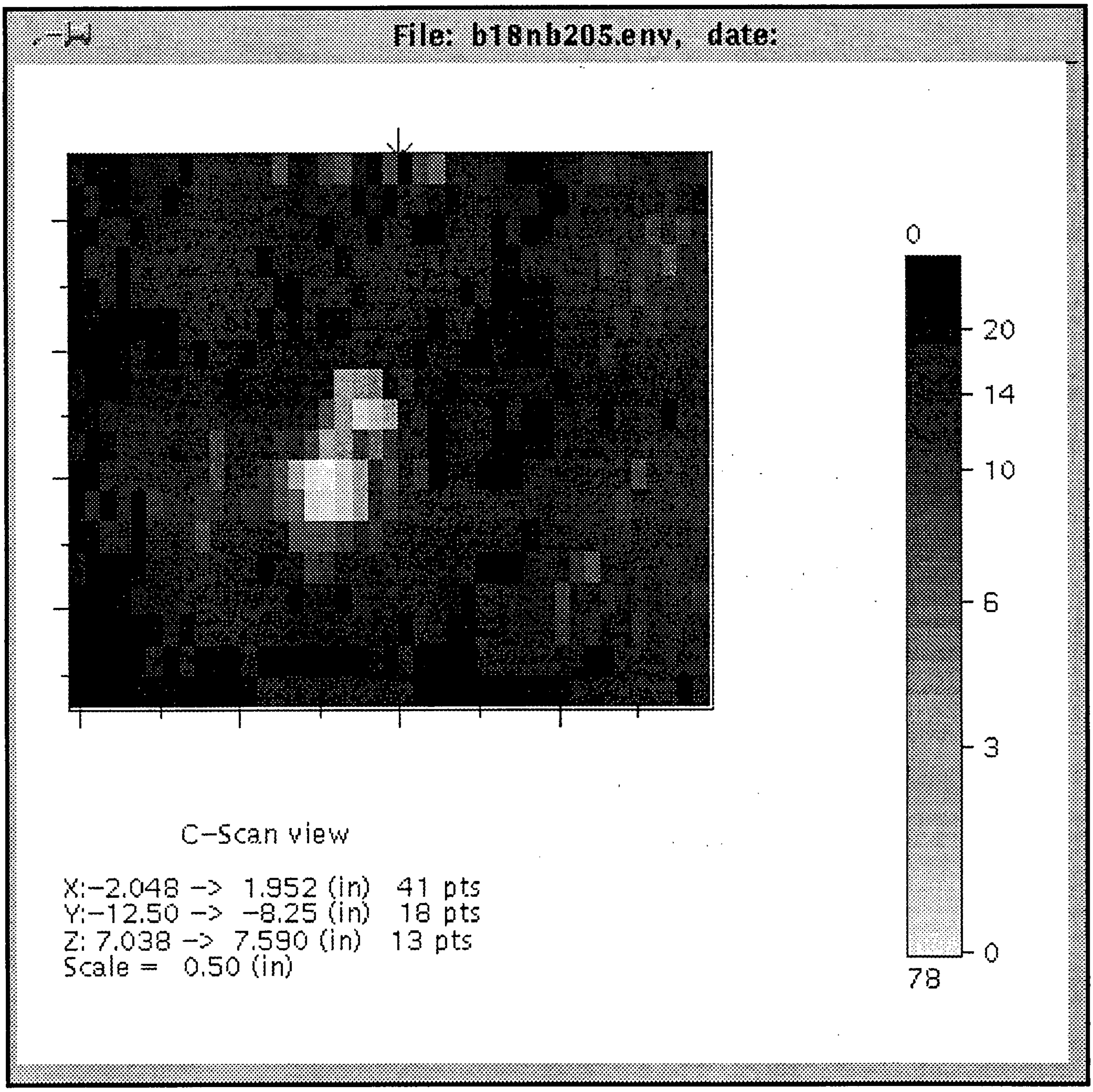


Figure 5.11c C-scan View (XY) of Base-Metal Indication in Block 1-8 at Y = -254 mm (-10.0 in.). Normal beam inspection from the clad side.

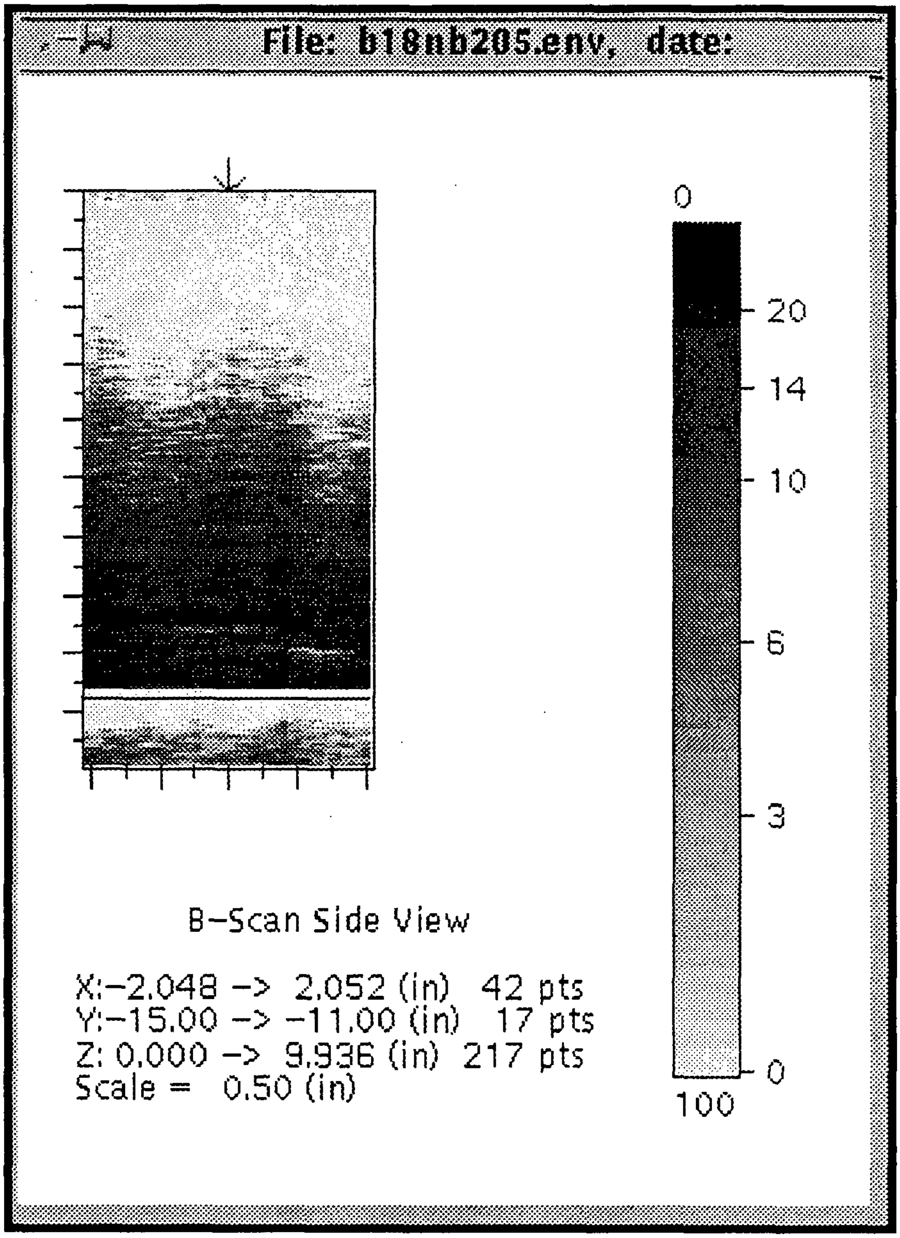


Figure 5.12a Side View (XZ) of Base-Metal Indication in Block 1-8 at Y = -325 mm (-12.8 in.). Normal beam inspection from the clad side.

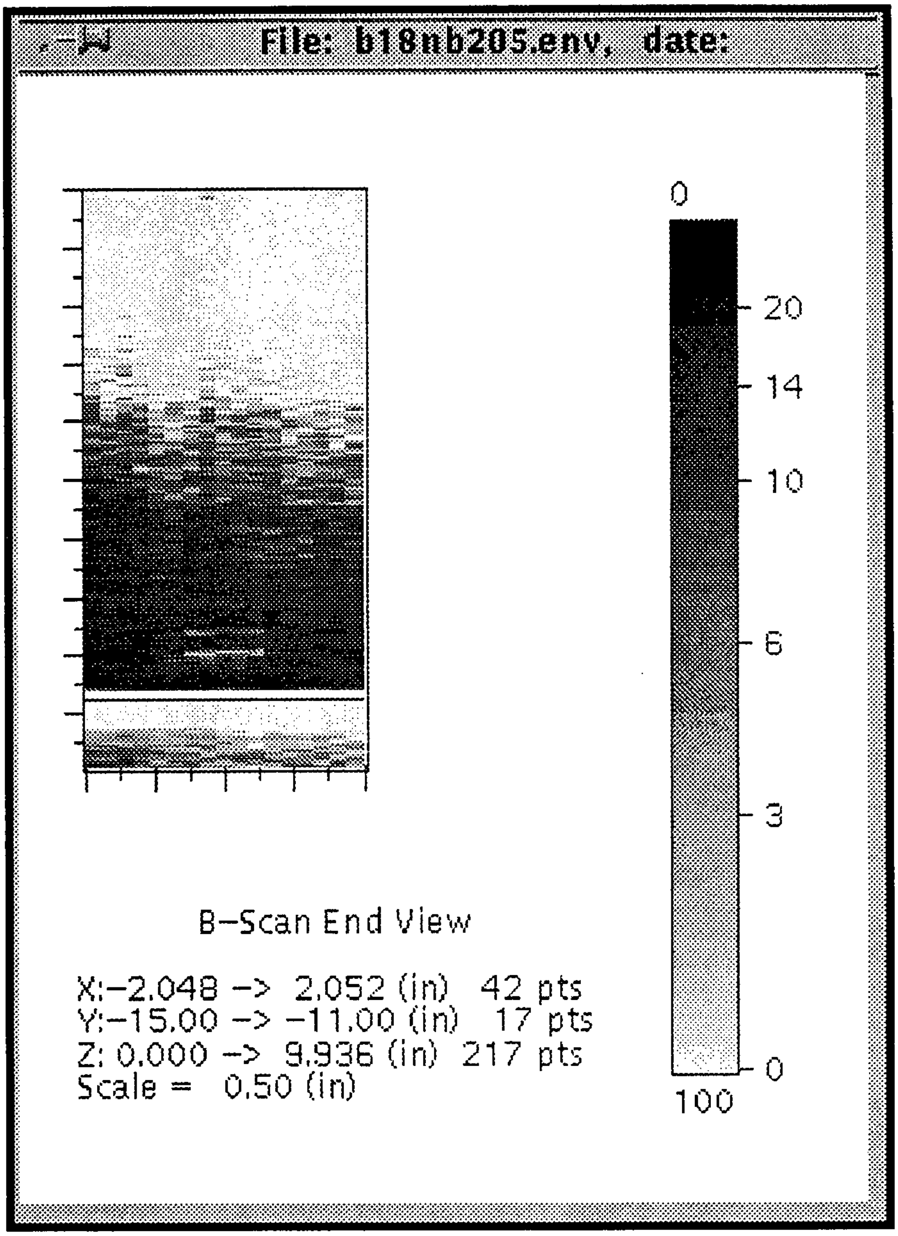


Figure 5.12b End View (YZ) of Base-Metal Indication in Block 1-8 at Y = -325 mm (-12.8 in.). Normal beam inspection from the clad side.

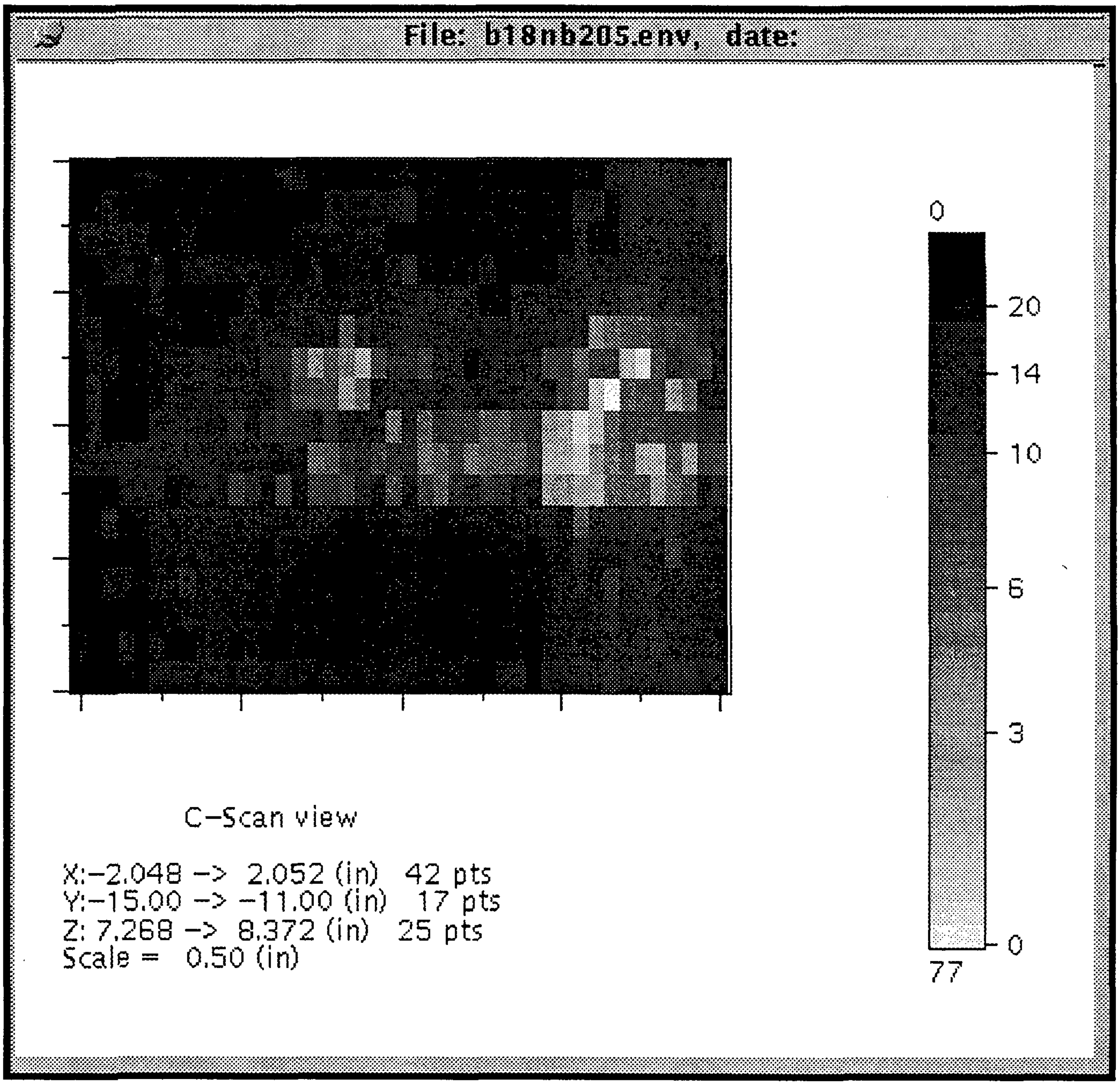


Figure 5.12c C-scan View (XY) of Base-Metal Indication in Block 1-8 at Y = -325 mm (-12.8 in.). Normal beam inspection from the clad side.

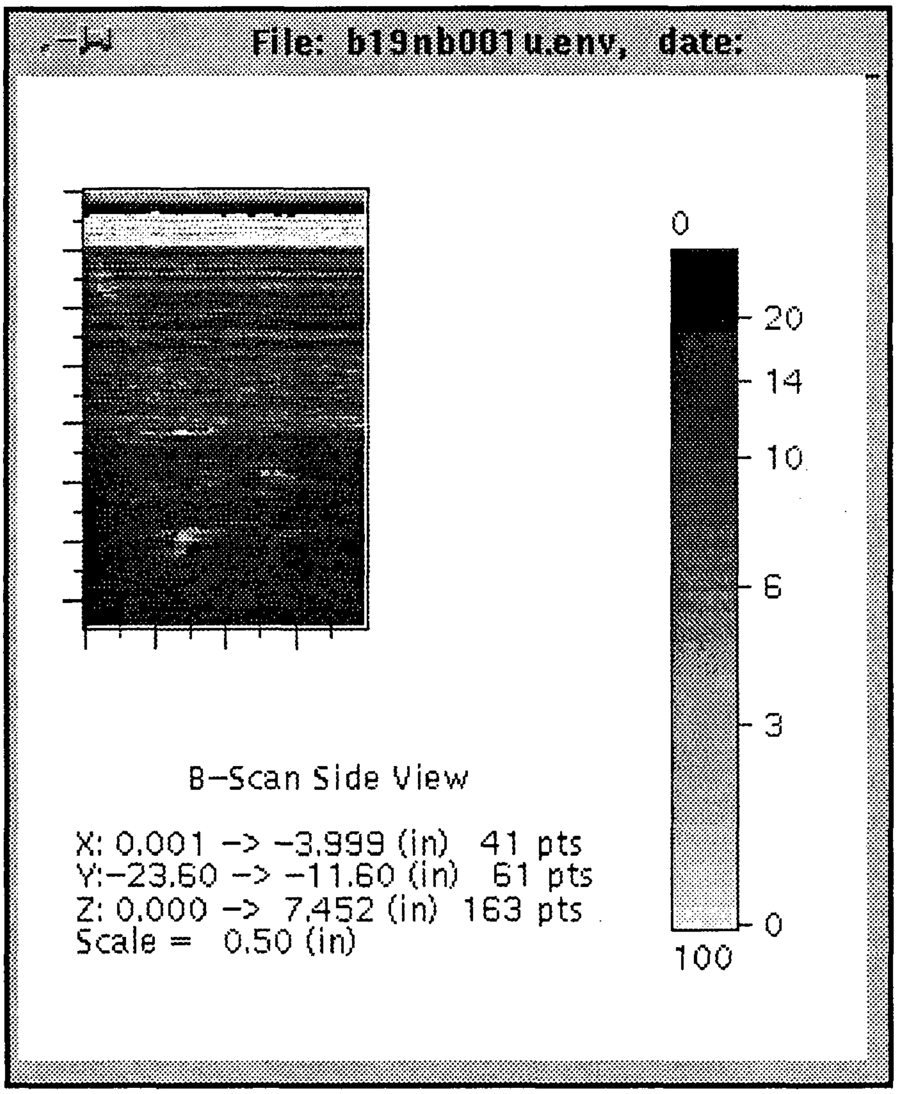


Figure 5.13a Side View (scanner coordinates xz) of Base-Metal Indication in Block 1-9 at Y = -582 mm (-22.9 in.). Normal beam inspection from the bottom side. Z in the figure corresponds to material coordinates of X from -152 mm (-6 in.) to +36.8 mm (+1.45 in.). X in the figure corresponds to material coordinates of Z from 216 mm (8.5 in.) to 114.3 (4.5 in.).

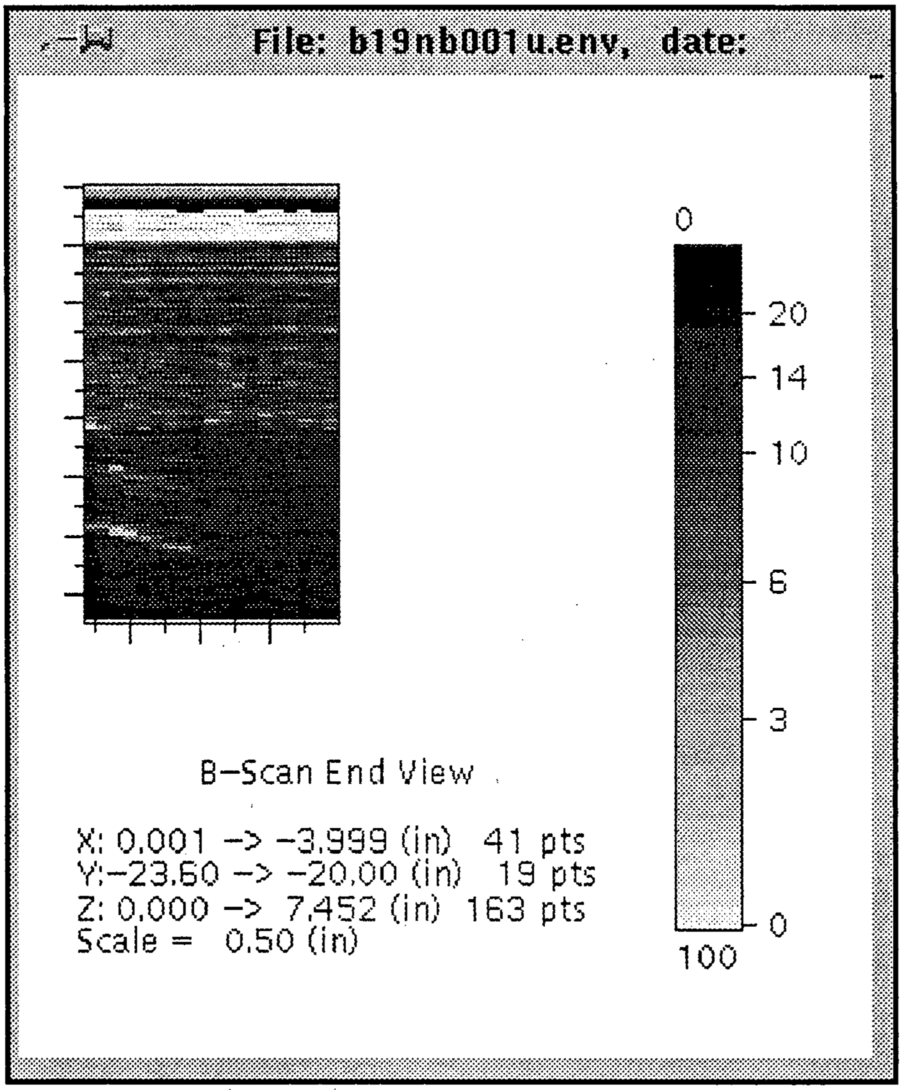


Figure 5.13b End View (scanner coordinates yz) of Base-Metal Indication in Block 1-9 at Y = -582 mm (-22.9 in.). Normal beam inspection from the bottom side. Z in the figure corresponds to material coordinates of X from -152 mm (-6 in.) to +36.8 mm (+1.45 in.). X in the figure corresponds to material coordinates of Z from 216 mm (8.5 in.) to 114.3 (4.5 in.).

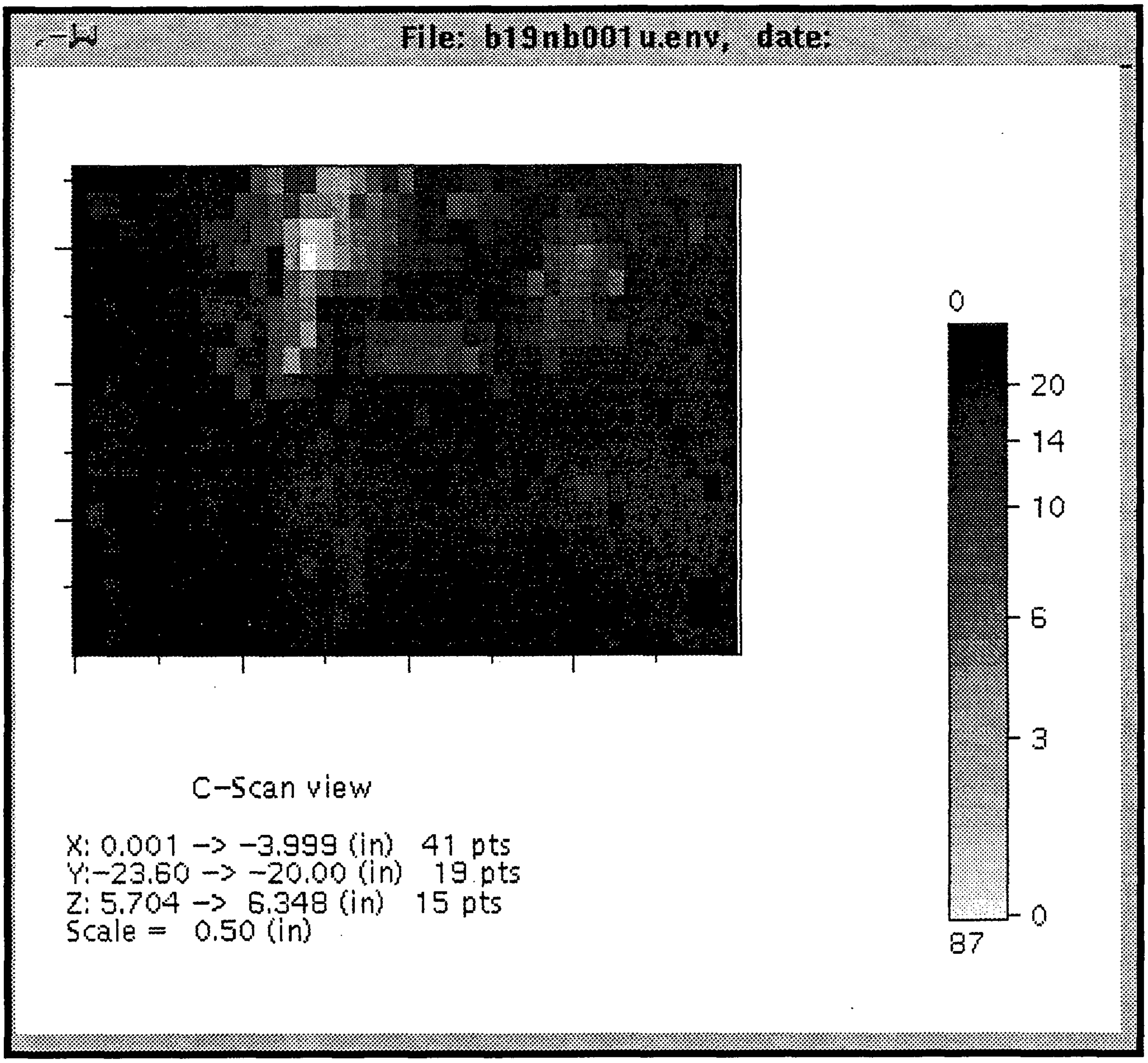


Figure 5.13c C-scan View (scanner coordinates xy) of Base-Metal Indication in Block 1-9 at Y = -582 mm (-22.9 in.). Normal beam inspection from the bottom side. Z in the figure corresponds to material coordinates of X from -152 mm (-6 in.) to +36.8 mm (+1.45 in.). X in the figure corresponds to material coordinates of Z from 216 mm (8.5 in.) to 114.3 (4.5 in.).

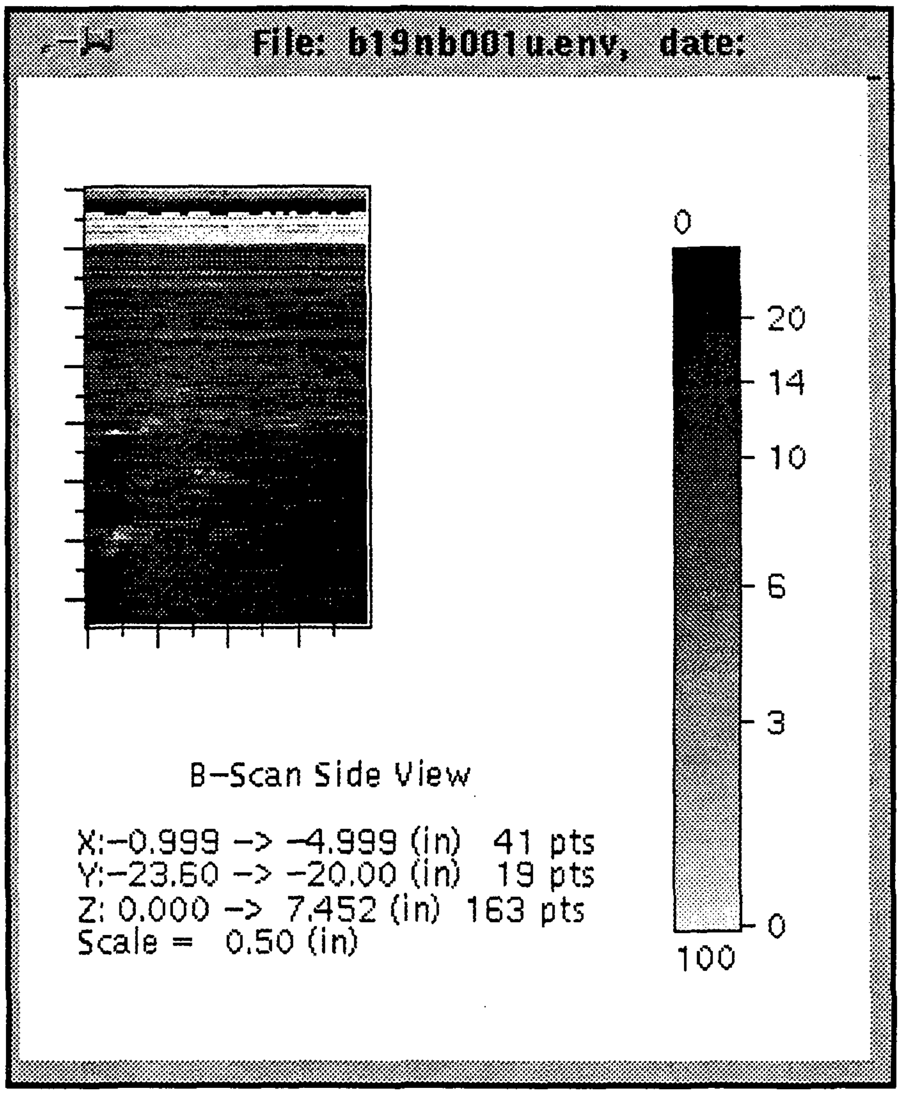


Figure 5.14a Side View (scanner coordinates xz) of Base-Metal Indication in Block 1-9 at Y = -584 mm (-23.0 in.).. Normal beam inspection from the bottom side. Z in the figure corresponds to material coordinates of X from -152 mm (-6 in.) to +368 mm (+1.45 in.). X in the figure corresponds to material coordinates of Z from 191 mm (7.5 in.) to 88.9 mm (3.5 in.).

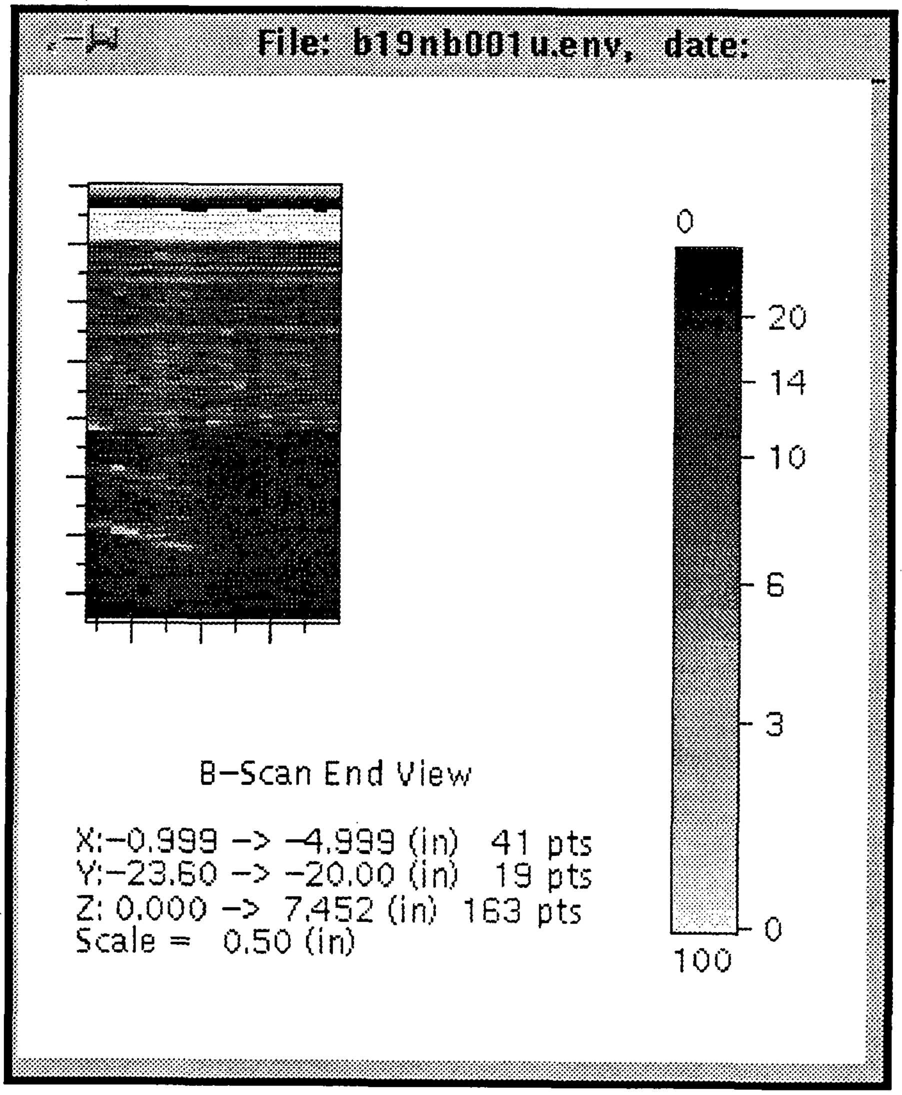


Figure 5.14b End View (scanner coordinates yz) of Base-Metal Indication in Block 1-9 at Y = -584 mm (-23.0 in.).. .Normal beam inspection from the bottom side. Z in the figure corresponds to material coordinates of X from -152 mm (-6 in.) to +368 mm (+1.45 in.). X in the figure corresponds to material coordinates of Z from 191 mm (7.5 in.) to 88.9 mm (3.5 in.).

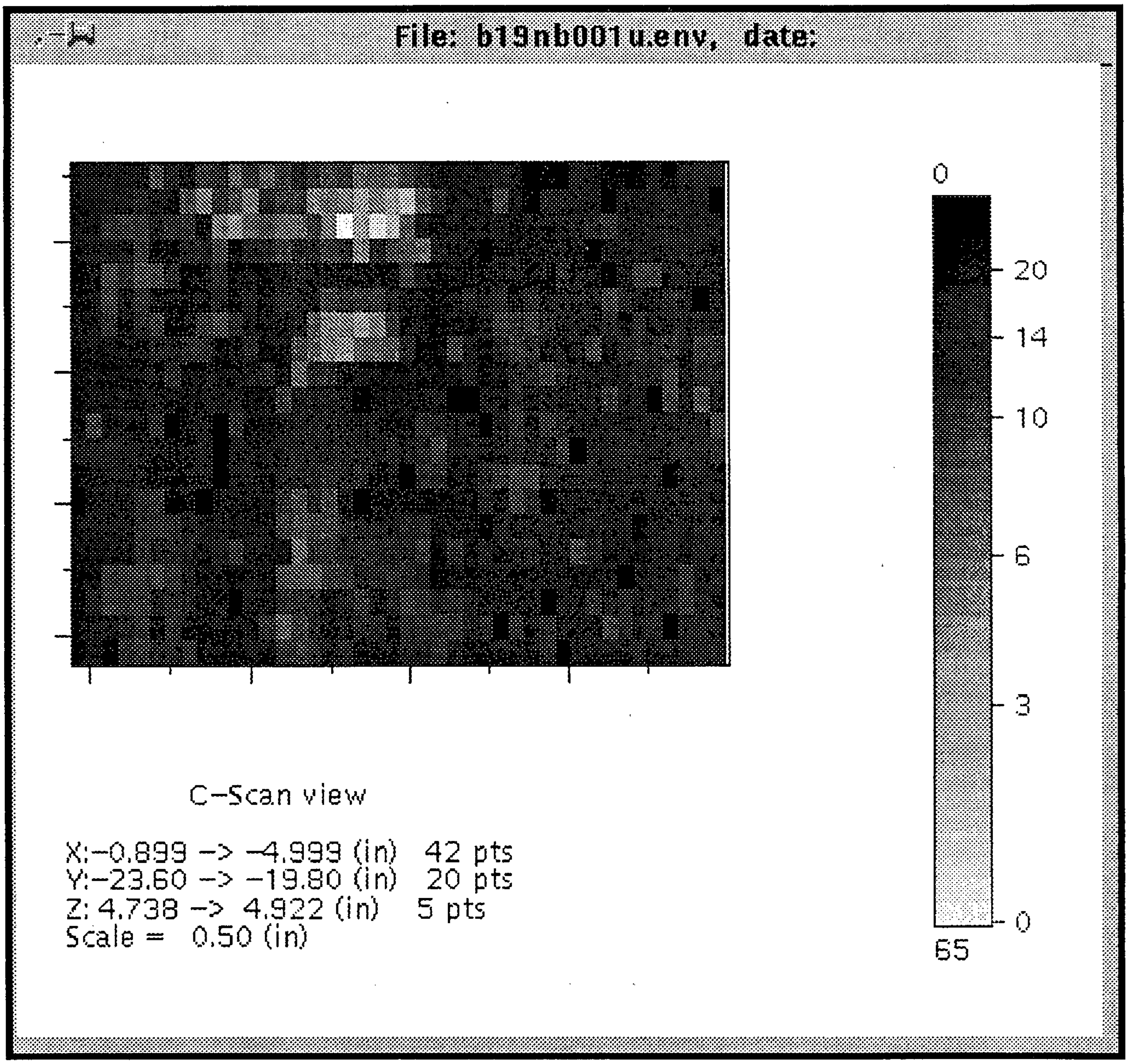


Figure 5.14c C-scan View (scanner coordinates xy) of Base-Metal Indication in Block 1-9 at Y = -584 mm (-23.0 in.).. Normal beam inspection from the bottom side. Z in the figure corresponds to material coordinates of X from -152 mm (-6 in.) to +368 mm (+1.45 in.). X in the figure corresponds to material coordinates of Z from 191 mm (7.5 in.) to 88.9 mm (3.5 in.).

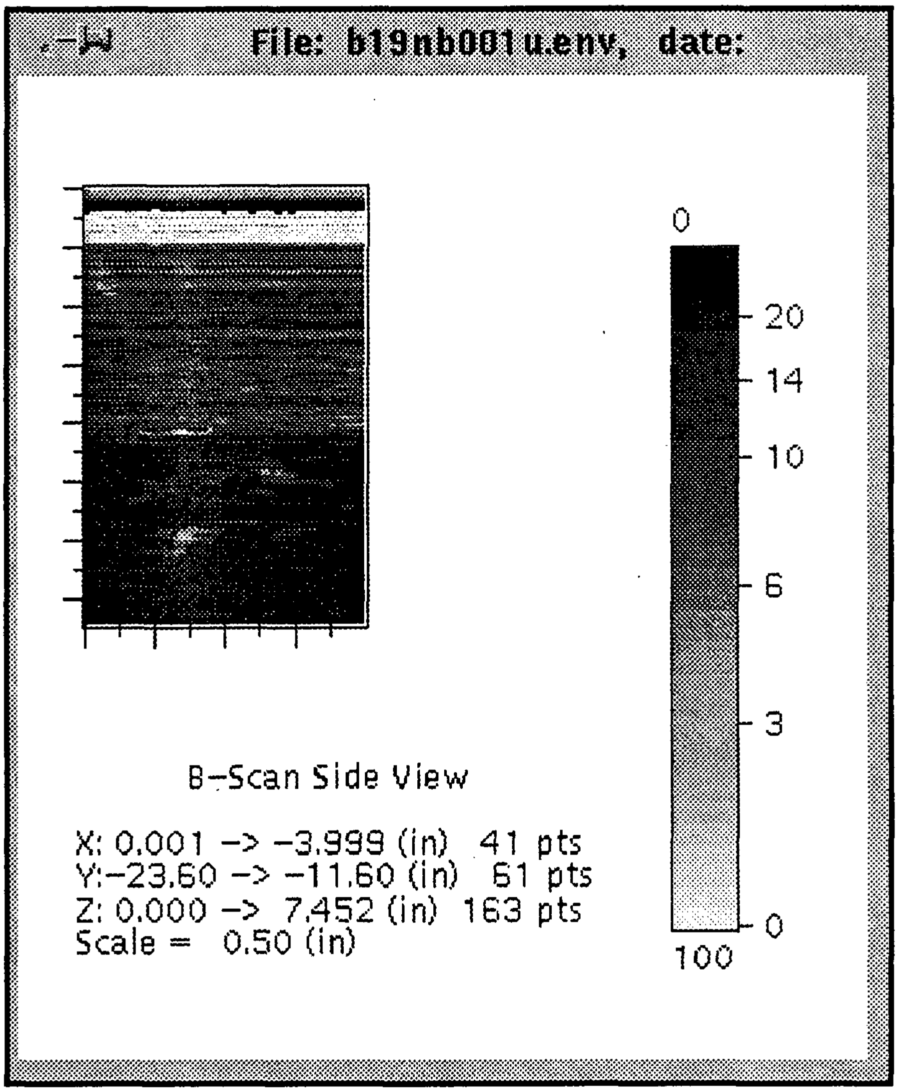


Figure 5.15a Side View (scanner coordinates xz) of Base-Metal Indication in Block 1-9 at Y = -597 mm (-23.5 in.). Normal beam inspection from the bottom side. Z in the figure corresponds to material coordinates of X from -152 mm (-6 in.) to +368 mm (+1.45 in.). X in the figure corresponds to material coordinates of Z from 216 mm (8.5 in.) to 114 mm (4.5 in.).

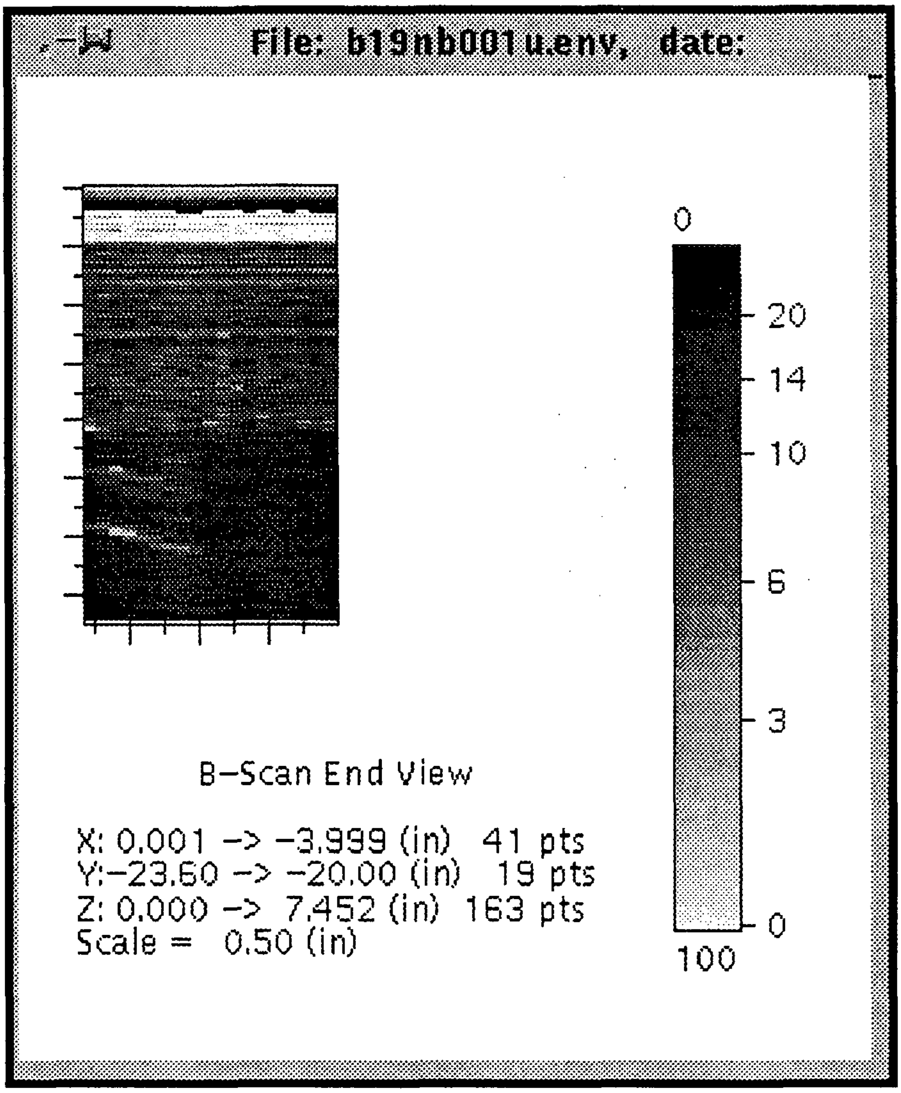


Figure 5.15b End View (scanner coordinates yz) of Base-Metal Indication in Block 1-9 at Y = -597 mm (-23.5 in.). Normal beam inspection from the bottom side. Z in the figure corresponds to material coordinates of X from -152 mm (-6 in.) to +368 mm (+1.45 in.). X in the figure corresponds to material coordinates of Z from 216 mm (8.5 in.) to 114 mm (4.5 in.).

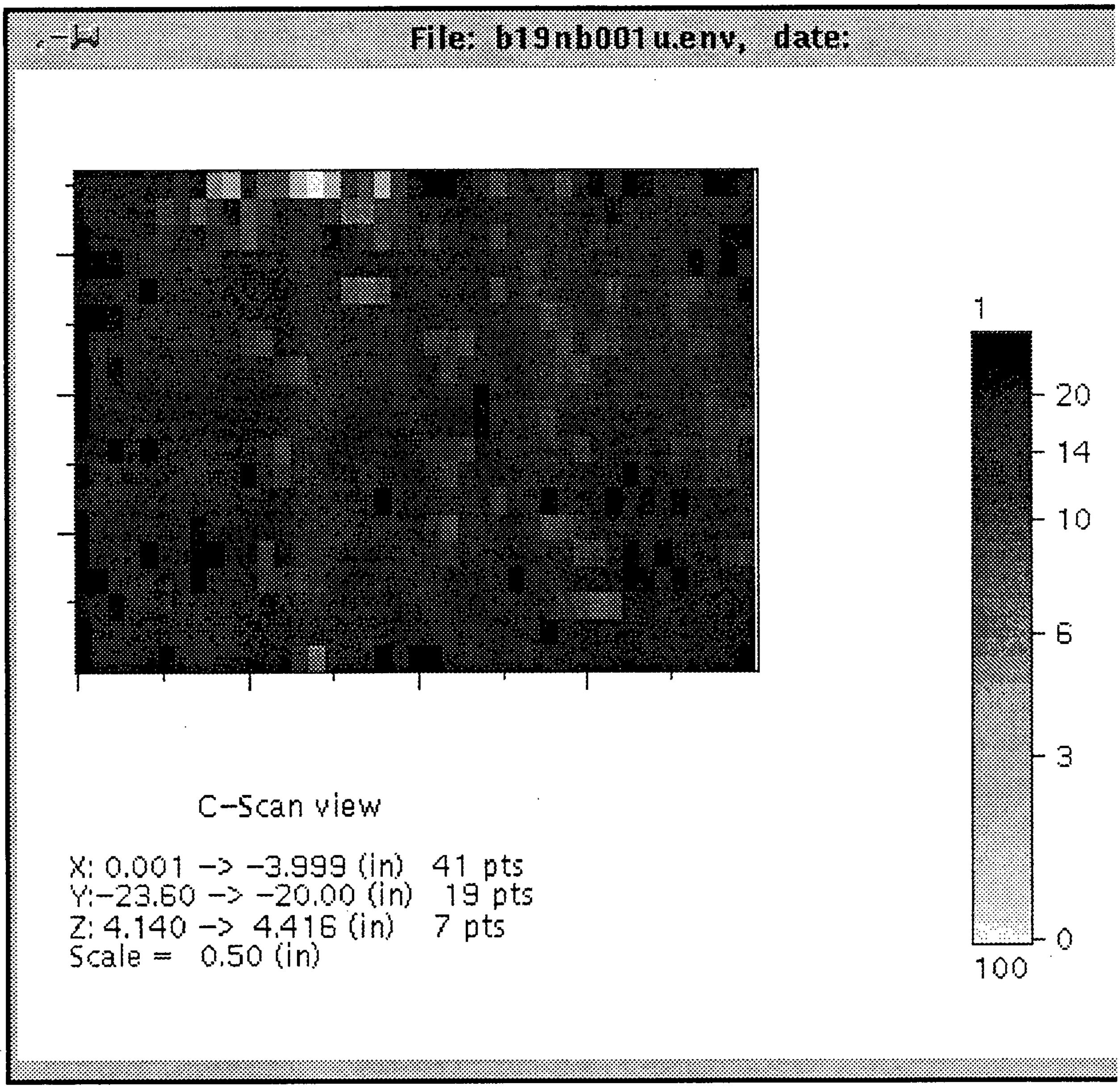


Figure 5.15c C-scan View (scanner coordinates xy) of Base-Metal Indication in Block 1-9 at Y = -597 mm (-23.5 in.). Normal beam inspection from the bottom side. Z in the figure corresponds to material coordinates of X from -48 mm (-1.9 in.) to -41 mm (-1.6 in.). X in the figure corresponds to material coordinates of Z from 216 mm (8.5 in.) to 114 mm (4.5 in.).

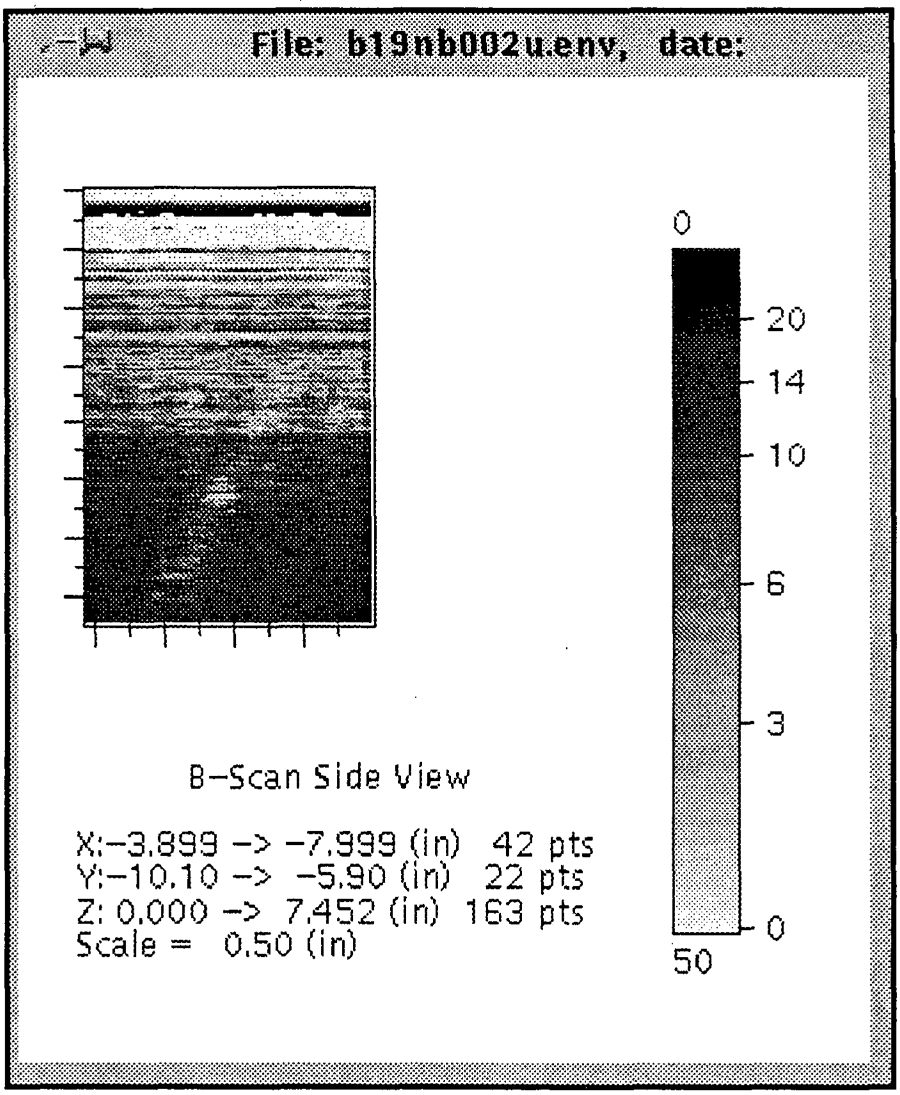


Figure 5.16a Side View (Scanner Coordinates XZ) of Base-Metal Indication in Block 1-9 at Y = -22.1 mm (-8.7 in.). Normal beam inspection from the bottom side. Z in the figure corresponds to material coordinates of X from -152 mm (-6 in.) to +368 mm (+1.45 in.). X in the figure corresponds to material coordinates of Z from 119 mm (4.7 in.) to 13 mm (0.5 in.).

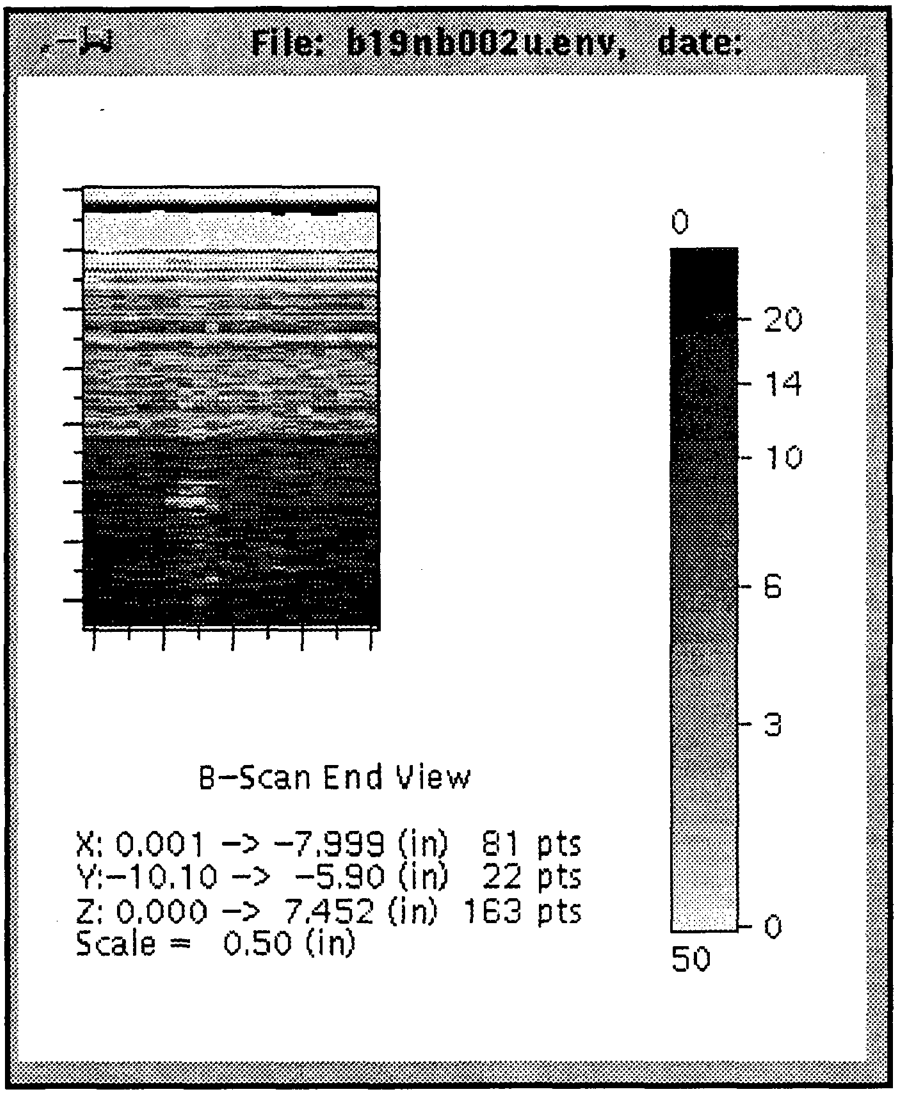


Figure 5.16b End View (Scanner Coordinates YZ) of Base-Metal Indication in Block 1-9 at Y = -22.1 mm (-8.7 in.). Normal beam inspection from the bottom side. Z in the figure corresponds to material coordinates of X from -152 mm (-6 in.) to 368 mm (1.45 in.).

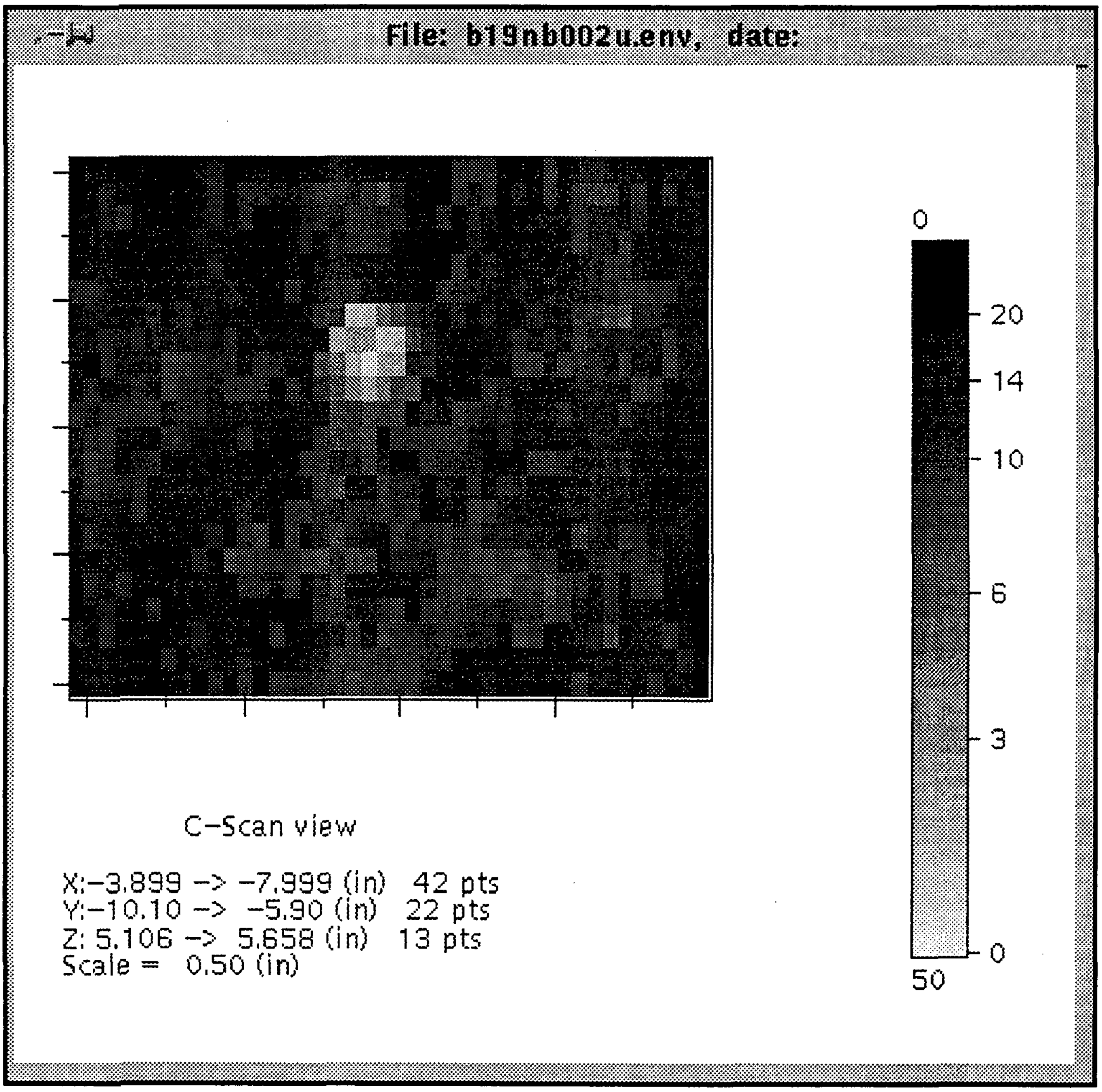


Figure 5.16c C-scan View (Scanner Coordinates XY) of Base-Metal Indication in Block 1-9 at Y = -22.1 mm (-8.7 in.). Normal beam inspection from the bottom side. X in the figure corresponds to material coordinates of Z from 119 mm (4.7 in.) to 13 mm (0.5 in.).

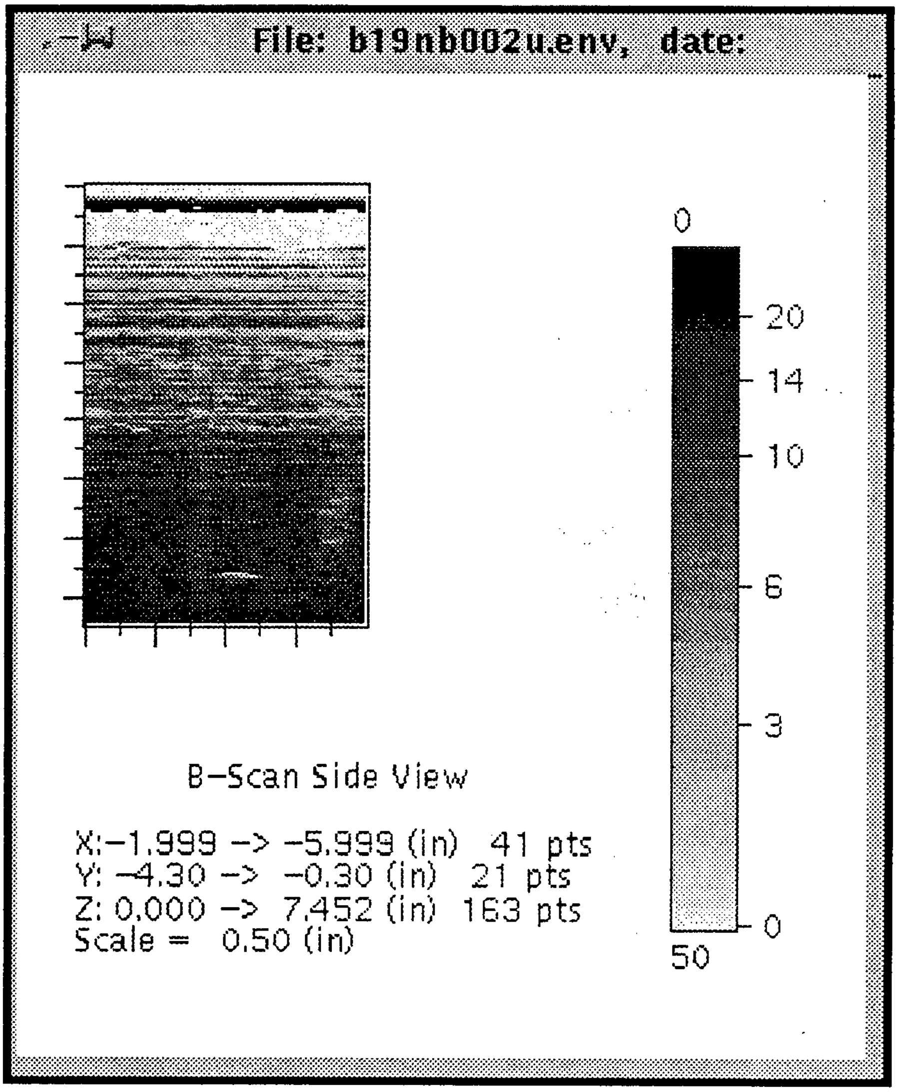


Figure 5.17a Side View (Scanner Coordinates XZ) of Base-Metal Indication in Block 1-9 at Y = -69 mm (-2.7 in.). Normal beam inspection from the bottom side. Z in the figure corresponds to material coordinates of X from -152 mm (-6 in.) to +368 mm (+1.45 in.). X in the figure corresponds to material coordinates of Z from 165 mm (6.5 in.) to 64 mm (2.5 in.).

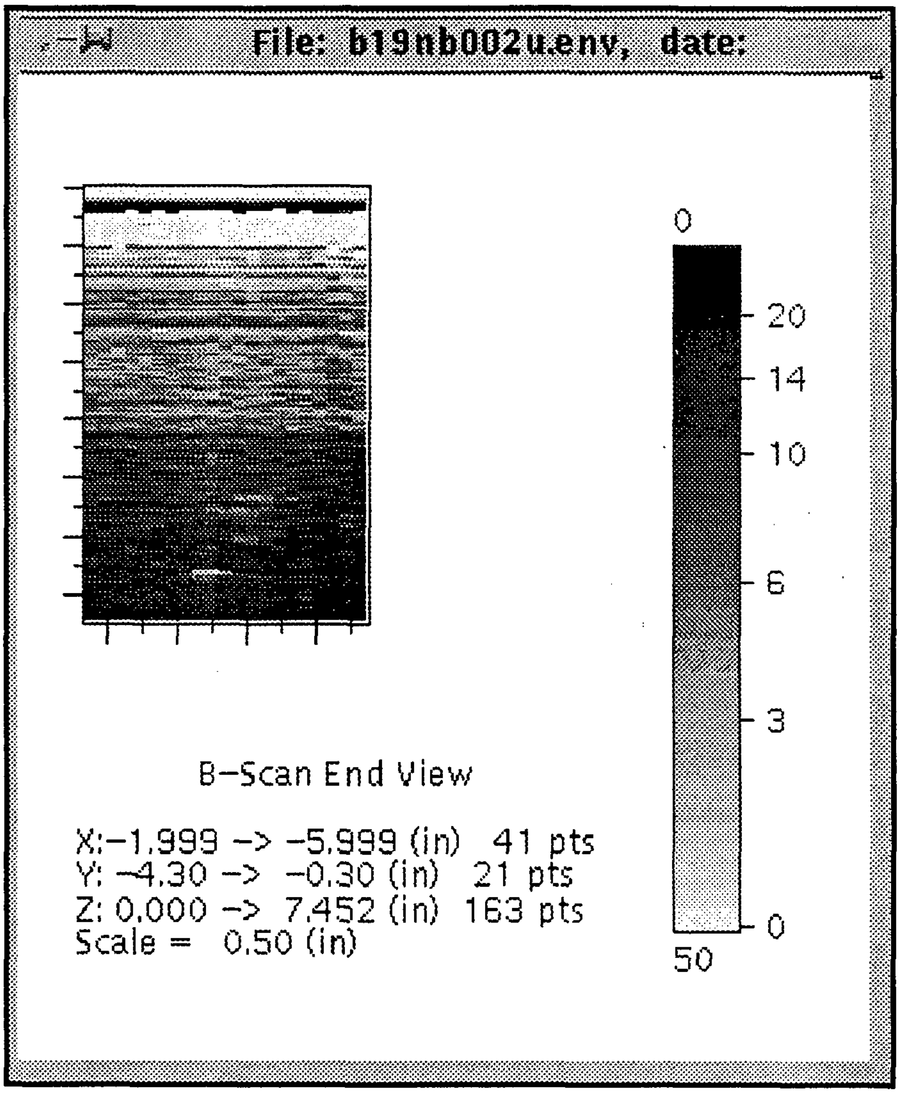


Figure 5.17b End View (Scanner Coordinates YZ) of Base-Metal Indication in Block 1-9 at Y = -69 mm (2.7 in.). Normal beam inspection from the bottom side. Z in the figure corresponds to material coordinates of X from -152 mm (-6 in.) to +368 mm (+1.45 in.).

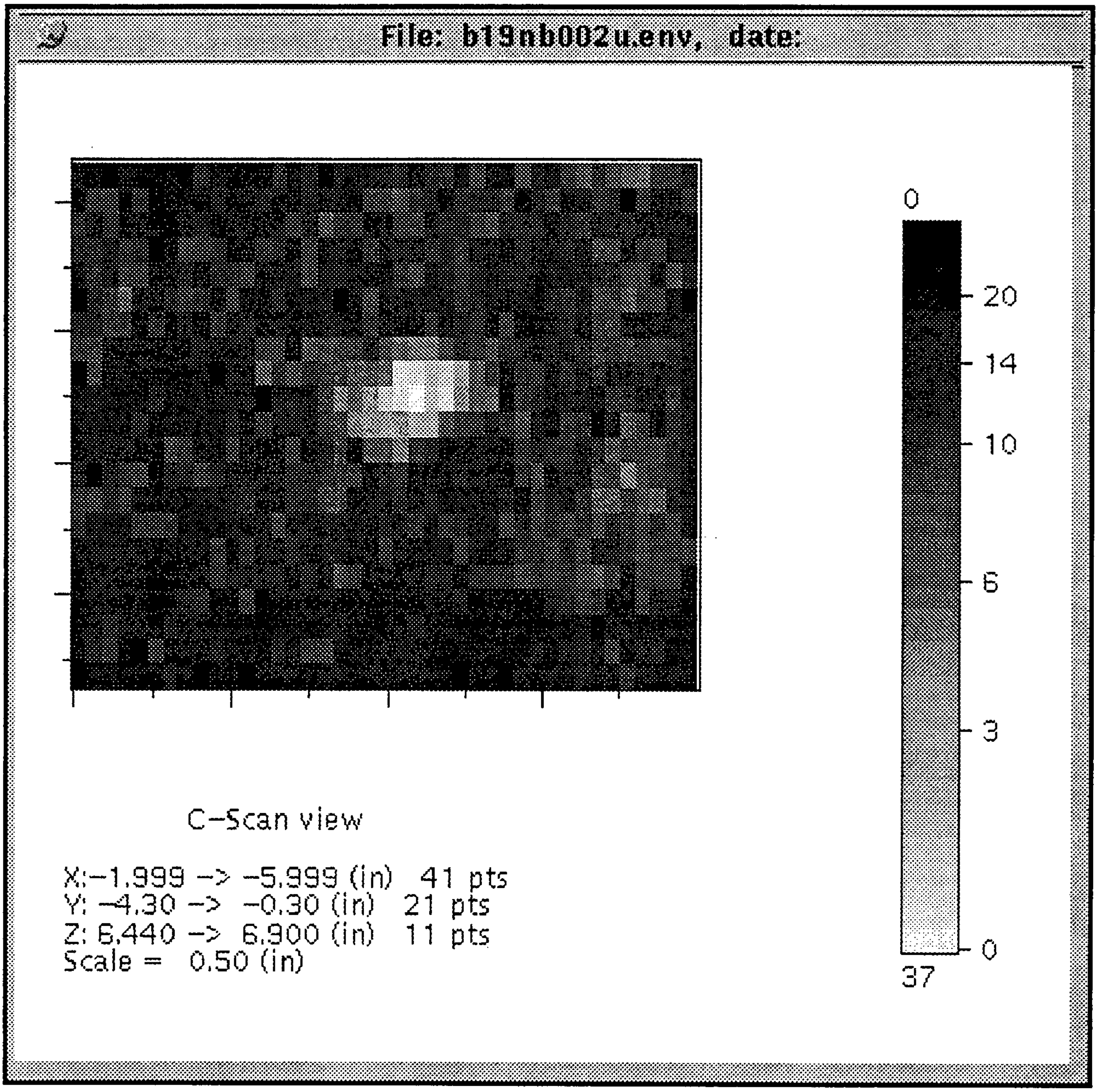


Figure 5.17c C-scan View (Scanner Coordinates XY) of Base-Metal Indication in Block 1-9 at Y = -69 mm (2.7 in.). Normal beam inspection from the bottom side. X in the figure corresponds to material coordinates of Z from 165 mm (6.5 in.) to 64 mm (2.5 in.).

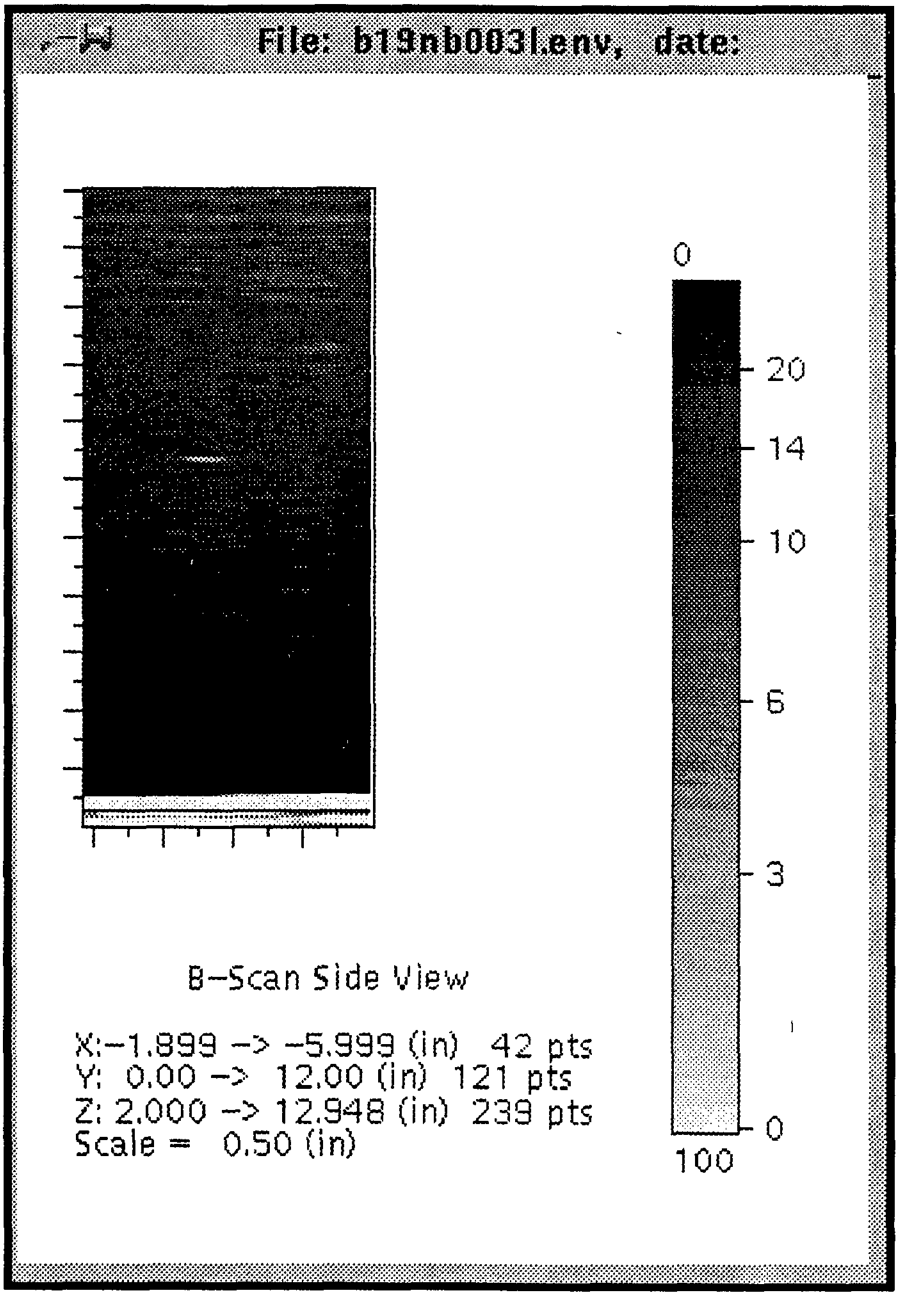


Figure 5.18a Side View (Scanner Coordinates XZ) of Base-Metal Indication in Block 1-9 at Y = 183 mm (7.2 in.). Normal beam inspection from the bottom side. Z in the figure corresponds to material coordinates of X from -102 mm (-4 in.) to 178 mm (7 in.). X in the figure corresponds to material coordinates of Z from 168 mm (6.6 in.) to 64 mm (2.5 in.).

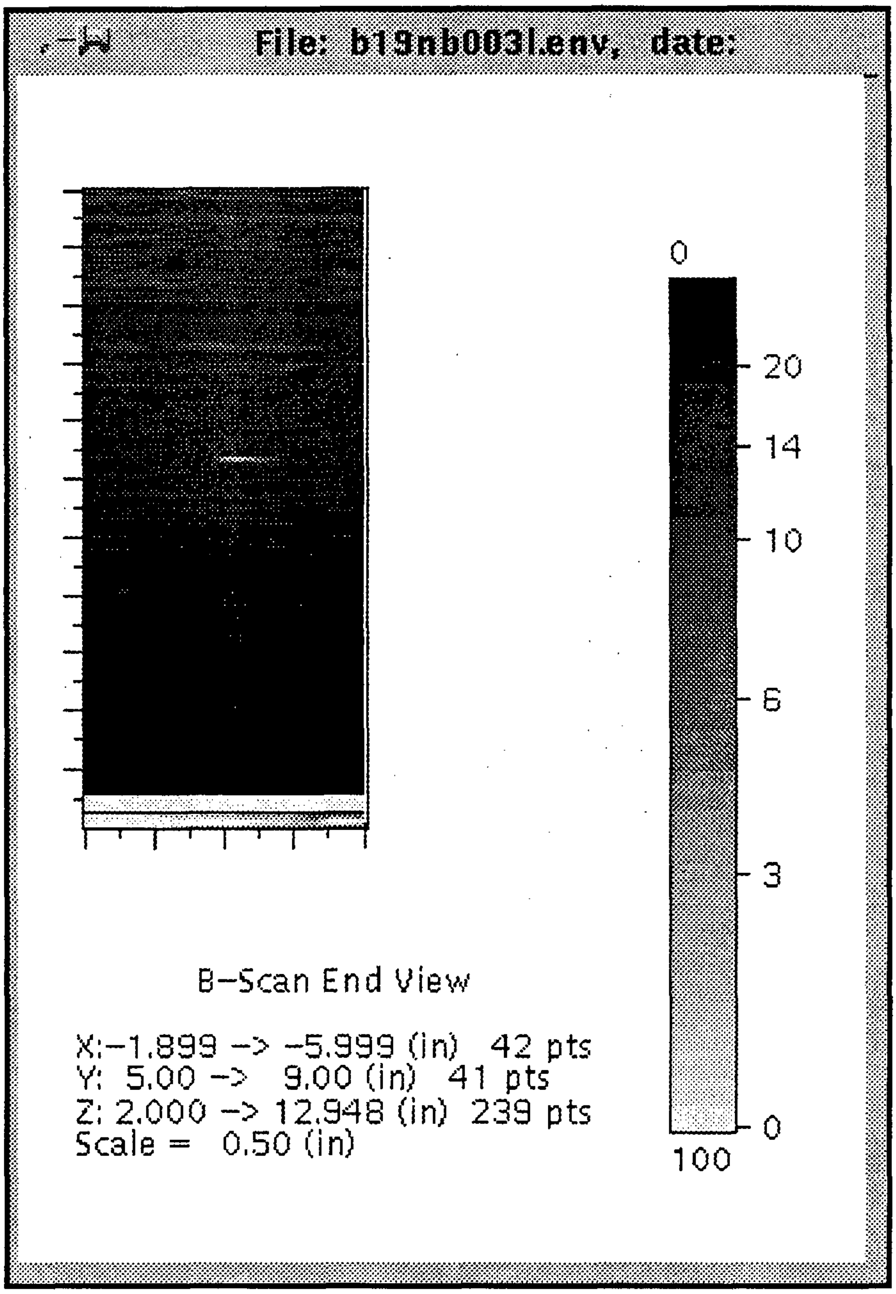


Figure 5.18b End View (Scanner Coordinates YZ) of Base-Metal Indication in Block 1-9 at Y = 183 mm (7.2 in.). Normal beam inspection from the bottom side. Z in the figure corresponds to material coordinates of X from -102 mm (-4 in.) to 178 mm (7 in.).

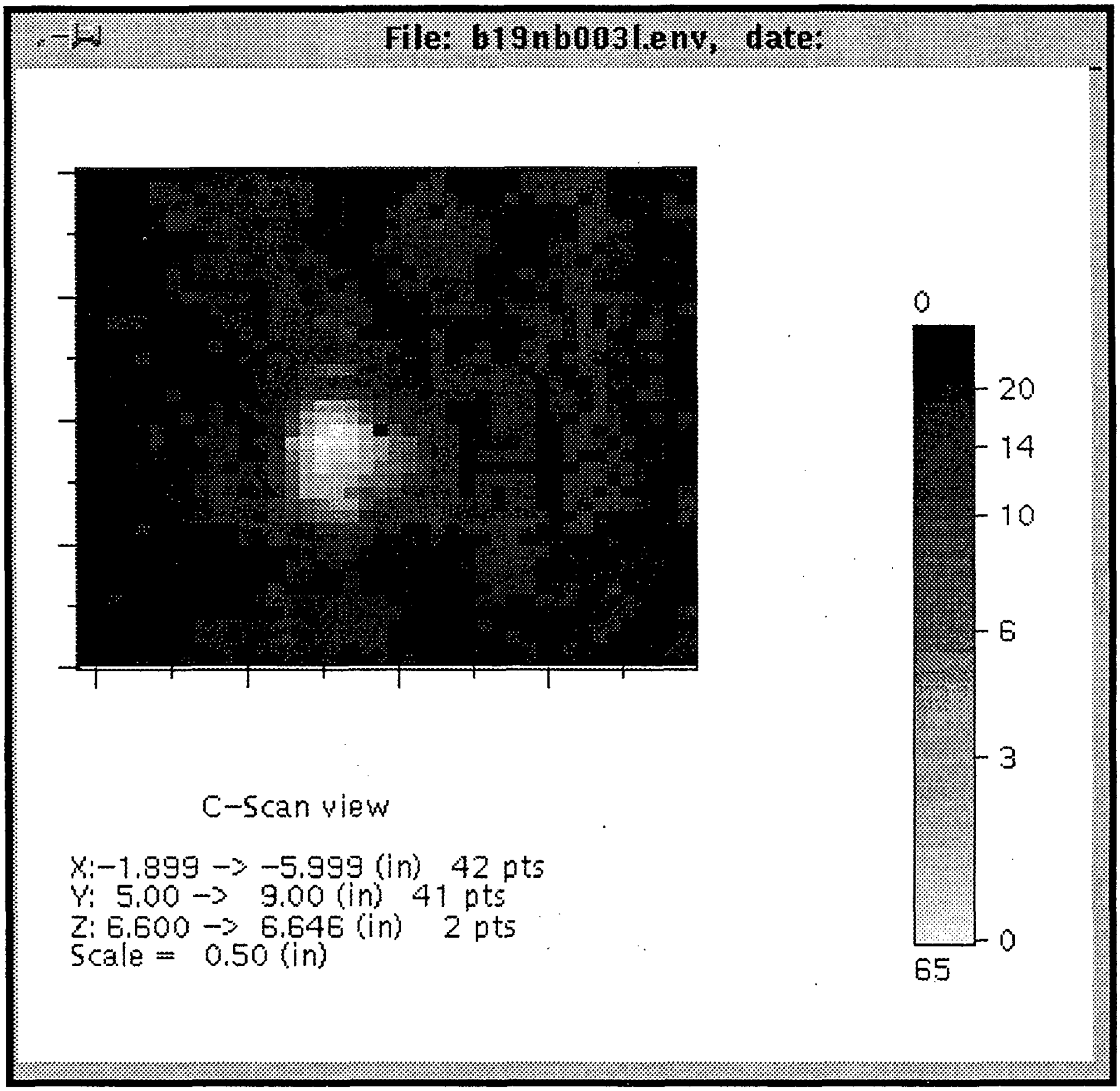


Figure 5.18c C-scan View (Scanner Coordinates XY) of Base-Metal Indication in Block 1-9 at Y = 183 mm (7.2 in.). Normal beam inspection from the bottom side. X in the figure corresponds to material coordinates of Z from 168 mm (6.6 in.) to 64 mm (2.5 in.).

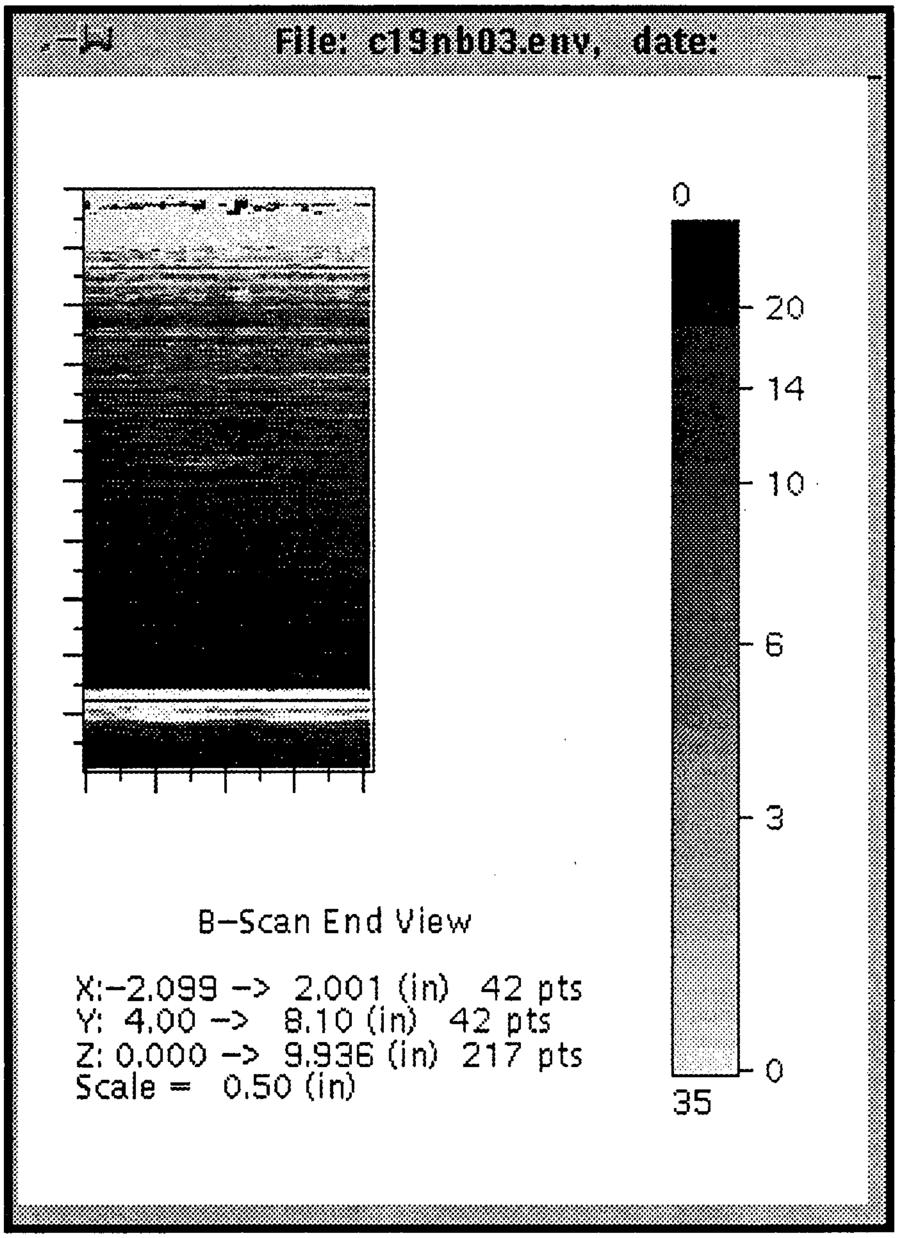


Figure 5.19a Side View (XZ) of Base-Metal Indication in Block 1-9 at Y = 203 mm (8.0 in.). Normal beam inspection from the clad side.

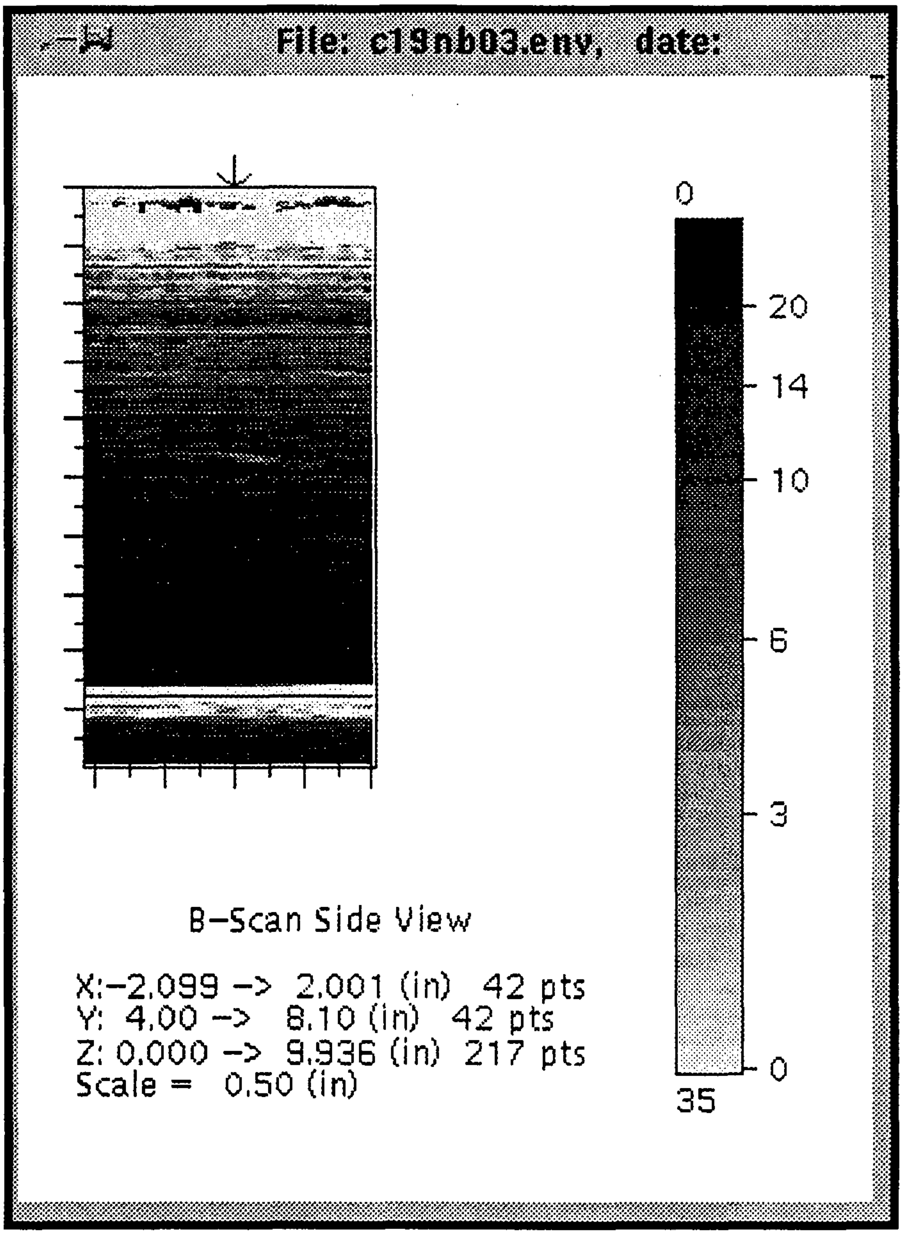


Figure 5.19b End View (YZ) of Base-Metal Indication in Block 1-9 at Y = 203 mm (8.0 in.). Normal beam inspection from the clad side.

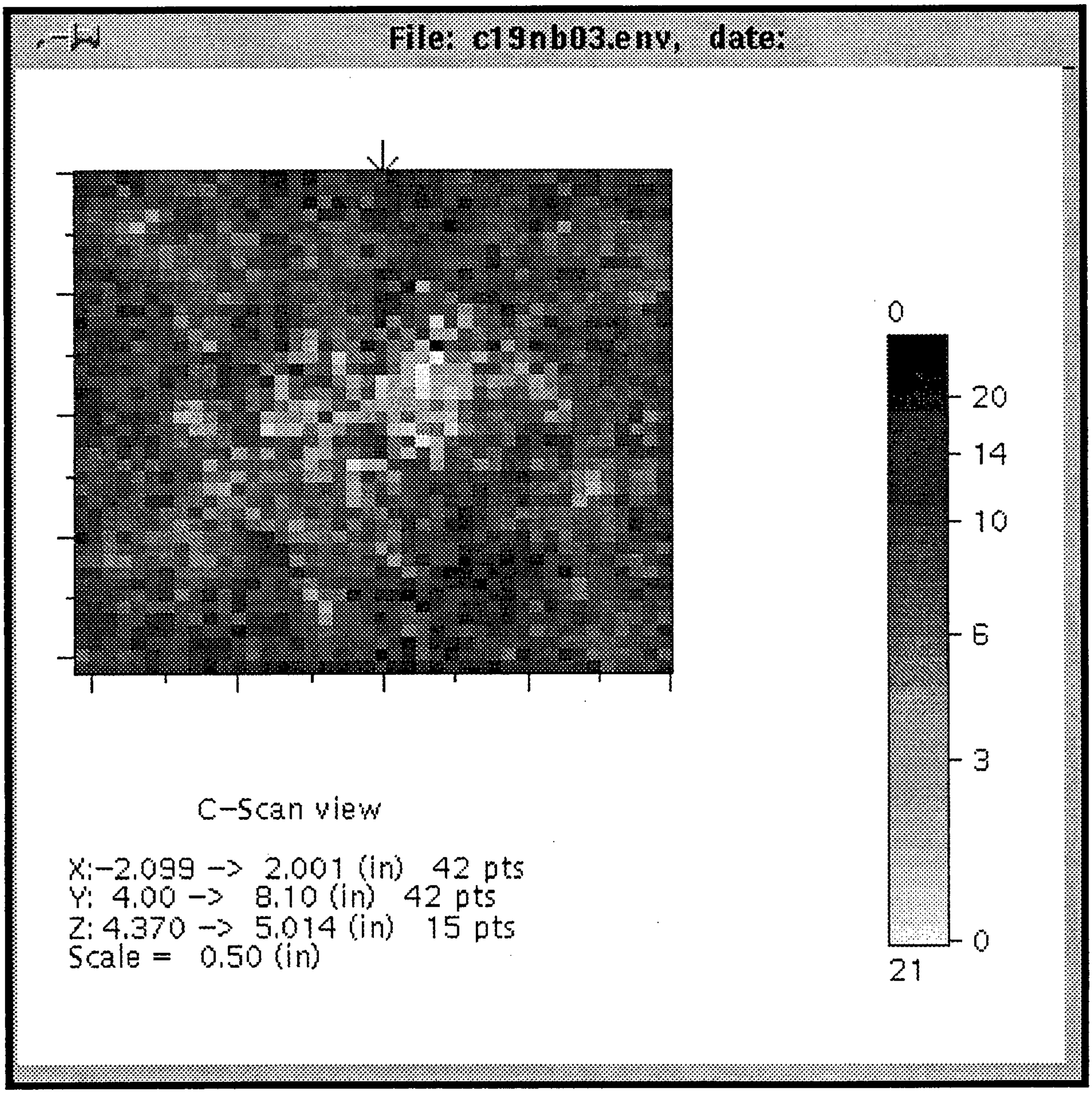


Figure 5.19c C-scan View (XY) of Base-Metal Indication in Block 1-9 at Y = 203 mm (8.0 in.). Normal beam inspection from the clad side.

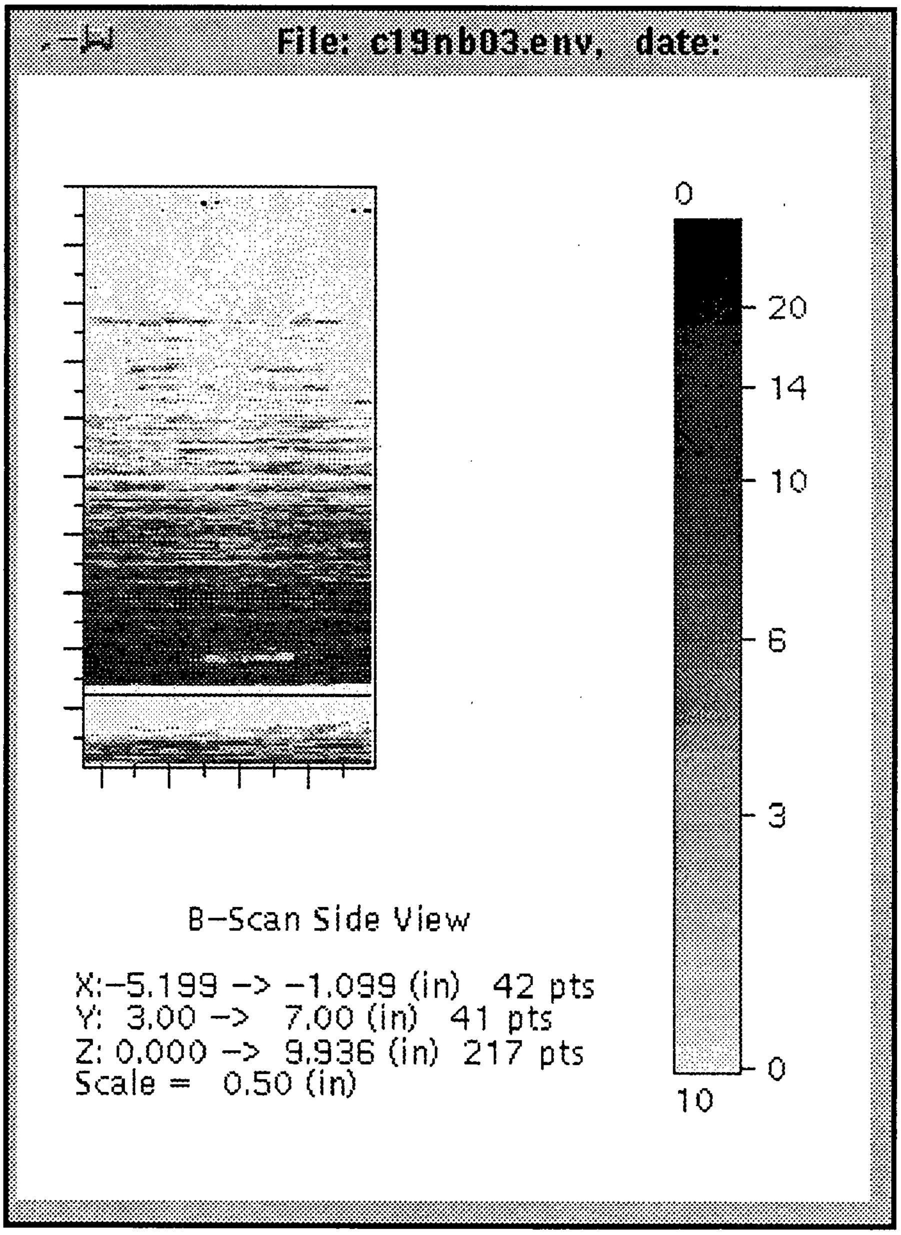


Figure 5.20a Side View (XZ) of Base-Metal Indication in Block 1-9 at Y = 185 mm (7.3 in.). Normal beam inspection from the clad side.

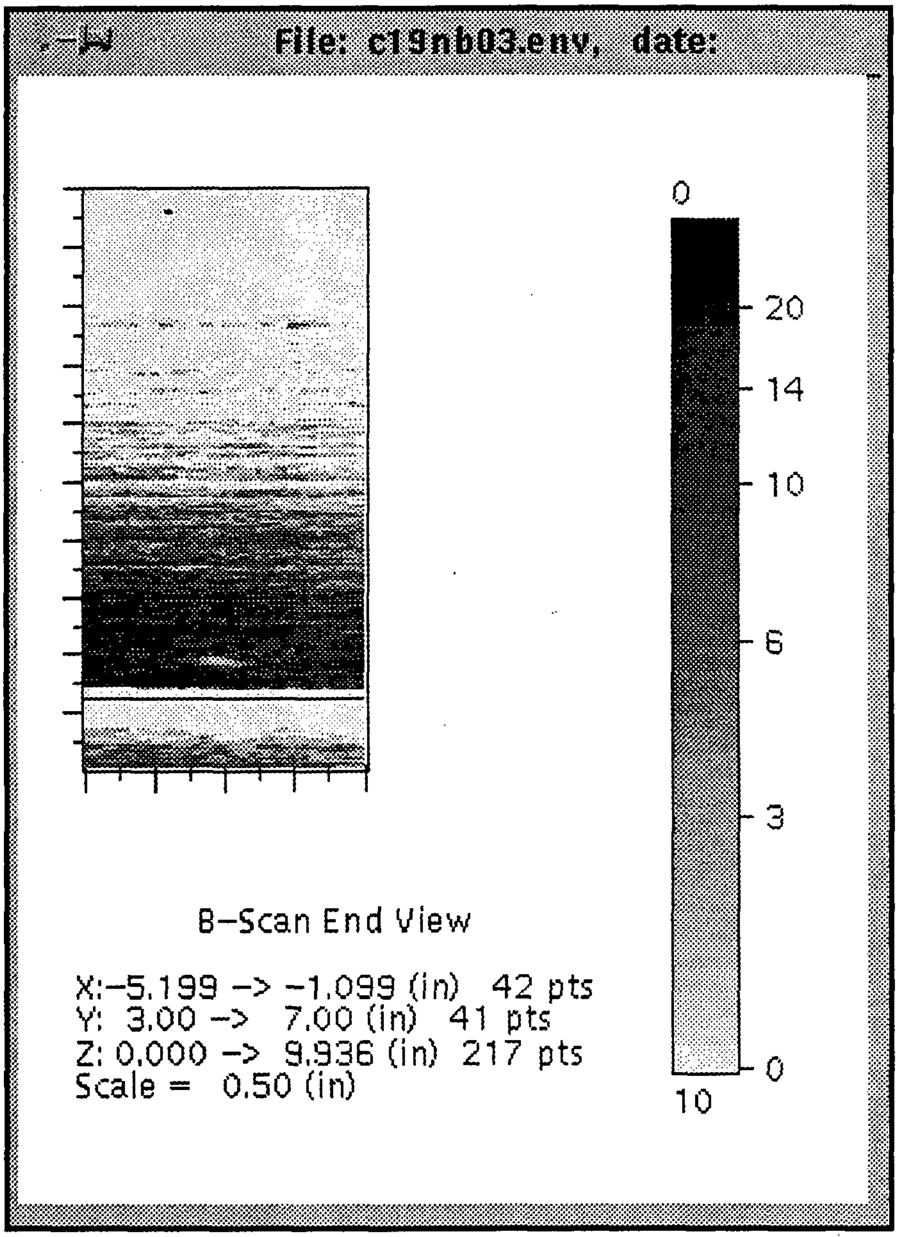


Figure 5.20b End View (YZ) of Base-Metal Indication in Block 1-9 at Y = 185 mm (7.3 in.). Normal beam inspection from the clad side.

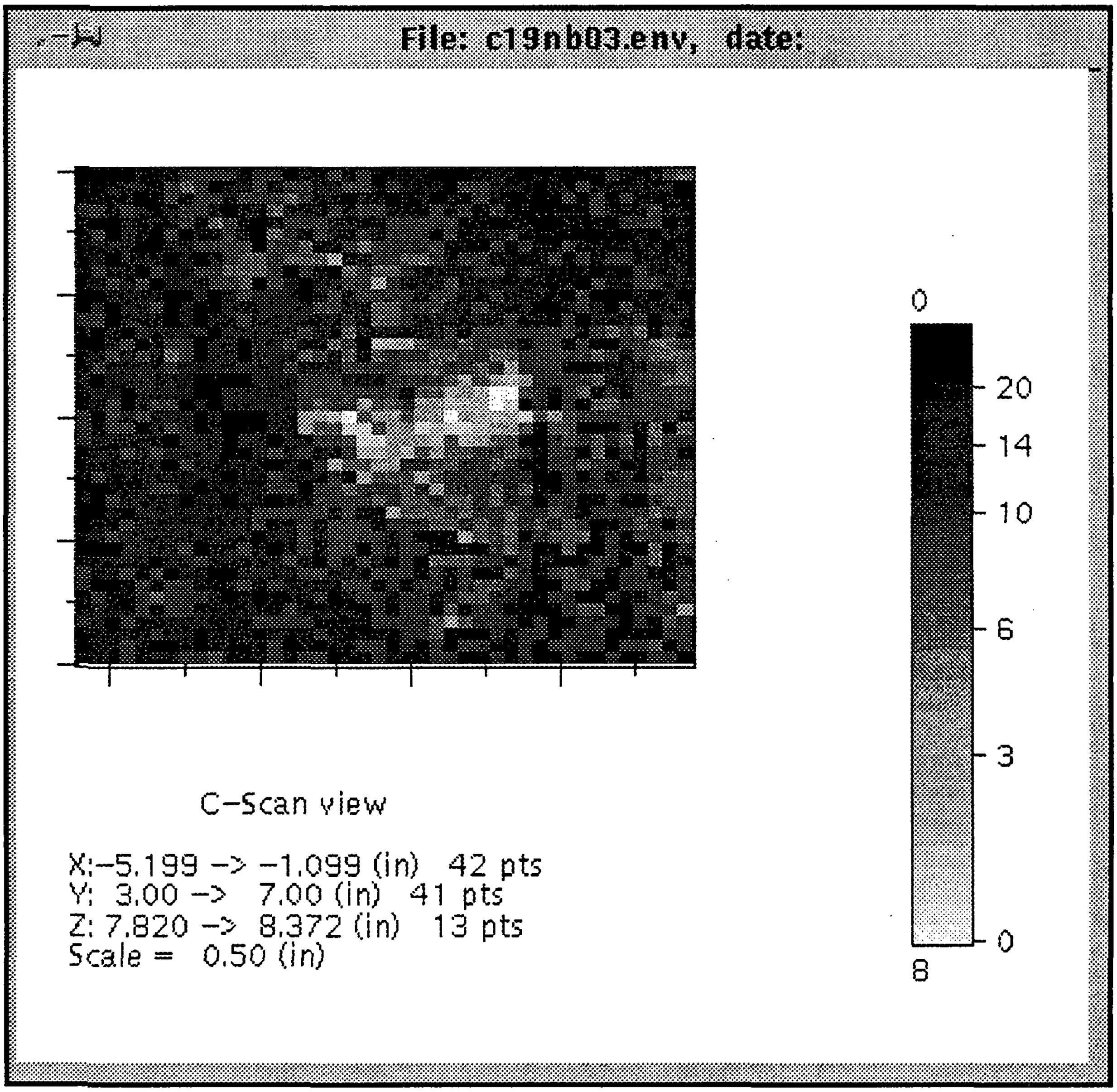


Figure 5.20c C-scan View (XY) of Base-Metal Indication in Block 1-9 at Y = 185 mm (7.3 in.). Normal beam inspection from the clad side.

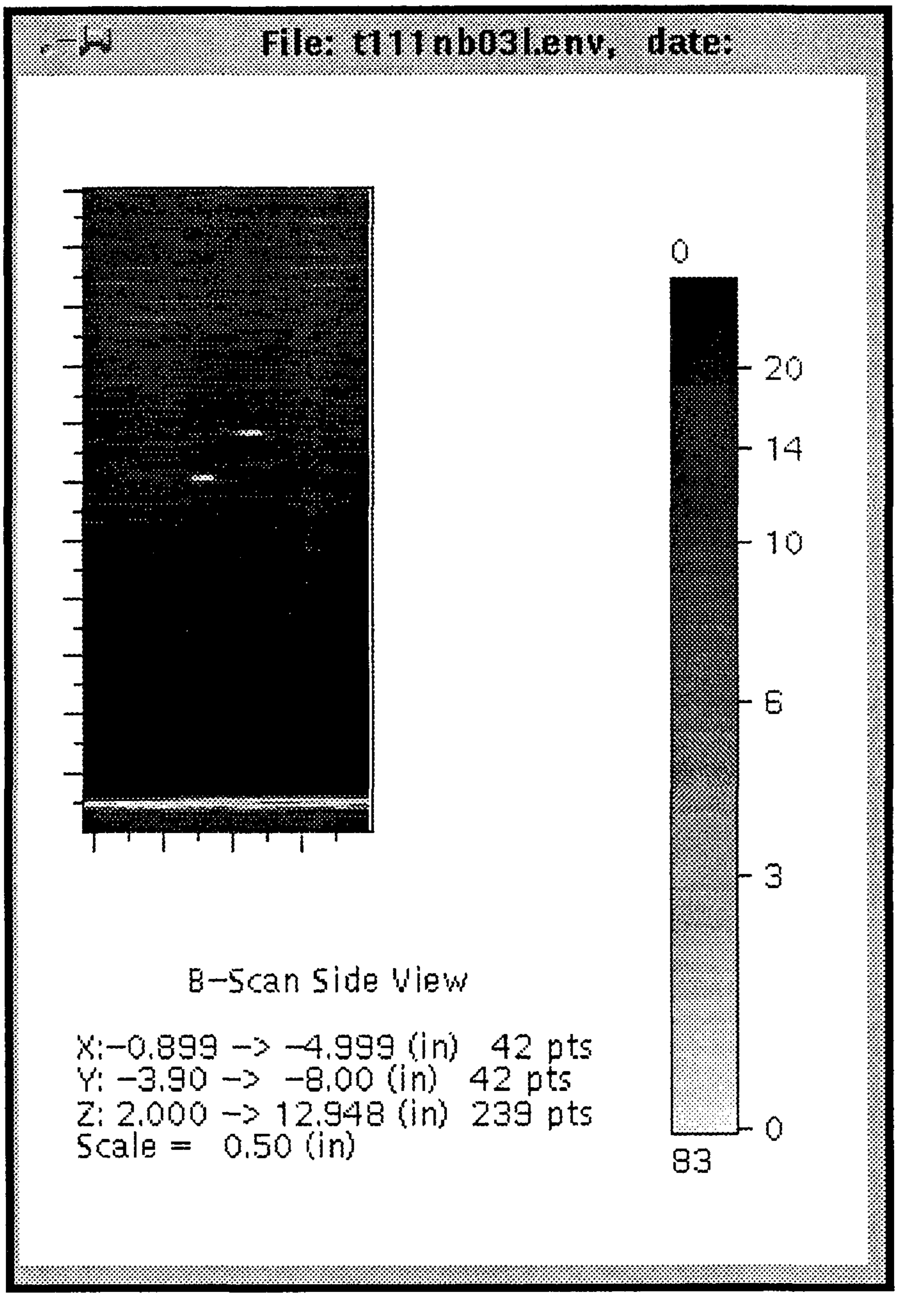


Figure 5.21a Side View (Scanner Coordinates XZ) of Base-Metal Indication in Block 1-11 at Y = -152 mm (-6.0 in.). Normal beam inspection from the top side. Z in the figure corresponds to material coordinates of X from -102 mm (-4 in.) to 178 mm (7 in.). X in the figure corresponds to material coordinates of Z from 188 mm (7.4 in.) to 84 mm (3.3 in.).

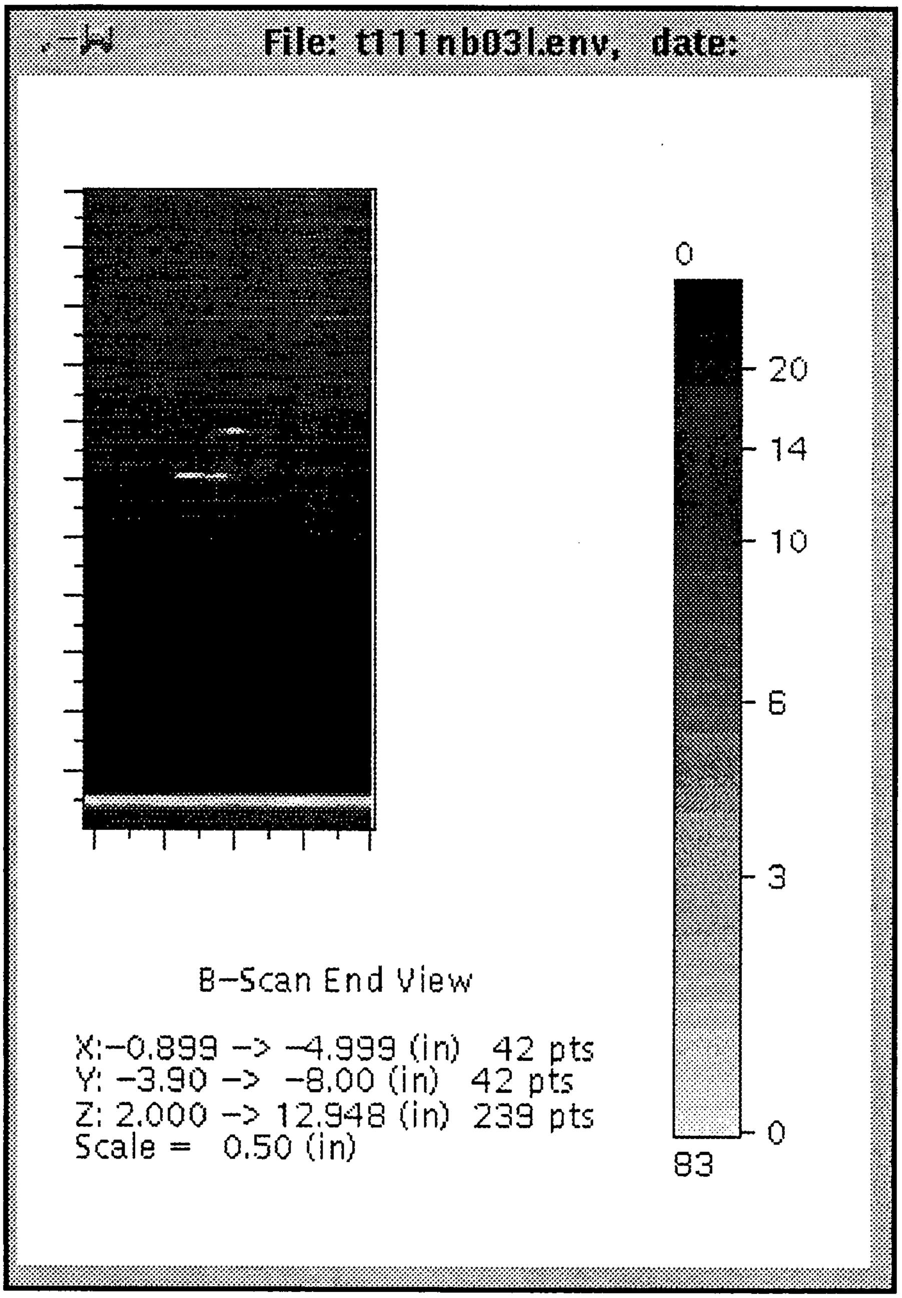


Figure 5.21b End View (Scanner Coordinates YZ) of Base-Metal Indication in Block 1-11 at Y = -152 mm (-6.0 in.). Normal beam inspection from the top side. Z in the figure corresponds to material coordinates of X from -102 mm (-4 in.) to 178 mm (7 in.).

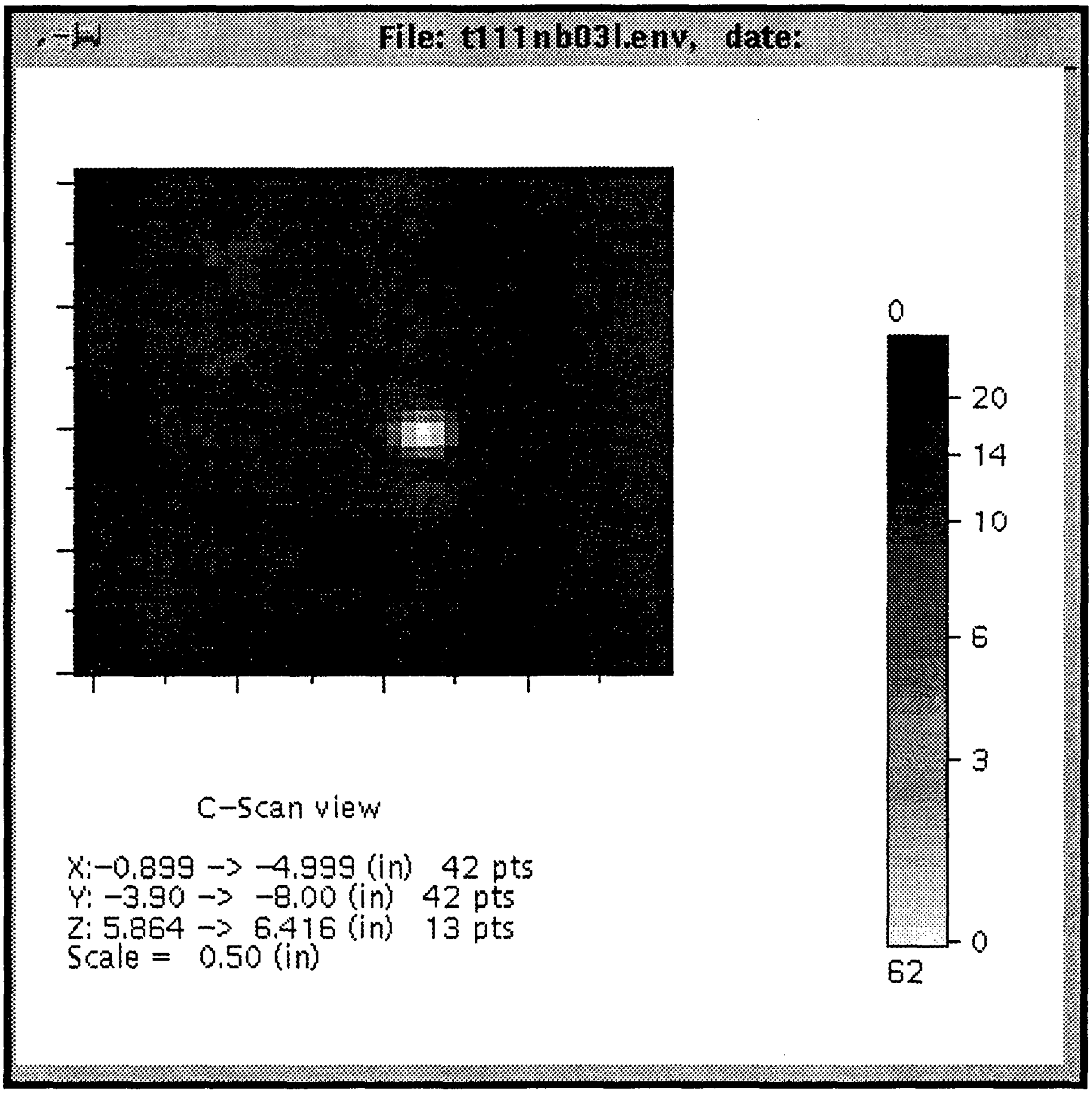


Figure 5.21c C-scan View (Scanner Coordinates XY) of Base-Metal Indication in Block 1-11 at Y = -152 mm (-6.0 in.). Normal beam inspection from the top side. X in the figure corresponds to material coordinates of Z from 188 mm (7.4 in.) to 84 mm (3.3 in.).

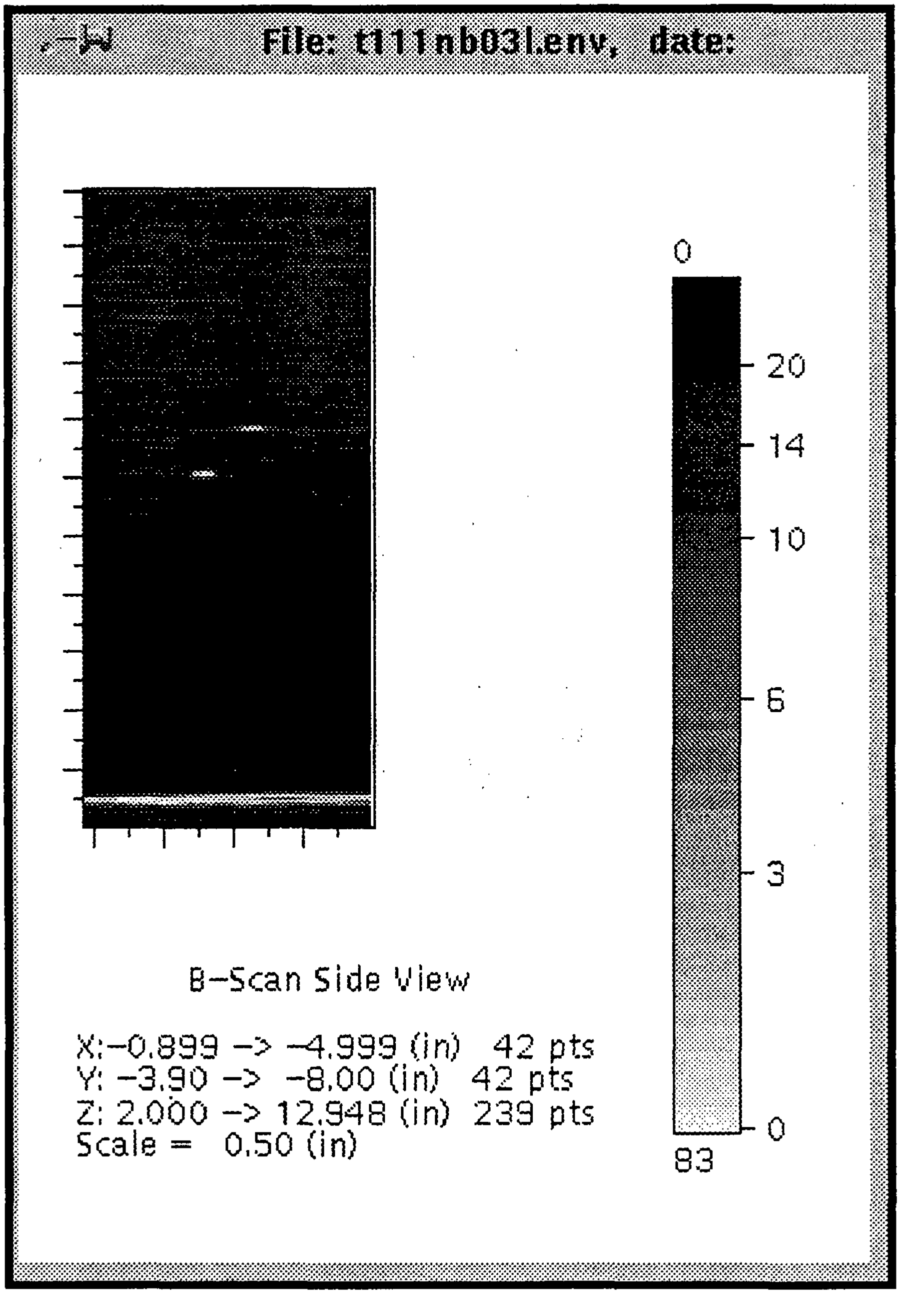


Figure 5.22a Side View (Scanner Coordinates XZ) of Base-Metal Indication in Block 1-11 at Y = -140 mm (-5.5 in.). Normal beam inspection from the top side. Z in the figure corresponds to material coordinates of X from -102 mm (-4 in.) to 178 mm (7 in.). X in the figure corresponds to material coordinates of Z from 188 mm (7.4 in.) to 84 mm (3.3 in.).

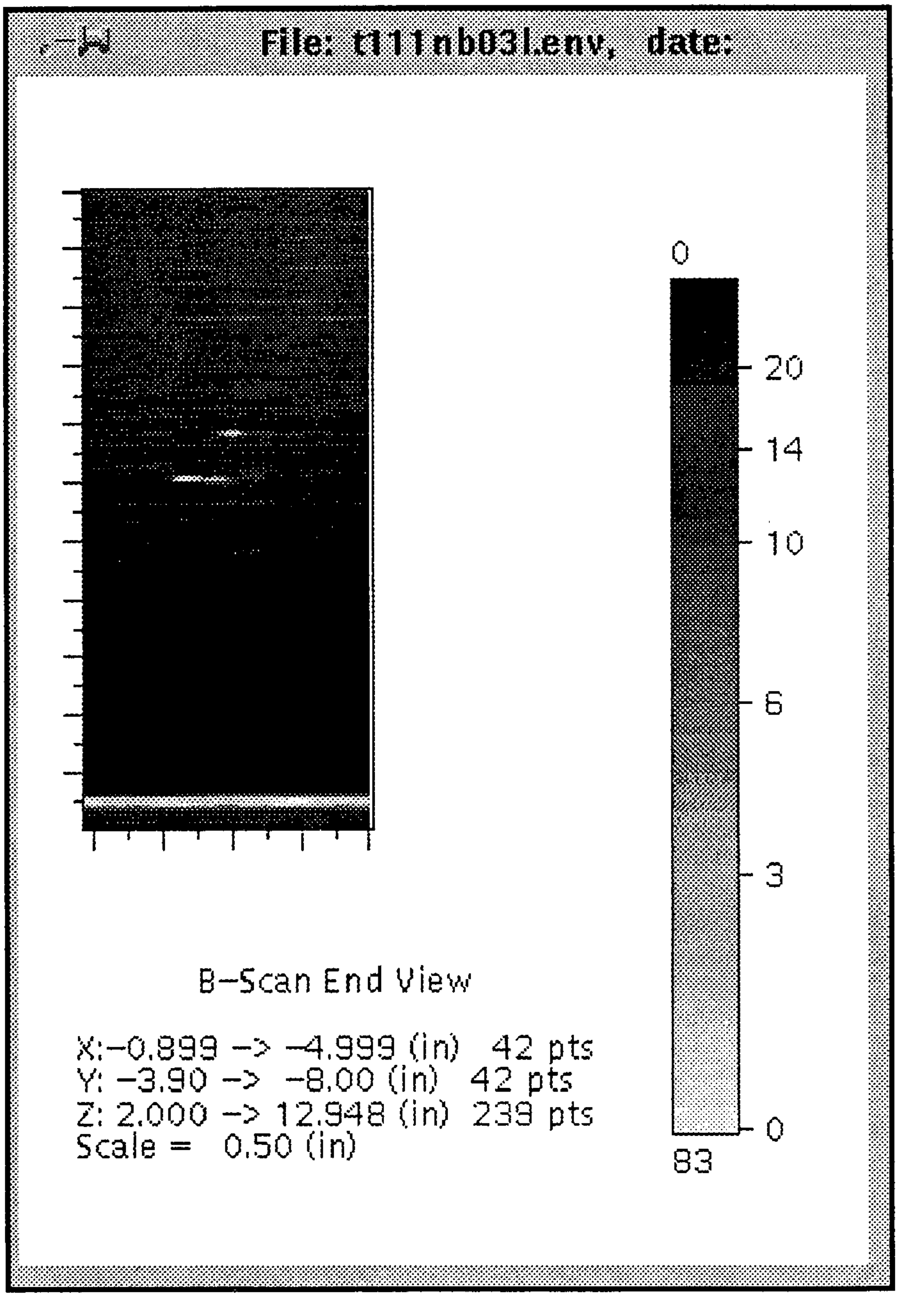


Figure 5.22b End View (Scanner Coordinates YZ) of Base-Metal Indication in Block 1-11 at Y = -140 mm (-5.5 in.). Normal beam inspection from the top side. Z in the figure corresponds to material coordinates of X from -102 mm (-4 in.) to 178 mm (7 in.).

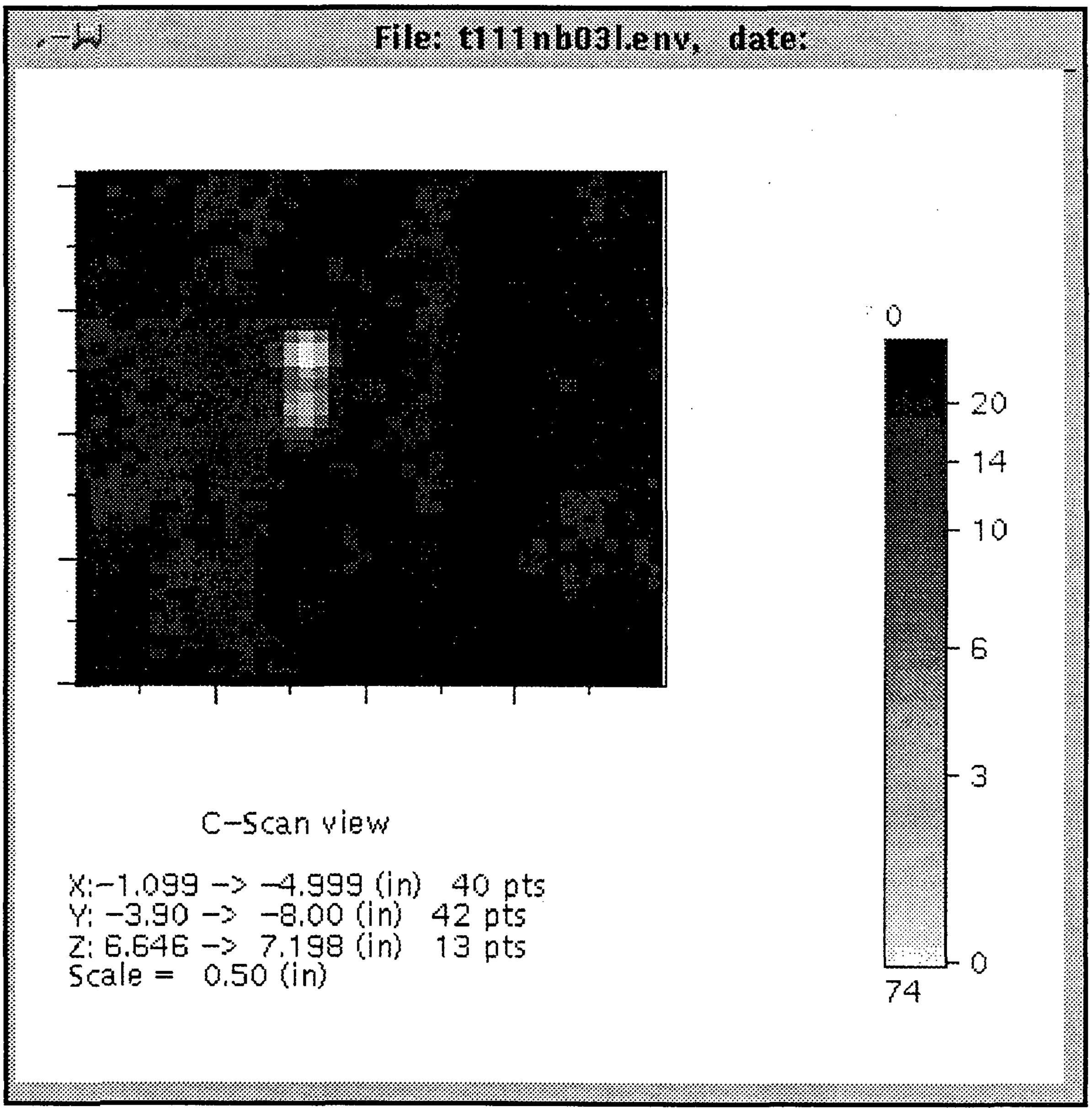


Figure 5.22c C-scan View (Scanner Coordinates XY) of Base-Metal Indication in Block 1-11 at Y = -140 mm (-5.5 in.). Normal beam inspection from the top side. X in the figure corresponds to material coordinates of Z from 188 mm (7.4 in.) to 84 mm (3.3 in.).

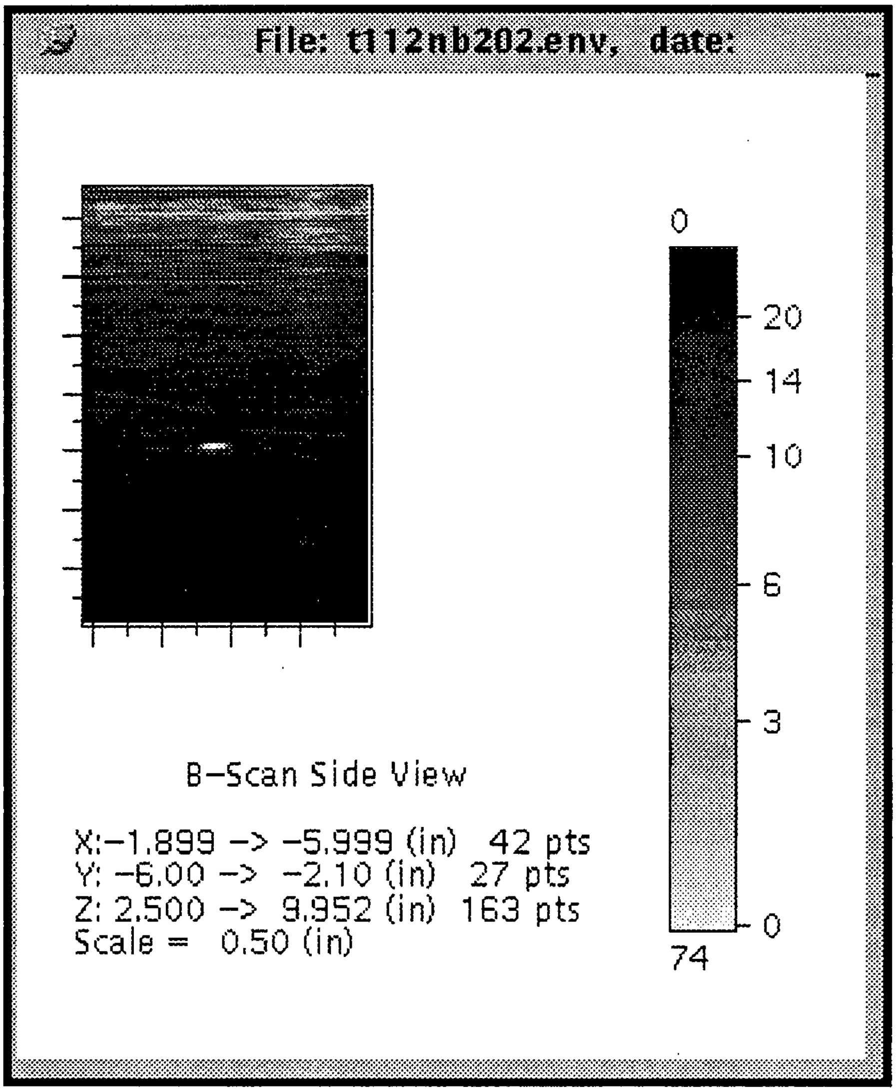


Figure 5.23a Side View (Scanner Coordinates XZ) of Base-Metal Indication in Block 1-12 at Y = -96 mm (-3.8 in.). Normal beam inspection from the top side. Z in the figure corresponds to material coordinates of X from 89 mm (3.5 in.) to 76 mm (3.0 in.). X in the figure corresponds to material coordinates of Z from 168 mm (6.6 in.) to 64 mm (2.5 in.).

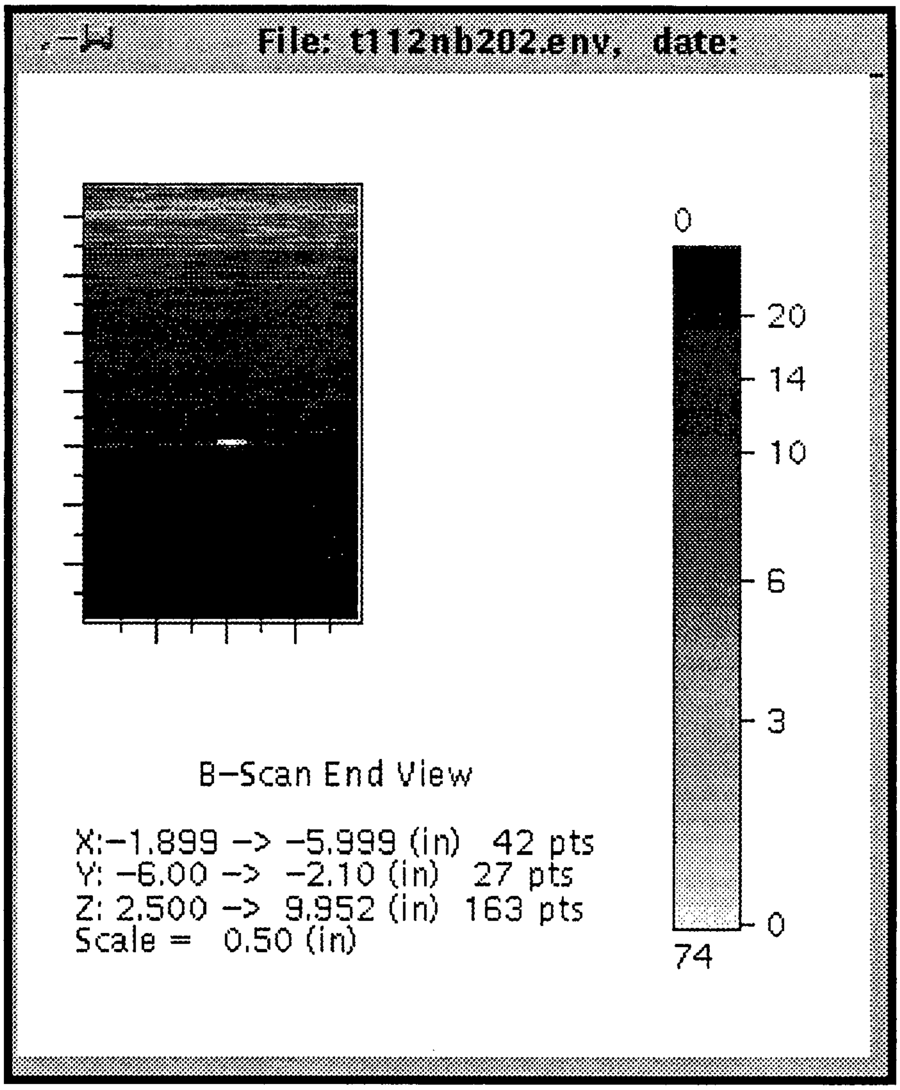


Figure 5.23b End View (Scanner Coordinates YZ) of Base-Metal Indication in Block 1-12 at Y = -96 mm (-3.8 in.). Normal beam inspection from the top side. Z in the figure corresponds to material coordinates of X from 89 mm (3.5 in.) to 76 mm (3.0 in.).

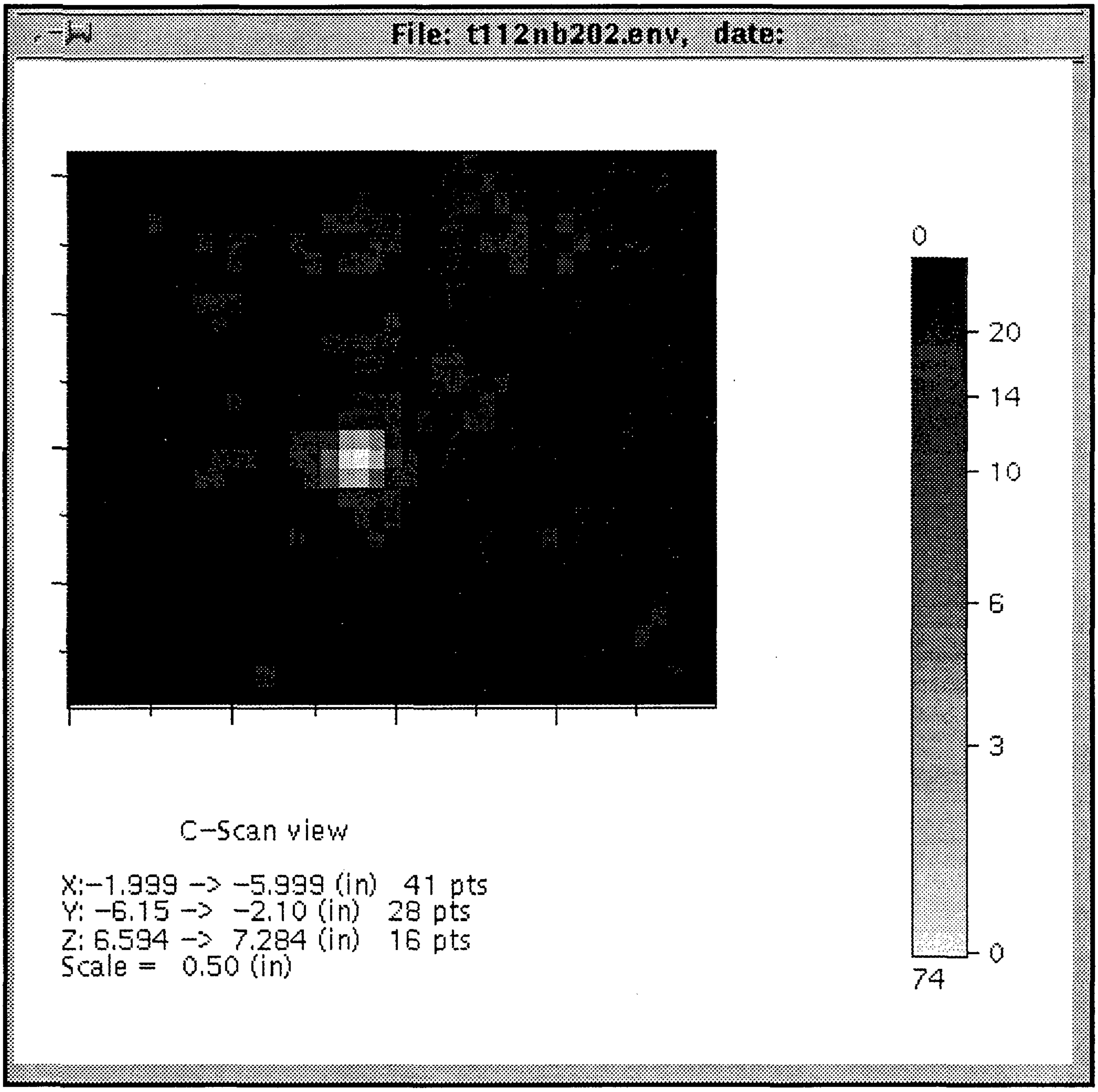


Figure 5.23c. C-scan View (Scanner Coordinates XY) of Base-Metal Indication in Block 1-12 at Y = -96 mm (-3.8 in.). Normal beam inspection from the top side. X in the figure corresponds to material coordinates of Z from 168 mm (6.6 in.) to 64 mm (2.5 in.).

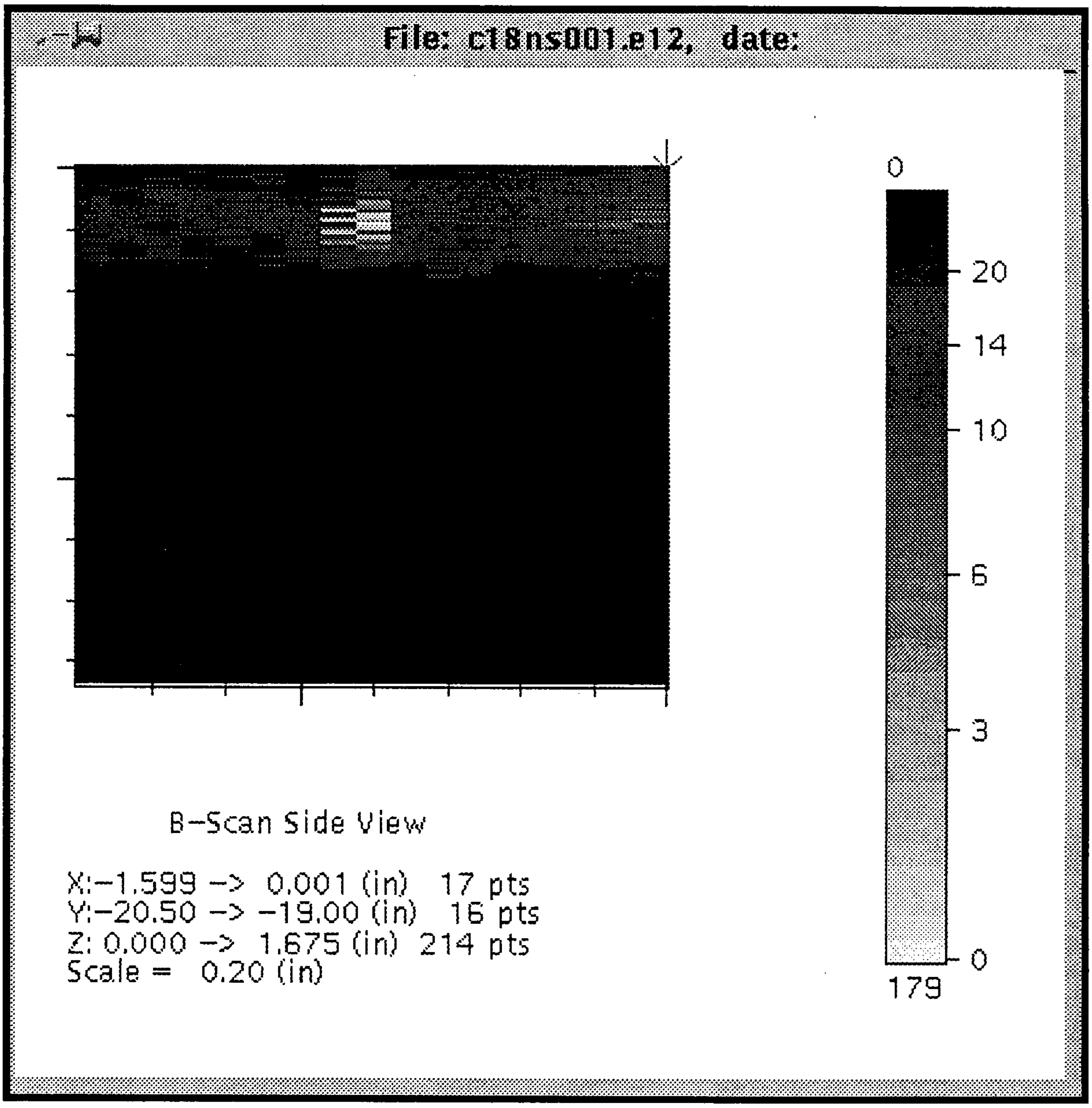


Figure 5.24a Side View (XZ) of Clad to Base-Metal Indication in Block 1-8 at Y = -526 mm (-20.7 in.). 70° L-wave inspection with beam direction of +X.

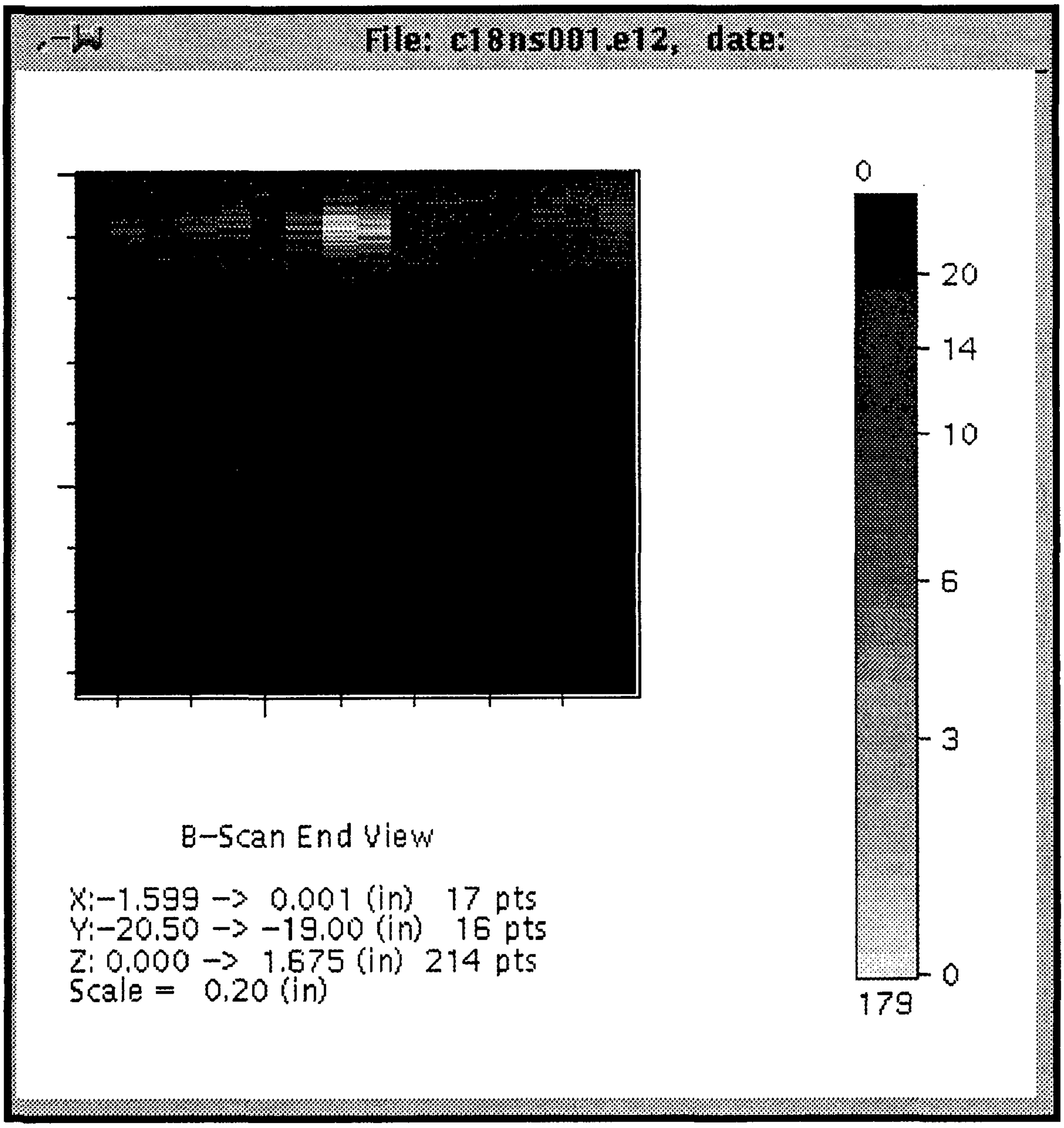


Figure 5.24b End View (YZ) of Clad to Base-Metal Indication in Block 1-8 at Y = -526 mm (-20.7 in.). 70° L-wave inspection with beam direction of +X.

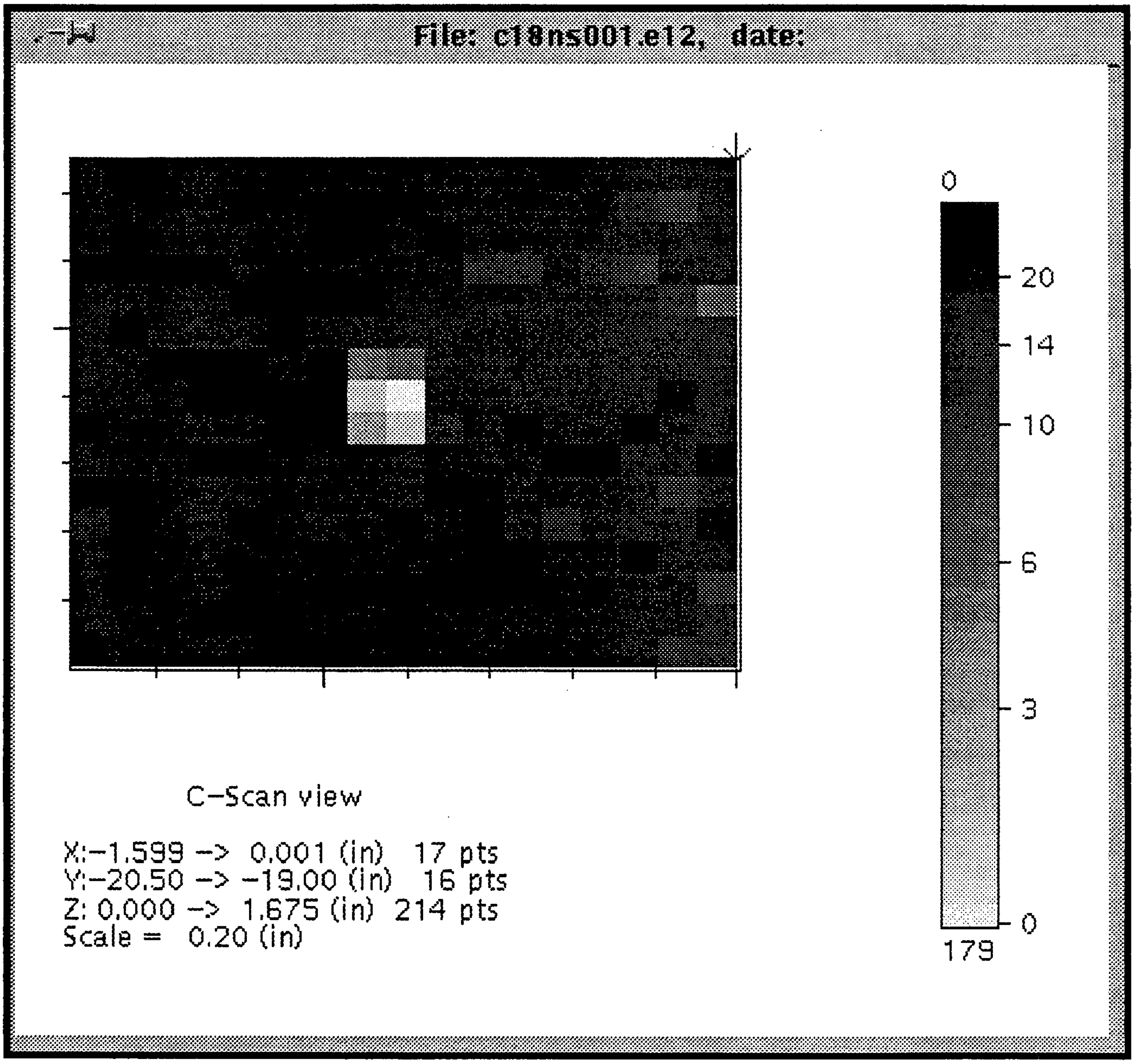


Figure 5.24c C-scan View (XY) of Clad to Base-Metal Indication in Block 1-8 at Y = -526 mm (-20.7 in.). 70° L-wave inspection with beam direction of +X.

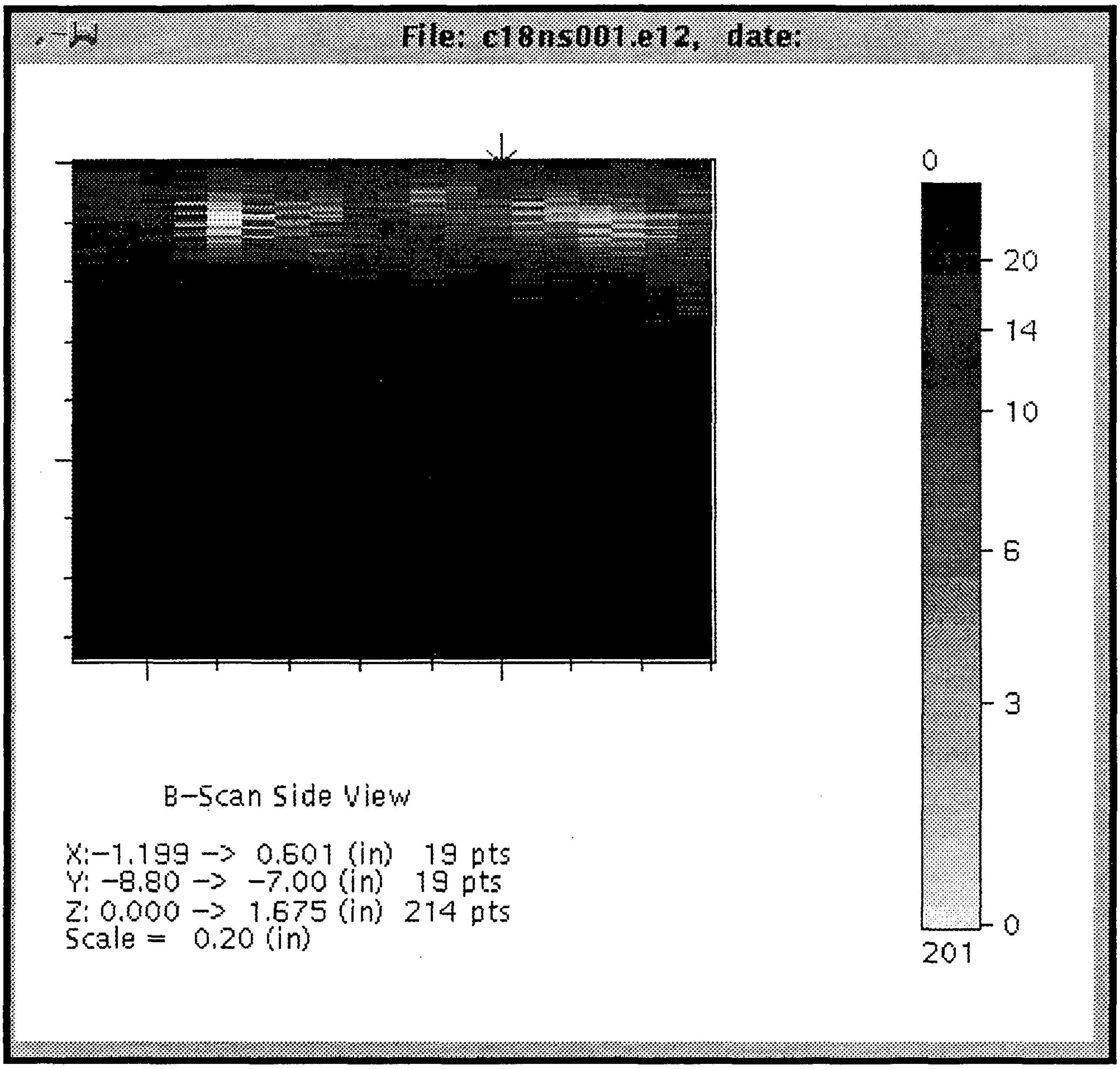


Figure 5.25a Side View (XZ) of Clad to Base-Metal Indication in Block 1-8 at Y = -211 mm (-8.3 in.). 70° L-wave inspection with beam direction of +X.

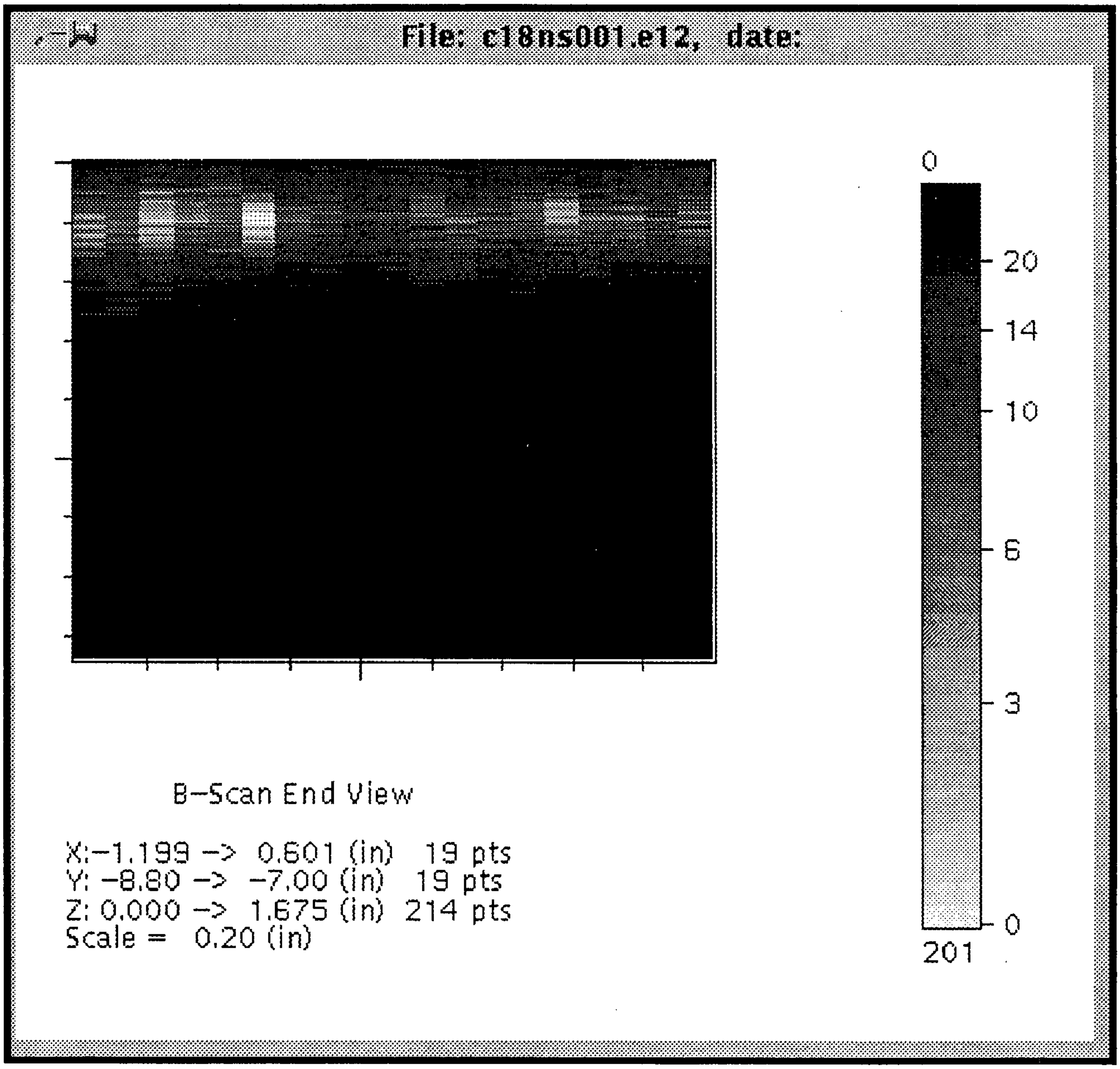


Figure 5.25b End View (YZ) of Clad to Base-Metal Indication in Block 1-8 at Y = -211 mm (-8.3 in.). 70° L-wave inspection with beam direction of +X.

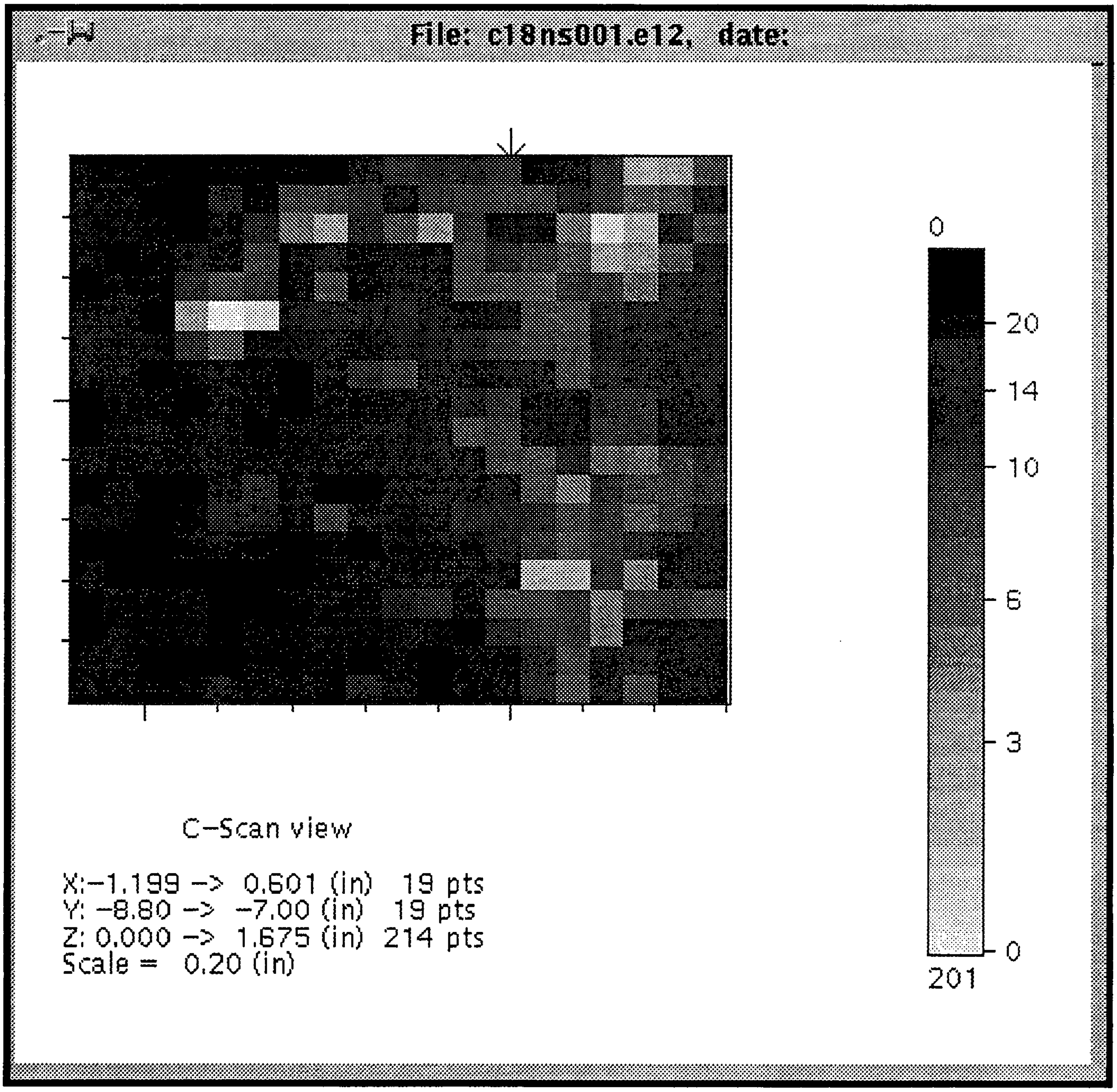


Figure 5.25c C-scan View (XY) of Clad to Base-Metal Indication in Block 1-8 at Y = -211 mm (-8.3 in.). 70° L-wave inspection with beam direction of +X.

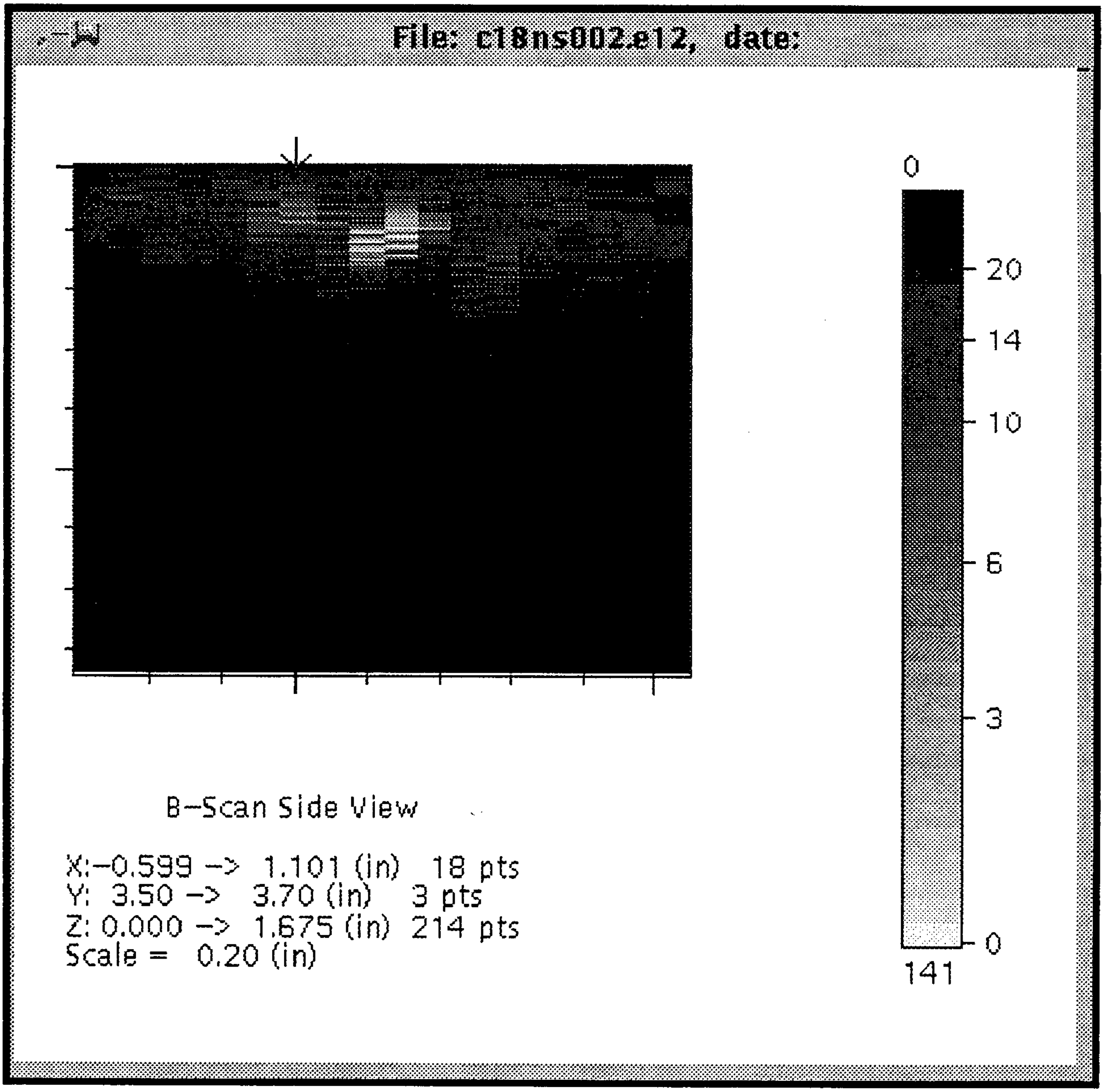


Figure 5.26a Side View (XZ) of Clad to Base-Metal Indication in Block 1-8 at Y = 89 mm (3.5 in.). 70° L-wave inspection with beam direction of +X. This indication corresponds to flaw #7 in the destructive analysis.

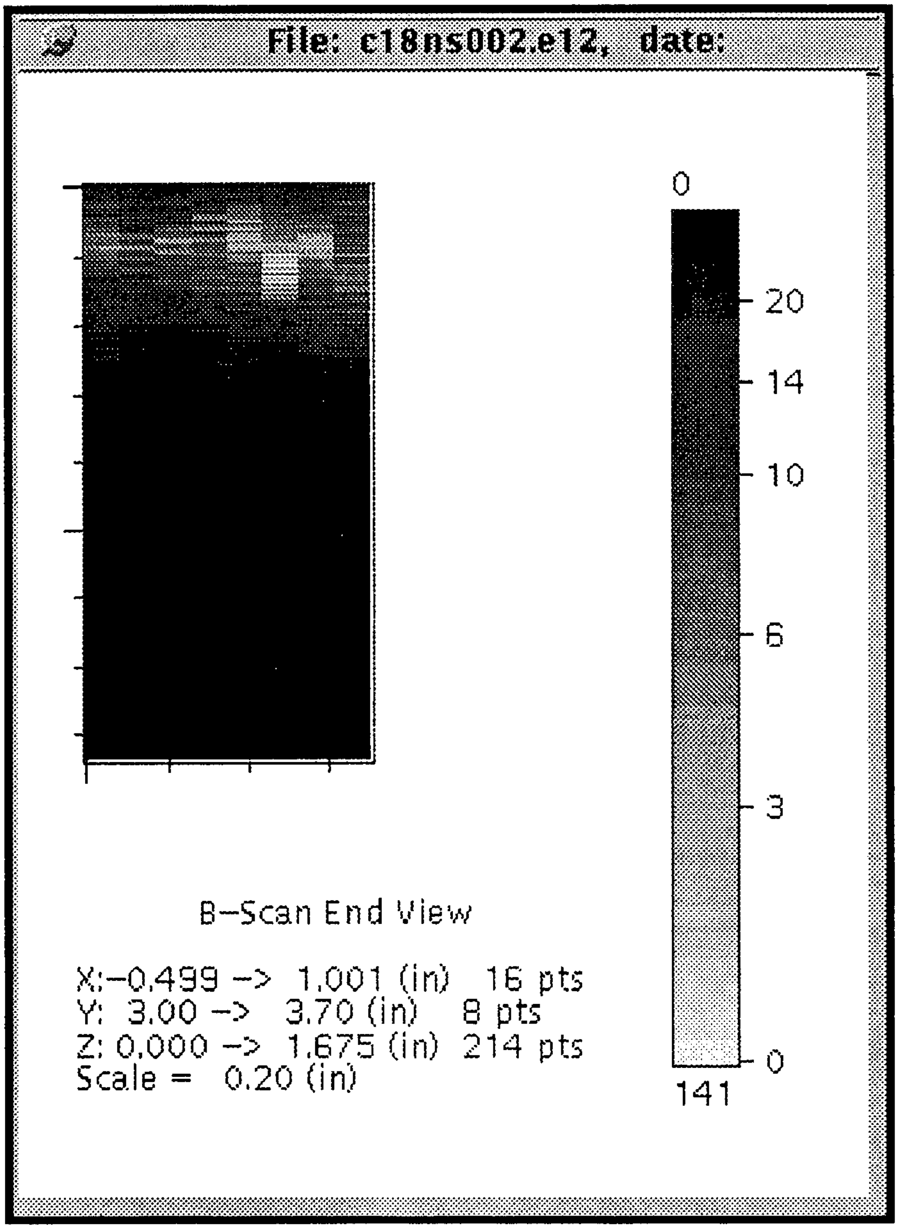


Figure 5.26b End View (YZ) of Clad to Base-Metal Indication in Block 1-8 at Y = 89 mm (3.5 in.). 70° L-wave inspection with beam direction of +X. This indication corresponds to flaw #7 in the destructive analysis.

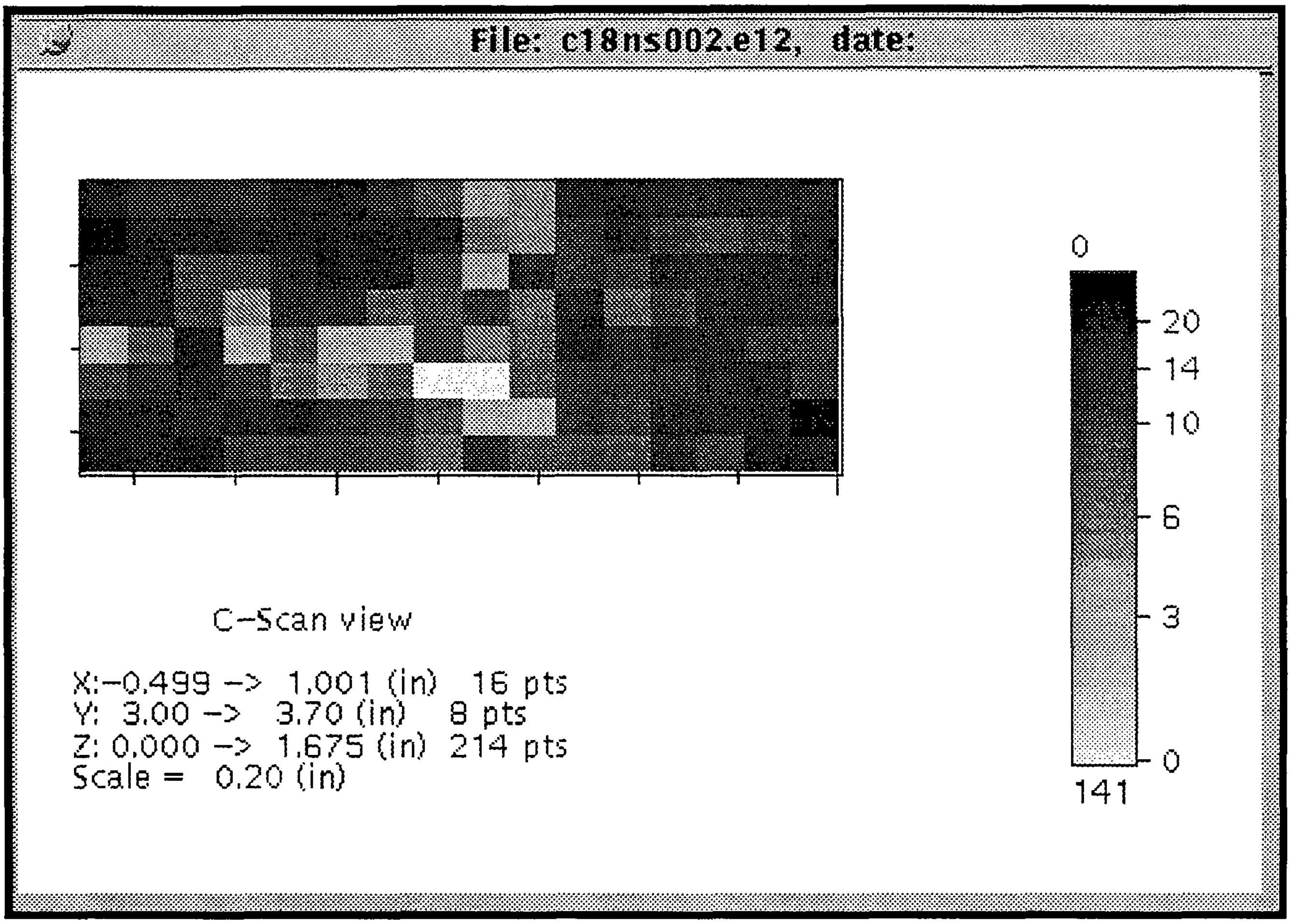


Figure 5.26c C-scan View (XY) of Clad to Base-Metal Indication in Block 1-8 at Y = 89 mm (3.5 in.). 70° L-wave inspection with beam direction of +X. This indication corresponds to flaw #7 in the destructive analysis.

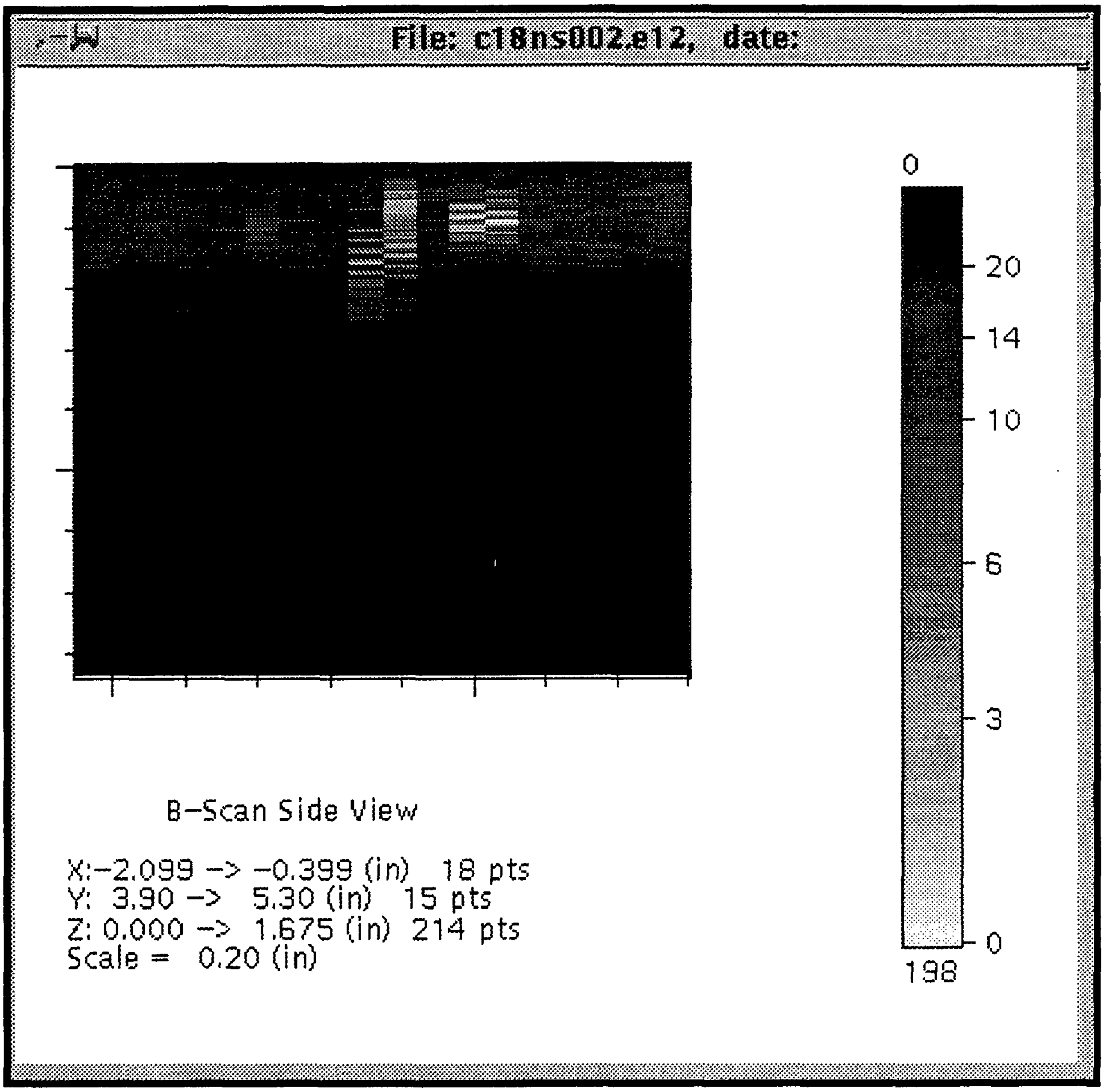


Figure 5.27a Side View (XZ) of Clad to Base-Metal Indication in Block 1-8 at Y = 112 mm (4.4 in.). 70° L-wave inspection with beam direction of +X. This indication corresponds to flaw #8 in the destructive analysis.

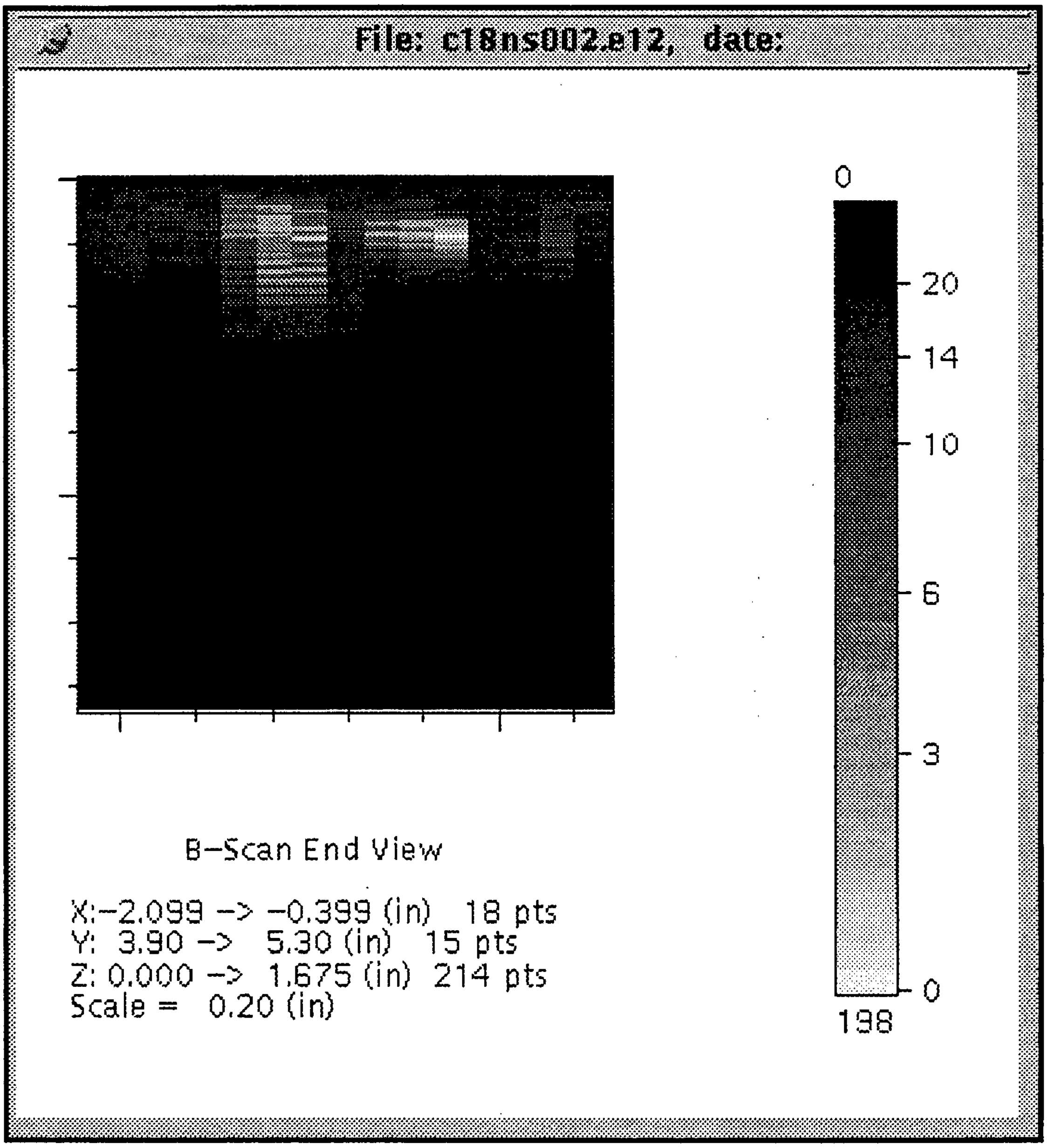


Figure 5.27b End View (YZ) of Clad to Base-Metal Indication in Block 1-8 at Y = 112 mm (4.4 in.). 70° L-wave inspection with beam direction of +X. This indication corresponds to flaw #8 in the destructive analysis.

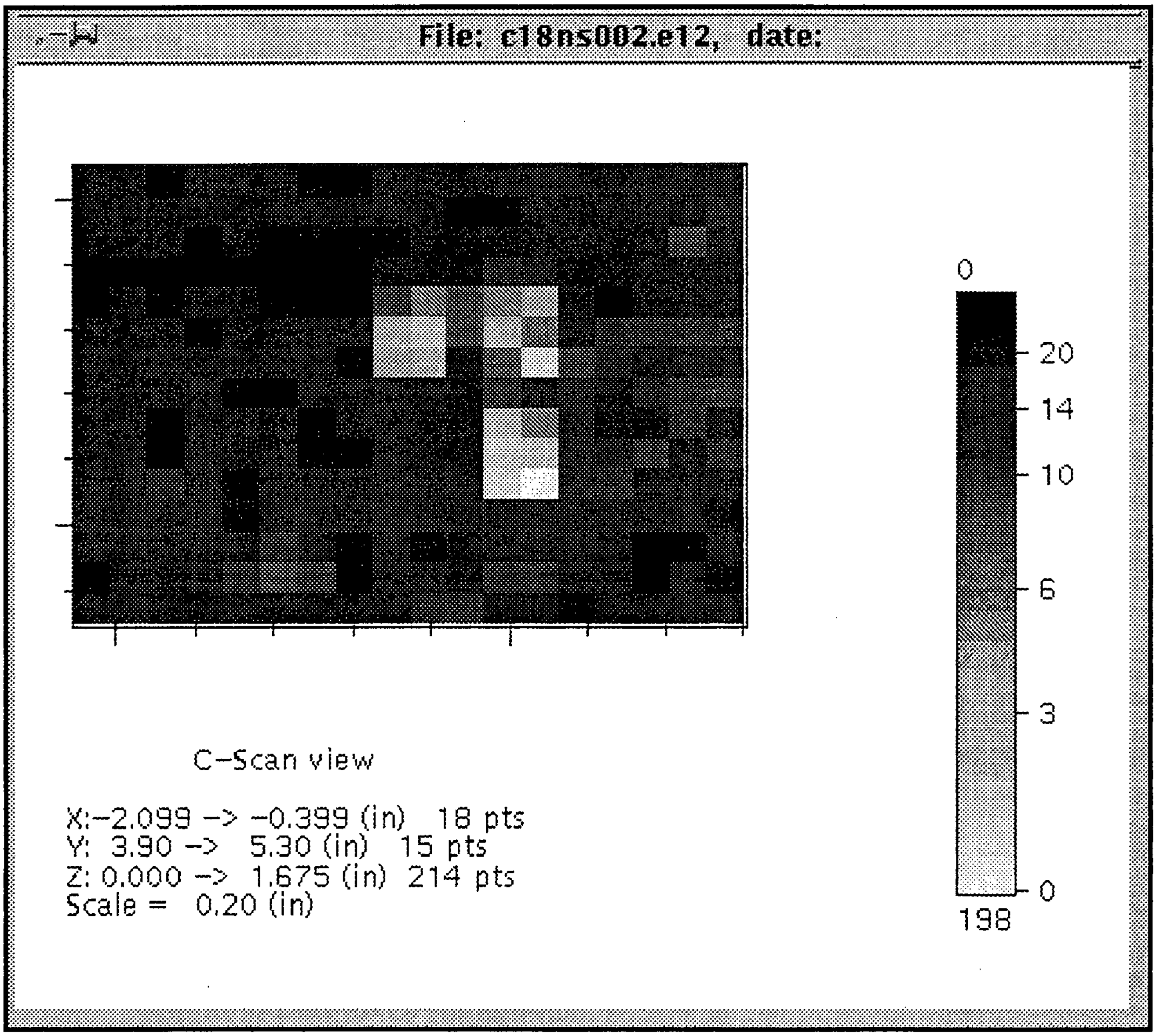


Figure 5.27c C-scan View (XY) of Clad to Base-Metal Indication in Block 1-8 at Y = 112 mm (4.4 in.). 70° L-wave inspection with beam direction of +X. This indication corresponds to flaw #8 in the destructive analysis.

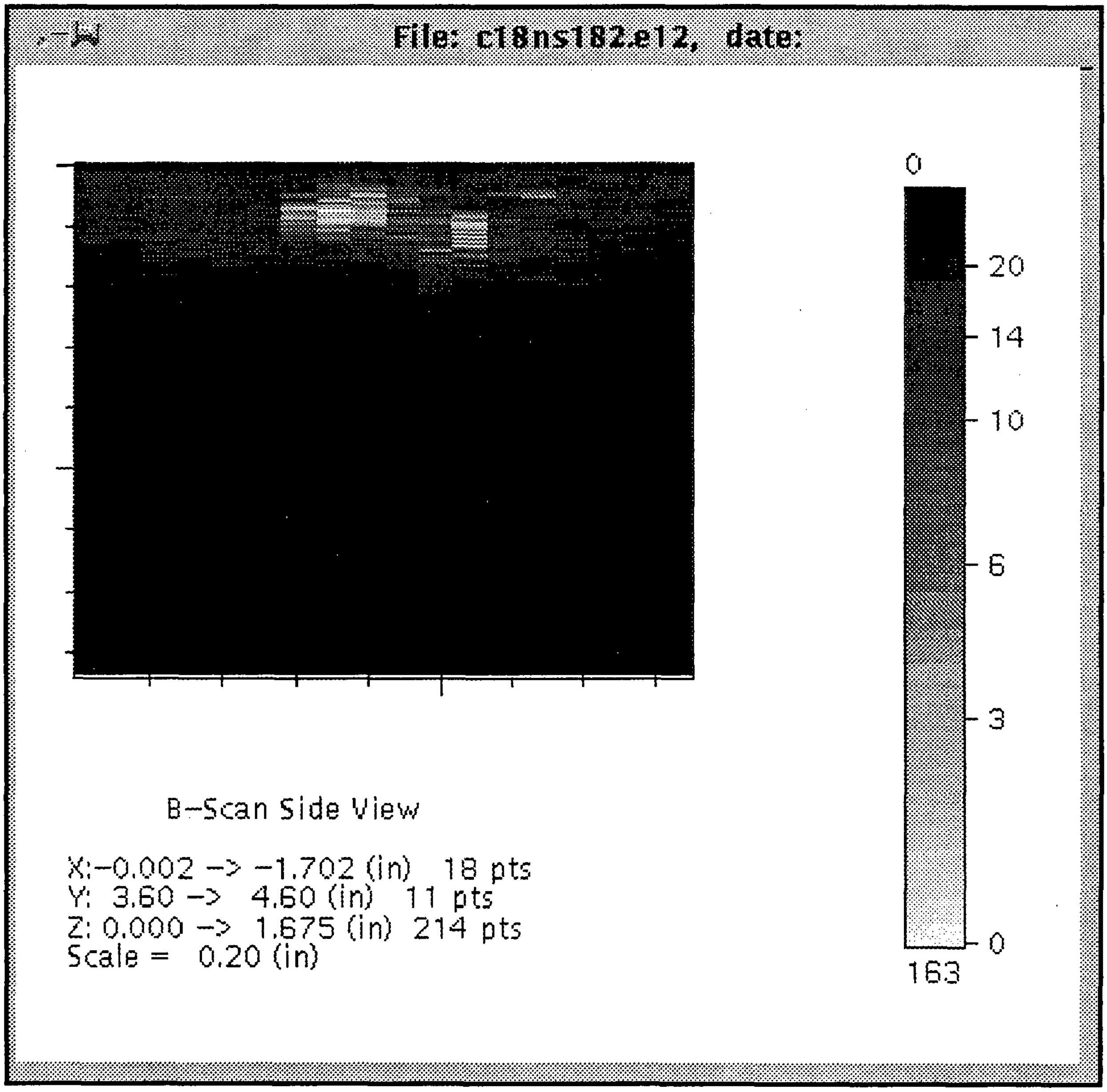


Figure 5.27d Side View (XZ) of Clad to Base-Metal Indication in Block 1-8 at Y = 112 mm (4.4 in.). 70° L-wave inspection with beam direction of -X. This indication corresponds to flaw #8 in the destructive analysis.

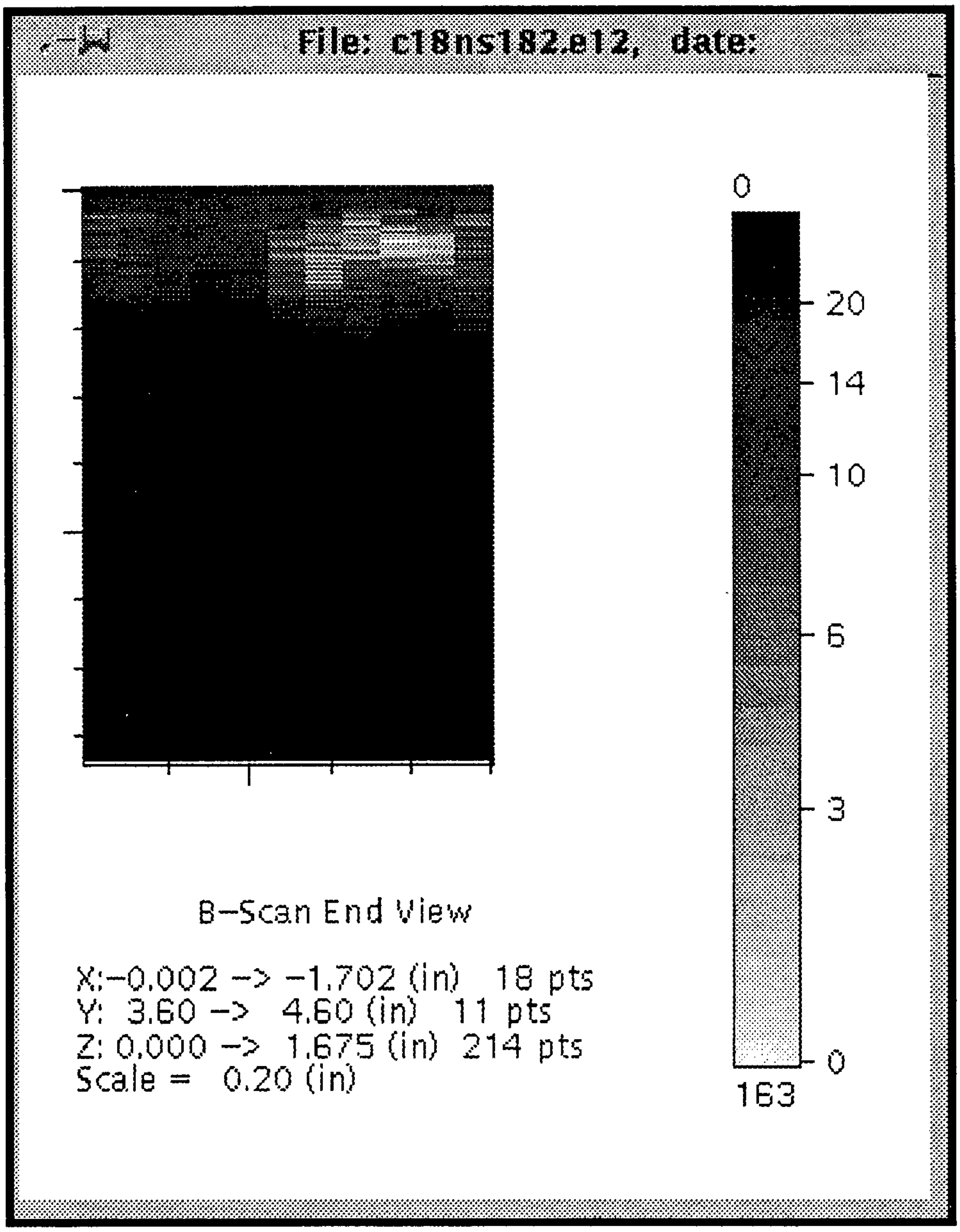


Figure 5.27e End View (YZ) of Clad to Base-Metal Indication in Block 1-8 at Y = 112 mm (4.4 in.). 70° L-wave inspection with beam direction of -X. This indication corresponds to flaw #8 in the destructive analysis.

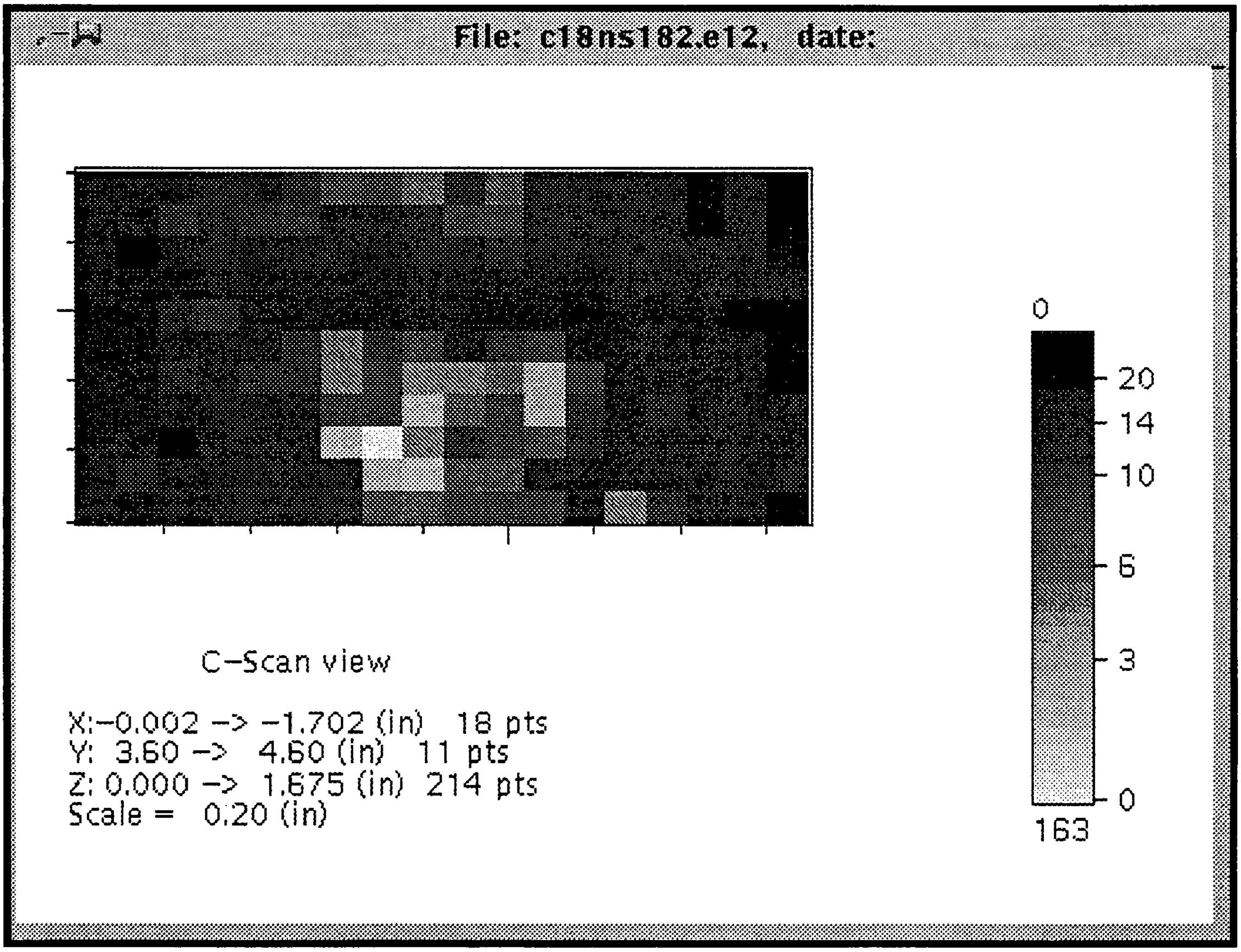


Figure 5.27f C-scan View (XY) of Clad to Base-Metal Indication in Block 1-8 at Y = 112 mm (4.4 in.). 70° L-wave inspection with beam direction of -X. This indication corresponds to flaw #8 in the destructive analysis.

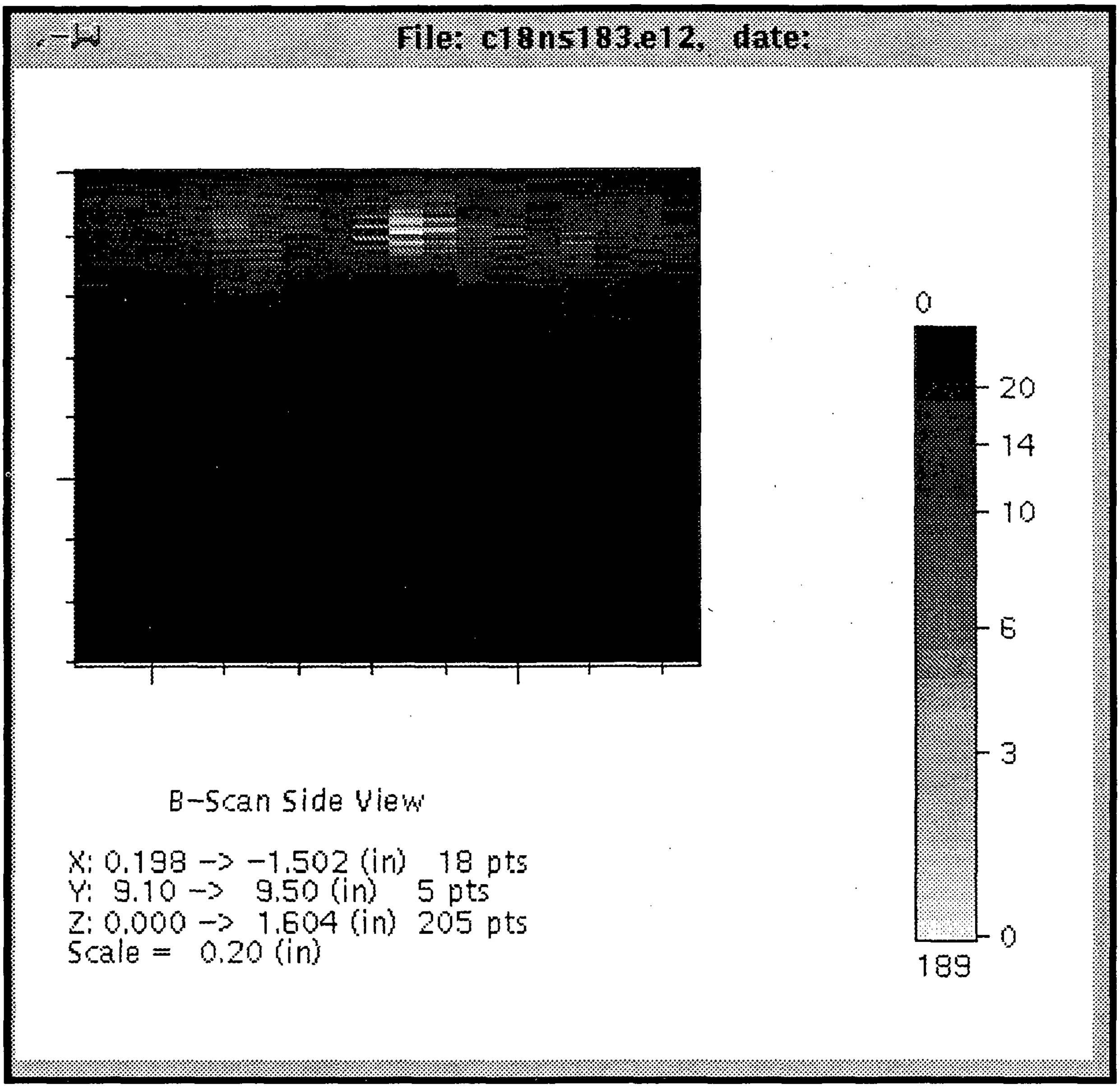


Figure 5.28a Side View (XZ) of Clad to Base-Metal Indication in Block 1-8 at Y = 236 mm (9.3 in.). 70° L-wave inspection with beam direction of -X. This indication corresponds to flaw #11 in the destructive analysis.

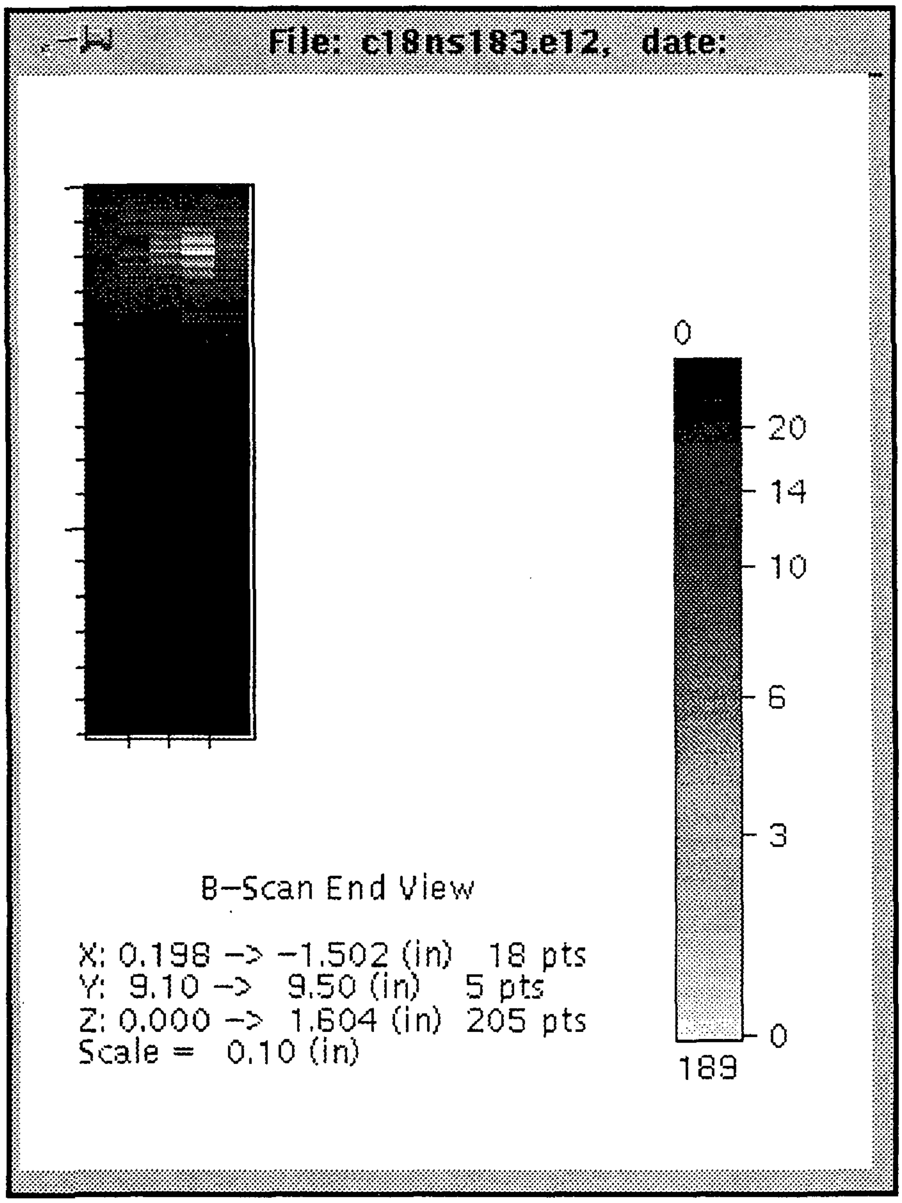


Figure 5.28b End View (YZ) of Clad to Base-Metal Indication in Block 1-8 at Y = 236 mm (9.3 in.). 70° L-wave inspection with beam direction of -X. This indication corresponds to flaw #11 in the destructive analysis.

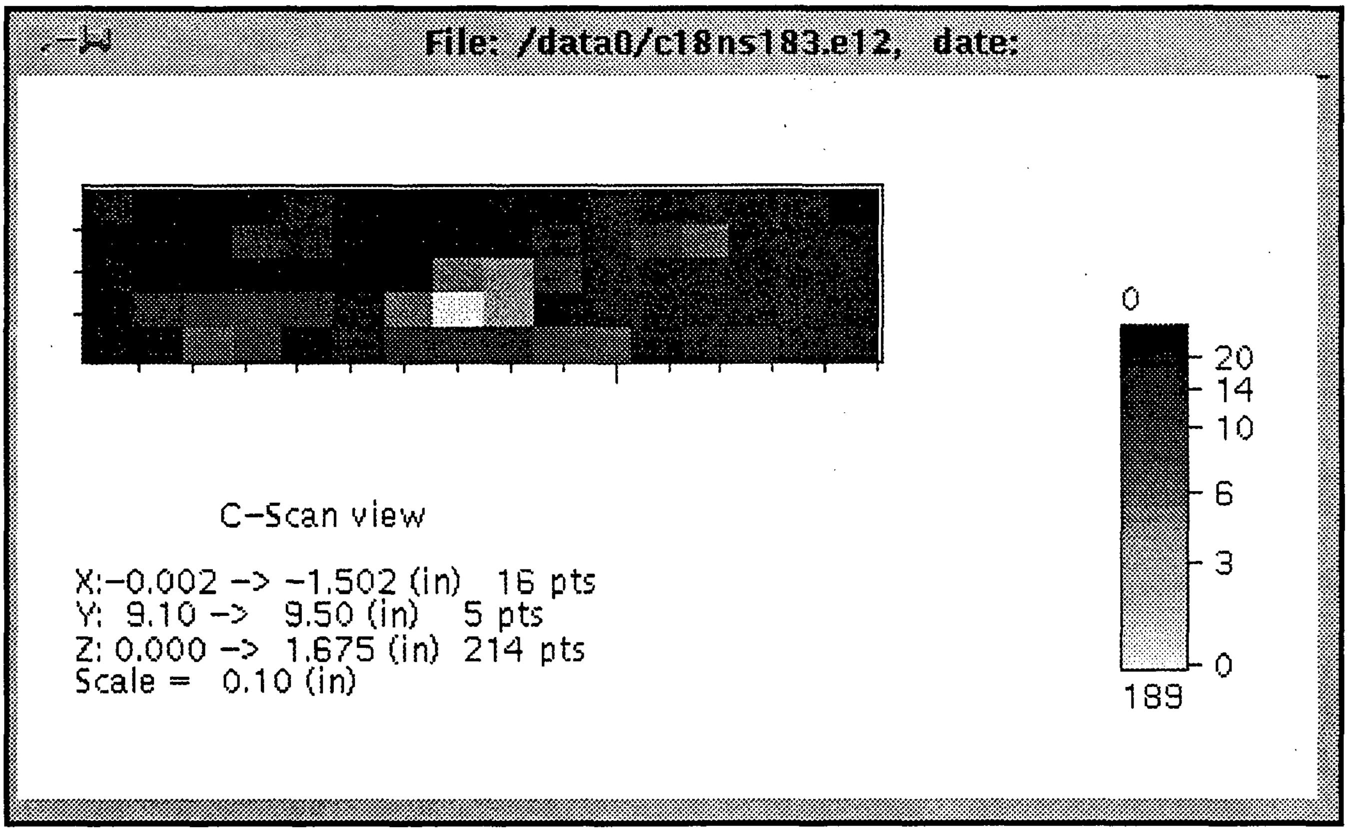


Figure 5.28c C-scan View (XY) of Clad to Base-Metal Indication in Block 1-8 at Y = 236 mm (9.3 in.). 70° L-wave inspection with beam direction of -X. This indication corresponds to flaw #11 in the destructive analysis.

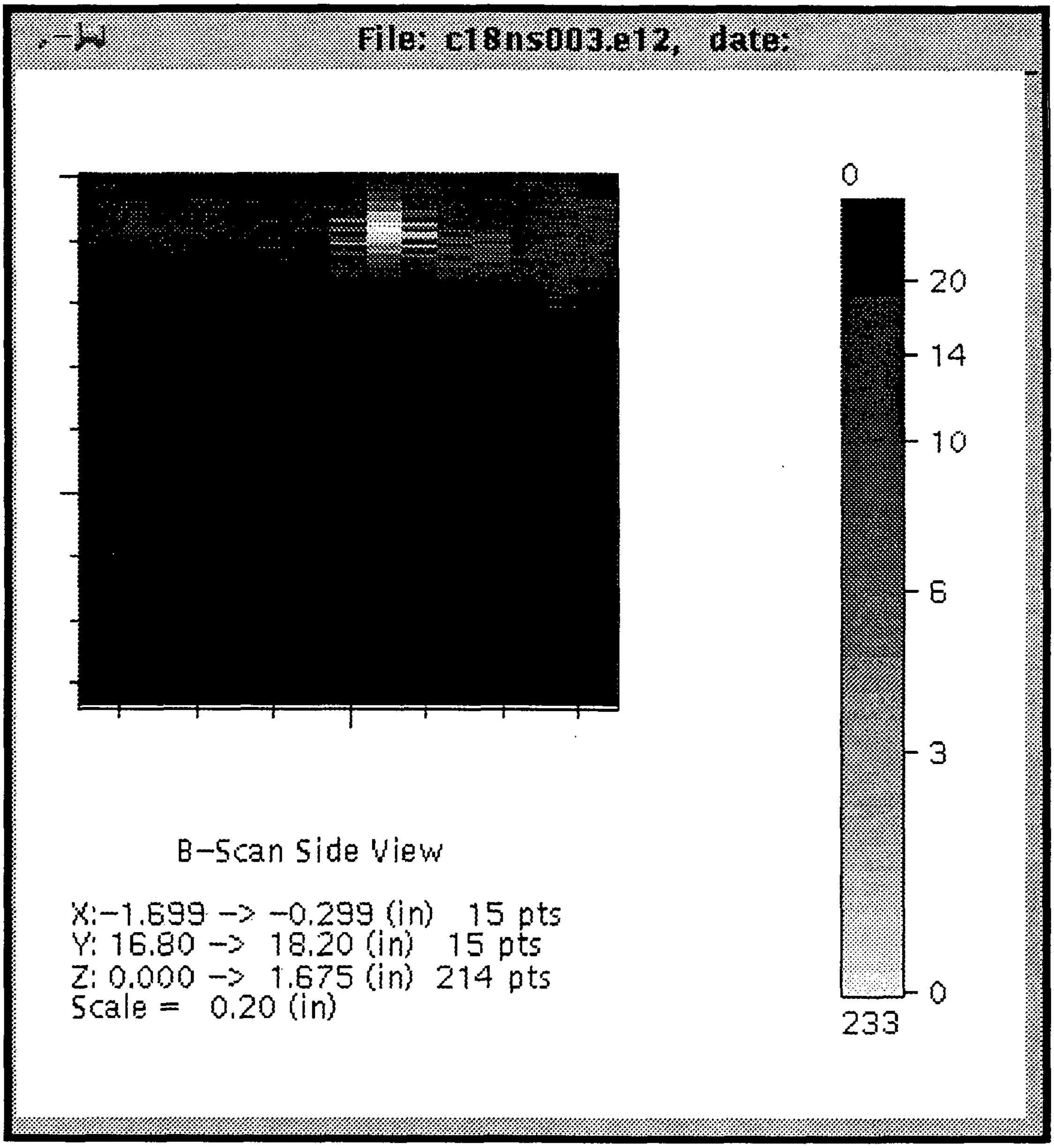


Figure 5.29a Side View (XZ) of Clad to Base-Metal Indication in Block 1-8 at Y = 442 mm (17.4 in.). 70° L-wave inspection with beam direction of +X.

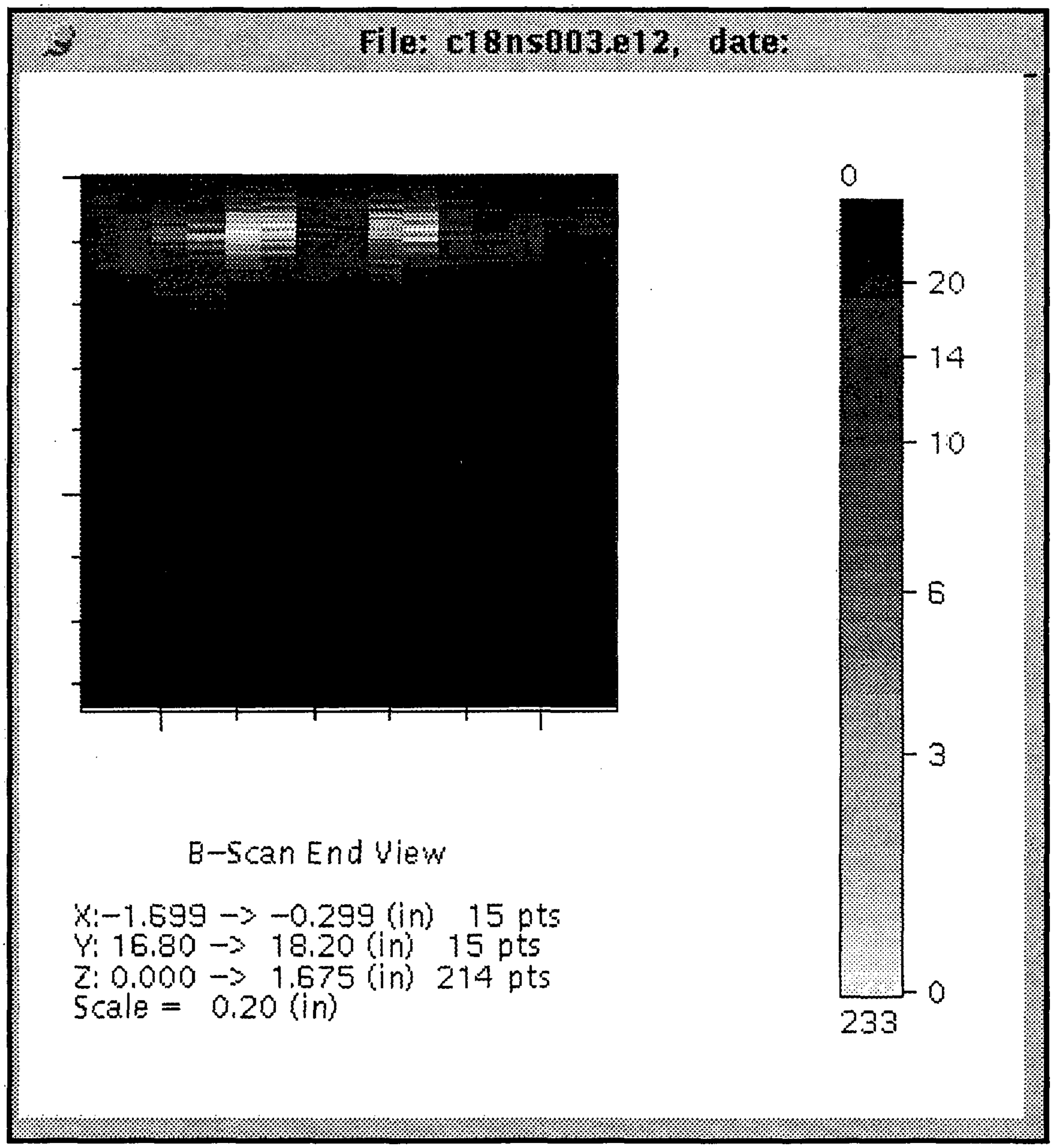


Figure 5.29b End View (YZ) of Clad to Base-Metal Indication in Block 1-8 at Y = 442 mm (17.4 in.). 70° L-wave inspection with beam direction of +X.

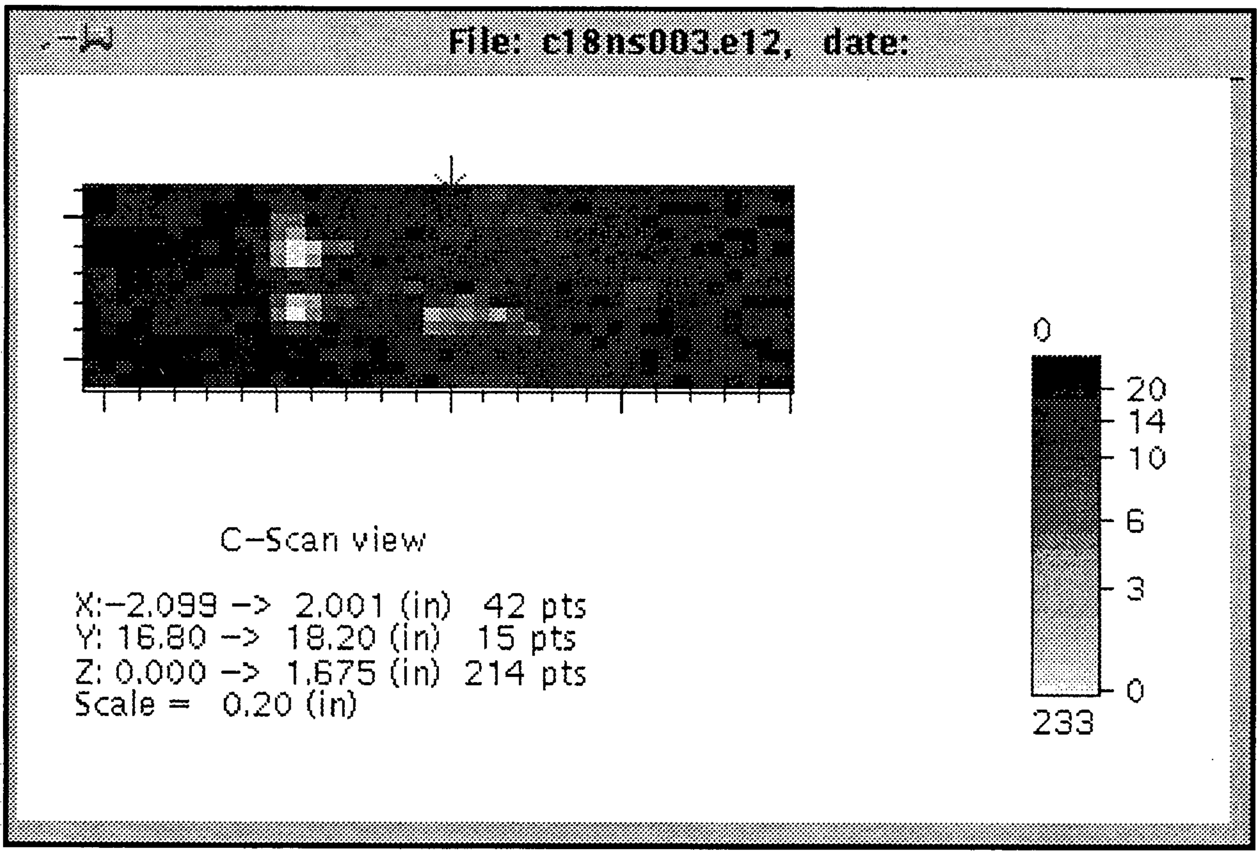


Figure 5.29c C-scan View (XY) of Clad to Base-Metal Indication in Block 1-8 at Y = 442 mm (17.4 in.). 70° L-wave inspection with beam direction of +X.

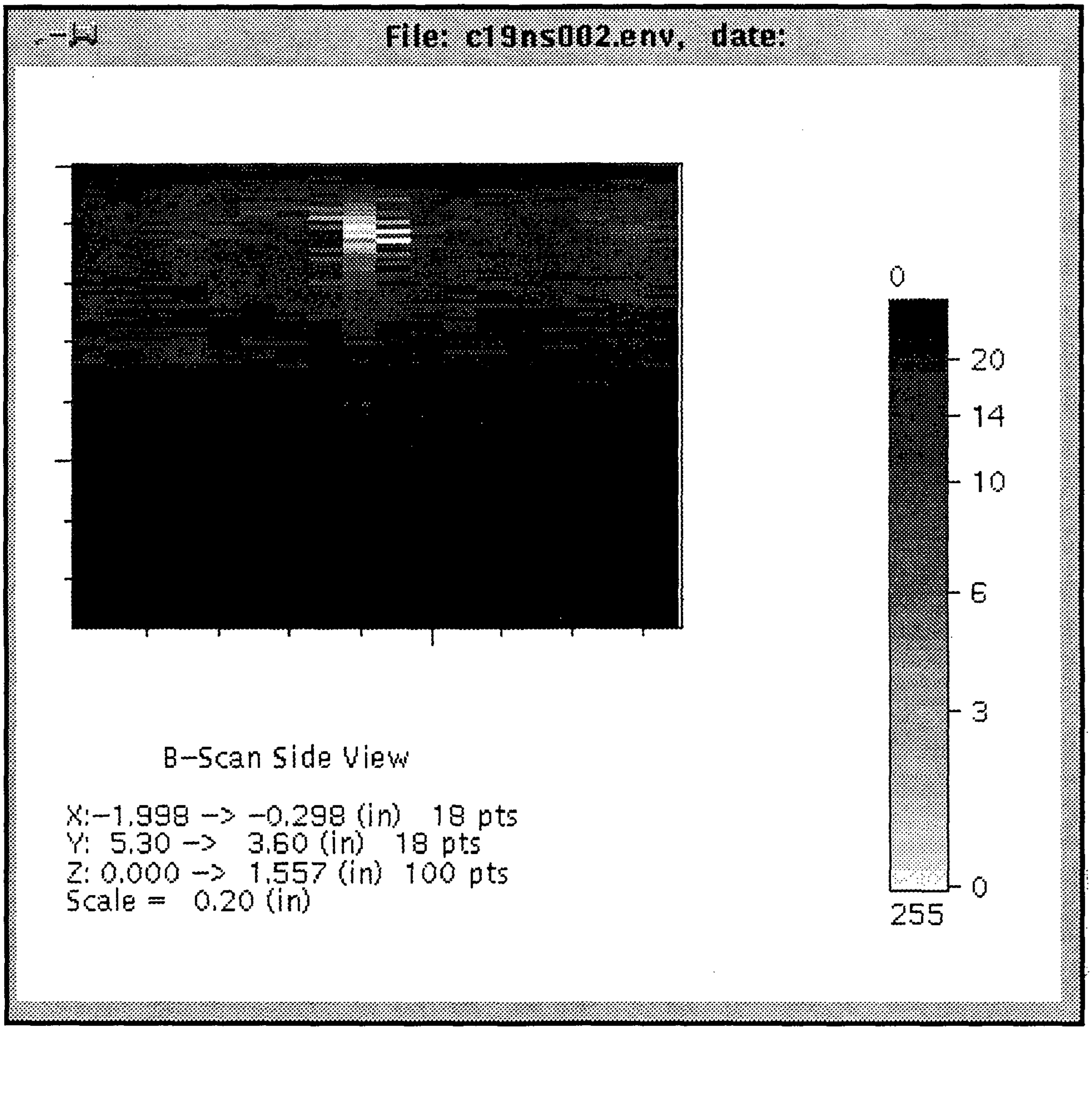


Figure 5.30a Side View (XZ) of Clad to Base-Metal Indication in Block 1-9 at Y = 117 mm (4.6 in.). 70° L-wave inspection with beam direction of +X.

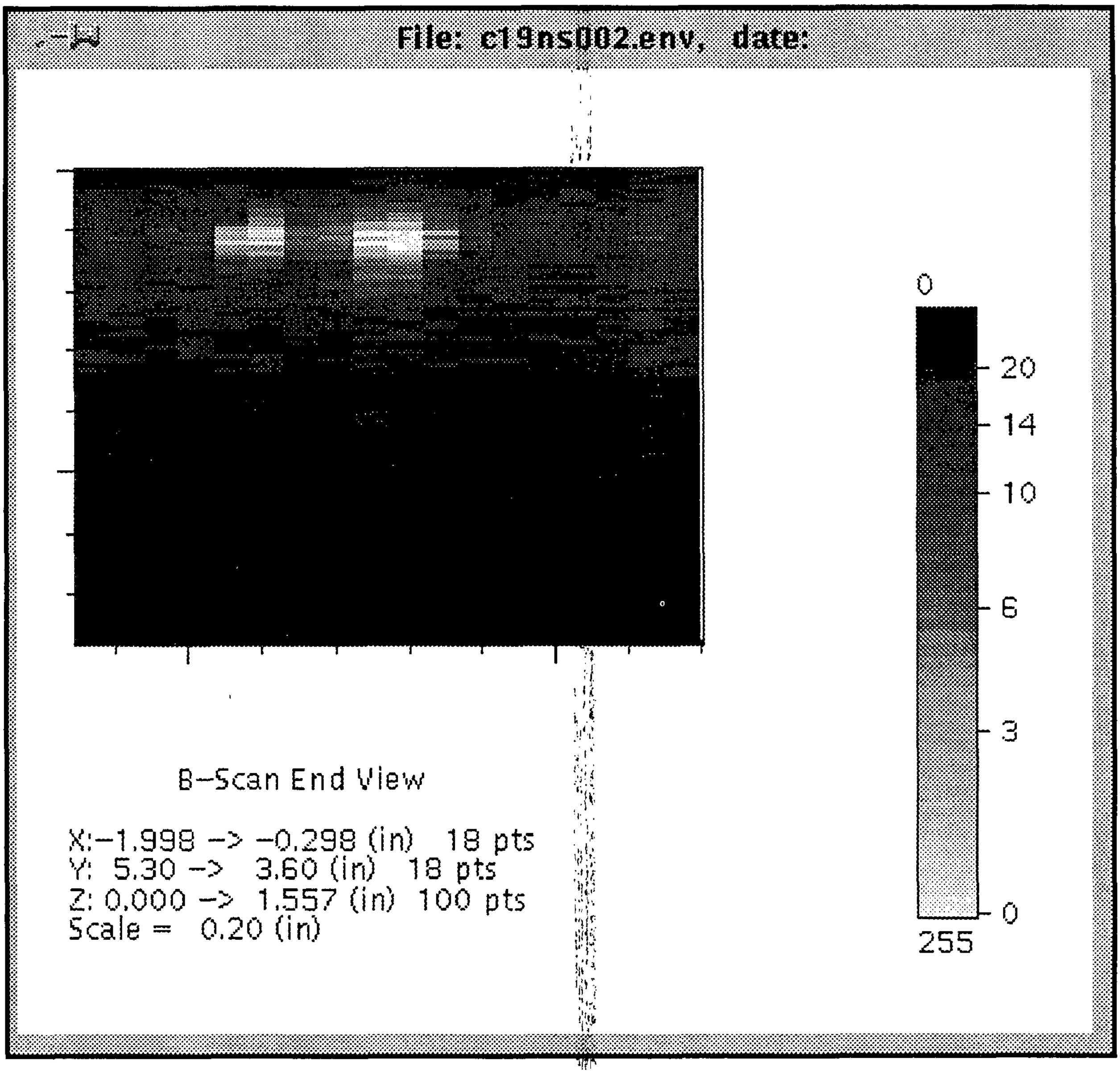


Figure 5.30b End View (YZ) of Clad to Base-Metal Indication in Block 1-9 at Y = 117 mm (4.6 in.). 70° L-wave inspection with beam direction of +X.

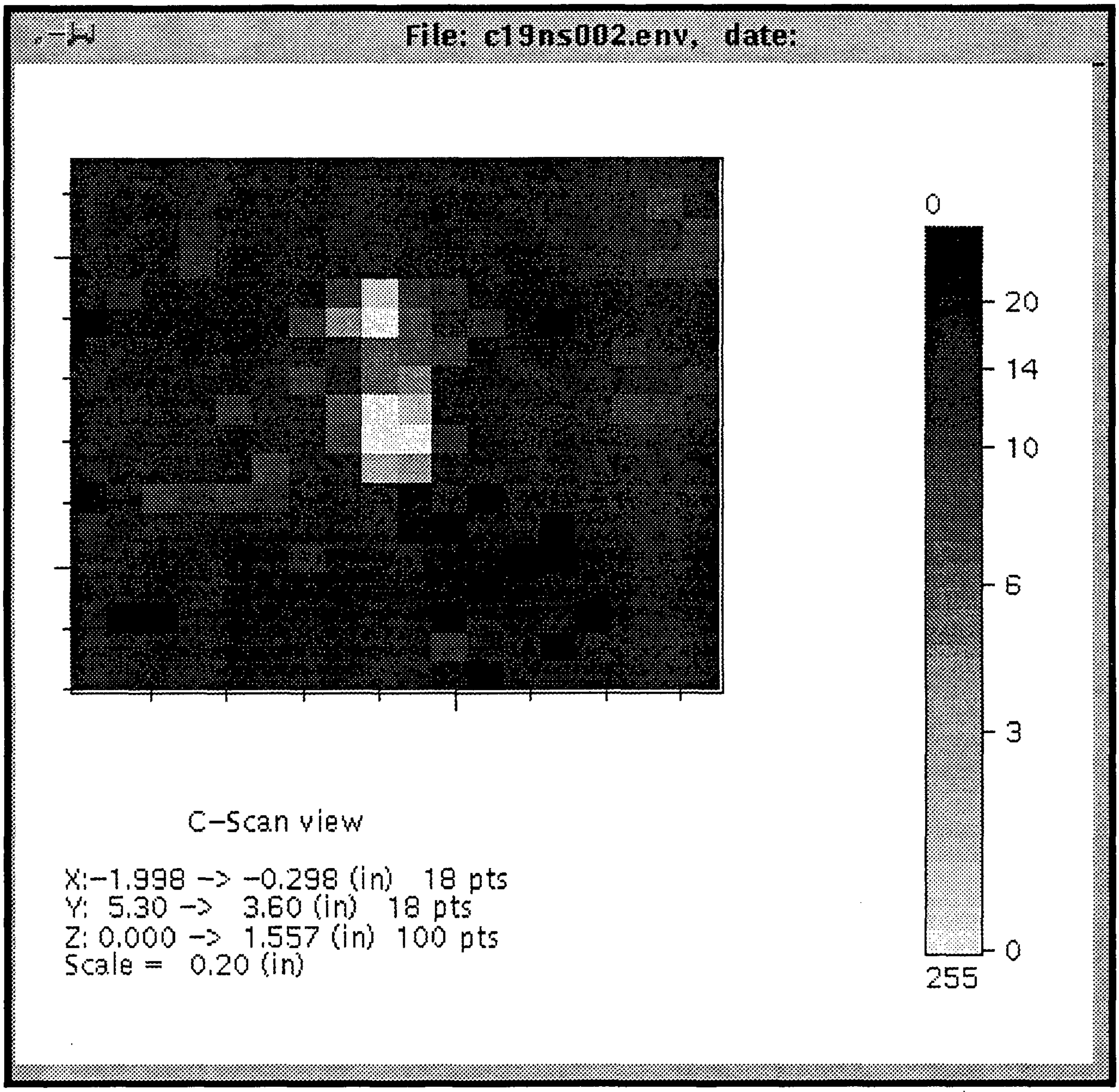


Figure 5.30c C-scan View (XY) of Clad to Base-Metal Indication in Block 1-9 at Y = 117 mm (4.6 in.). 70° L-wave inspection with beam direction of +X.

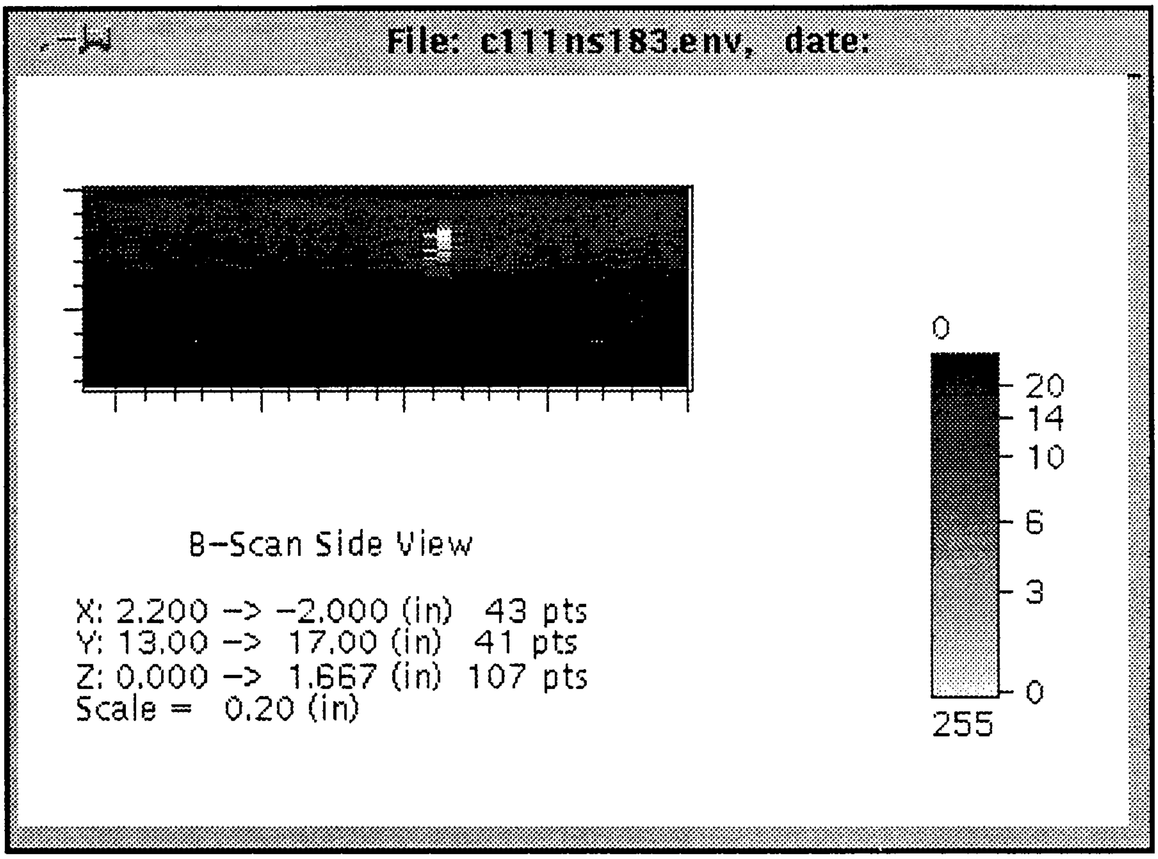


Figure 5.31a Side View (XZ) of Clad to Base-Metal Indication in Block 1-11 at Y = 387 mm (15.3 in.). 70° L-wave inspection with beam direction of -X.

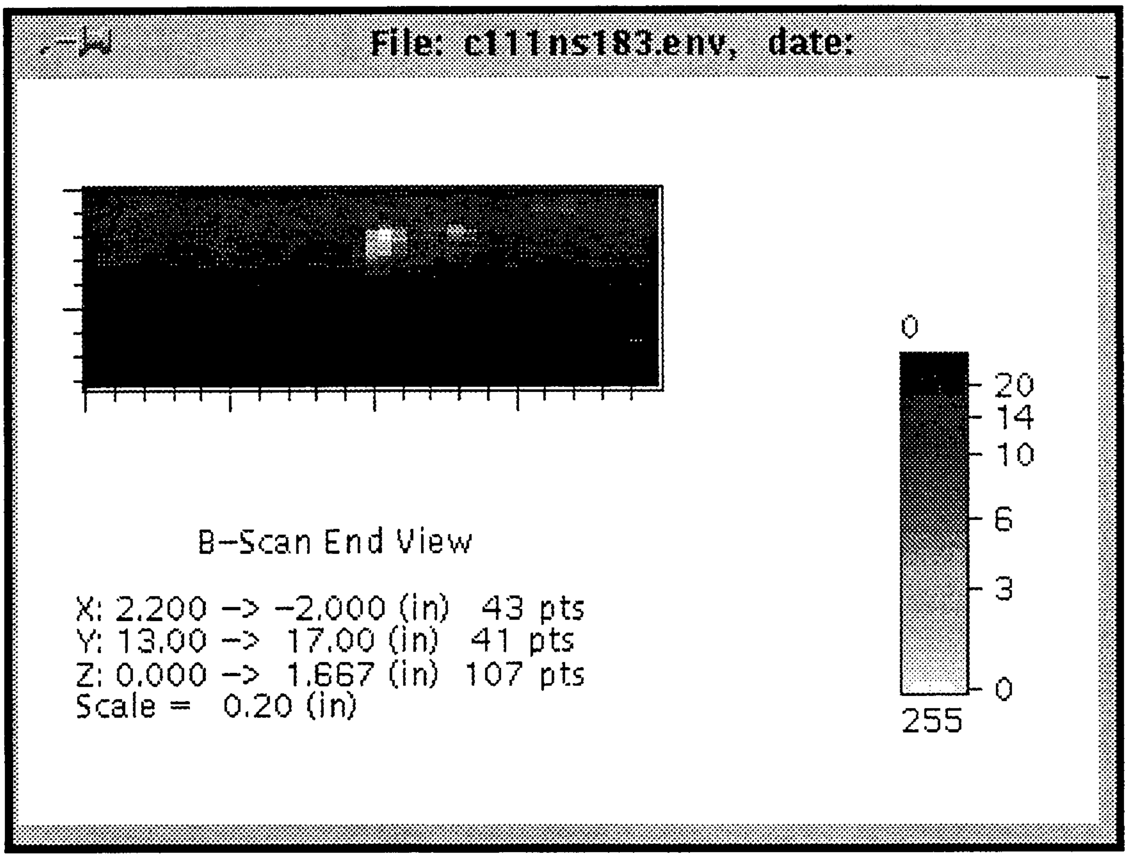


Figure 5.31b End View (YZ) of Clad to Base-Metal Indication in Block 1-11 at Y = 387 mm (15.3 in.). 70° L-wave inspection with beam direction of -X.

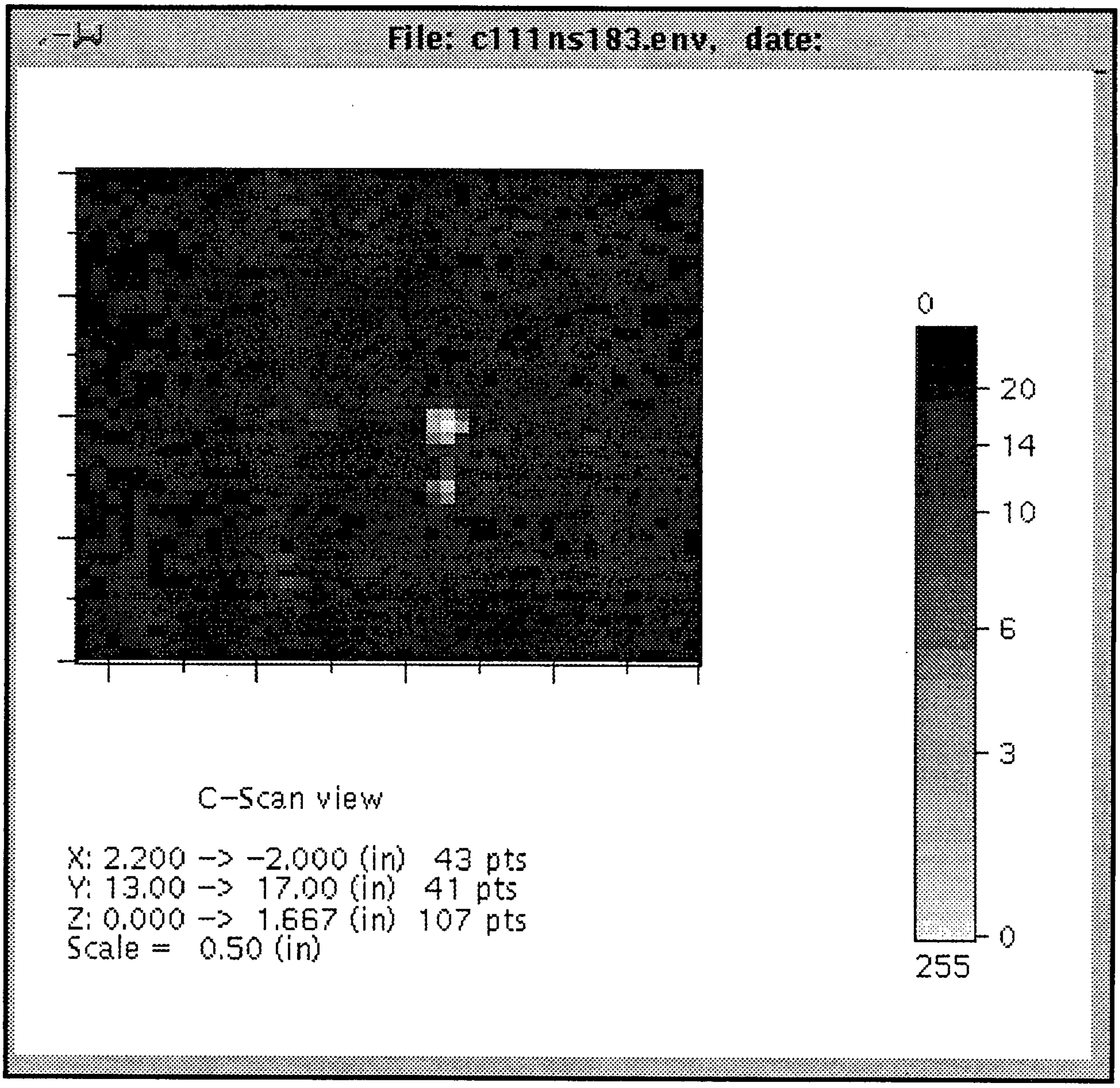


Figure 5.31c C-scan View (XY) of Clad to Base-Metal Indication in Block 1-11 at Y = 387 mm (15.3 in.). 70° L-wave inspection with beam direction of -X.

6.0 Distribution of Flaws in the Midland Blocks

Characteristics of the fabrication flaws in reactor pressure vessels are necessary inputs to the application of fracture mechanics calculations for assessments of reactor pressure vessel integrity. The features of the indications found by SAFT-UT in four Midland blocks have been extracted from the data. The flaws are distributed across the important feature types (location, type, and size). SAFT-UT Probability of Detection (POD), False Call Probability (FCP), and sizing error are estimated in this section. Flaw rates are estimated in this section without adjustment for POD, FCP, or sizing error.

6.1 Features of SAFT-UT Indications

Tables 6.1 and 6.2 show the location, type, and size for the 31 flaws found in the SAFT-UT data from the inspections of the Midland blocks. These tables are summaries of the detailed information contained in Section 5 of this report.

6.1.1 Location

Five categories were defined for classifying the location of indications in the Midland blocks: the near-surface zone (including the clad-to-base metal interface), weld root, weld, weld fusion zone, and base metal. In the first category are the indications at the clad-to-base metal interface. The near-surface zone is defined as the inner 25 mm of the vessel. Eight indications were found in this category. In the second category are indications near the weld root; four indications were found in this category, between 80 and 95 mm below the clad surface and within ± 12 mm of the weld centerline. In the third category are the indications within the weld. Ten indications were found in this category, where the weld cross section shown in Figure 2.2 was used for the location of the weld material. In the fourth category are indications in the weld fusion zone. Four indications were found in this zone, where the fusion zone was assumed to extend 6 mm beyond the weld-metal cross section shown in Figure 2.2. In the last category are indications in the base metal. Five indications were found in this category.

6.1.2 Type

The 31 flaws found in the Midland blocks have been categorized as either planar or volumetric. Planar flaws in this categorization are meant to include those flaws that are most important to calculations of vessel integrity such as vertically oriented cracks, lack of fusion in the weld, etc. Volumetric flaws in this categorization are meant to include flaws such as inclusions, pores, and laminations. The method used to determine the flaw type is described in Section 5.

6.1.3 Size

Tables 6.1 and 6.2 show both through-wall extent and circumferential extent of the 31 flaws.

6.2 Number of Flaws in the Categories

Table 6.3 shows the distribution of the 31 flaws as a function of through-wall extent, location, and type. The table also shows some interesting features of the flaw distribution, such as, the flaws found in the near-surface zone, weld root, and HAZ are all less than 2.2 mm in through-wall extent.

6.3 Probability of Detection, False Call Probability, and Sizing Error

In order to use the SAFT-UT results in an estimation procedure for flaw rates, it is necessary to determine the detection and sizing capabilities of SAFT-UT. Some valuable detection and sizing information can be obtained from this data set; that is, the SAFT-UT inspections of the Midland blocks and the destructive analysis of Midland Block 1-8. Additional information can be extracted from other tests that SAFT-UT has been used in and from the PISC II program.

6.3.1 Probability of Detection (POD)

The results from the PISC II program have shown that three distinct defect types should be considered when quantifying the POD of defects in heavy section steel (Crutzen, 1988). Smooth, planar defects (e.g., thermal fatigue cracks) are the most difficult to detect, rough planar defects are easier to detect, and volumetric defects such as slag inclusions and porosity have significantly higher POD than the other two defect types.

In the PISC II exercises, advanced UT techniques were used to inspect extensive amounts of pressure vessel material. Using these inspection data, the POD estimates shown in Table 6.4 were obtained from a logistic curve fit (Heasler 1993). As one can see from the table, the advanced procedures do best with volumetric defects.

The SAFT-UT probability of detection for volumetric defects with through-wall extent in the range of 1 to 2 mm can be estimated at 0.7 for both near-surface and sub-surface defects in the Midland blocks. This estimate uses the SAFT-UT detection results, reported in Section 4, of three detections for four defects inspected in the near-surface zone and two indications for three defects inspected in the weld root.

Since three of the Midland blocks (1-9, 1-11, and 1-12) received SAFT-UT inspections from the top or bottom machined face of the blocks, the POD for vertically oriented planar reflectors is increased and assumed to be the same as for volumetric flaws. The POD for SAFT-UT in the inspections of Midland blocks is estimated in Table 6.5.

6.3.2 False Call Probability

The results of the advanced method inspections of the PISC II program give an upper limit for FCP of 0.12 (0.08 clad) for volumetric flaws in thick section material. This value was reported in Heasler (1993) and was calculated from the number of detections in material without known flaws. But this number is only an upper limit because no destructive test was made to confirm that the material was blank.

The Midland destructive test results do not directly apply to a calculation of false call probability for SAFT-UT. The destructive test was performed to examine selected indications in the EPRI NDE Center UT data (Foulds 1993). The selection of the locations for destructive analysis was reported to be biased toward the more significant indications (the larger ones) in the UT data.

6.3.3 Sizing Error

SAFT-UT was used in the PISC III Full Scale Vessel (FSV) test located in Stuttgart, Germany at the Materialpru-fungsanstalt (MPA) Laboratory that involved the characterization of 12 indications in a full-scale reactor pressure vessel (PISC III report, 1993). The flaws in that FSV test had a range of 6 to 110 mm in through-wall extent; the statistical results for sizing error showed that SAFT-UT tended to undersize the flaws by 3.7 mm and the standard deviation of the SAFT-UT results from the true state was 4.7 mm (Doctor et al. 1994).

destructive analysis for defects numbers 1, 4, 9, 11, and 12 and, for this reason, no comparison can be made to a SAFT-UT estimate. Two defects (numbers 2 and 10) were not detected in the SAFT-UT data. One defect (number 3) was not inspected by SAFT-UT because it was at the end of the block.

The two small defects in the weld root (numbers 5 and 6) were undersized by SAFT-UT. The three small defects at the clad-to-base metal interface were oversized by SAFT-UT.

6.4 Flaw Rate Estimates

A parametric form for the flaw rate function, a two-parameter Weibull function, has been used to represent the rate of occurrence of flaws as a function of through-wall extent as follows:

$$\Lambda_0(s) = \beta_0 \exp\left(-\left(\frac{s}{\alpha}\right)^{\beta_1}\right)$$

where $\Lambda_0(s)$ is the number of flaws with through-wall extent greater than s, per unit of weld length;
β_0 is the total number of flaws per unit of weld length;
s is the through-wall extent of a flaw; and
α and β_1 are the two parameters of Weibull function that are to be fit to the empirical data.

In this report, we fit the raw data in Tables 6.1 and 6.2 to the Weibull model. The resulting estimate shows what the results are when detection or sizing errors are not included. This approach gives the most "optimistic" result that can be obtained from the data, because the introduction of detection and sizing error will increase the flaw rate function and also widen the confidence bounds.

Figures 6.1 and 6.2 present the results of a maximum likelihood Weibull fit to the SAFT-UT data for the 31 flaws. Figure 6.1 displays the estimates and confidence bounds for the parameters α and β_1, which determine the shape of the cumulative flaw rate function. This plot shows the 50%, 80%, 90%, and 95% confidence bounds on these parameters. Figure 6.2 presents a plot of $\Lambda(s)$, surround by 95% confidence bounds.

Tables 6.8 shows five different flaw rate parameters set for the Weibull model that have been published (Found et al. 1993) including the data in this report. The Marshall estimates for parameters α and β_1 fall somewhat outside the 95% confidence region produced by the maximum likelihood fit to the SAFT-UT data. The significance of this discrepancy is not great because the confidence bounds on the Marshall distribution would show significant overlap with the SAFT-UT distribution. The estimate for β_0 for Marshall distribution does not agree with the SAFT-UT results. According to the maximum likelihood fit to the SAFT-UT data, a 95% confidence bound on β_0 is (3.5 to 14.4) flaws/m; much higher than the Marshall Committee estimate of 0.003 to 0.3 flaw/m (0.4 to 40 flaws/m^3), where we have used a narrow gap weld cross section of 0.008 m^2.

In summary, the SAFT-UT data from the four Midland blocks does not support the assumption of a Marshall distribution of flaws in this material. The most significant differences between the two distributions is that the total flaw density as measured by SAFT-UT is higher than that assumed in the Marshall distribution. The other published flaw density estimates shown in Table 6.8 have that property as well. But the number of flaws that support these estimates of the flaw rate function is small.

Table 6.1 Summary of Base Metal Defects found by SAFT-UT

Block	Depth, mm	Depth Extent, mm	Circum. Extent, mm	Defect Type	Material
1-8	89	1.3	5	Volumetric	Root
	91	1.3	20	Planar	Root
	91	1.3	15	Volumetric	Root
	109	1.3	5	Volumetric	Weld
	112	-	10	Volumetric*	Weld
	79	-	10	Volumetric*	Weld
	86	-	10	Volumetric*	Root
	109	1.3	10	Planar	Fusion
	183	-	15	Volumetric*	Weld
	155	-	15	Volumetric*	Base
	183	-	20	Volumetric*	Fusion
	208	-	20	Volumetric*	Weld
1-9	178	18	36	Planar	Weld
	145	5	23	Planar	Base
	178	10	-	Planar	Base
	64	5	13	Planar	Base
	114	5	13	Planar	Weld
	121	8	25	Planar	Weld
	119	-	10	Volumetric*	Weld
	206	-	23	Volumetric*	Base
1-11	132	2	10	Planar	Weld
	150	2	20	Planar	Fusion
1-12	119	2	10	Planar	Fusion

* These defects were only detected in normal beam from the clad or unclad side. For this reason, they are estimated to be volumetric in nature without measurable through-wall extent.

Table 6.2 Summary of Clad-to-Base Metal Defects found by SAFT-UT

Block	Depth, mm	Depth Extent, mm	Circum. Extent, mm	Defect Type	Location
1-8	5	<2.2	5	Volumetric	Near-surface
	5	<2.2	2	Volumetric	Near-surface
	8	<2.2	5	Volumetric	Near-surface
	10	<2.2	5	Volumetric	Near-surface
	5	<2.2	5	Volumetric	Near-surface
	5	<2.2	15	Volumetric	Near-surface
1-9	5	<2.2	15	Volumetric	Near-surface
1-11	11	<2.2	23	Planar	Near-surface

Table 6.3 Midland: Number of Flaws in Categories

	Through-Wall Extent of Flaw											
	<2.2 mm		5 mm		8 mm		10 mm		18 mm		Total	
Flaw Location	V*	P**	V	P	V	P	V	P	V	P	V	P
Near Surface	8	0	0	0	0	0	0	0	0	0	8	0
Root	3	1	0	0	0	0	0	0	0	0	3	1
Weld	6	1	0	1	0	1	0	0	0	1	6	4
Fusion (HAZ)	1	3	0	0	0	0	0	0	0	0	1	3
Base	2	0	0	2	0	0	0	1	0	0	2	3
Total	20	5	0	3	0	1	0	1	0	1	20	11

* Volumetric
** Planar

Table 6.4 POD for Advanced Procedures from Fits to PISC-II Data

Flaw Type	Material	POD (2 mm*)	POD (6 mm*)	POD (12 mm*)
Smooth Planar	Base	**	0.19	0.23
	Clad	**	0.19	0.25
Rough Planar	Base	**	0.35	0.60
	Clad	**	0.16	0.40
Volumetric	Base	0.30	0.84	0.99
	Clad	0.18	0.60	**

* Through-Wall Extent of Defect
** No estimation

Table 6.5. Estimated POD for SAFT-UT Inspections of the Midland Blocks

Through-Wall Extent	1-2 mm	6 mm	12 mm
POD for Near-Surface	0.7	--	--
POD for Weld and Base Metal	0.7	0.84	0.99

Table 6.7 True-State Table for Through-Wall Extent

EPRI NDE Center Indication Number	True State from Destructive Analysis	SAFT-UT Estimate	Material
1	Not determined	Not applicable	Root
2	1 mm	Not detected	Root
3t 3b	0.75 mm 3 mm	Not inspected	Root
4	Not determined	Not applicable	Root
5	2 mm	1.3 mm	Root
6t 6b	2 mm* 3.5 mm	1.3 mm	Root
7	1 mm	< 2.2 mm	CBI**
8	2 mm	< 2.2 mm	CBI
9	Not determined	Not applicable	CBI
10a 10b	1 mm 1 mm	Not detected	CBI
11	0.5 mm	< 2.2 mm	CBI
12	Not determined	Not applicable	CBI
13	Not determined	Not applicable	CBI

* Two defects found and sized but no data provided on spatial relationship.
** Clad-to-Base Interface zone

Table 6.8 Flaw Rate Function Parameters

Data Set	α, mm^{-1} (in.$^{-1}$)	β_1	β_0, Flaws/m (Flaws/ft.)	95% Confidence Bounds on β_0, Flaws/m (Flaws/ft.)
Marshall Distribution[(a)]	6.25 (0.246)	1	0.003 to 0.3 (0.02)	
SAFT-UT, 31 flaws[(b)]	3.81 (0.15)	1.39	7.4 (2.30)	3.5 to 14.4 (1.06 to 4.41)
SAFT-UT, 11 flaws[(c)]	7.11 (0.28)	1.49	2.1 (0.66)	1.9 to 13.2 (0.59 to 4.02)
SAFT-UT, Sandia Report[(d)]	1.27 (0.05)	0.61	11.0 (3.4)	
EPRI NDE Center UT, Sandia Report	4.70 (0.185)	1.30	3.0 (0.93)	

(a) Marshall, 1982.

(b) Data from this report. SAFT-UT inspections of four Midland blocks without adjustment for POD or sizing error.

(c) Data reported in Doctor (1991). SAFT-UT inspection results without correlation with destructive analysis and without adjustment for POD or sizing error.

(d) Data reported in Foulds (1993).

Table 6.9 Estimates of Cumulative Flaw Rates

Data Set	Λ (2.5 mm) Flaws/m	Λ (5 mm) Flaws/m	95% Confidence Bounds on β_0, Flaws/m (Flaws/ft.)
Marshall[(a)]	.02 - .2	0.0013 - 0.13	0.0004 - .04
SAFT-UT, 31 flaws[(b)]	4.2	1.7	0.054
SAFT-UT, 11 flaws[(c)]	1.7	1.2	0.24
SAFT-UT, Sandia Report[(d)]	2.4	1.1	0.21
EPRI NDE Center UT, Sandia Report	1.9	1.0	0.10

(a) The flaw distribution for preservice condition of vessels recommended in U.S. Nuclear Regulatory Guide 1.154 for use in probabilistic fracture mechanics analysis of PWR vessel integrity under pressurized thermal shock.

(b) Data from this report. SAFT-UT inspections of four Midland blocks without adjustment for POD or sizing error.

(c) Data reported in Doctor (1991). SAFT-UT inspection results without correlation with destructive analysis and without adjustment for POD or sizing error.

(d) Data reported in Foulds (1993).

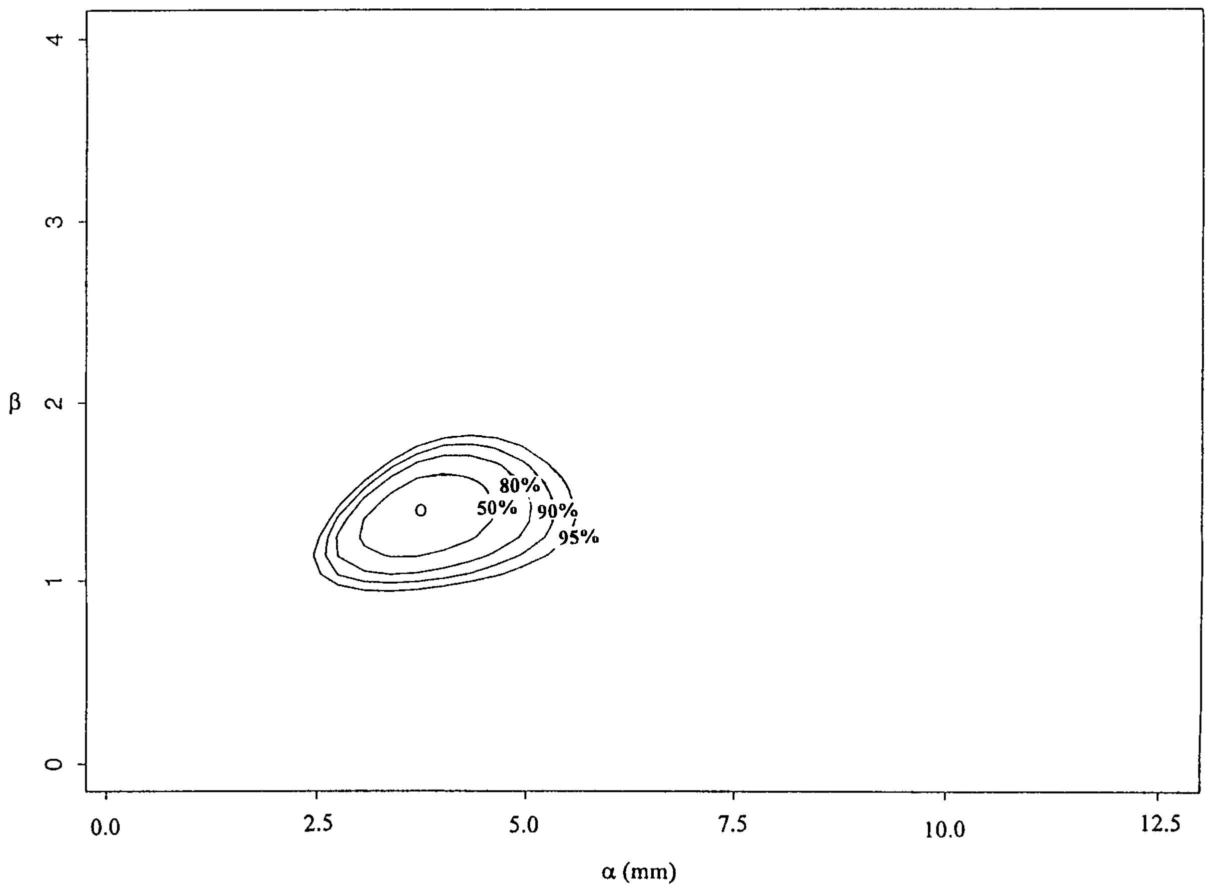


Figure 6.1 Parameter Estimates with Confidence Bounds for Simple Weibull Fit to the SAFT-UT Data of 31 Flaws

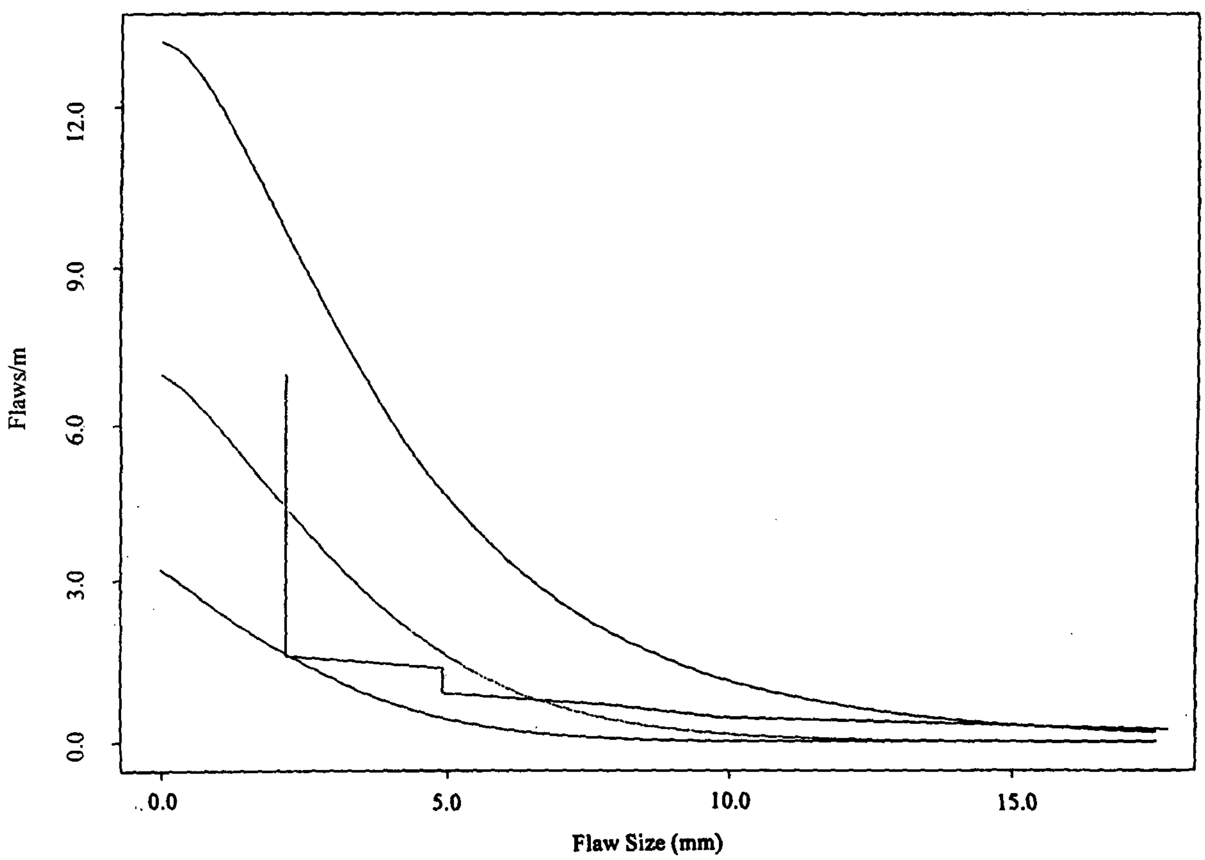


Figure 6.2 Estimate of Cumulative Flaw Rate Function with 95% Confidence Interval for Simple Weibull Fit to the SAFT-UT Data of 31 Flaws

7.0 Recommendations for the Use of SAFT-UT on Vessel Material

The SAFT-UT field system was designed to provide a spatial sampling that would provide high-resolution images for defects that are of potential importance to structural integrity. It was in this configuration that the SAFT-UT system was used for the inspection of the Midland blocks. In general, the flaws found by SAFT-UT were small. Destructive analysis of Block 1-8 found mainly slag inclusions that were sometimes less than 1 mm (0.04 in.) in extent in one or more dimensions. After the SAFT-UT system was used on the Midland blocks, improvements were made to the system to permit more accurate characterization of these small fabrication defects. The changes to the SAFT-UT system are described in this section.

The SAFT-UT normal beam inspections of the Midland blocks were made with a 2.25 MHZ transducer. A 5.0 MHZ transducer is recommended for the inspection of small fabrication defects in the base metal of vessel material in order to gain better performance in measuring lateral extent.

The inspections of the clad-to-base metal interface are composed mostly of 70°, 2.0-MHZ, L-wave inspections. An inspection of this type has a wavelength in the metal of 3 mm (0.12 in.). Objects greater than 2.2 mm in depth extent will show some measurable size. Unfortunately, the use of a higher frequency for the 70° L-wave inspections is not recommended. The clad-to-base metal region is a difficult medium for the propagation of higher frequencies. But because of the occurrence of volumetric indications (slag inclusions) at the clad-to-base metal interface, the use of a 4.0-MHZ dual-element, normal beam, near-surface transducer is recommended to supplement the 70°, 2.0 MHZ SAFT-UT inspections.

The above discussion of minimum measurable lateral extent has not considered the spacial sampling intervals that must accompany the SAFT-UT scanning process. For the inspections of the Midland blocks most of the data were taken with 2.5 mm steps in X and Y. Because the spatial sampling locations are made randomly with respect to the location of the small fabrication defects, the minimum measurable lateral extent must be increased by one step size interval. This significantly increases the minimum measurable lateral extent, and we recommend that step sizes in X and Y be set to one-half wavelength for SAFT-UT inspections. This is 0.64 mm (0.025 in.) for 5 MHZ normal beam and 1.5 mm (0.060 in.) for 70° L-wave inspections.

The implications of the above recommendations, where one wants to detect and accurately size very small indications, on the computer methods are significant. File sizes for RF data will exceed 100 MBytes. The SAFT-UT system was not configured to acquire, process, or display inspections with such large data sizes when the Midland blocks were inspected. Even on the present SAFT-UT system, based on an 80 MIP processing CPU, the SAFT focusing can require more than 24 hours when the use of high gain causes large amounts of both signal and noise to be present in the RF (raw) data. For analyzing small indications, the data must be taken with very high density. The reality is that, for these kinds of inspections, the file sizes can become so large that some difficulties remain for fieldable systems. We expect that the implementation of the above recommendations will become more manageable as computer methods advance.

A significant additional recommendation regards the use of material coordinates in the acquisition of SAFT-UT data. The SAFT-UT system used scanner coordinates for its computer records (file header information) and for display purposes when the Midland data was taken. A recommendation for the analysis of multiple inspections of vessel material is that all of the images be presented in material coordinates and that the material coordinates should be documented as a computer record when the data is taken. Such presentation simplifies the interpretation of inspections from different angles and from different sides of the vessel, instills confidence in the interpretation, and reduces ambiguity.

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11. ABSTRACT *(200 words or less)*

Characterization of Flaws in U.S. Reactor Pressure Vessels is a multi-volume report. Volume 1, this document, provides the results of a nondestructive examination conducted at the Oak Ridge National Laboratory's Pressure Vessel Research User Facility (PVRUF) on a vessel fabricated for a canceled nuclear power plant. Volume 2, in preparation, will document the results of Pacific Northwest National Laboratory's (PNNL) destructive validation of the flaw rates in the PVRUF evaluation. Twenty linear meters of weldment were inspected by SAFT-UT including the entire circumferential beltline weld of the vessel. There were 2500 detectable indications in the SAFT-UT inspections of the PVRUF vessel. The largest number of these, 982, were found at the clad-to-base metal interface, but 978 of these were less than 2mm (0.08 in.) in size. In the near surface zone, the weld metal contained 98 detectable planar indications. The density of indications was four times higher in the weldment than in the base metal. The distribution of the empirical data provided enough information to apply a parametric model of the cumulative flaw rate to six different subsets of the data, and to obtain reasonable confidence bounds on the results. Recommendations are given for validating the indication rates by selective destructive analysis to provide the necessary high quality flaw statistics for use in fracture mechanics calculations such as those used in pressurized thermal shock (PTS) analysis.

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