SLAM INVESTIGATIONS ON HST-SA1 SOLAR CELL WELDS

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ABSTRACT

The welds between the solar cell and interconnector are prone to fatigue induced by the thermal cycle as seen by the solar panels. This fatigue phenomenon on the welds shows itself as a reduction of the welded area between the solar cell and the interconnector. Scanning Laser Acoustic Microscopy is used as an non destructive tool to determine the the size of these welds. Comparison will be made between HST-SA1 welds, virgin welds (mannufactured according to the same standard) and welds made in the past using the same process.

Keywords: solar cell weld, Scanning laser acoustic microscopy, SLAM, Fatigue, Thermal cycle

1. INTRODUCTION

Starting from mid 1986 the Metallic Materials and Processes Section in ESTEC is performing Scanning Laser Acoustic Microscopy (SLAM) examination on solar cell welds. The SLAM examination originates from the idea to have a non-destructive way to examine the weld between the solar cell and the interconnector. The welds between the solar cell and the interconnector are prone to thermal fatigue during thermal cycling. The difference in thermal expansion of the blanket substrate and the silicon cell has to be bridged by the interconnector. The stress relief loop of the interconnector is designed for this purpose.

The bond between the solar cell and the interconnector is produced by parallel gap welding. The thermal mismatch between the silver metallisation and the silicon of the solar cell over a temperature range of ~190 ^{o}C generates dislocations within the metallisation. These dislocations produce surface slip, extrusions and tilting of the grainboundaries. On the interface between the silver metallisation and the silver on the interconnects microvoids will grow. This effect and the cycling peak stresses at the circumference of the welding area due to the pull stresses transferred from the interconnect itself, will result in a decrease in weld area between the cell and the interconnector.

2. MATERIAL

The HST solar generator consisted of four flexible blankets. Two blankets were integrated into one wing. One wing was retrieved and brought back to earth. after being exposed for 1315 days in low earth orbit. One of these ten solar panel assemblies (SPA) was cut for the post flight investigation. These solar cells have seen approx. 21000 thermal cycles between +90 ^{o}C and -100 ^{o}C. Samples were cut from SPA-D following the pattern indicated in figure 1. Samples from the width of the panel were always cut out as a pair. In this way the weld area to be investigated was not stressed by the cutting method. Samples from the edge of the SPA which included the busbar usually consisted of a row of 10 cells. The locations of these cut outs were recorded and the respected samples were di-

sectioned to have a clear access to the welded region at both p and n-sides. The di-sectioning process consisted of dissolving the silicone adhesive between the substrate and the solar cell and between the solar cell and the coverglass. Silgest SD0001 was used as a solvent. The di-sectioning process was performed at 50 ^{O}C for a period of approx. 10 days. After this period the substrate could be removed was easily from the solar cell. With the aid of a small scalpel blade the coverglass could be lifted (or sometimes broken away) from the cell surface. A solar cell assembly is shown in figure 2. The layout of the individual welds can be seen in figure 3.
Weldsize comparison will be performed between these returned samples and samples investigated in the past during the qualification programme. Comparison will also be made with newly manufactured weldjoints.
A total of 100 p-welds, 100 n-welds, 72 busbar welds and 42 newly made welds (18 p, 18 n and 6 busbar welds) were examined. Each weld consists of two weld imprints.

3. INSTRUMENTATION

The instrument employed in this investigation is a SONOSCOPE Model 130 manufactured by SONOSCAN inc. Bensenville, USA. The scanning laser acoustic microscope instrument uses unfocused plane wave ultrasound, which is usually beamed into the bottom surface of a sample. When the ultrasound exits from the top surface, it encounters a this-film gold mirror on a plastic coverslip. The acoustic pressure of the exiting ultrasound creates minute wrinkles in the mirror which accurately replicate the features which the ultrasound encountered during its journey through the sample. A laser beam scans a rectangular area of the coverslip and reflected laser signals impinge on a photodiode which converts the data into electrical signals which are transformed in a video image and displayed on a CRT. The brightness of the image is a direct measure of sound transmission through the sample.

4. RESULTS AND DISCUSSION

The quality of the solar cell to interconnector weld is given by its size and its density. The size and the density of the weld is given by the size of the electrodes, electrode pressure and the current-time integral. The right combination of parameters produces a proper diffusion weld where no melting has taken place. The SLAM image of such a weld is as two squares separated by a small gap and a high acoustic transmission through this area. A natural variation in weld quality exists. As long as this variation is within predefined limits, these welds are acceptable. The weldings returned from HST show this variation and on top of that the effect of thermal cycling is imposed.
When we look at the weld quality of the welds through the width of the solar panel assembly (sample I-Z through III-A) and compare this with the non-cycled virgin samples a small influence of the thermal cycle can be observed. Figures 4a to 4c of the p-welds from samples I-Z 24-25 through II-C 24-25 to III-A 24-25 should be compared with figure 6 of the virgin welds and figures 5a to 5c of the n-welds from the HST samples should be compared with figures 7 of the virgin welds. These SLAM images are typical examples found in these regions. In both cases (n and p-welds) the size as well as the acoustic transmission is smaller, rep. lower than in the case of the virgin samples. This reduction in weld quality should be compared with the welding samples performed during the qualification programme. In this programme welds at beginning of life and after 15000 and 30000 fast thermal cycles between +100 ^{O}C and -100 ^{O}C were evaluated. Some of these results are given in figures 8a to 8c and show the natural variation of the weld quality and the effect of the thermal cycling.
The weldings to the busbar usually show a somewhat lower quality than those on the solar cell as is illustrated in figures 9a to c. Also here the effect of the thermal cycle is present but minimal.

It seems that the stresses due to the thermal expansion are taken by the busbar/interconnector weld and did not influence the weld on the cell at the other side of the interconnector.

5. CONCLUSION

The effect of thermal cycling on the size of the weld area is as expected. In most cases a decrease in weldsize is observed. This weldsize reduction was also observed during qualification programme. The welds on the busbars are somewhat smaller than other welds, while the welds next to the busbar are hardly influenced by the thermal cycle environment on the Hubble Space Telescope.

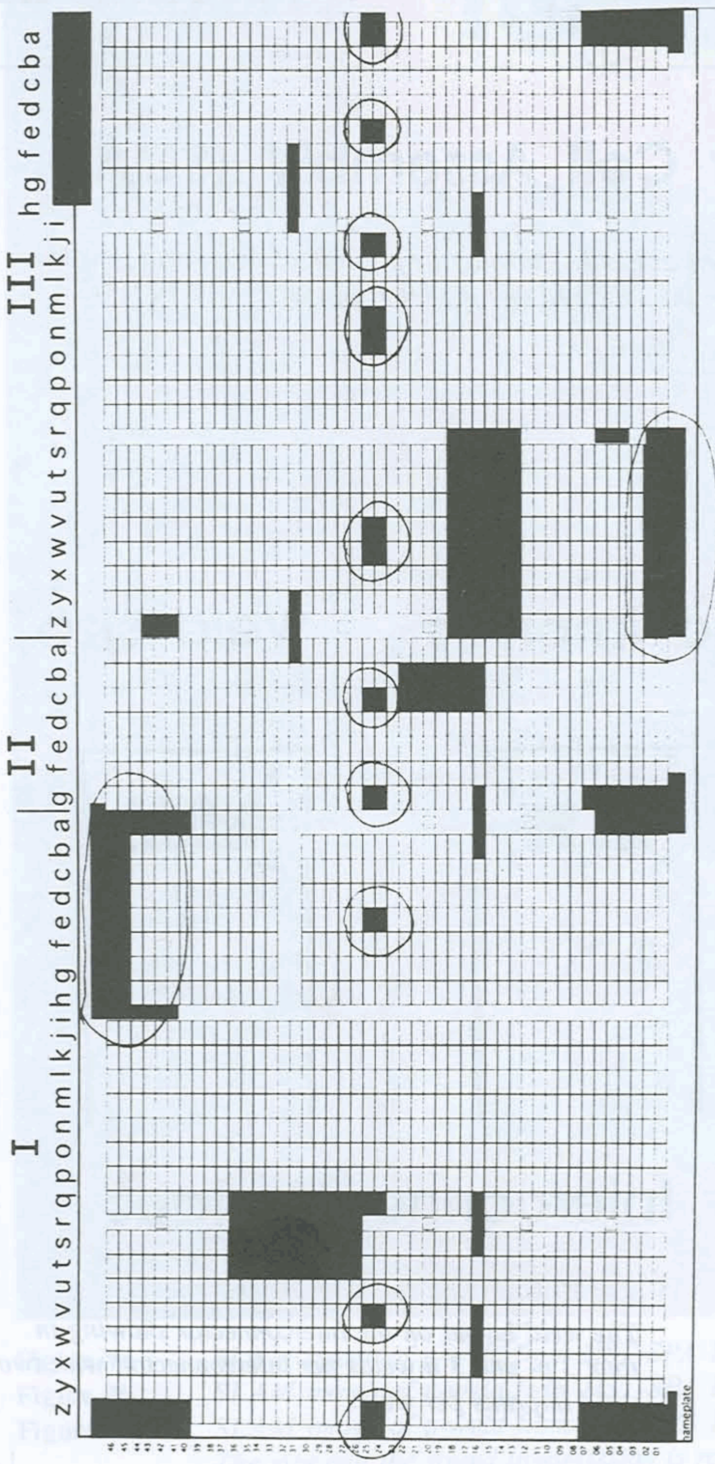


Figure 1. *Sample positions for SLAM investigations. The cut outs are circled.*

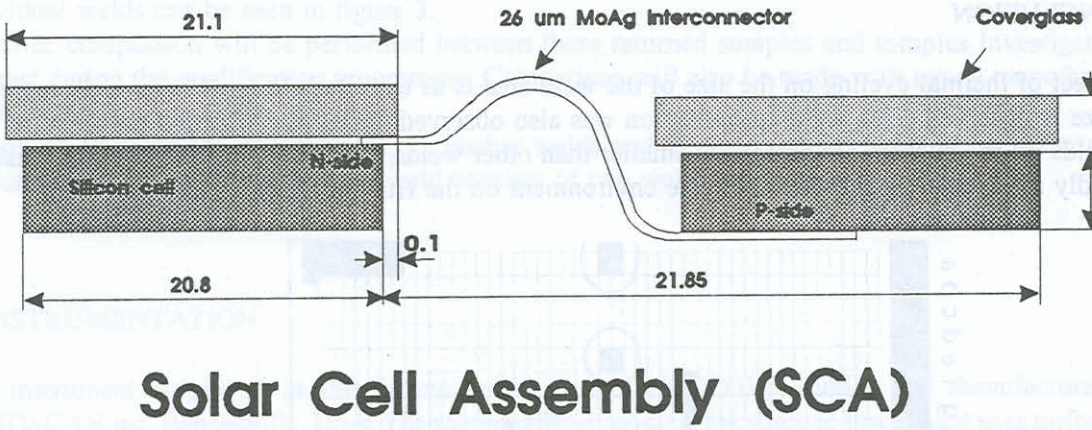


Figure 2. *Solar cell assembly showing the position of the n- and p welds between the solar cell and the interconnector.*

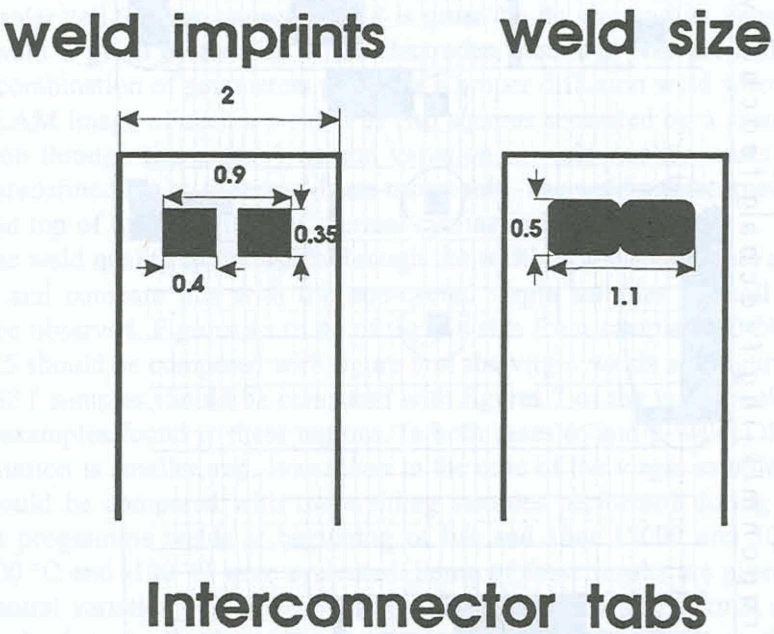
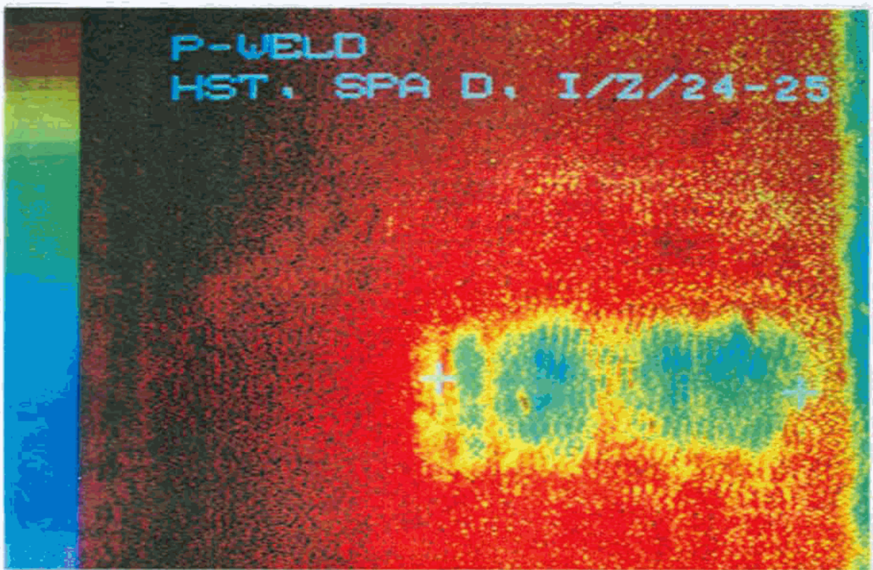
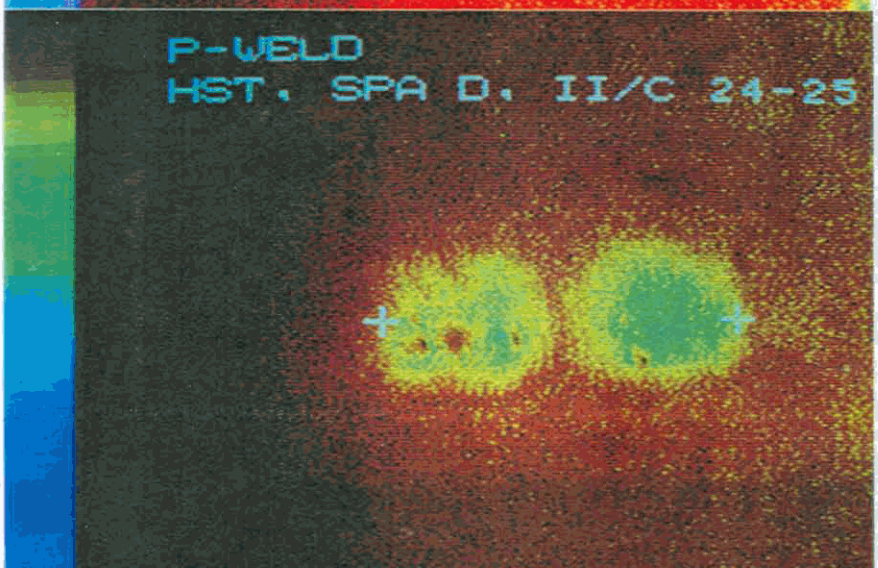


Figure 3. *The weld layout on the interconnector showing in total 3 p- and 3 n welds per interconnector, with two weld imprints per weld.*





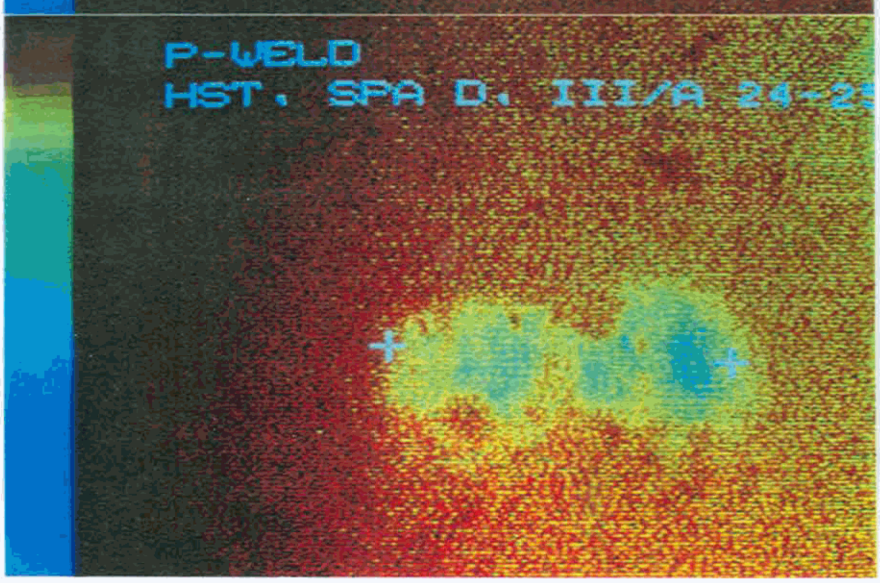


Figure 4a. *SLAM image of p-weld from HST-SPA D, location I-Z 24-25.*
Figure 4b. *SLAM image of p-weld from HST-SPA D, location II-C 24-25.*
Figure 4c. *SLAM image of p-weld from HST-SPA D, location III-A 24-25. The size and the sound transmission is reduced compared to the virgin weld given in figure 6.*

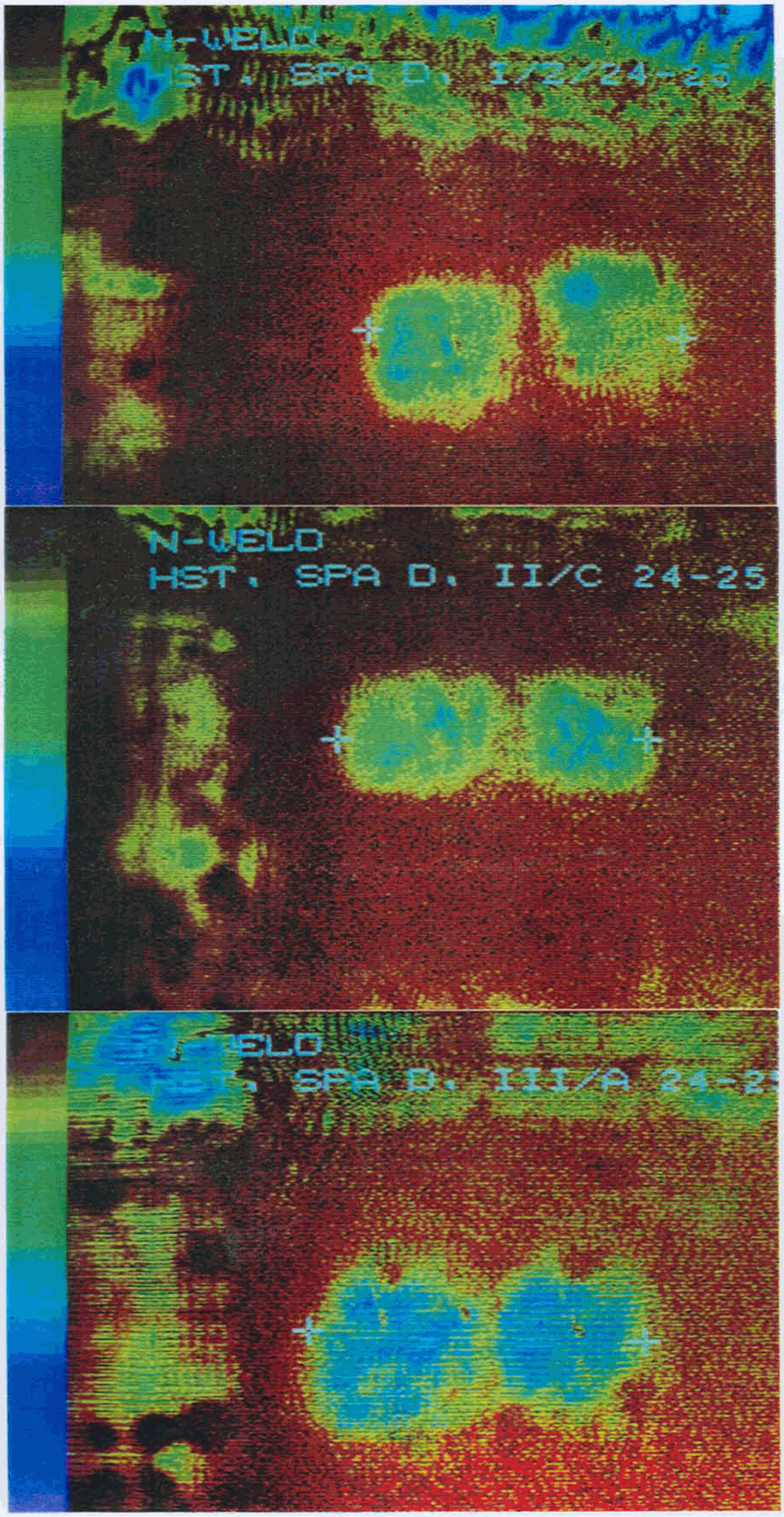


Figure 5a. *SLAM image of n-weld from HST-SPA D, location I/Z 24-25.*
Figure 5b. *SLAM image of n-weld from HST-SPA D, location II/C 24-25.*
Figure 5c. *SLAM image of n-weld from HST-SPA D, location III/A 24-25. The size and the sound transmission is reduced compared to the virgin weld given in figure 7.*

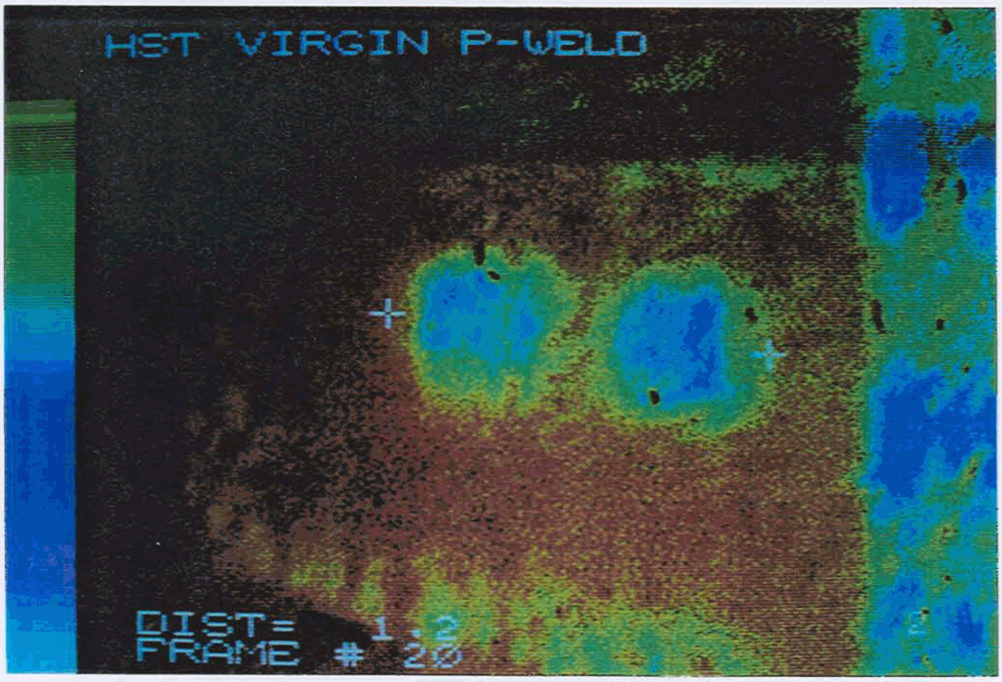


Figure 6. *SLAM image of virgin p-weld (not thermal cycled and not space exposed). Clear defined welds are visible with a good sound transmission.*

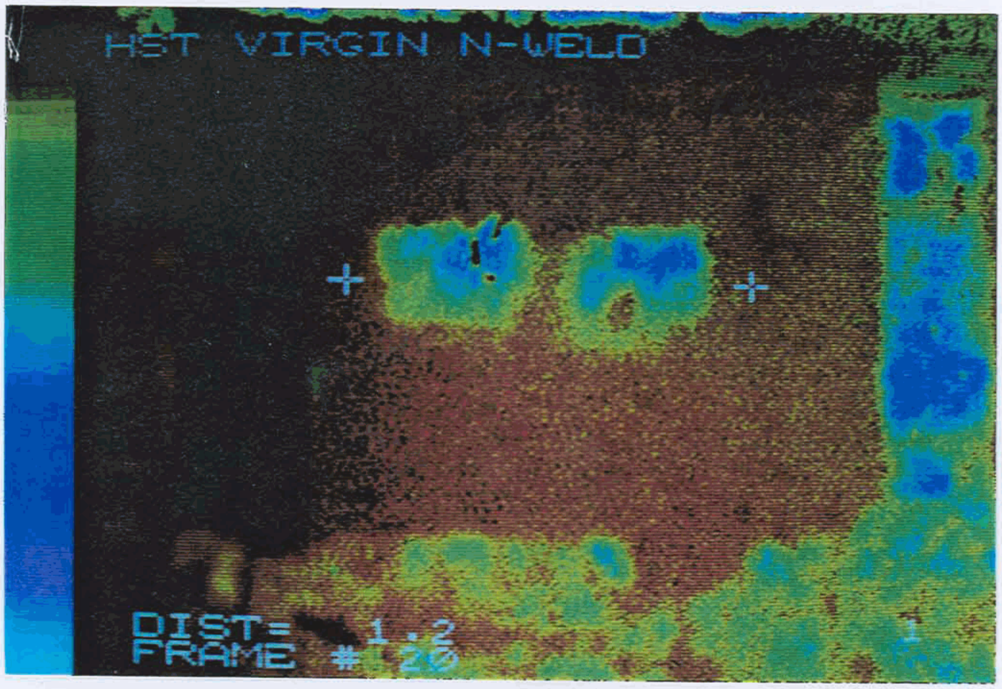


Figure 7. *SLAM image of virgin n-weld (not thermal cycled and not space exposed). Clear defined welds are visible with a good sound transmission.*

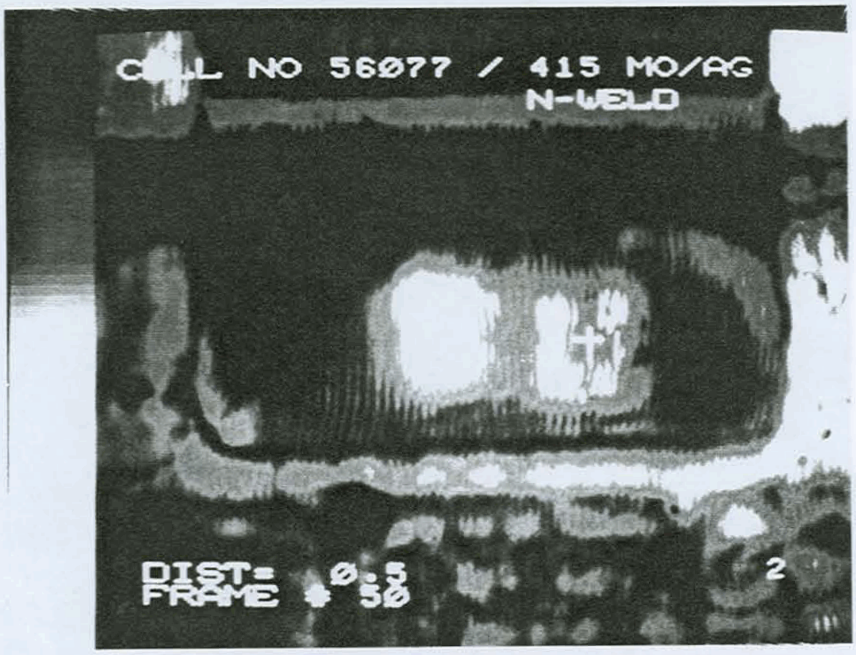


Figure 8a *SLAM image of weld at beginning of life at the start of the qualification programme.*

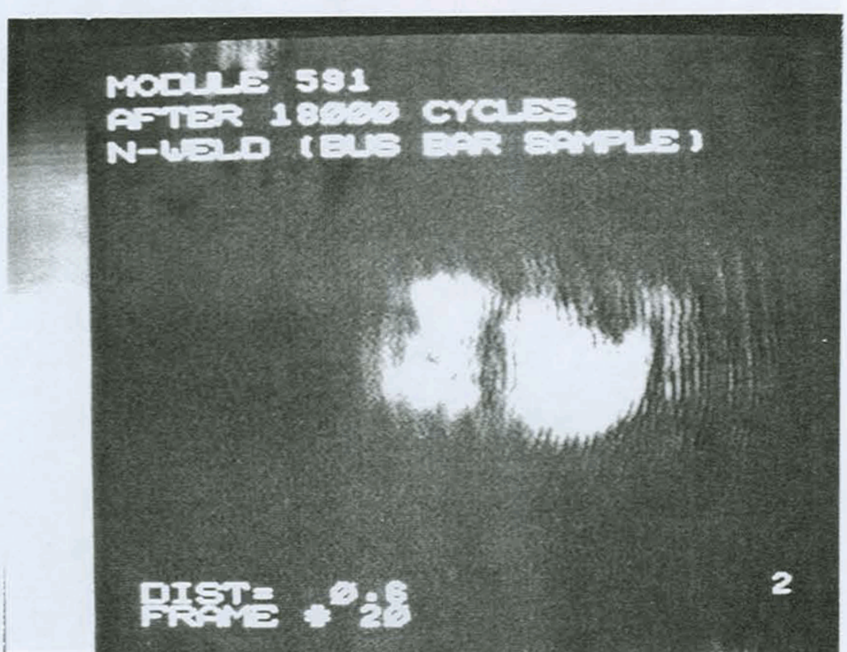
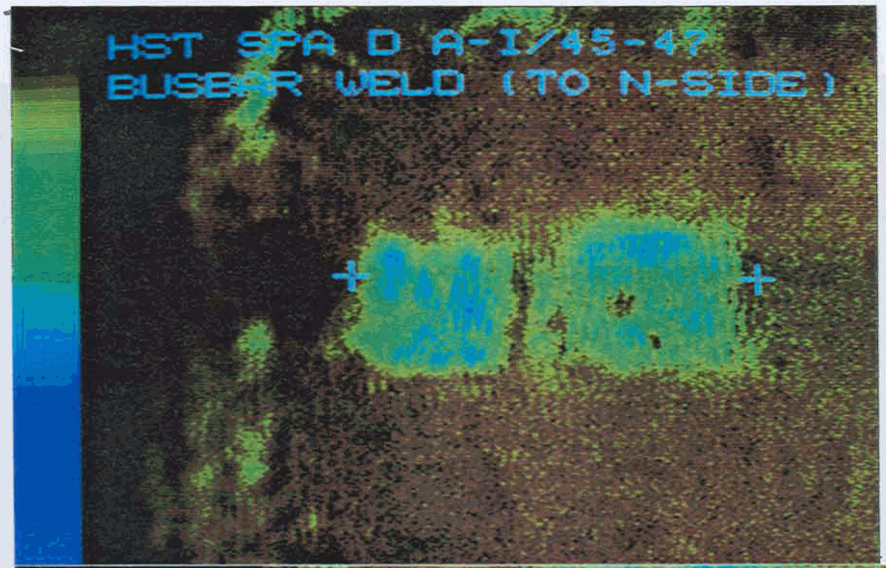
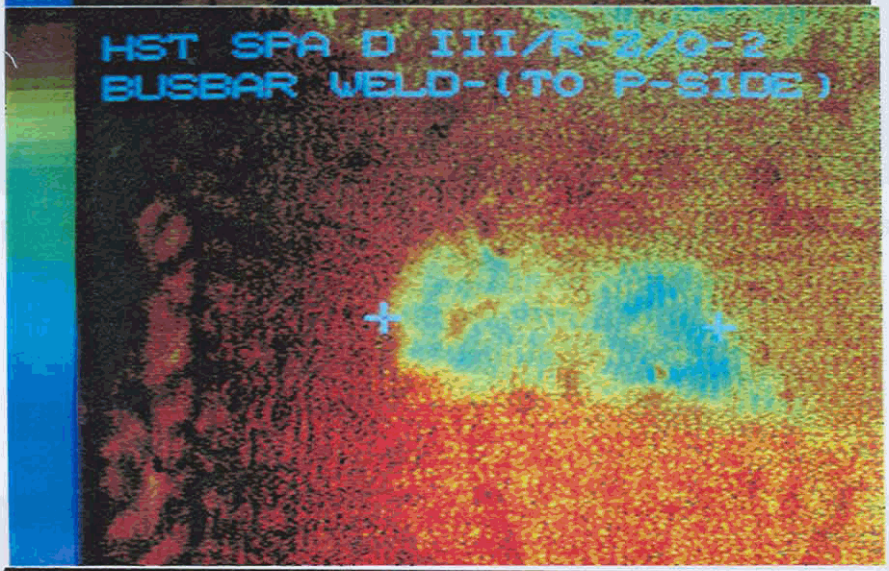


Figure 8b *SLAM image after 18000 thermal cycles between -100 °C and +100 °C, showing a reduction of the weld area.*





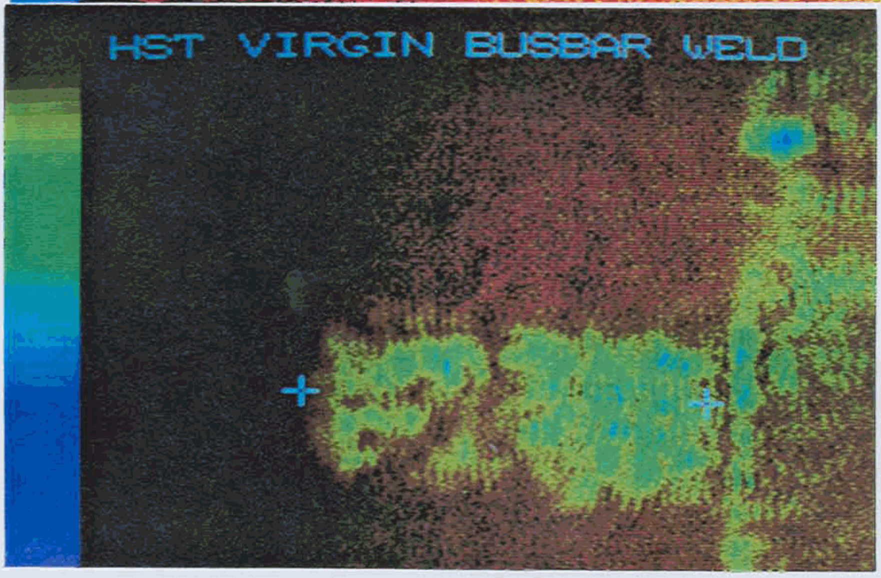


Figure 9a *SLAM image of busbar weld from HST-SPA D, location I/A-I 45-47 (welding to p-side on cell, see figure 10a)*

Figure 9b *SLAM image of busbar weld from HST-SPA D, location III/R-Z 0-2 (welding to n-side on cell)*

Figure 9c *SLAM image of virgin busbar weld (not thermal cycled and not space exposed).*

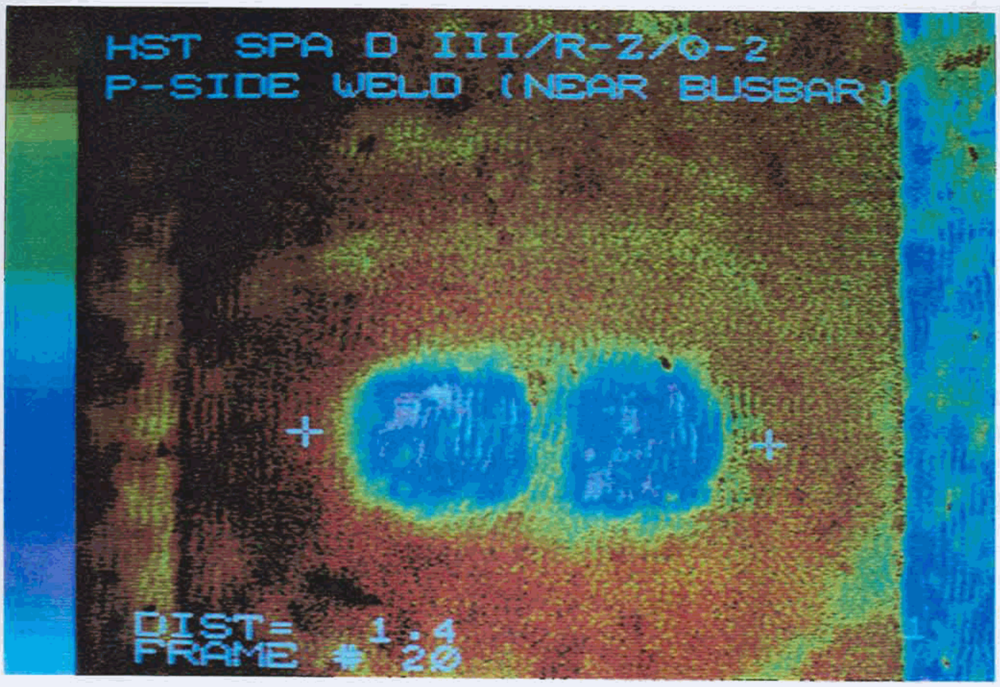


Figure 10a *SLAM image from p-weld of connector connected to busbar, location I/A-I 45-47, see also figure 9a.*

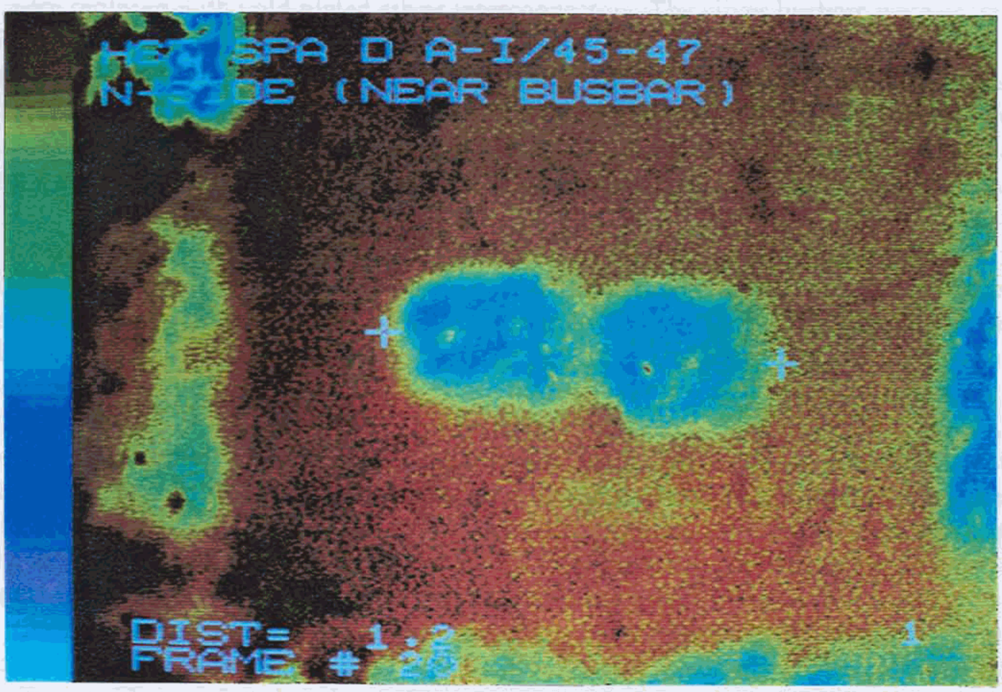


Figure 10b *SLAM image from n-weld of connector connected to busbar, location III/R-Z 0-2, see also figure 9b.*