

NRC Publications Archive Archives des publications du CNRC

B707 lap joint specimen No. 349 - NDI inspections Taremi, F.; Bellinger, N.; Brothers, M.; Gould, R.

For the publisher's version, please access the DOI link below./ Pour consulter la version de l'éditeur, utilisez le lien DOI ci-dessous.

Publisher's version / Version de l'éditeur:

<https://doi.org/10.4224/40002729>

Laboratory Technical Report (National Research Council Canada. Institute for Aerospace Research. Structures, Materials and Propulsion Laboratory); no. LTR-SMPL-2003-0271, 2003-09-25

NRC Publications Archive Record / Notice des Archives des publications du CNRC :

<https://nrc-publications.canada.ca/eng/view/object/?id=86a78733-0669-4025-9956-b9979bd2d5b>

<https://publications-cnrc.canada.ca/fra/voir/objet/?id=86a78733-0669-4025-9956-b9979bd2d5b2>

Access and use of this website and the material on it are subject to the Terms and Conditions set forth at

<https://nrc-publications.canada.ca/eng/copyright>

READ THESE TERMS AND CONDITIONS CAREFULLY BEFORE USING THIS WEBSITE.

L'accès à ce site Web et l'utilisation de son contenu sont assujettis aux conditions présentées dans le site

<https://publications-cnrc.canada.ca/fra/droits>

LISEZ CES CONDITIONS ATTENTIVEMENT AVANT D'UTILISER CE SITE WEB.

Questions? Contact the NRC Publications Archive team at

PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca. If you wish to email the authors directly, please see the first page of the publication for their contact information.

Vous avez des questions? Nous pouvons vous aider. Pour communiquer directement avec un auteur, consultez la première page de la revue dans laquelle son article a été publié afin de trouver ses coordonnées. Si vous n'arrivez pas à les repérer, communiquez avec nous à PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca.

INSTITUTE FOR
AEROSPACE RESEARCH

**REPORT
RAPPORT**

INSTITUT DE RECHERCHE
AEROSPATIALE

Pages: 38

Tables: 4

Figures: 28

STRUCTURES, MATERIALS AND
PROPULSION LABORATORY

LABORATOIRE DES
STRUCTURES, DES MATERIAUX
ET DE PROPULSION

Report No.: **LTR-SMPL-2003-0271**

Date: 25 September 2003

Classification: Unclassified
Distribution: Unlimited

For:

Reference:

LTR-SMPL-2003-0271

**B707 LAP JOINT SPECIMEN No. 349
NDI INSPECTIONS**

Submitted by: N. Bellinger
Presente par:

Approved by:
Approuve par:

Author(s): F. Taremi
Auteur(s): N. Bellinger
M. Brothers
R. W. Gould

THIS REPORT MAY NOT BE PUBLISHED WHOLLY OR
IN PART WITHOUT THE WRITTEN CONSENT OF THE
INSTITUTE FOR AEROSPACE RESEARCH.

CE RAPPORT NE DOIT PAS ETRE REPRODUIT, NI EN
ENTIER PARTIE SANS UNE AUTORISATION ECRITE DE
L'INSTITUT DE RECHERCHE AEROSPATIALE.

Table of Contents

1 INTRODUCTION..... 3

2 NDE EQUIPMENT AND CALIBRATIONS 5

3 SPECIMEN 349A..... 6

3.1 CLOSE VISUAL INSPECTION.....7

3.2 D SIGHT INSPECTION 11

3.3 ULTRASONIC INSPECTIONS..... 15

3.4 EDDY CURRENT INSPECTIONS 15

3.5 PULSED EDDY CURRENT INSPECTIONS..... 16

3.6 X-RAY INSPECTIONS..... 16

4 SPECIMEN 349B..... 18

4.1 CLOSE VISUAL INSPECTION..... 18

4.2 D SIGHT INSPECTION 21

4.3 ULTRASONIC INSPECTIONS..... 24

4.4 EDDY CURRENT INSPECTIONS 24

4.5 PULSED EDDY CURRENT INSPECTIONS..... 25

4.6 X-RAY INSPECTIONS..... 26

5 SPECIMEN 349C..... 28

5.1 CLOSE VISUAL INSPECTION..... 28

5.2 D SIGHT INSPECTION 32

5.3 ULTRASONIC INSPECTIONS..... 35

5.4 EDDY CURRENT INSPECTIONS 35

5.5 PULSED EDDY CURRENT INSPECTIONS..... 36

5.6 X-RAY INSPECTIONS..... 36

6 CONCLUSIONS..... 38

List of Figures

Figure 1. STR24L BS480-600D on B707-338C, s/n 18954 as of 1/17/2000 4

Figure 2. Multi-frequency Eddy Current Calibration..... 5

Figure 3. Pulsed eddy current calibration results..... 6

Figure 4. Front and rear surface views of Specimen 349A..... 8

Figure 5. Photographs showing 349A problem areas..... 10

Figure 6. Schematic of lap joint 349A showing DAIS Placements 1 to 4 and locations of pillowing cracks (Red boxes). 12

Figure 7b). D Sight inspection results for 349A. De-painted, SolidHi..... 14

Figure 8. Ultrasonic C-scan inspection results at 15 MHz for 349A..... 15

Figure 9. Multi Frequency Eddy Current inspection results at four frequencies for Specimen 349A..... 15

Figure 10. Pulsed eddy current inspection results for Specimen 349A 16

Figure 11. Sketch of Specimen 349A. Numbered boxes indicate nominal location of test coupons..... 17

Figure 12. Front and Rear surface views of lap joint Specimen 349B. 19

Figure 13. Close-up photographs showing various problem areas for Specimen 349B. 20

Figure 14. Schematic of lap joint 349B showing DAIS Placements 1 to 4 and locations of pillowing cracks (Red boxes).	21
Figure 15b). D Sight inspection results for 349B, De-painted, SolidHi.	23
Figure 16. Ultrasonic inspection results using a frequency of 15 MHz for Specimen 349B.....	24
Figure 17. Multi Frequency Eddy Current inspection results for Specimen 349B.....	24
Figure 18. Pulsed eddy current inspection result for Specimen 349B.	25
Figure 19. . X-ray inspection result for a section of lap joint 349B.....	26
Figure 20. Sketch of Specimen 349B. Numbered boxes indicate nominal location of test coupons.....	27
Figure 21. Front and Rear surface views of lap joint Specimen 349C.....	29
Figure 22.. Photographs showing problem areas in lap joint of Specimen 349C.....	31
Figure 23. Schematic of lap joint 349C showing DAIS Placements 1 to 4 and locations of pillowing cracks (Red boxes).	32
Figure 24b). D Sight inspection results for lap joint 349C. De-painted, SolidHi.....	34
Figure 25. Ultrasonic inspection results at a 15 MHz frequency for Specimen 349C.	35
Figure 26. Multi Frequency Eddy current inspection results for Specimen 349C.	35
Figure 27. Pulsed eddy current inspection result for Specimen 349C.	36
Figure 28. Sketch of Specimen 349C. Numbered boxes indicate nominal location of test coupons.....	37

List of Tables

Table 1. Specimen identification and NDE inspection summary	3
Table 2. Specimen 349A Visual Inspection results	7
Table 3 Specimen 349B Visual Inspection results.....	18
Table 4. Specimen 349C Visual Inspection results.....	28

1 Introduction

Three lap joint sections taken from a B707 aircraft were initially inspected using x-ray inspection techniques to determine if corrosion pillowing cracks were present. Since numerous pillowing cracks were found in all three lap joints, four other nondestructive inspection (NDI) techniques were used to characterize the damage present in each joint. A visual inspection was first made to assess the damage present on the outer surfaces of each joint (both inboard and outboard skins). The NDI techniques that were used included multi frequency eddy current, pulsed eddy current, ultrasonic (C Scan) and D Sight™ inspections. The level of corrosion and corrosion pillowing that was present in these specimens was sufficient to cause a number of the rivet heads to “fail”. Some of the rivets had been replaced, probably during prior maintenance but had since failed due to the stress caused by the corrosion pillowing. There was also corrosion present on the inboard surface as well as on the stringers. The paint had not been stripped and there were no surface cracks visually apparent. The three specimens were separately inspected and all the results obtained are shown in the figures presented below. The eddy current inspections were carried out using four different frequencies 1.1 kHz, 2.4 kHz, 4.3 kHz and 9.6 kHz. Ultrasonic inspection was performed at a frequency of 15 MHz. The X-ray inspection displayed several cracks around the majority of the rivets. High beam energy levels were required to detect pillowing cracks in the intact joint and resulted in extremely dark images thus only one X-ray image, from 349B, is shown in this report. From all of the x-ray inspections the areas indicated to have significant pillowing cracks are noted on the schematic of each specimen.

The three specimens were sectioned from one contiguous joint 145 inches long by 20 inches high, harvested from Stringer 24 Left on a retired aircraft in February 2001 (Figure 1). The original specimen was catalogued in the IAR Aircraft Specimen Library as No. 349. The parent aircraft was a B707-338C manufactured in December 1965 and withdrawn from use November 1985 and placed in storage in Tucson, AZ. The general information for the three specimens is given in Table 1.

ASL No.	SPECIMEN	JOINT TYPE	LOCATION	Dimensions (inch) Longitudinal x Circumferential	Skin Thickness (inch) Upper / Lower	NDE Inspections				
						D Sight	X-ray	Eddy Current	Pulsed Eddy Current	Ultrasonic
349A	N449J-01A	Lap	STR24L BS<480->520	48.25 x 20	0.054 / 0.045	Y	Y	Y	Y	Y
349B	N449J-01B	Lap	STR24L BS>520->560	47 x 20	0.054 / 0.045	Y	Y	Y	Y	Y
349C	N449J-01C	Lap	STR24L BS<580->600D	49 x 20.75	0.055 / 0.046	Y	Y	Y	Y	Y

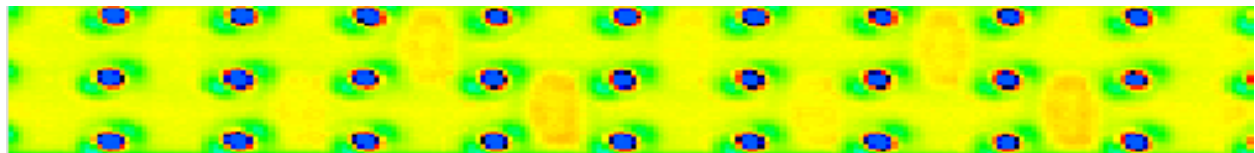
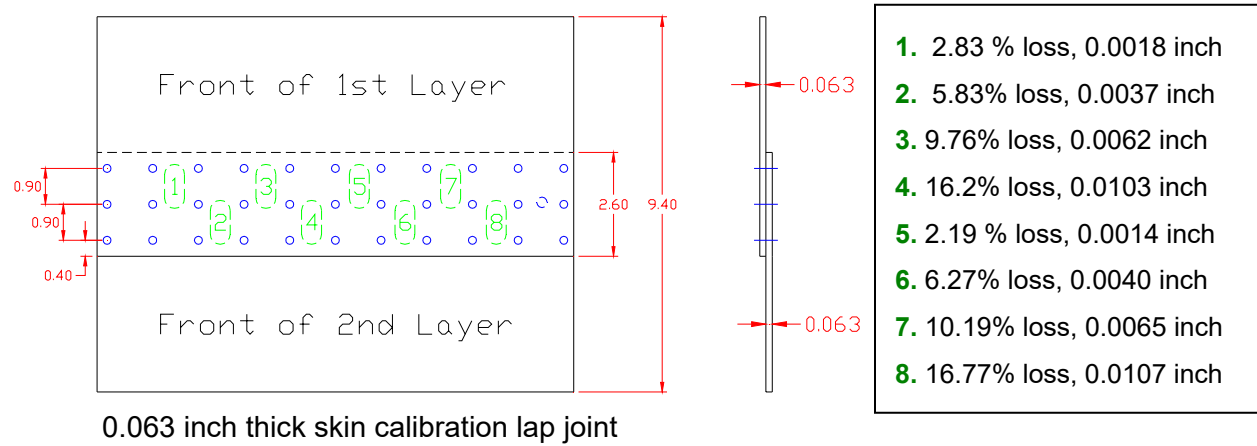
Table 1. Specimen identification and NDE inspection summary



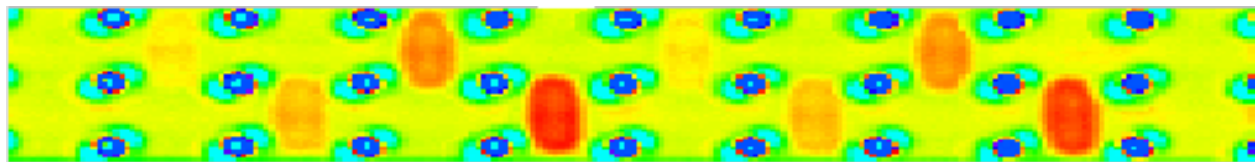
Figure 1. STR24L BS480-600D on B707-338C, s/n 18954 as of 1/17/2000

2 NDE Equipment and Calibrations

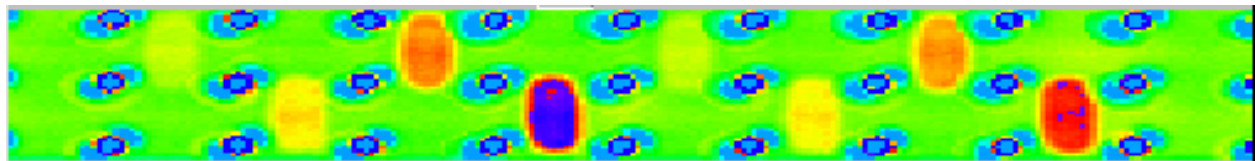
Prior to carrying out the eddy current inspections, a calibration was performed on a lap joint that contain measured amounts of machined thickness loss and the results are shown in Figure 2. **Error! Reference source not found..**



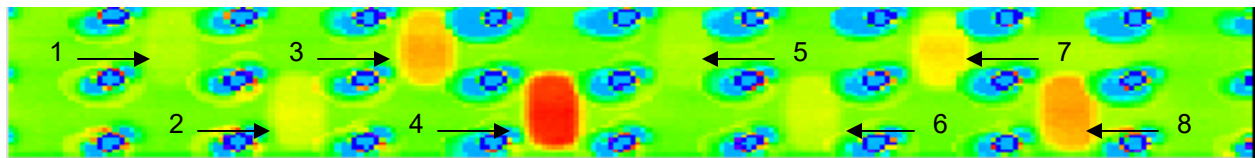
(a) MFEC Cal 1.1 kHz



(b) MFEC Cal 2.4 kHz



(c) MFEC Cal 4.3 kHz



(d) MFEC Cal 9.6 kHz

Figure 2. Multi-frequency Eddy Current Calibration

The Pulsed Eddy Current calibration was performed on the same master as used for the multi-frequency eddy current equipment and the results are shown in Figure 3.

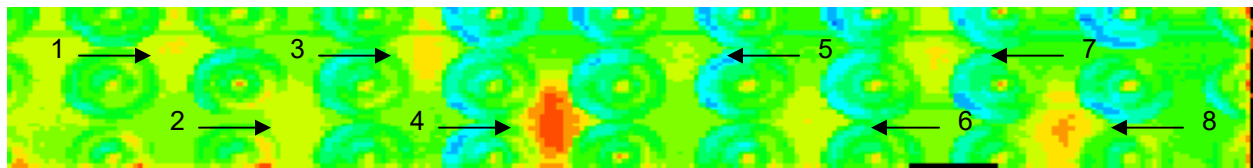
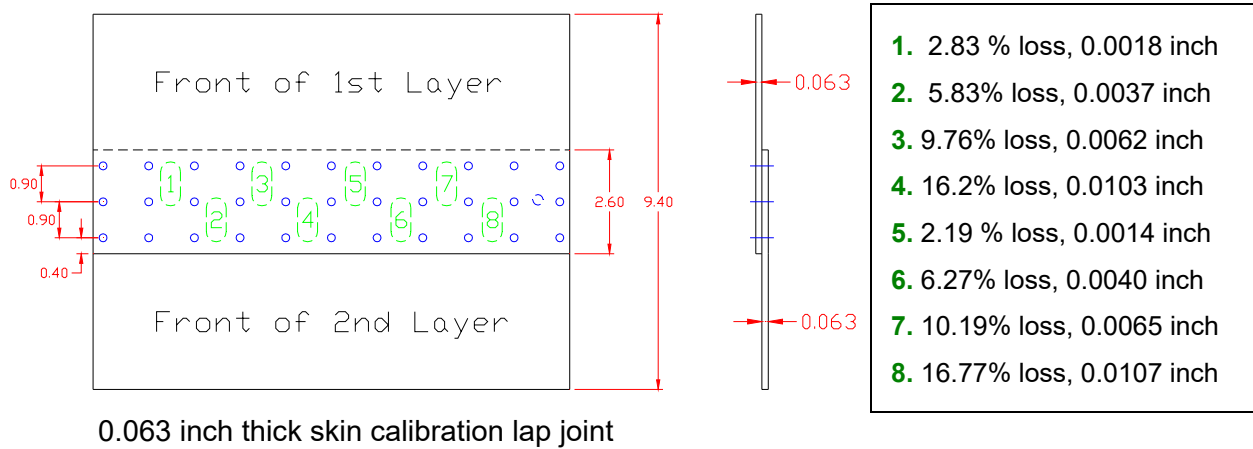


Figure 3. Pulsed eddy current calibration results.

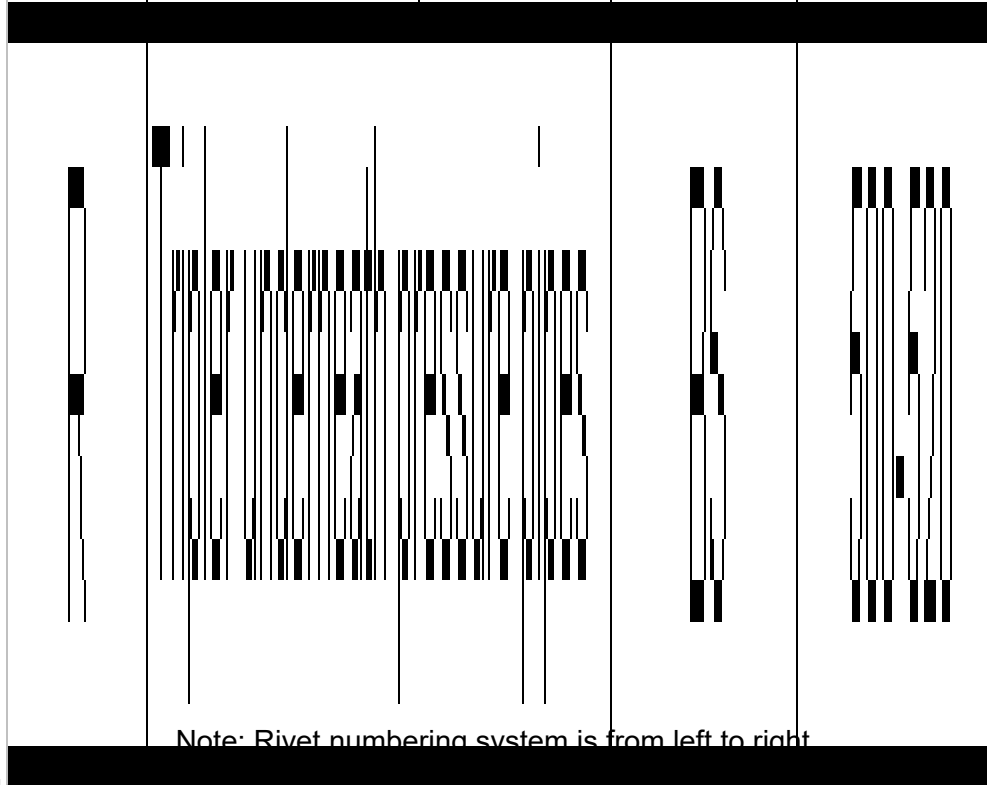
3 Specimen 349A

This 48.25 inch long lap joint specimen was located between BS480 and BS520 on STR24L. There is an internal skin doubler at the BS480 fuselage frame. The pilot's and co-pilot's data probe mounted above the lap joint between BS510-520 incorporates both a skin doubler and a tripler. Front and rear surface images of this specimen are shown in Figure 4.

3.1 C

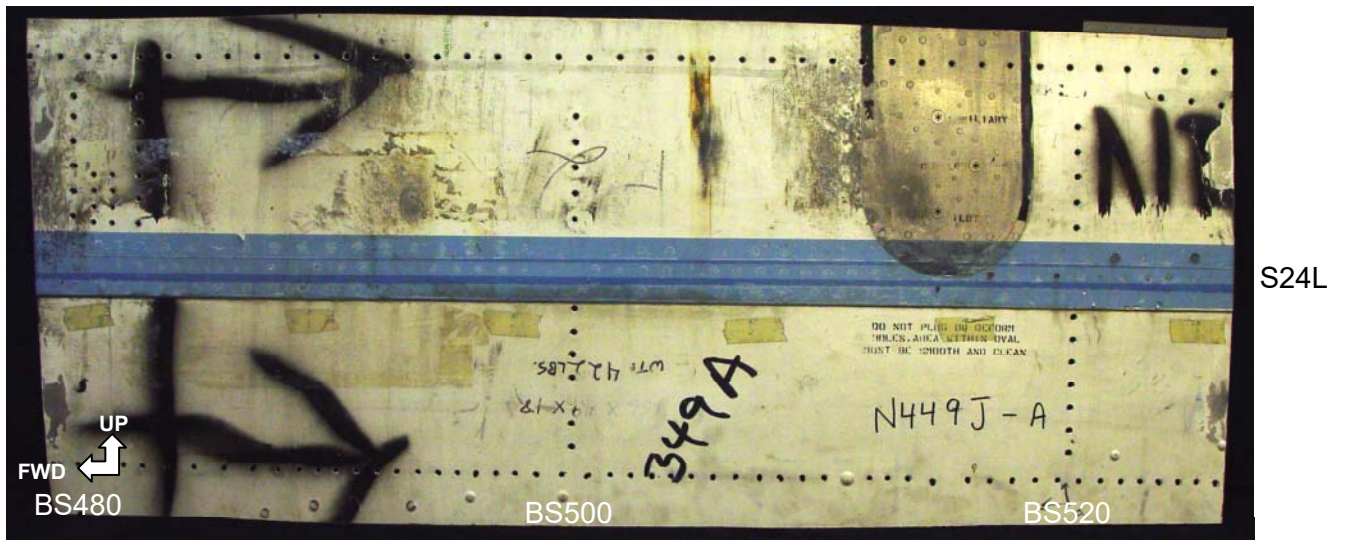
The specimen and adjacent rivets replaced with new rivets. No pitting was observed. Rivets replaced/fabricated: none. No source of failure was found.

The surface had been cracked or pitted. No source of failure was found.

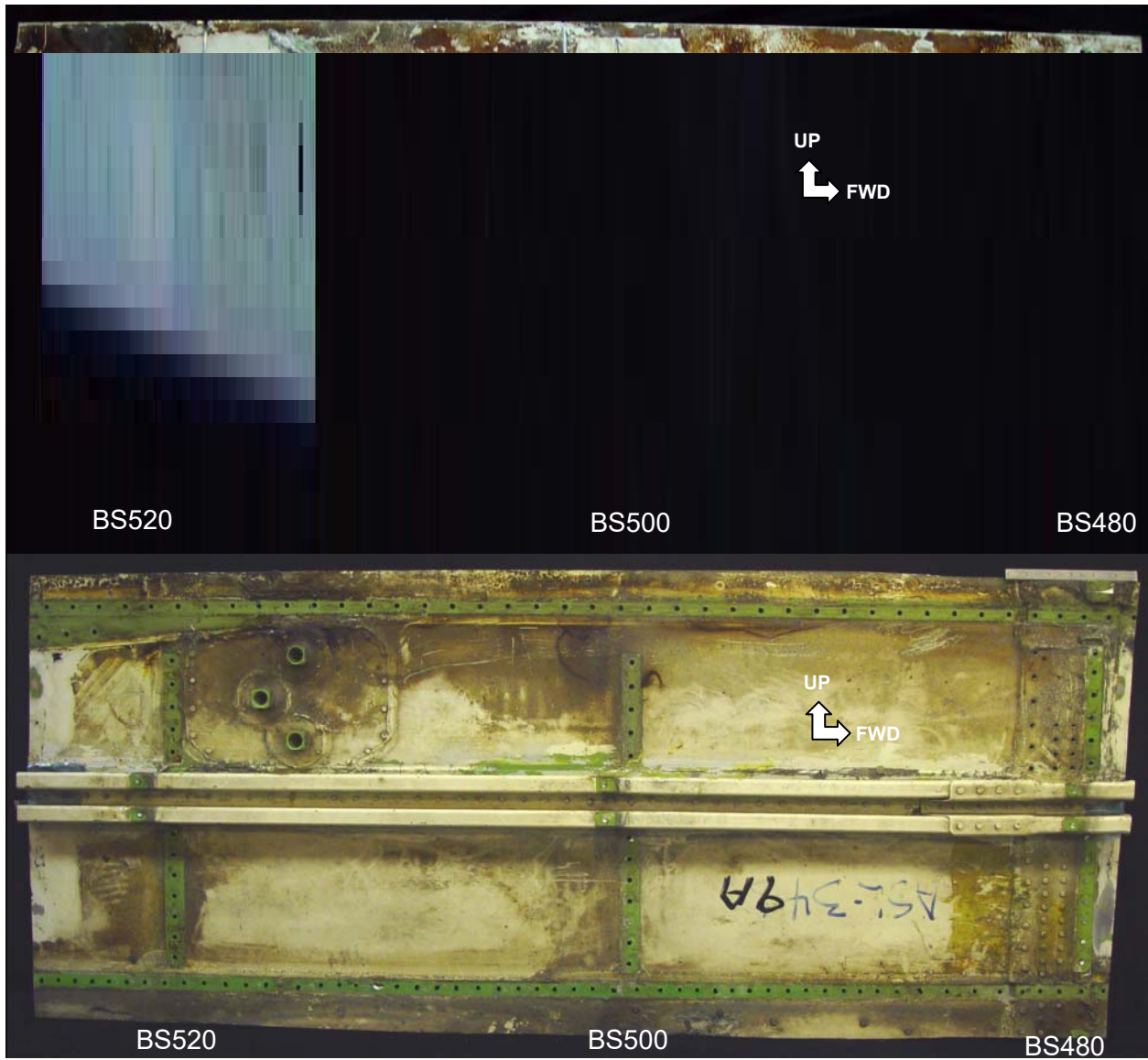


Note: Rivet numbering system is from left to right

Table 2. Specimen 349A visual inspection results



(a) Front view



(b) Rear views before and after substructure removal

Figure 4. Front and rear surface views of Specimen 349A



T 40

T 43

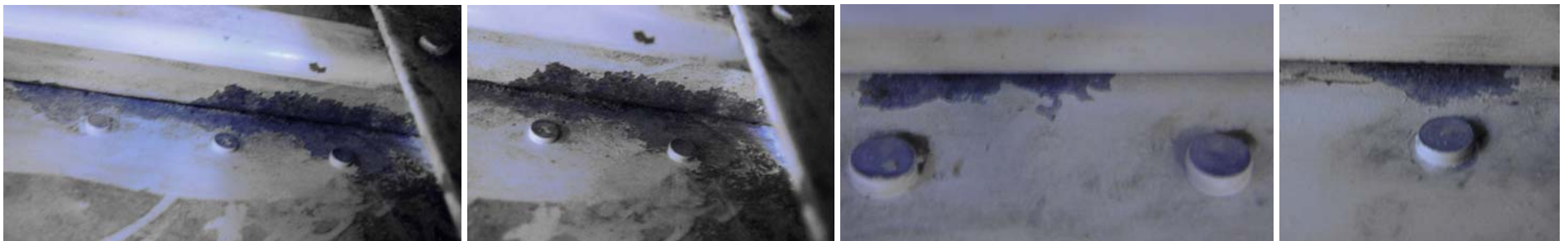
RH: M 46 - 54



M15 (failed 02/12/2004) M 44

M 47

M 52,53



B 22 - 24 Rear

B 22 - 23 Rear

B 32-33 Rear

B 42 Rear

Figure 5. Photographs showing 349A problem areas.

3.2 D Sight Inspection

A drawing of 349A is shown in Figure 6**Error! Reference source not found.** The specimen was inspected for corrosion using the D Sight™ Aircraft Inspection System (DAIS). A DIAS-250C inspection head was used resulting in inspection images covering 23 inches of joint length at a time. As a result, four D Sight images were obtained to cover the entire length of the joint (nominal 50% overlap). These images are shown in Figure 7a)**Error! Reference source not found.**

Significant amounts of corrosion pillowing as well as failed and deformed rivets were observed. An advantage of using D Sight over other automated NDI methods was that the ends of the specimen could be inspected. The surface roughness can significantly affect the D Sight images because this technique uses reflected light to highlight the out of plane deformation caused by corrosion pillowing. To obtain better D Sight signatures of the joint surface the paint was removed. The surface was inspected with the aid of SolidHi™ as negative pressure was applied to conform a 10 mil black vinyl sheet. The use of the SolidHi technique provided uniform reflectivity over the inspection area. These inspection images are shown in Figure 7b).

Figure 6 is also used to mark the areas containing pillowing cracks as detected by X-ray inspection of the joint.

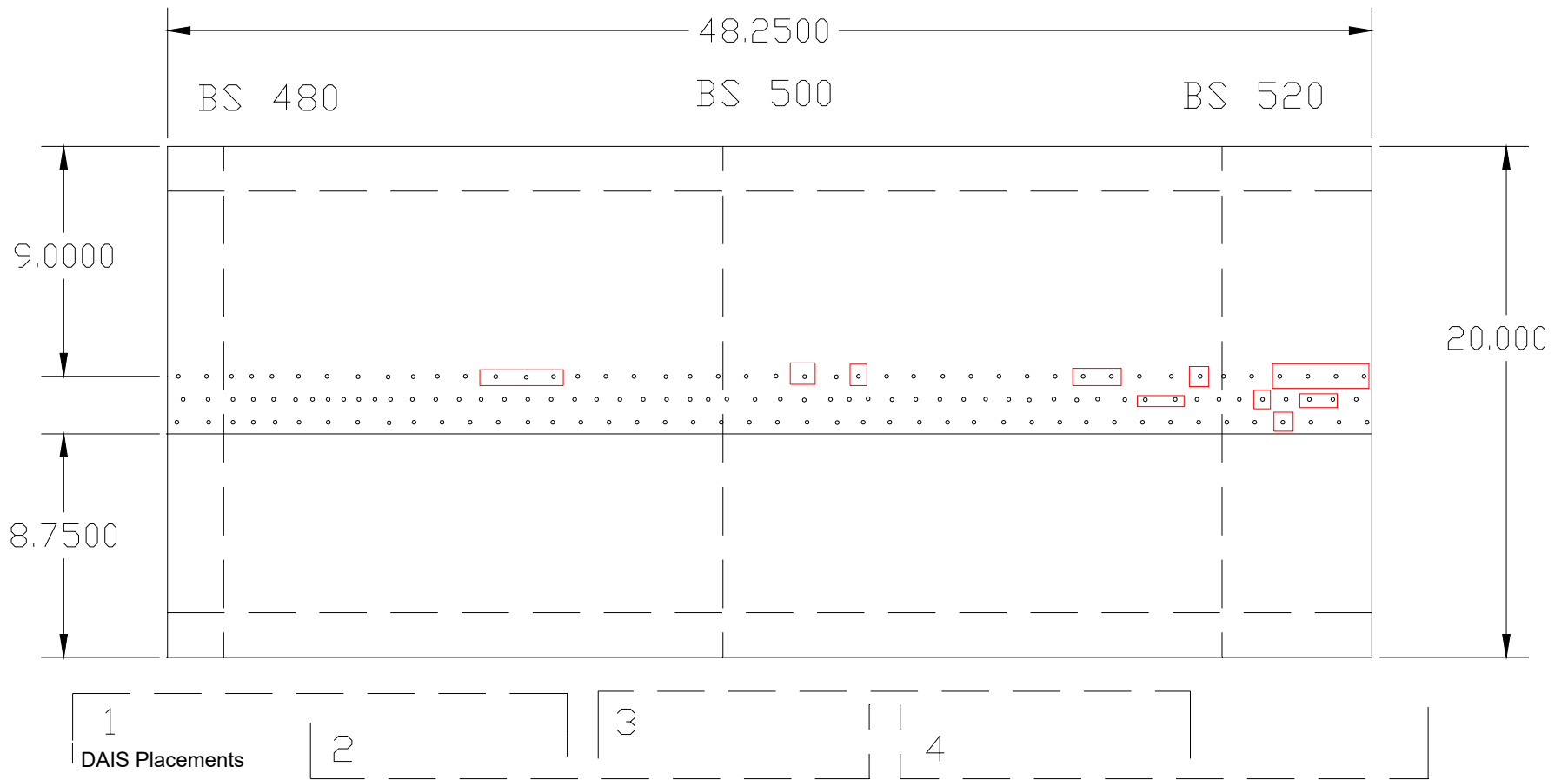
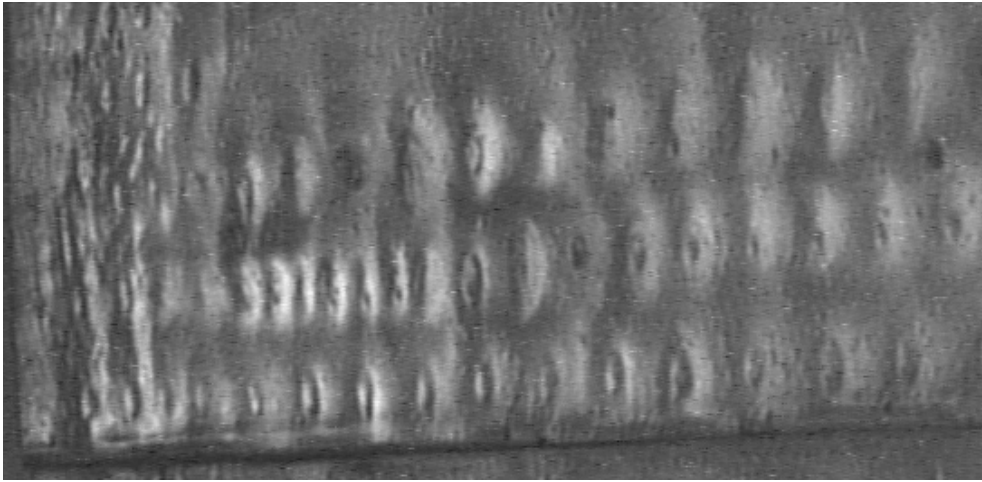
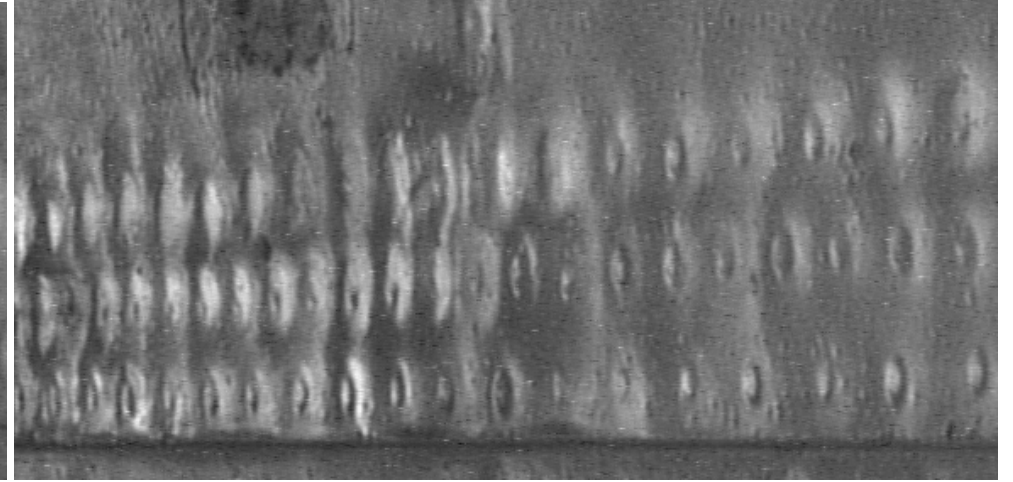


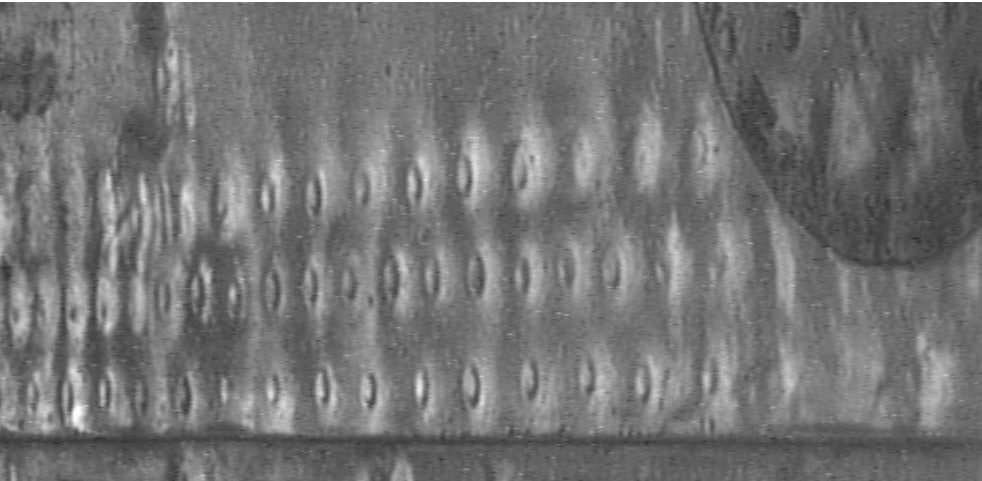
Figure 6. Schematic of lap joint 349A showing DAIS Placements 1 to 4 and locations of pillowing cracks (Red boxes).



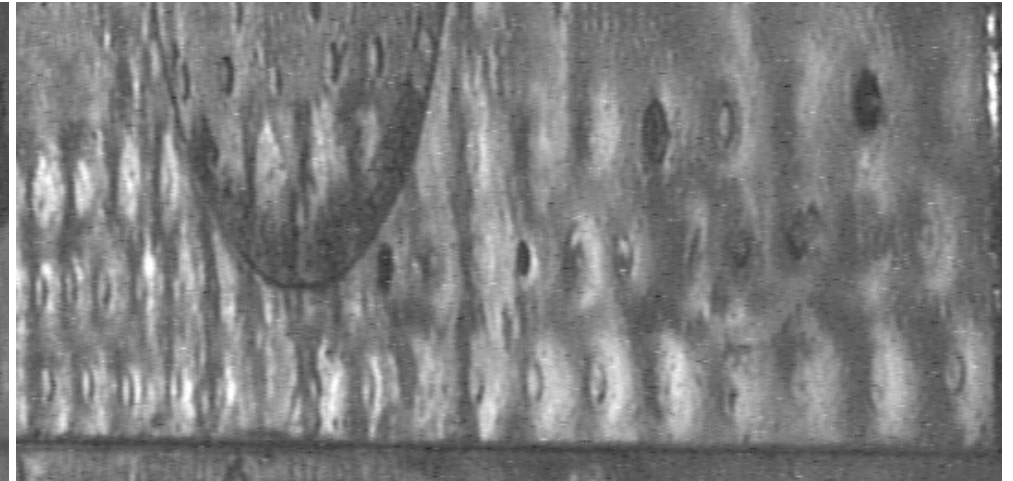
1



2

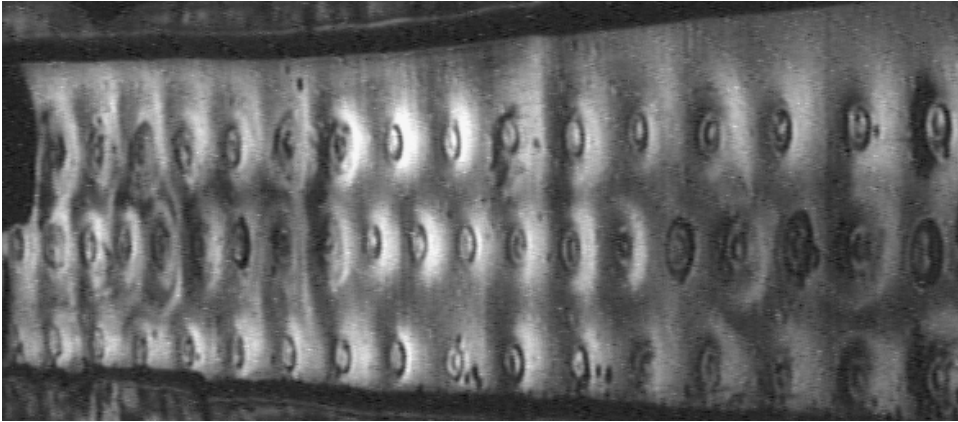


3

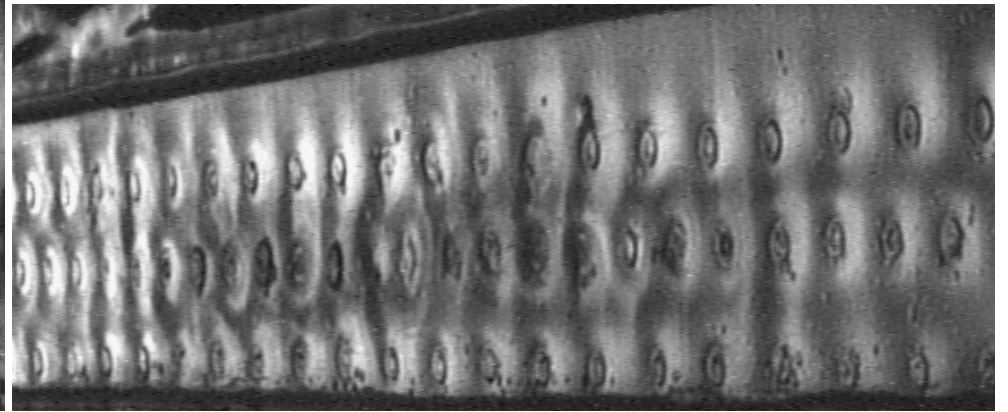


4

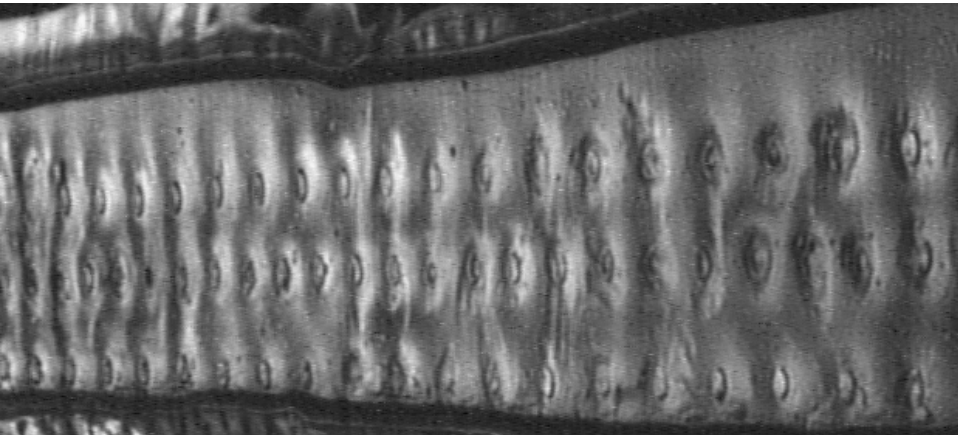
Figure 7a). D Sight inspection results for 349A - Painted.



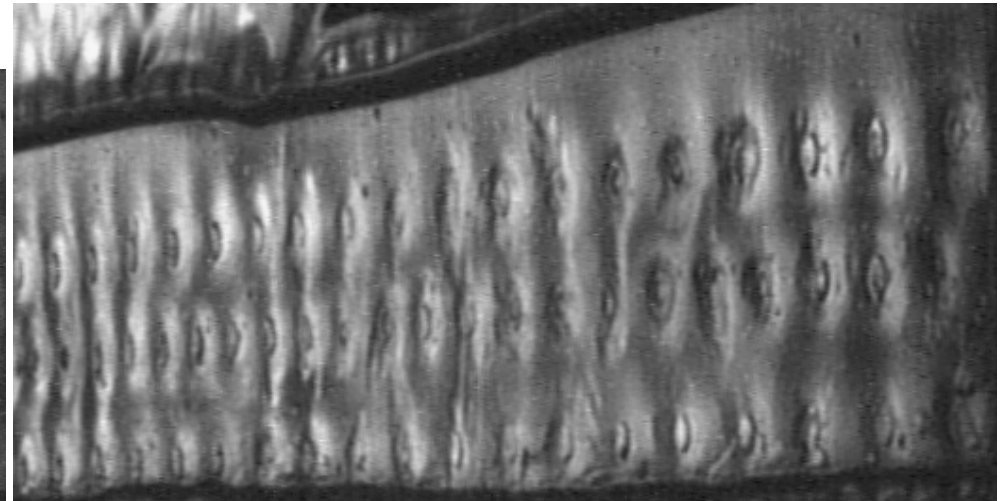
1



2



3



4

Figure 7b). D Sight inspection results for 349A. De-painted, SolidHi.

3.3 Ultrasonic Inspections

Since this specimen was 48.25 inches long, two Ultrasonic inspections were carried out and the combined results are shown in Figure 8 **Error! Reference source not found.**

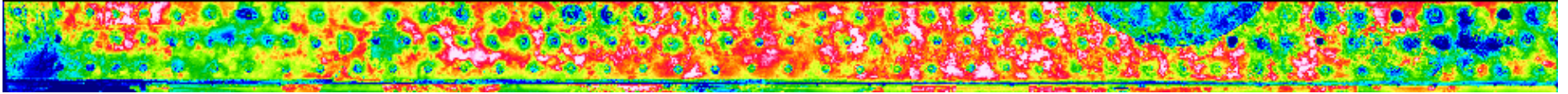
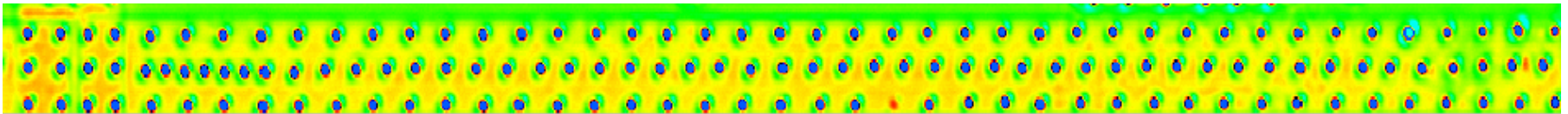
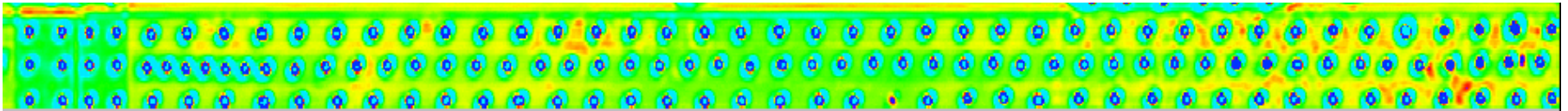


Figure 8. Ultrasonic C-scan inspection results at 15 MHz for 349A.

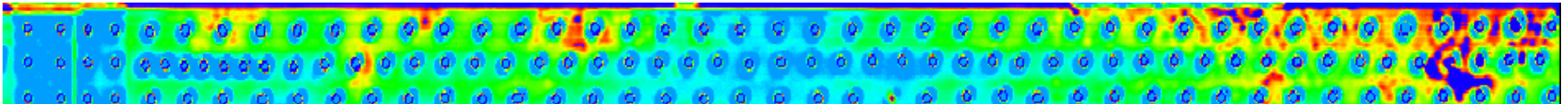
3.4 Eddy Current Inspections



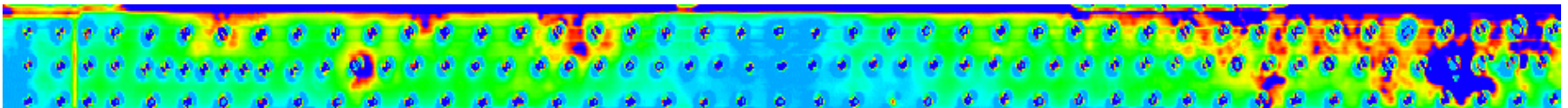
a) MFEC at 1.1 kHz.



b) MFEC at 2.4 kHz.



c) MFEC at 4.3 kHz.



d) MFEC at 9.6 kHz.

Figure 9. Multi Frequency Eddy Current inspection results at four frequencies for Specimen 349A

3.5 Pulsed Eddy Current Inspections

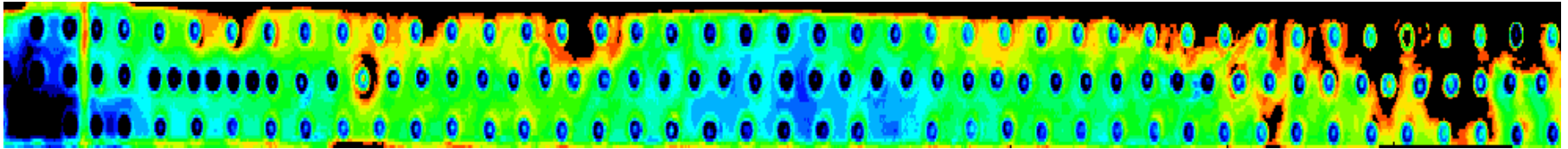


Figure 10. Pulsed eddy current inspection results for Specimen 349A

3.6 X-ray Inspections

The X-ray inspection results are not presented for this lap joint. The areas of X-ray detected pillowing cracks are marked with red boxes in Figures 6 and 11.

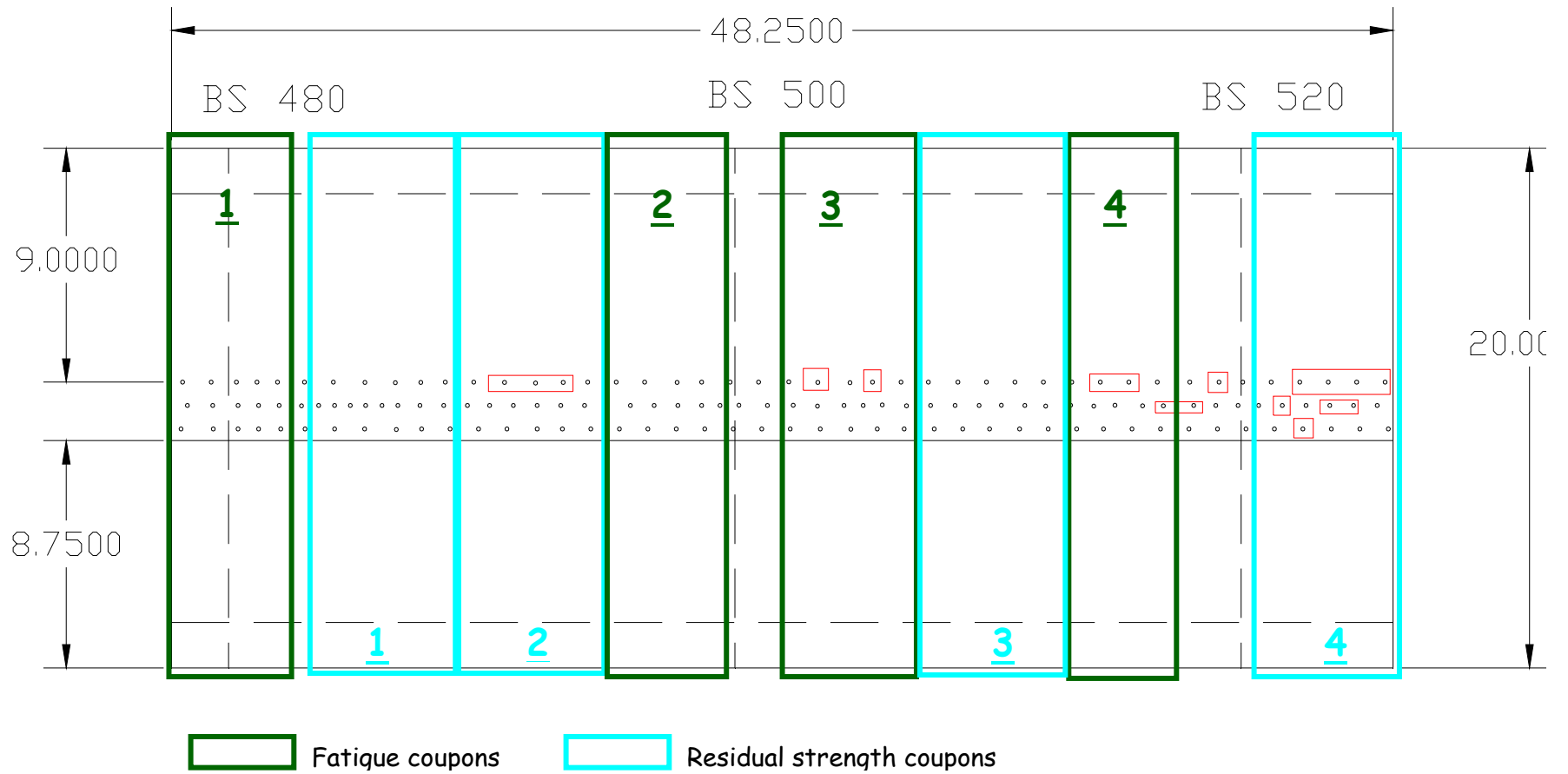
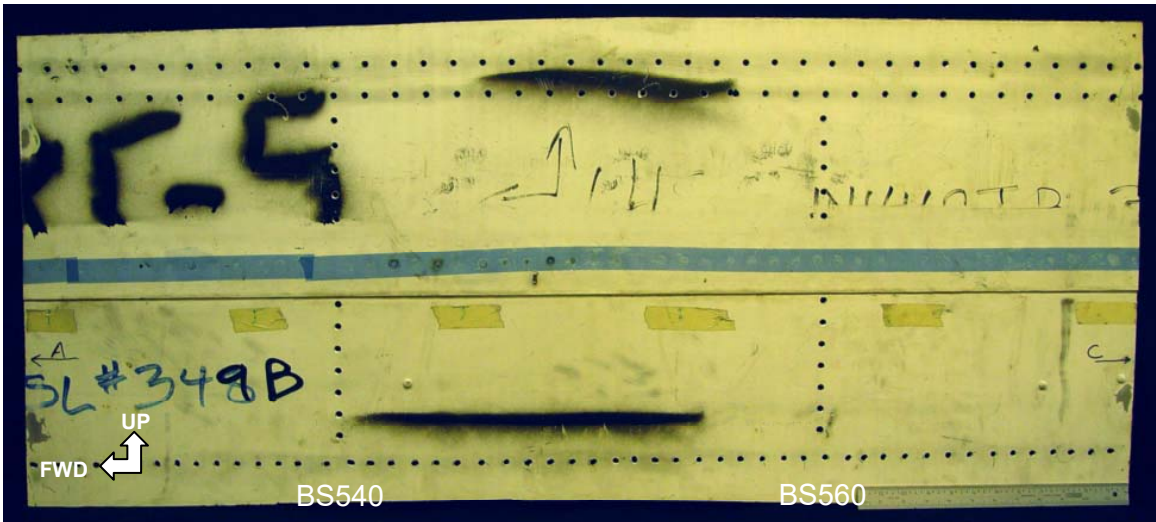
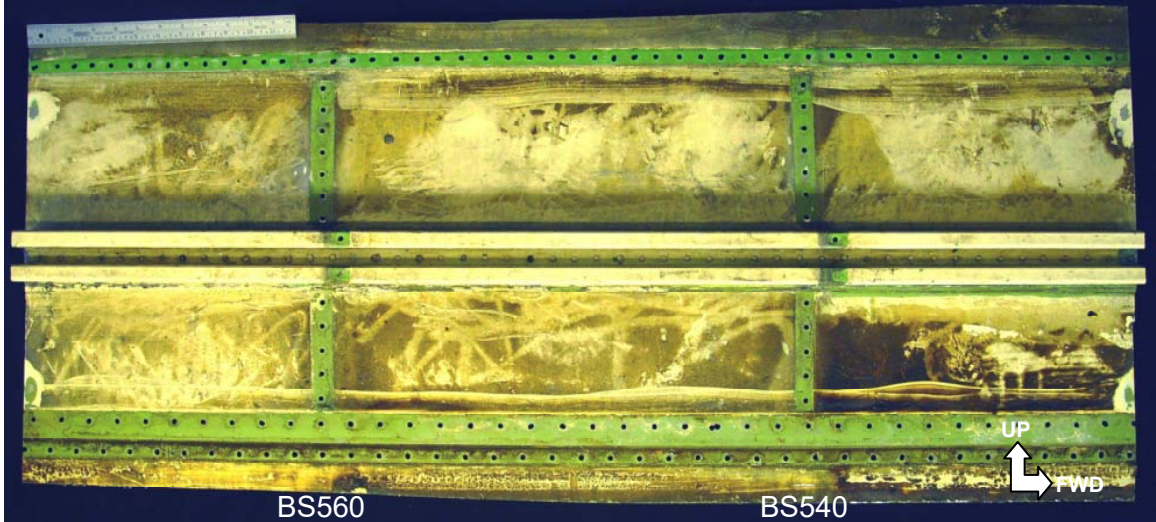


Figure 11. Sketch of Specimen 349A. Numbered boxes indicate nominal location of test coupons.

Boxes (Red) indicate presence of pillowing cracks.

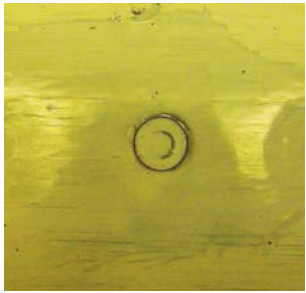


(a) Front view

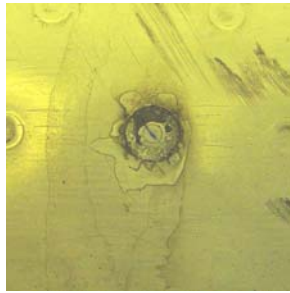


(b) Rear view before and after substructure removal

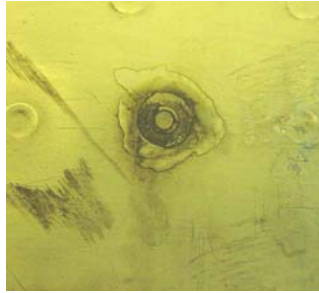
Figure 12. Front and Rear surface views of lap joint Specimen 349B.



M 8



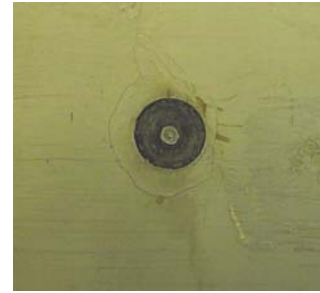
M 17



M 19



M 21



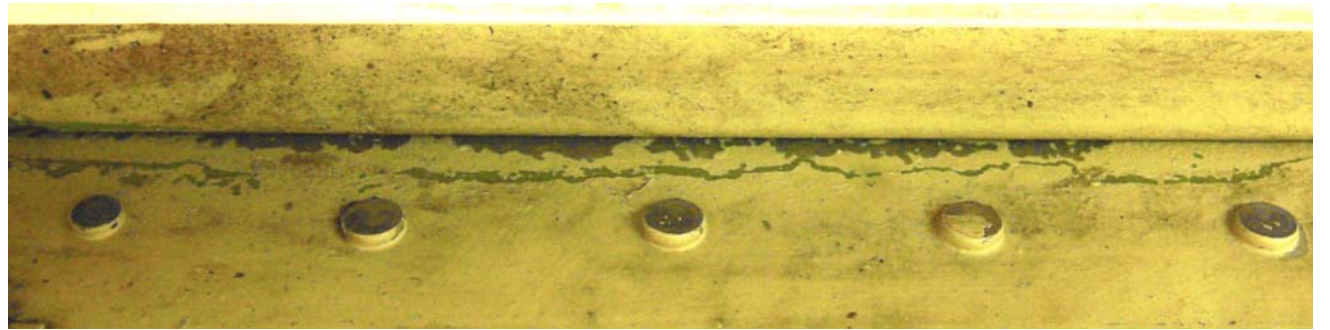
M 24



M 25



M 22, 23



B 8 - 12 Rear

Figure 13. Close-up photographs showing various problem areas for Specimen 349B.

4.2 D Sight Inspection

A schematic of lap joint 349B showing the location of the DAIS 250C inspections is shown in Figure 14. Four D Sight images were taken with 50% overlap to cover the total length of the joint and the results are shown in Figure 15a. To obtain better D Sight signatures of the joint surface the paint was removed. The surface was inspected with the aid of SolidHi and negative pressure to conform a 10 mil black vinyl sheet. These inspection images are shown in Figure 15b). Figure 14 is also used to mark the areas containing pillowing cracks as detected by X-ray inspection of the joint.

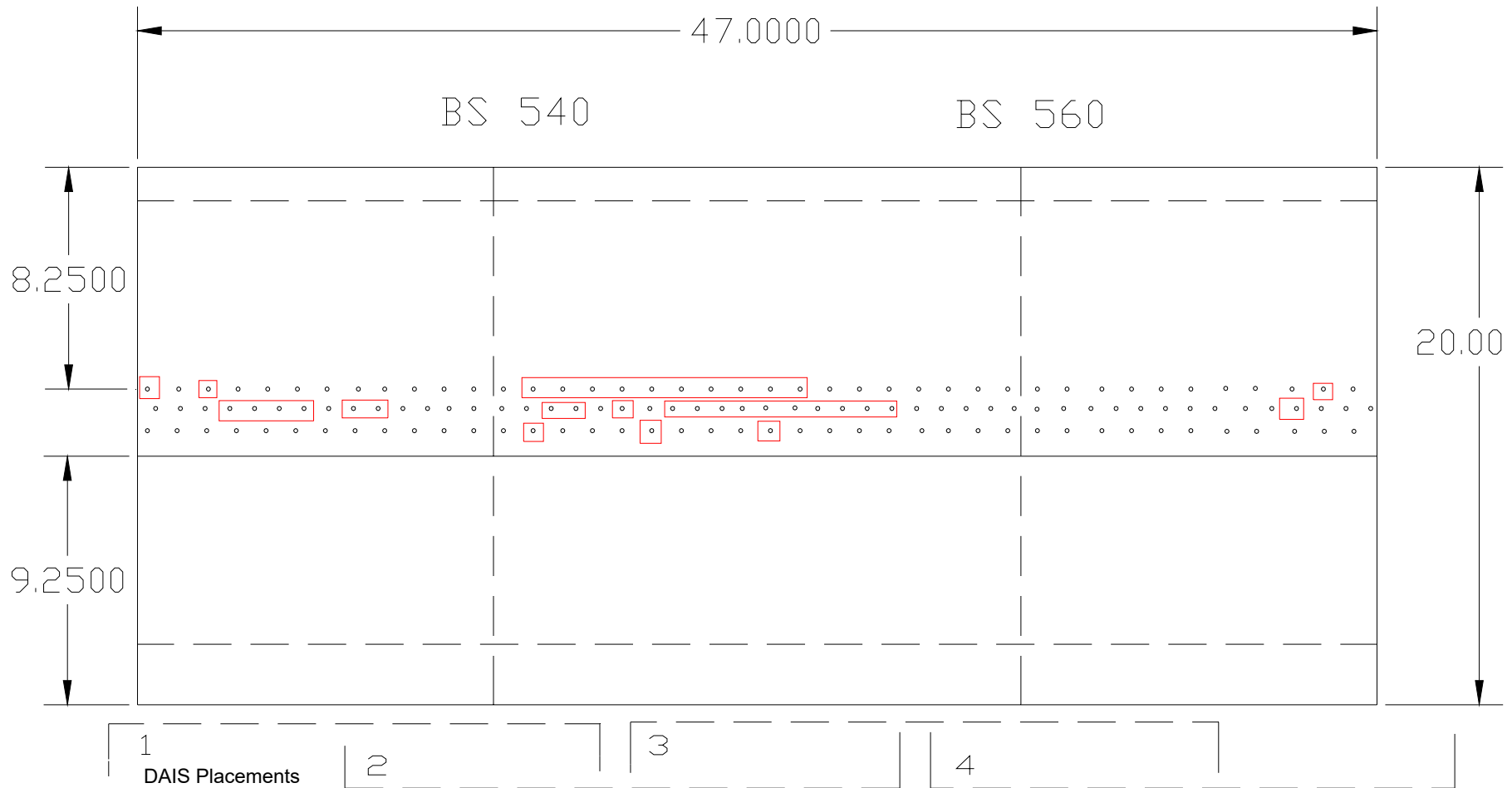
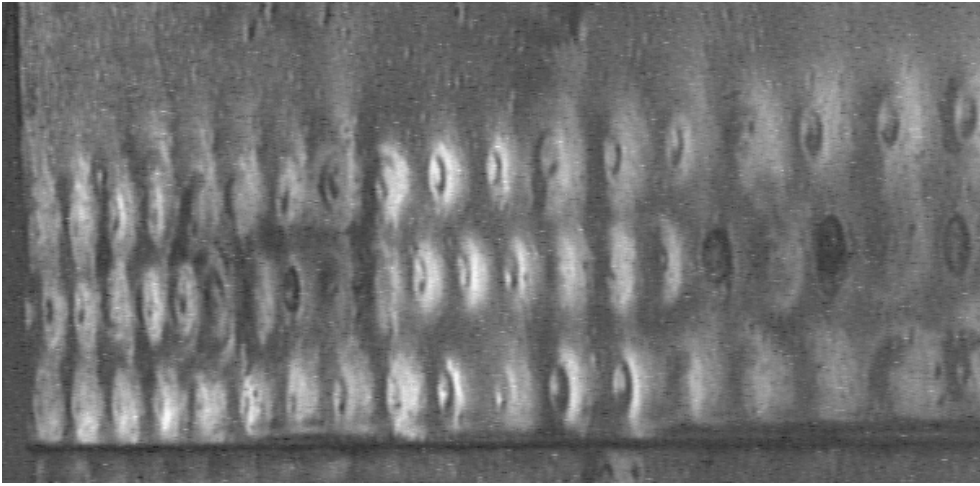
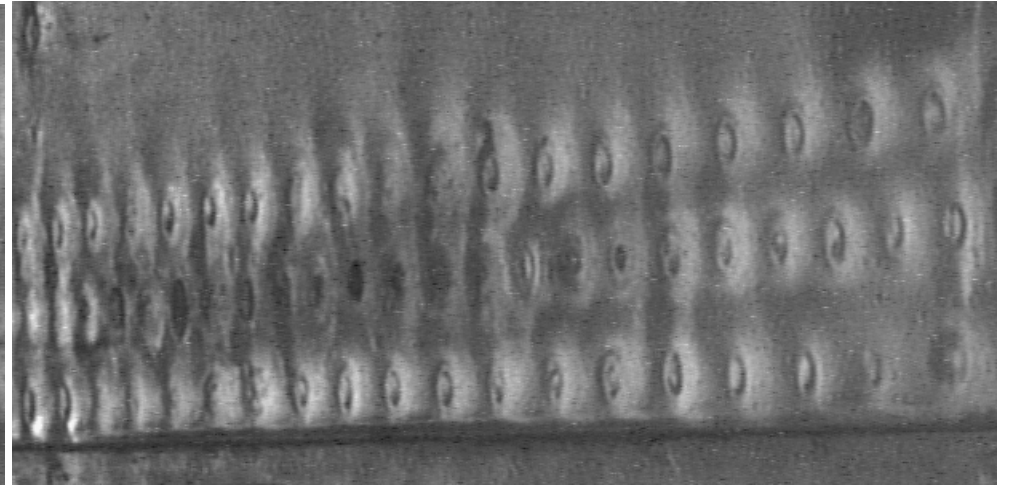


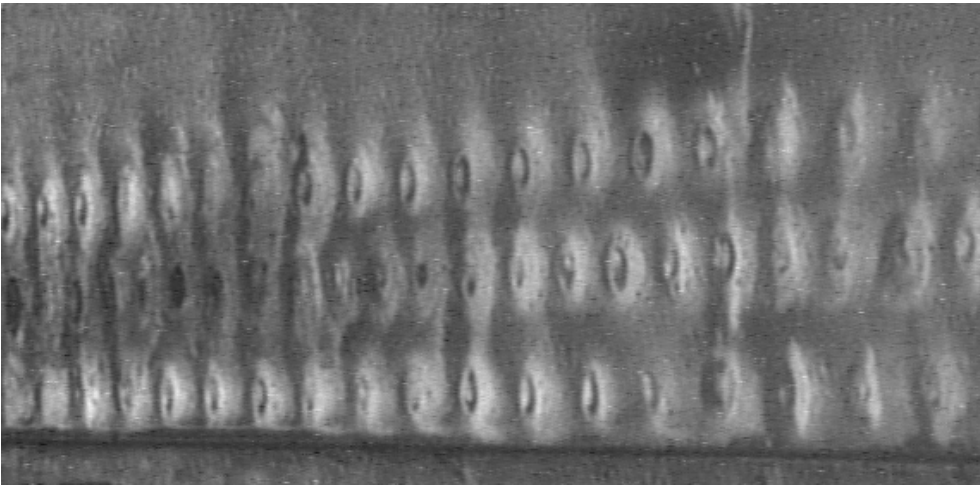
Figure 14. Schematic of lap joint 349B showing DAIS Placements 1 to 4 and locations of pillowing cracks (Red boxes).



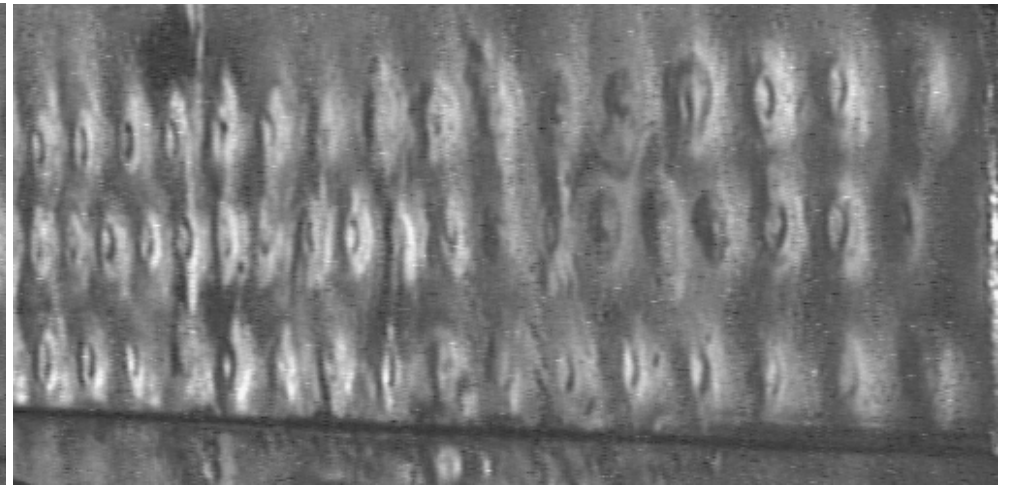
1



2

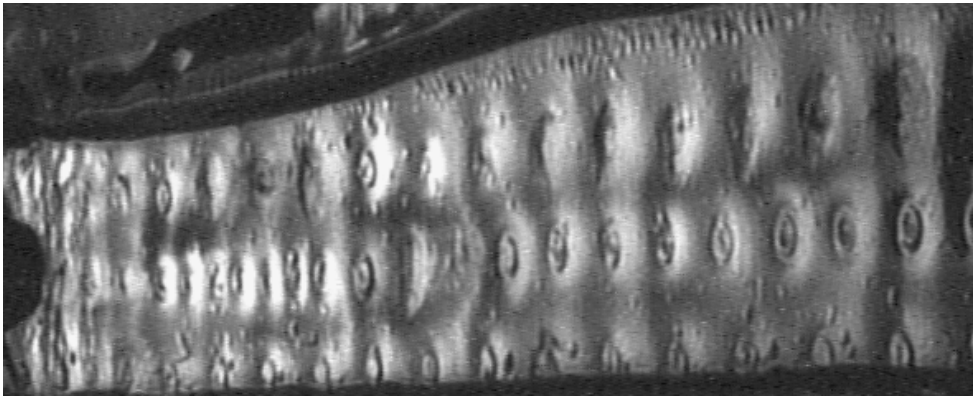


3

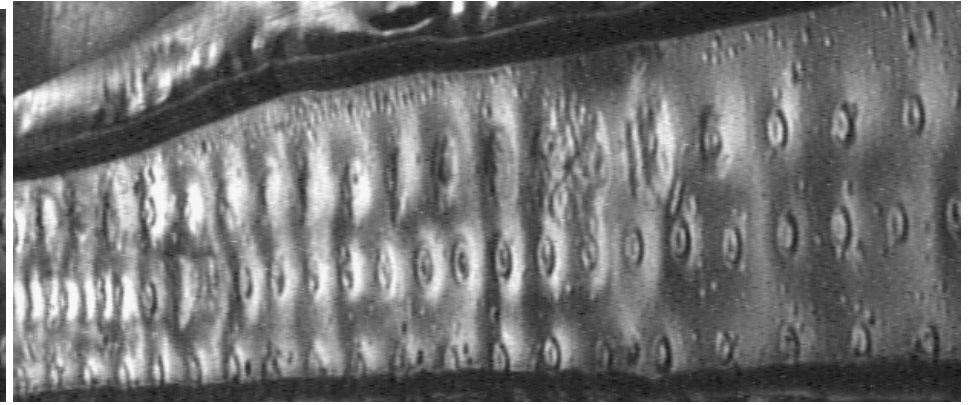


4

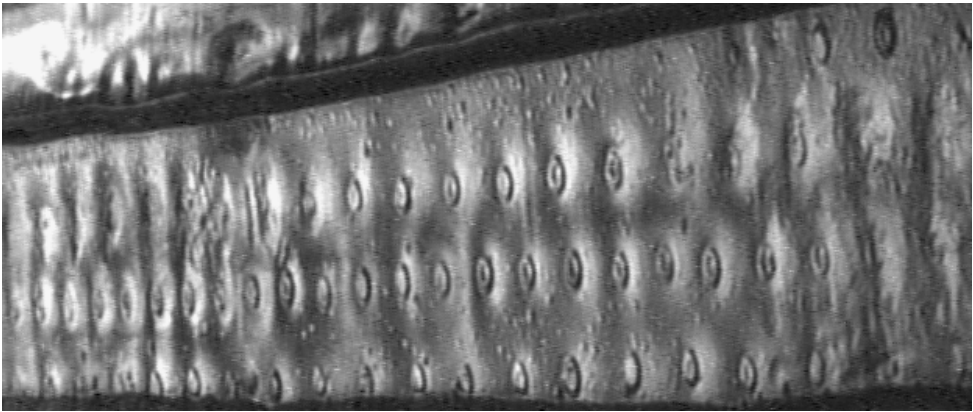
Figure 15a). D Sight inspection results for 349B, Painted.



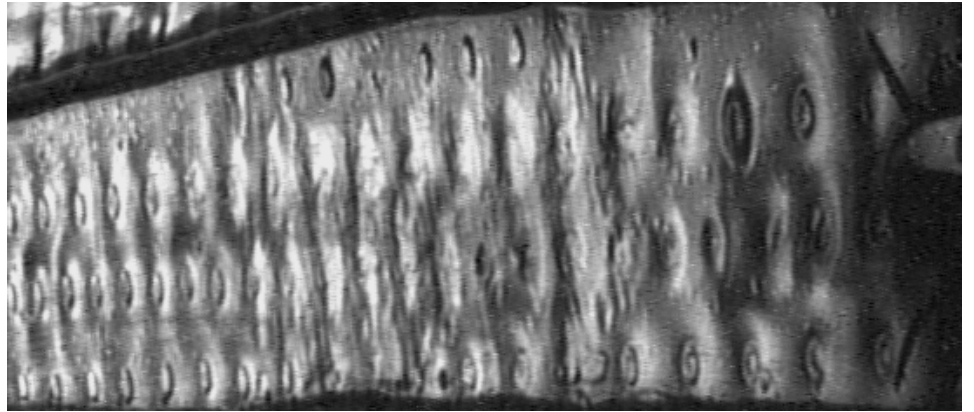
1



2



3



4

Figure 15b). D Sight inspection results for 349B, De-painted, SolidHi.

4.3 Ultrasonic Inspections

The Specimen 349B lap joint was 47 inches long and as a result the Ultrasonic inspection was carried out in 2 parts. The combined results are shown in Figure 16 **Error! Reference source not found.**

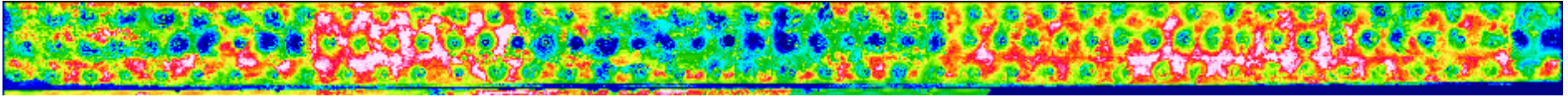
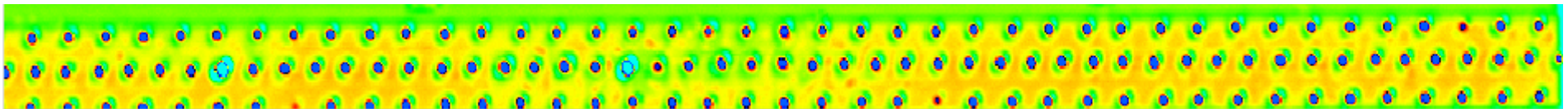
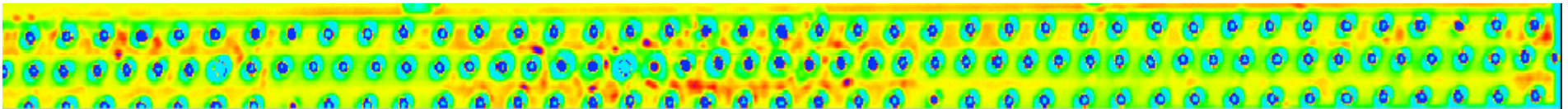


Figure 16. Ultrasonic inspection results using a frequency of 15 MHz for Specimen 349B.

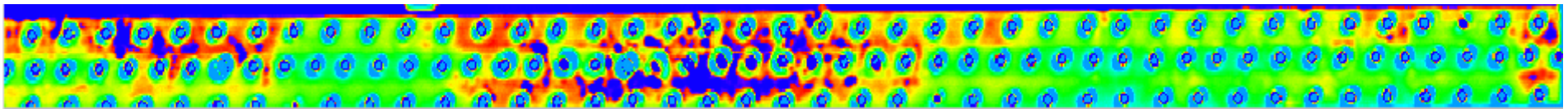
4.4 Eddy Current Inspections



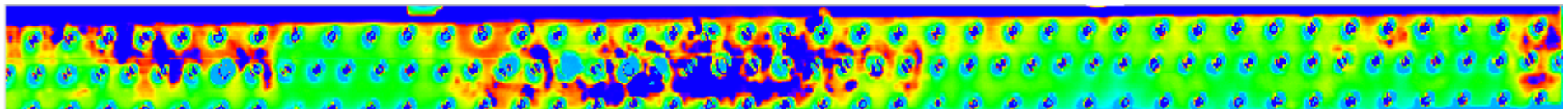
a) MFEC at 1.1 kHz.



b) MFEC at 2.4 kHz.



c) MFEC at 4.3 kHz.



d) MFEC at 9.6 kHz.

Figure 17. Multi Frequency Eddy Current inspection results for Specimen 349B

4.5 Pulsed Eddy Current Inspections

Addition inspections will be carried out to determine if this technique is capable of detecting pillowing cracks.

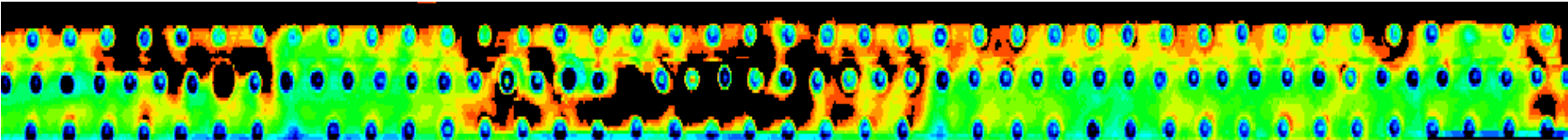


Figure 18. Pulsed eddy current inspection result for Specimen 349B.

4.6 X-ray Inspections

The X-ray inspection displayed several cracks around the majority of the rivets. The X-Ray image for a portion of Specimen 349B is shown in Figure 19. The areas of X-ray detected pillowing cracks are marked with red boxes in Figures 14 and 20. Four films were required to cover the length of the joint.

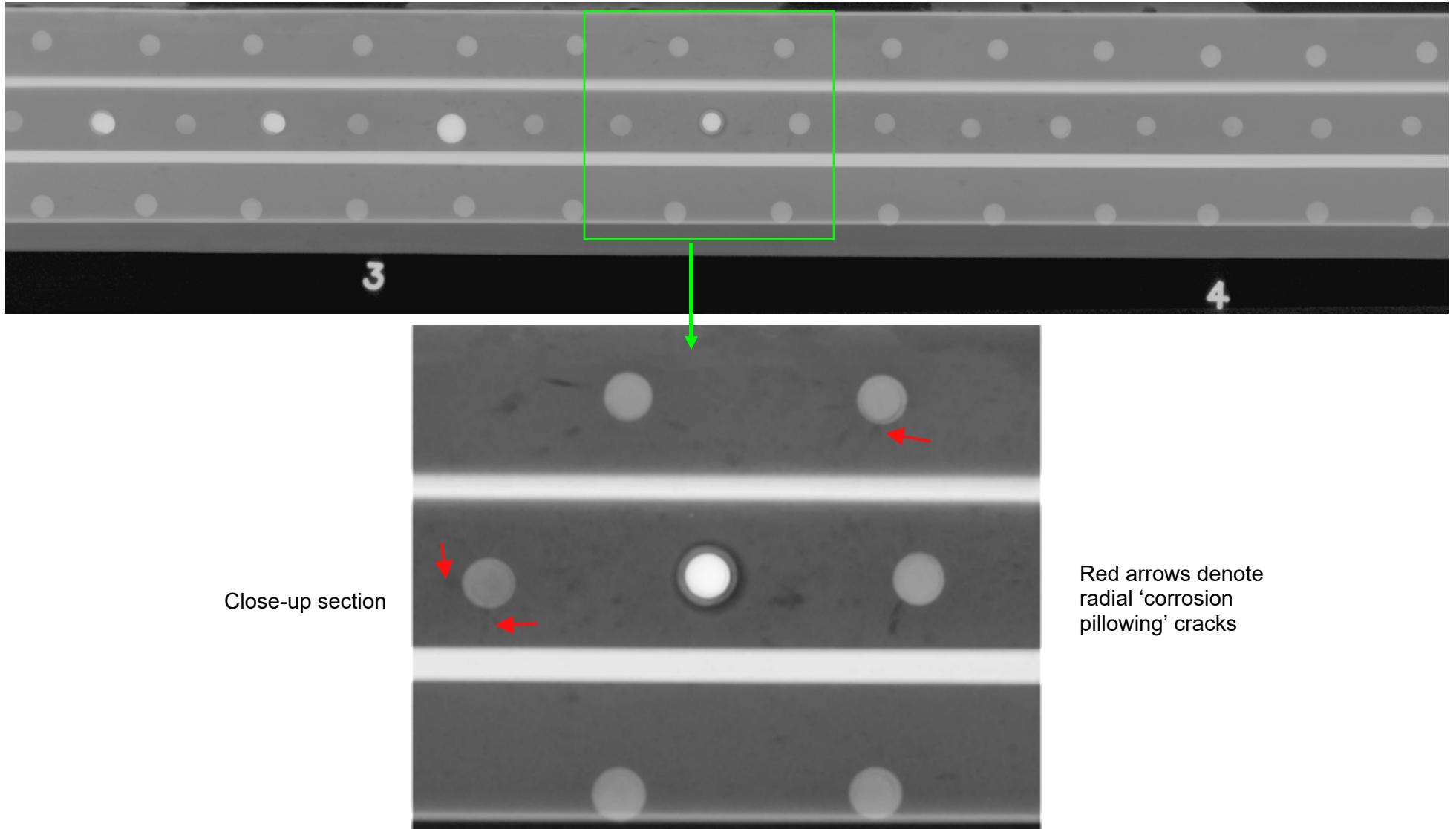


Figure 19. . X-ray inspection result for a section of lap joint 349B.

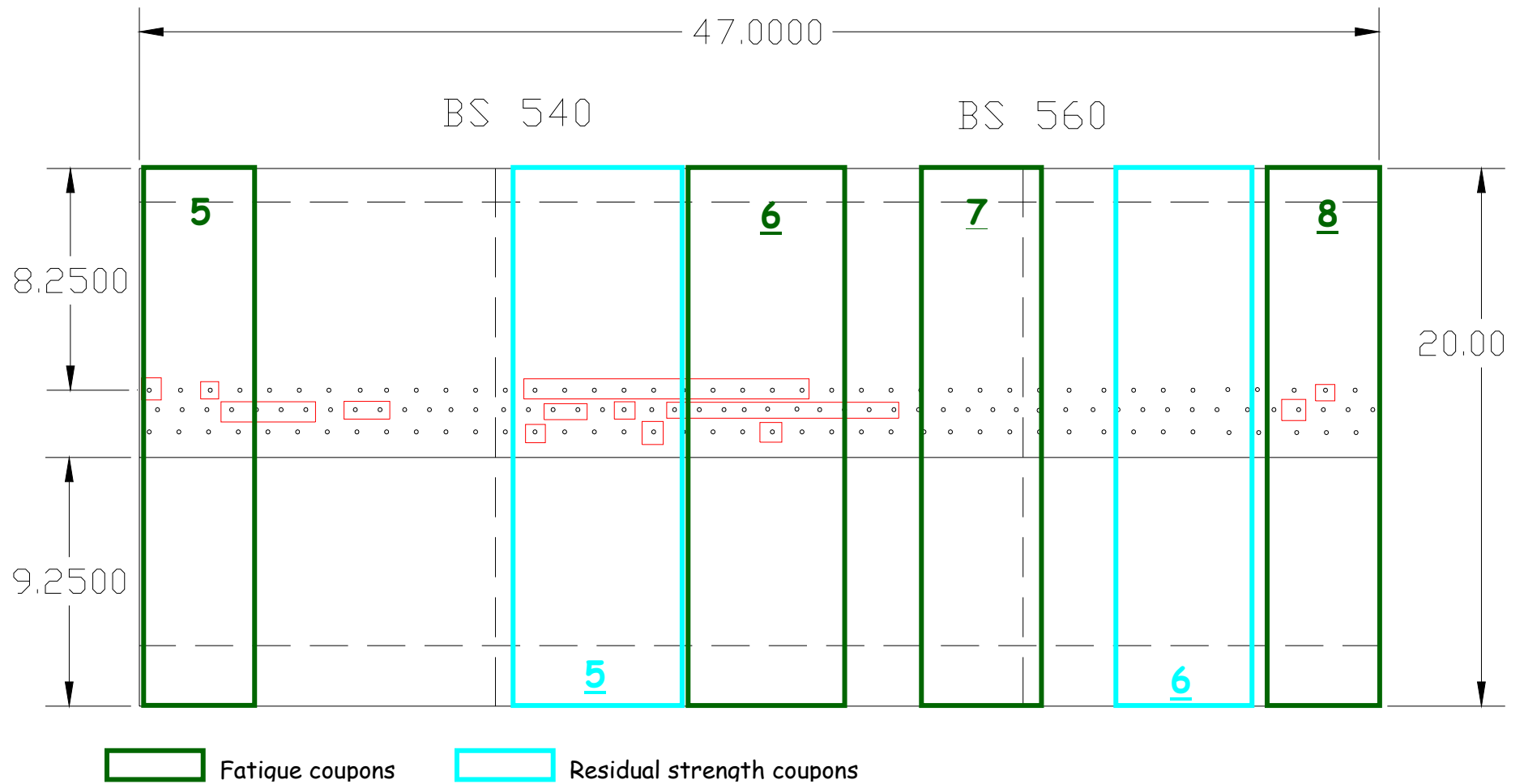


Figure 20. Sketch of Specimen 349B. Numbered boxes indicate nominal location of test coupons.

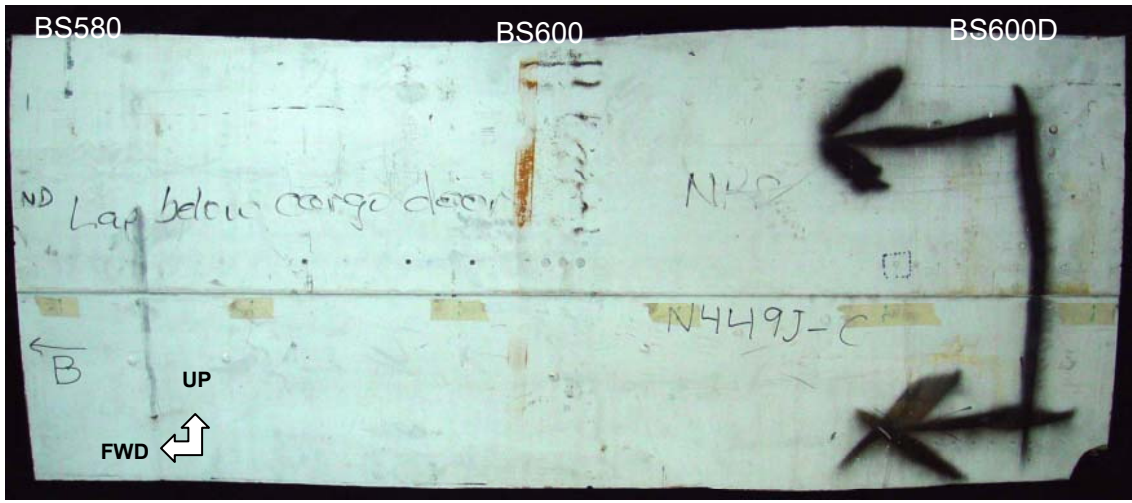
5 Specimen 349C

5.1 Close Visual Inspection

This 49 inch long lap joint specimen was located between BS580 and BS600D on STR24L. The specimen suffered from pillowing due to corrosion as well as corrosion on the inboard skin and stringer. Some of the original rivets replaced with steel fasteners, while others were sheared off due to the pillowing stress. Some of the rivets were cracked or had pitting corrosion and some were on the verge of popping out. Photographs of both front and rear surfaces of the specimen are shown in Figure 21 **Error! Reference source not found.**. The results from the visual inspections indicating the problem areas such as replaced or popped out rivets are presented in Table 4 and images of these areas are shown in Figure 22 **Error! Reference source not found.**.

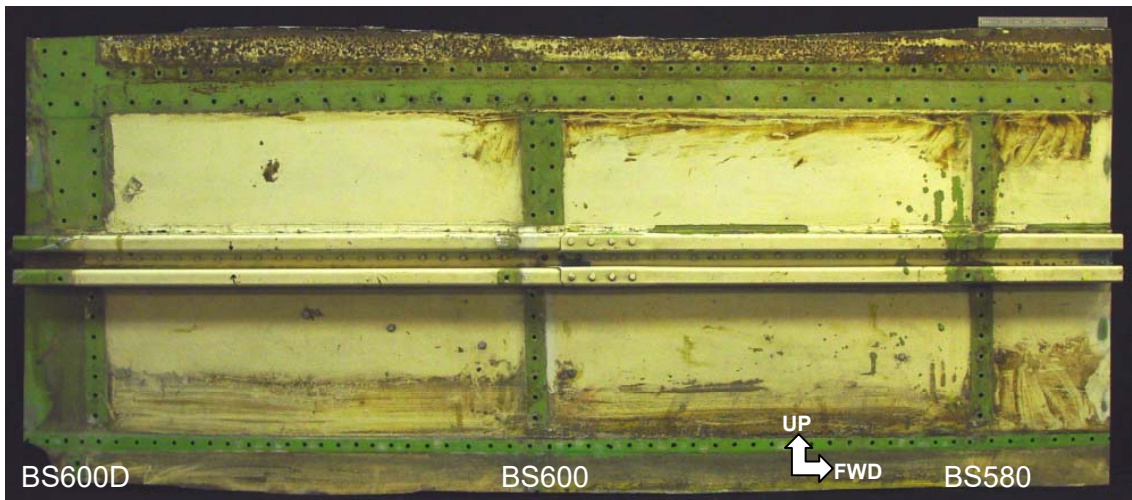
Front (F) / Rear (R)	Damage Description	Rivet Location	
		Row	Number
F	Cracked rivet	T	18
F	Popped out rivet	T	40
F	Popped out rivet	M	10
F	Cracked rivet	M	11
F	Popped out rivet	M	15
F	Cracked rivet	M	16
F	Popped out rivet	M	17
F	Popped out rivet	M	20
F	Replaced rivet, same size	M	21
F	Popped out rivet	M	23
F	Deformed rivet	M	26
F	Replaced rivet, larger, deformed	M	27-29
F	Replaced rivet, same size, popped out	M	43
F	Popped out rivet	M	44
F	Filiform corrosion	M	45
F	Popped out during disassembly	M	46
R	Rivet missing (not popped out), exfoliation on the inboard skin	M	29-30

Table 4. Specimen 349C Visual Inspection results.



S24L

(a) Front view



(b) Rear view before and after substructure removal

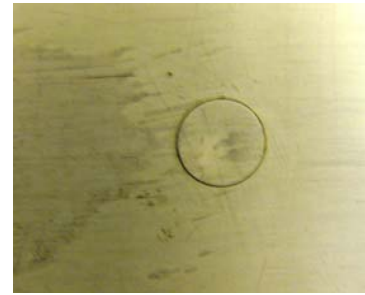
Figure 21. Front and Rear surface views of lap joint Specimen 349C.



T 18



T 23



T 24



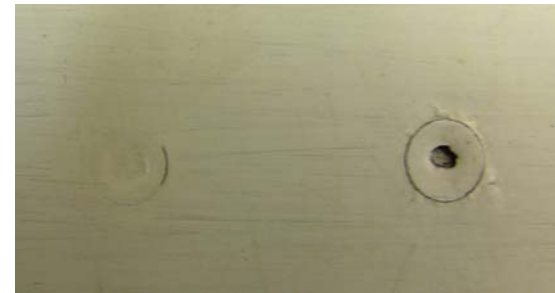
T 40



M 10,11



M 15



M 16,17



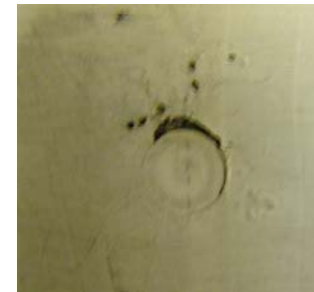
M 20



M 21



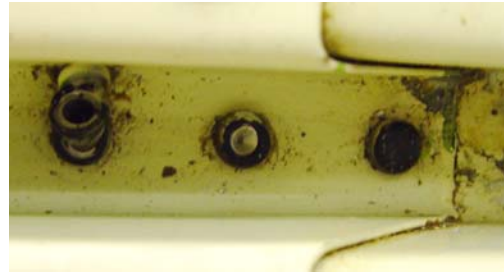
M 23



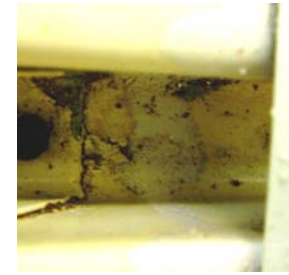
M 26



M 27-29



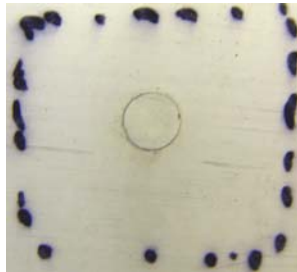
M 27-29 Rear



M between 29-30



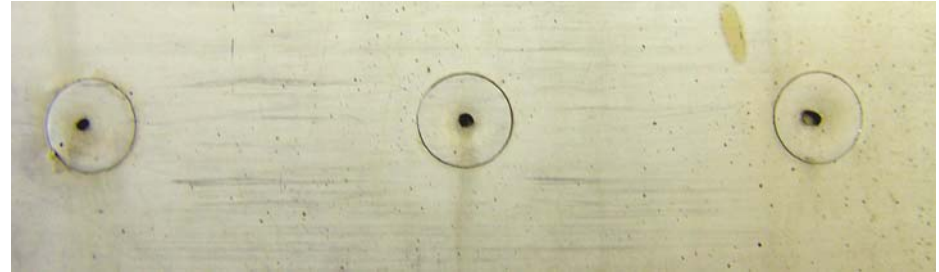
M40



M 43



M43 w/ head rivet
popped out



M 44-46



LHS of BS600

Figure 22.. Photographs showing problem areas in lap joint of Specimen 349C.

5.2 D Sight Inspection

A schematic of lap joint 349C showing the location of the DAIS 250C inspections is shown in Figure 23. Four D Sight images were taken with 50% overlap to cover the total length of the joint and the results are shown in Figure 24a. To obtain better D Sight signatures of the joint surface the paint was removed. The surface was inspected with the aid of SolidHi and negative pressure to conform a 10 mil black vinyl sheet. These inspection images are shown in Figure 24b). Figure 23 is also used to mark the areas containing pillowing cracks as detected by X-ray inspection of the joint.

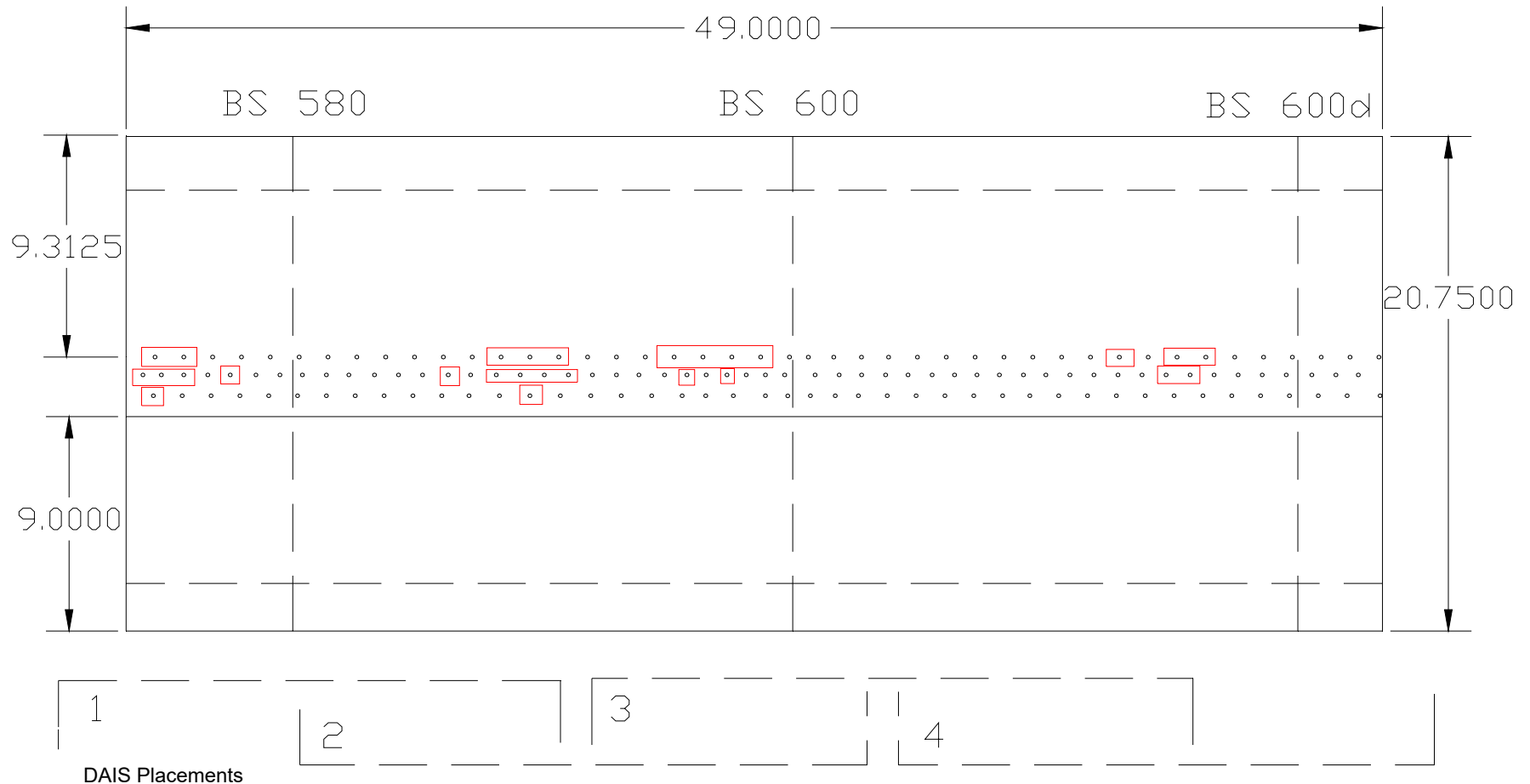
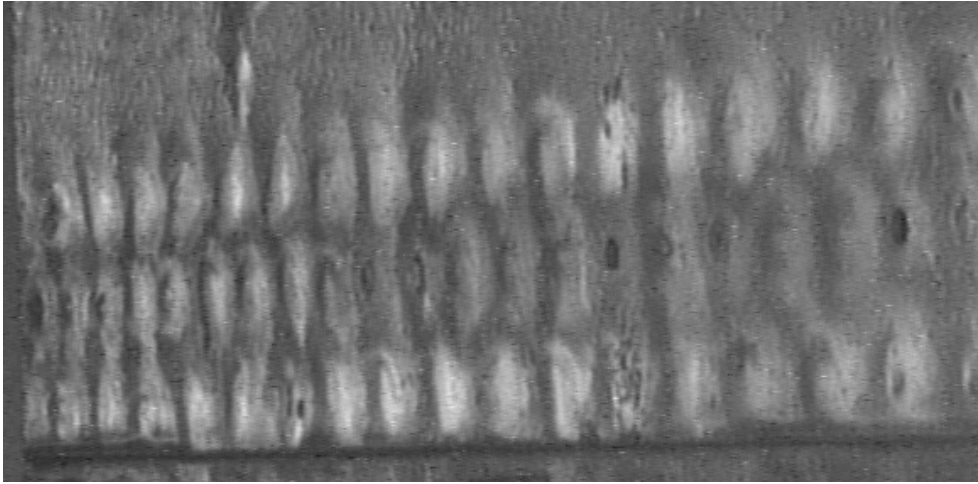
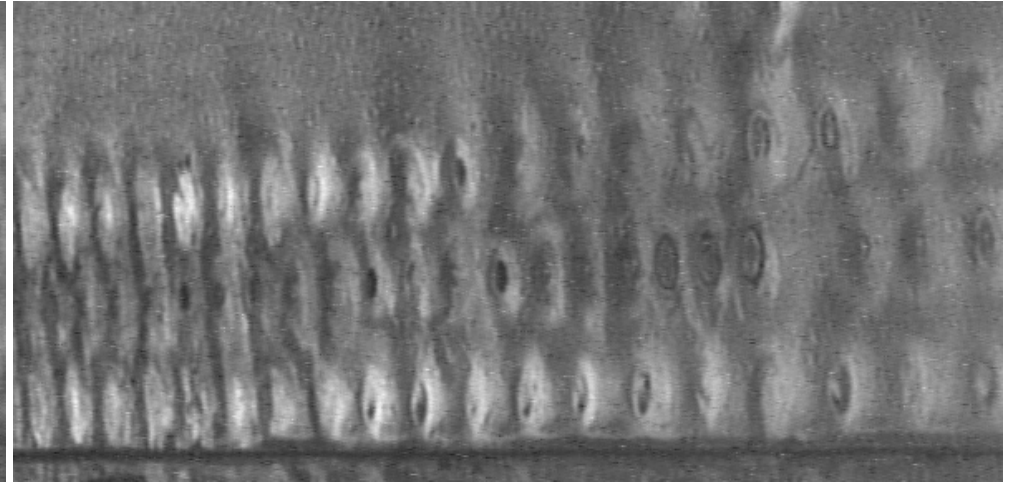


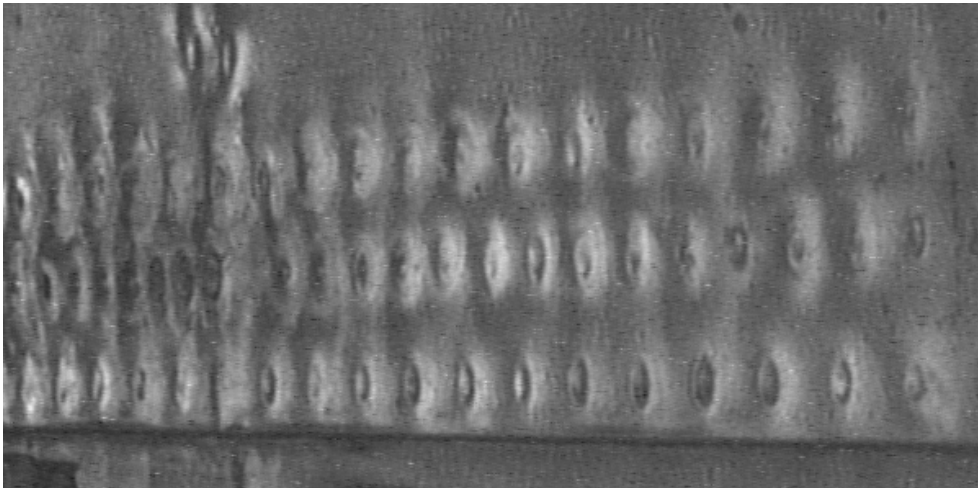
Figure 23. Schematic of lap joint 349C showing DAIS Placements 1 to 4 and locations of pillowing cracks (Red boxes).



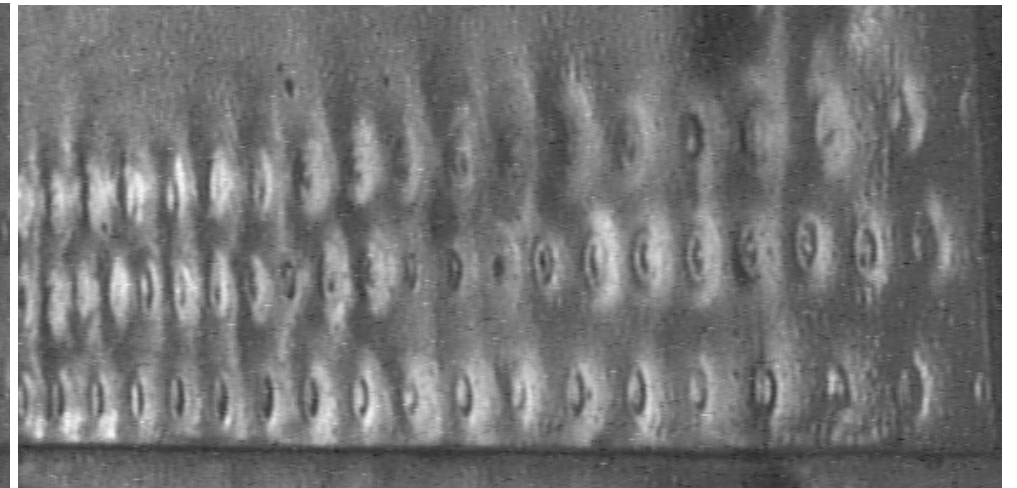
1



2

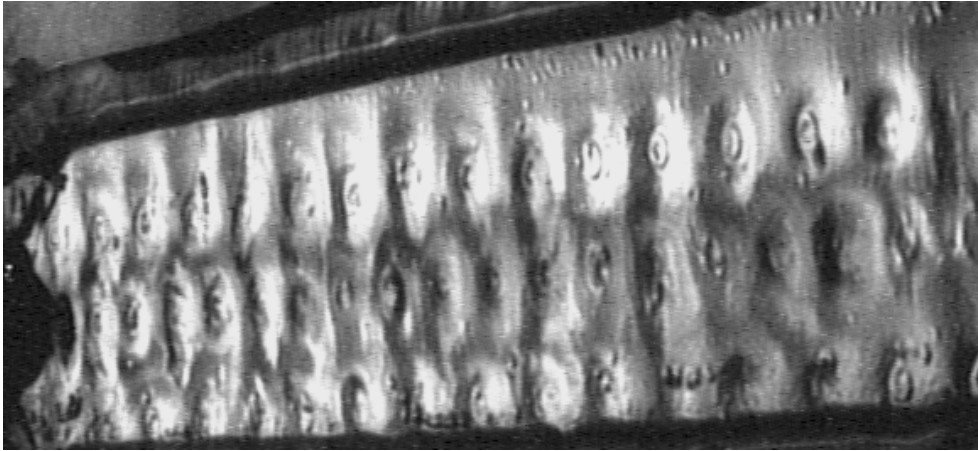


3

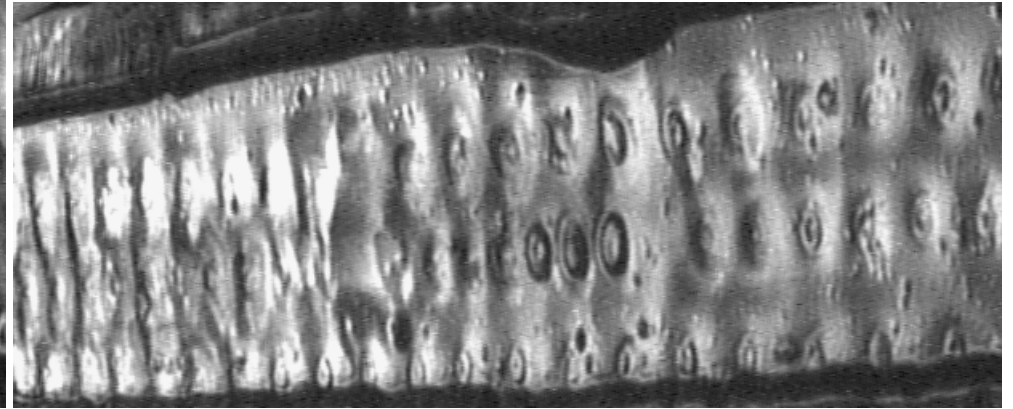


4

Figure 24a). D Sight inspection results for lap joint 349C. Painted.



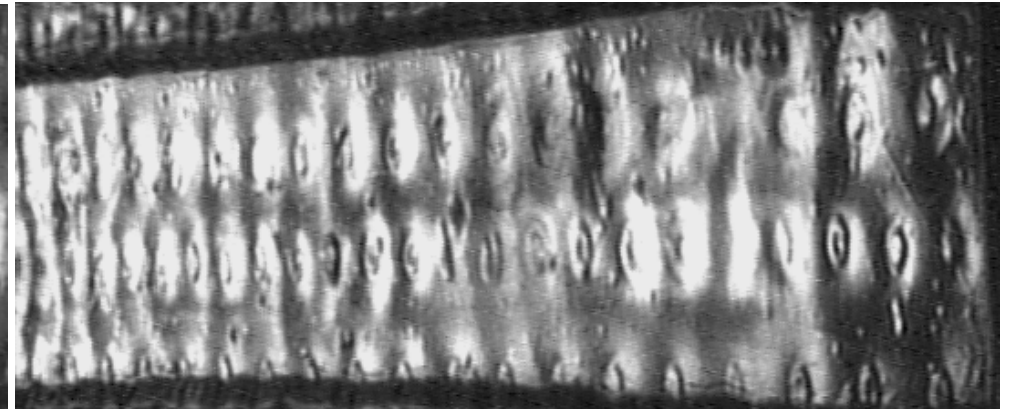
1



2



3



4

Figure 24b). D Sight inspection results for lap joint 349C. De-painted, SolidHi.

5.3 Ultrasonic Inspections

This specimen was 49 inches long and the ultrasonic inspection was carried out in two parts. The combined images are shown in Figure 25. **Error! Reference source not found..**

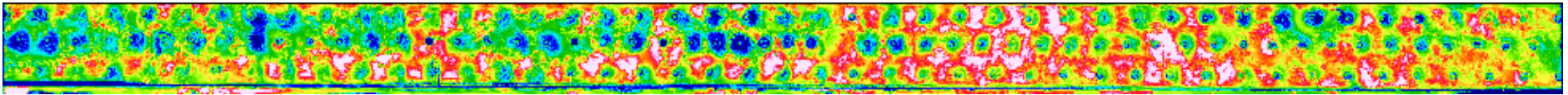
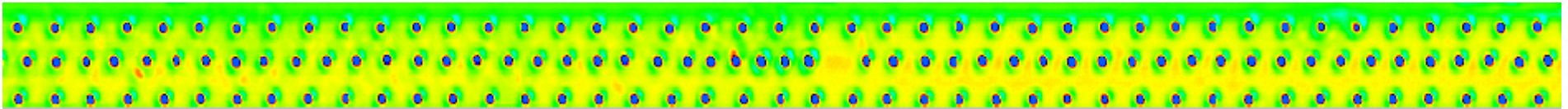
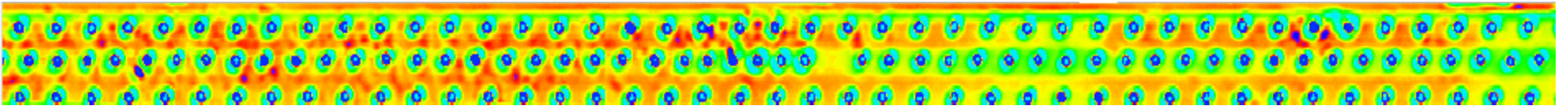


Figure 25. Ultrasonic inspection results at a 15 MHz frequency for Specimen 349C.

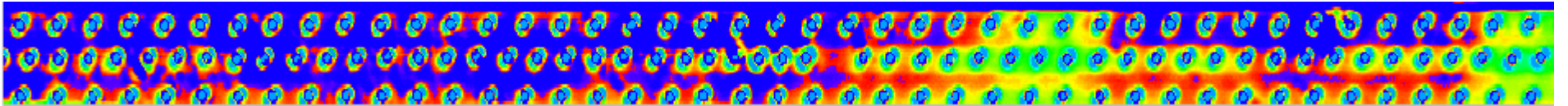
5.4 Eddy Current Inspections



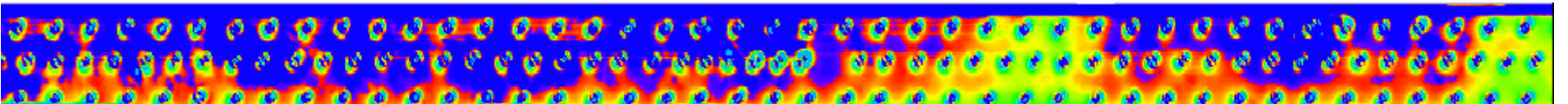
a) MFEC at 1.1 kHz.



b) MFEC at 2.4 kHz.



c) MFEC at 4.3 kHz.



d) MFEC at 9.6 kHz.

Figure 26. Multi Frequency Eddy current inspection results for Specimen 349C.

5.5 Pulsed Eddy Current Inspections

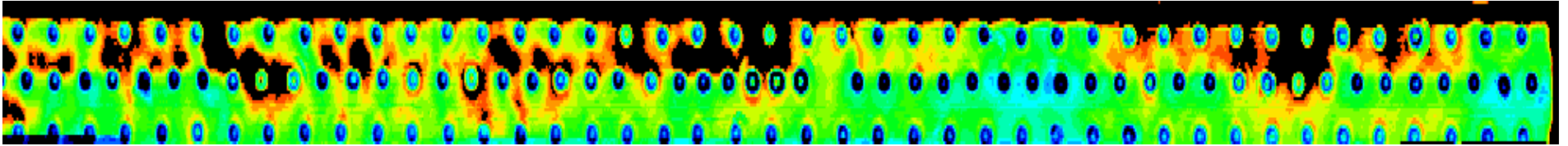


Figure 27. Pulsed eddy current inspection result for Specimen 349C.

5.6 X-ray Inspections

The X-Ray inspections are not presented for this lap joint. The areas detected to contain pillowing cracks are marked by the red boxes in Figure 28.

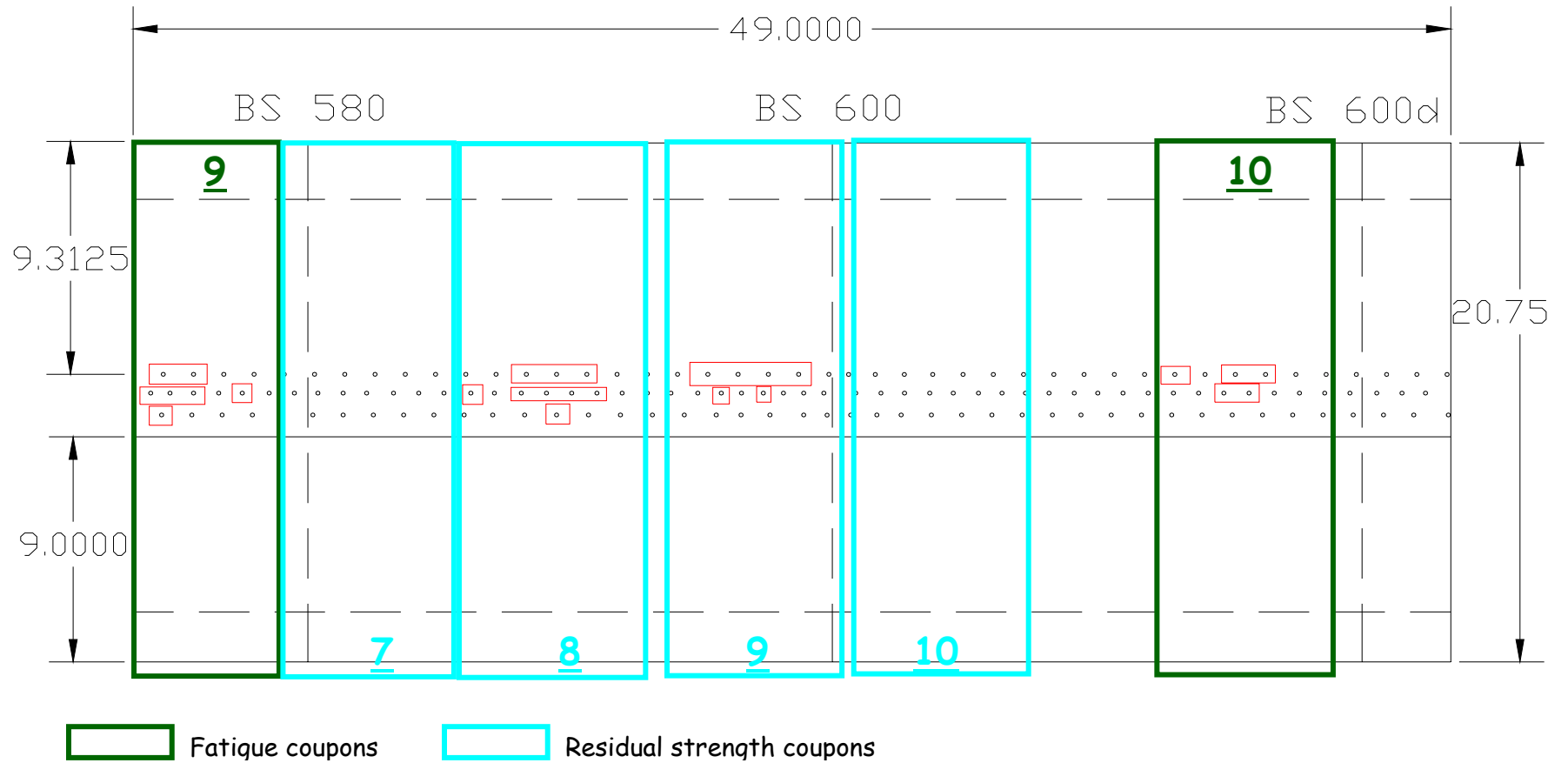


Figure 28. Sketch of Specimen 349C. Numbered boxes indicate nominal location of test coupons.

6 Conclusions