Cokebusters

Final Coke Removal Verification Report

SAMPLE XXX

DD/MM/YYYY

Merlin

SMART PIGGING INSPECTION TECHNOLOGY

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1 EXECUTIVE SUMMARY

Non-destructive ultrasonic testing was carried out by the latest generation MK IV intelligent pig on XXX Furnace, in the Convection and Radiant tubes. The objective of this particular inspection was to assess the internal cleanliness of the tubes after decoking operations.

During the course of the decoking process, Cokebusters decoking operators requested that the intelligent pig be run to determine the cleanliness of the tubes or the presence of internal fouling. The inspections aid the decoking operators by showing them the exact locations and thickness of the internal fouling within the heater. This allows them the ability to concentrate on areas with internal fouling and can speed up the decoking process, while minimizing any potential damage that could be caused by pigging clean tubes.

It was determined by XXX that these areas were not significant enough to continue the pigging process and risk tube damage. Primarily we are looking for a reduction in internal diameter and a scattering of the UT measurements in the same location to determine if internal fouling is present, rather than there being a variation in the topical surface of the tube. The remaining internal fouling left in the tubes is roughly 0.019" to 0.078" in thickness or less and is typically split between two different surfaces of the tube. The internal fouling will show in blue on the 3D's but with the coke being so thin, natural reductions and variations in the tube internal diameter will also show in blue on the 3D C-scans. This is one reason we provide the internal diameter section graphs and coke table for each tube so they can be used in conjunction with the 3D C-scans.

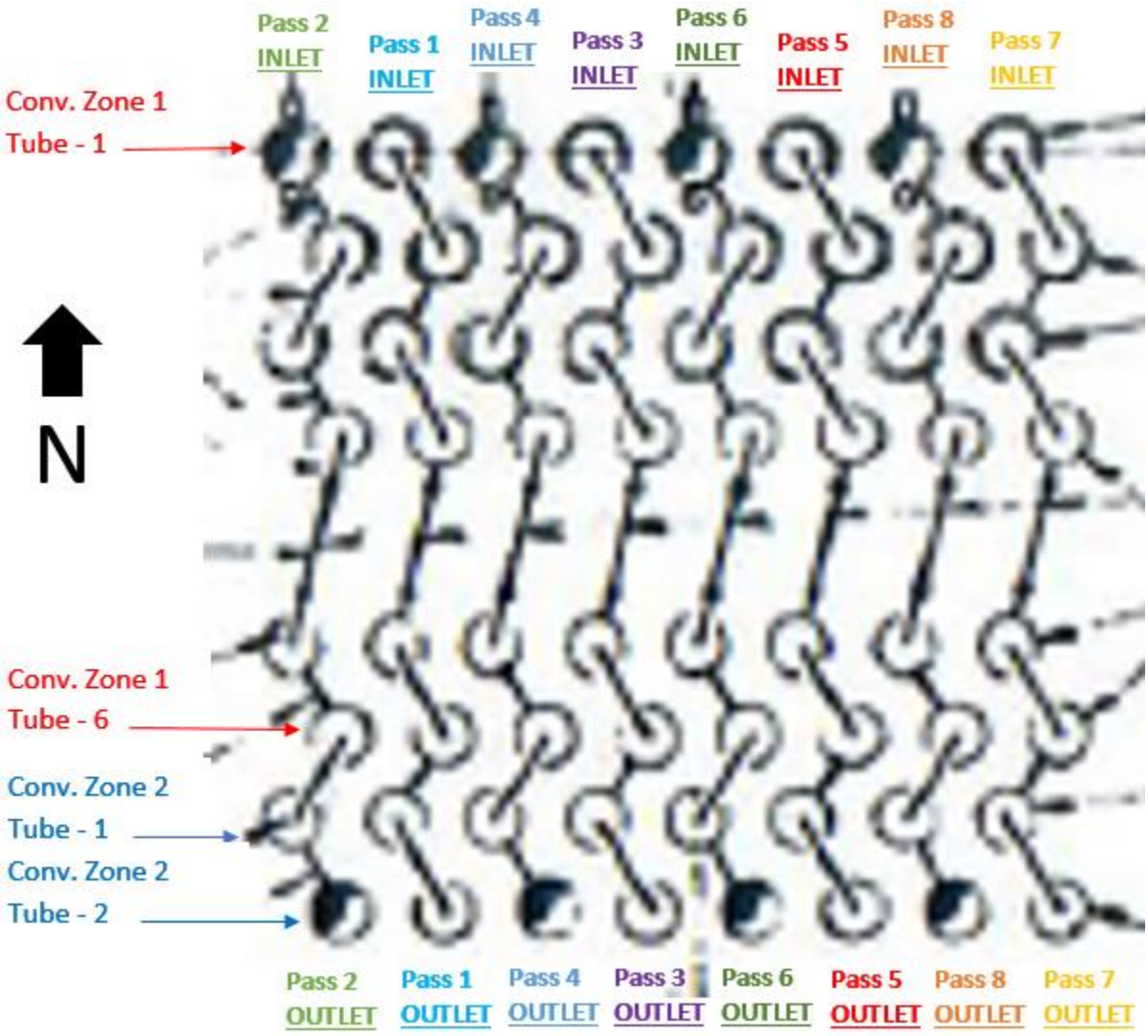
Pass 6 was brought to our attention by XXX as an area of concern at the start of the pigging operation, due to a significant hotspot while the heater was online. A large area of coke was found in Tube 2 of Convection Zone 2. The initial inspection showed 0.314" of coke, split between the top and bottom of the tube from 19 – 82 feet. *Figure 1* highlights this area with a top and bottom 3D view and *Figure 2* shows the section graph for this tube on the initial inspection. After the initial inspection Cokebusters resumed decoking operations on the pass to concentrate on this area and did 60 runs with a cleaning pig. The 2nd inspection showed that we had reduced the thickness of the coke to 0.197". Decoking operators continued operations and ran an additional 150 runs with a cleaning pig, concentrating on Tube 2. The 3rd inspection showed we had significantly reduced the thickness and area of internal fouling. Reducing the thickness to 0.078" located primarily on the bottom of the tube and reduced the area of internal fouling to 44 – 78 feet. *Figure 3* highlights this area with a top and bottom 3D view and *Figure 4* shows the section graph for this tube on the final inspection. XXX reviewed the data from the final inspection and decided the amount of internal fouling remaining was acceptable and signed off on the pass. The remainder of the tubes within Pass 6 were determined to be clean.

We recommend regular inspections to be performed on future shutdowns of the heater to accurately assess the life/cleanliness of the tubes.

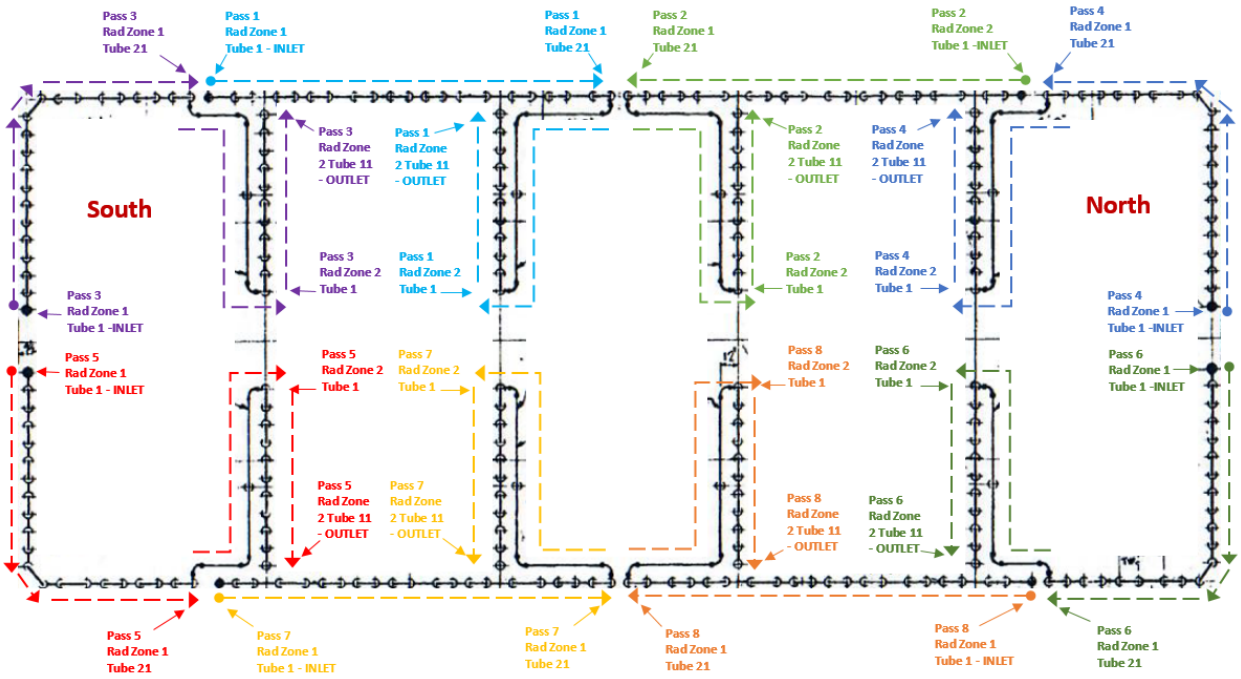
XXX
level III - Inspection Supervisor – Merlin Inspection Technology
Cokebusters
DD/MM/YYYY

2 SUMMARY OF OPERATIONS	
Client:	
Address:	
Inspection Start:	
Inspection Completion:	
Inspectors:	
Report Author:	
Report ID:	
Approval:	
3 PROCESS OVERVIEW	
Furnace ID:	
Process:	
Passes Inspected:	
Tube Metallurgy:	Convection Zone 1 - 5Cr Convection Zone 2 - CS Radiant Zone 1 - CS Radiant Zone 2 - 9Cr
Nominal OD:	6.625”

4 GENERAL ARRANGEMENT DRAWING - CONVECTION



5 GENERAL ARRANGEMENT DRAWING - RADIANT



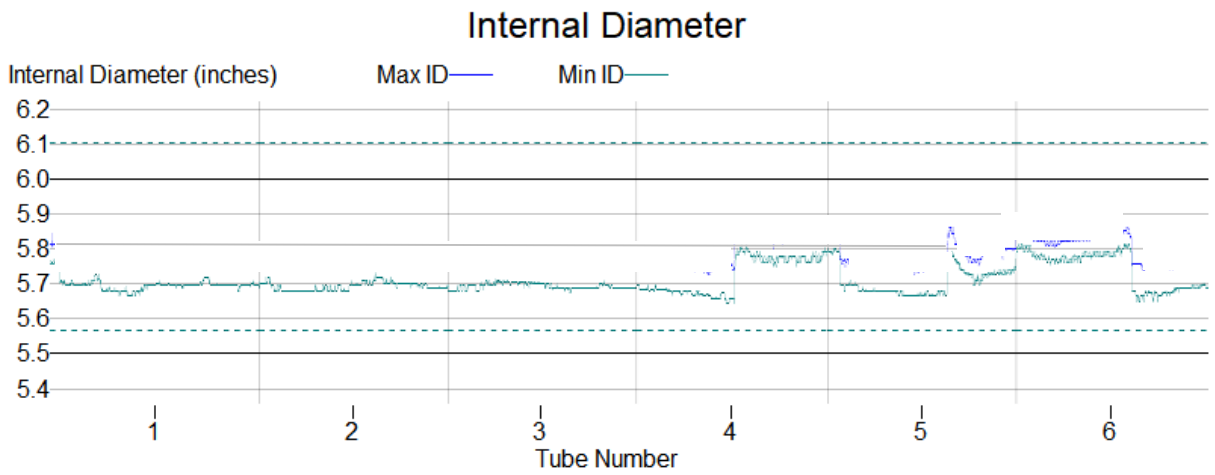
6 PASS 1 - CONVECTION ZONE 1 ANALYSIS

6.1 Pass 1 - Convection Zone 1: Internal Diameter Data Table

6.1.1 Nominal ID: 5.760inches

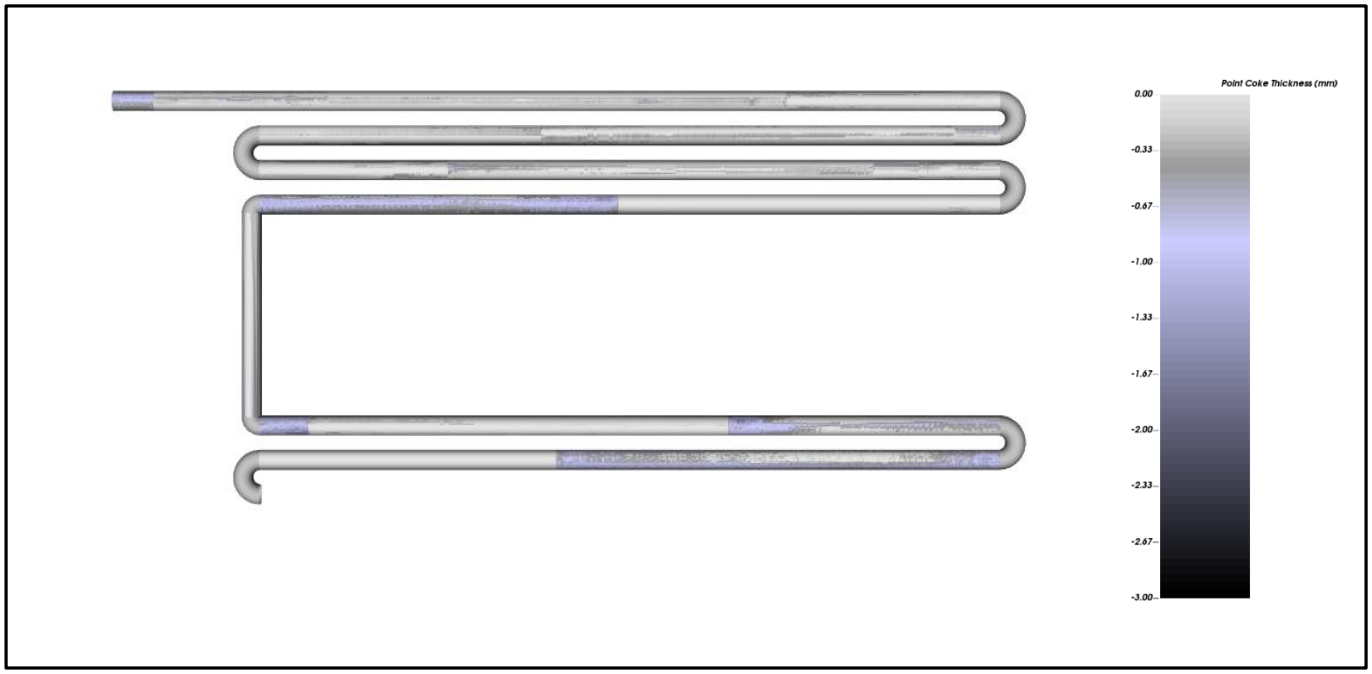
Tube Identity Number	Average ID (inches)	Minimum ID (inches)	Minimum ID Location (x'x")	Comments
1	5.734	5.667	31'6"	No internal fouling detected
2	5.734	5.681	20'6"	No internal fouling detected
3	5.733	5.675	45'10"	No internal fouling detected
4	5.759	5.644	36'4"	No internal fouling detected
5	5.743	5.666	39'12"	No internal fouling detected
6	5.775	5.652	45'6"	No internal fouling detected

6.2 Pass 1 - Convection Zone 1: Summary Graphs

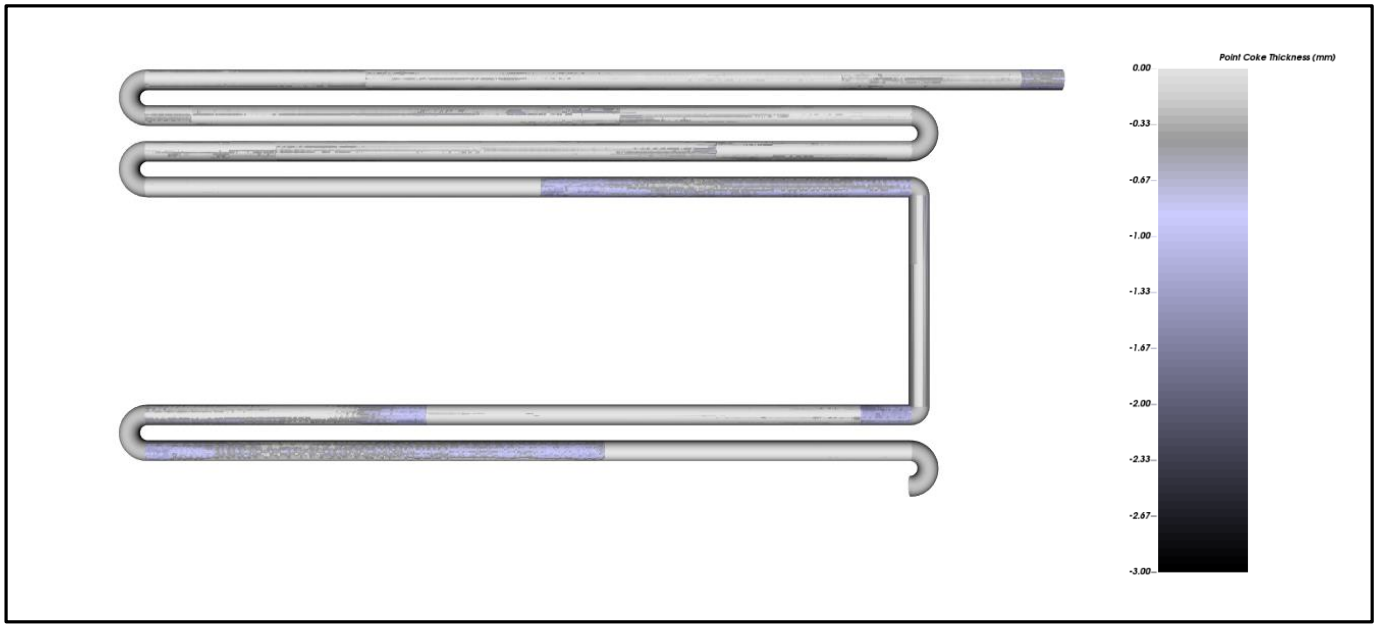


6.3 Pass 1 - Convection Zone 1: 3D Coke Scans

Front View



Rear View



7 PASS 6 - CONVECTION ZONE 2 ANALYSIS

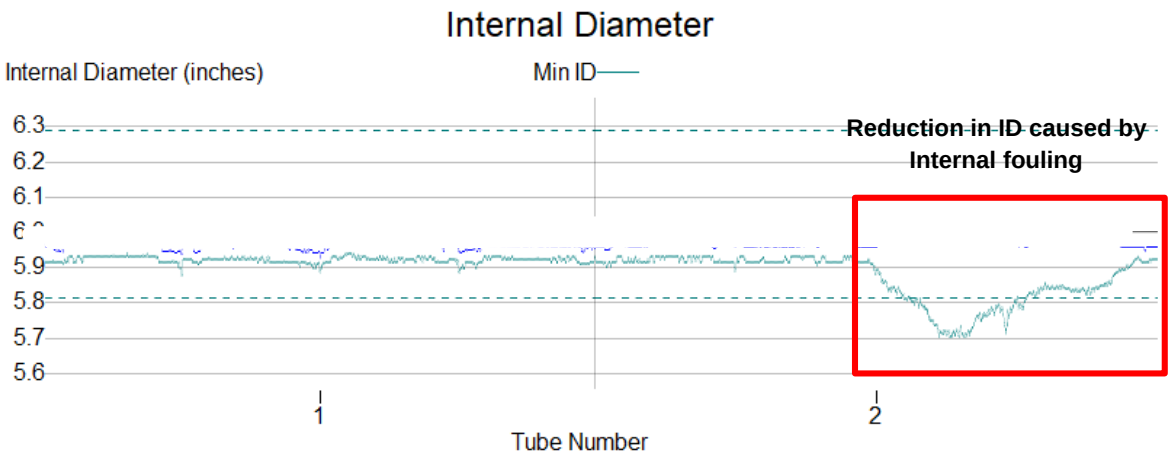
7.1 Pass 6 - Convection Zone 2: Internal Diameter Data Table

7.1.1 Nominal ID: 5.973inches

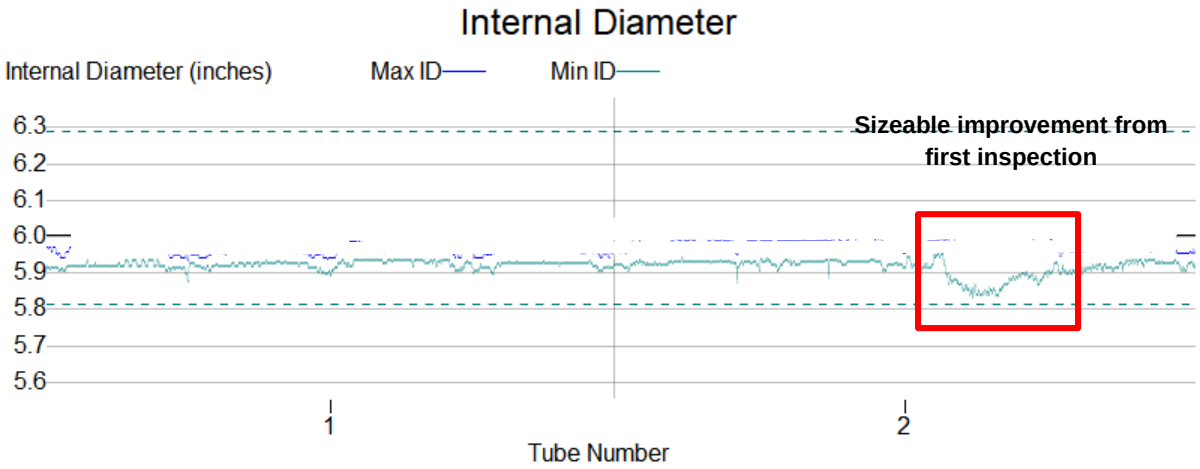
Tube Identity Number	Average ID (inches)	Minimum ID (inches)	Minimum ID Location (x'x")	Comments
1	5.942	5.877	17'8"	No Internal fouling detected
2	5.947	5.829	52'5"	Internal Fouling approx. 0.039"-0.078" thick @ 45'-70' from weld

7.2 Pass 6 - Convection Zone 2: Summary Graphs

First Inspection

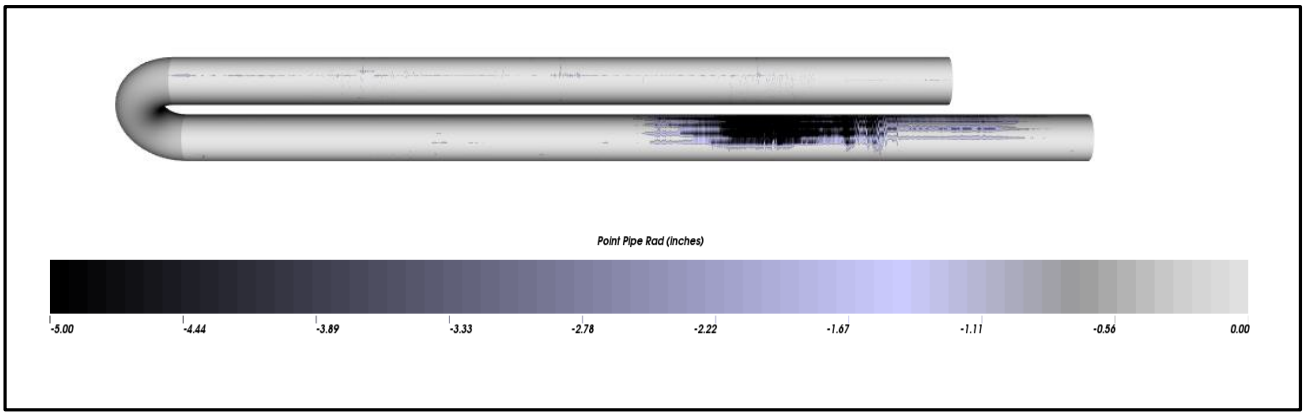


Final Inspection

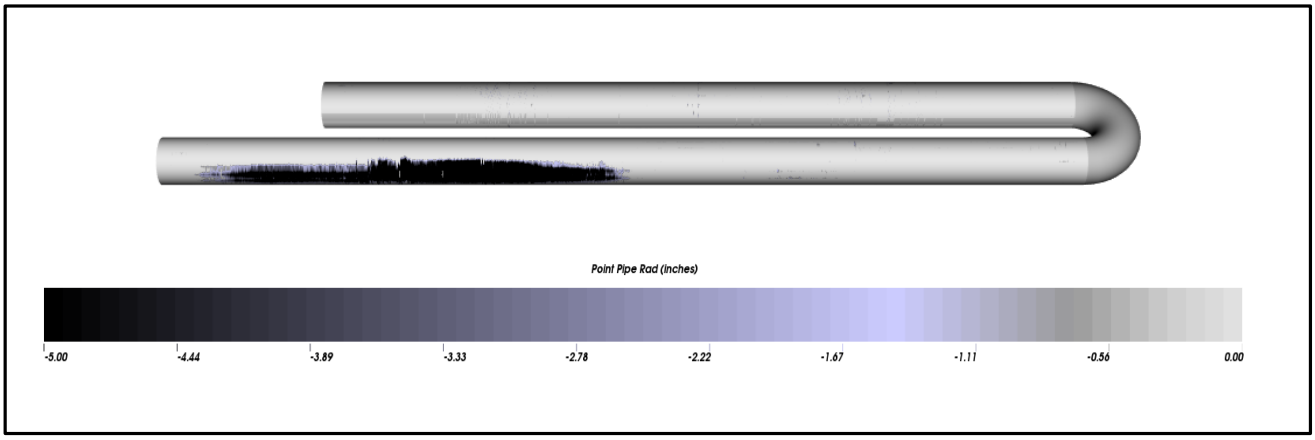


7.3 Pass 6 - Convection Zone 2: 3D Coke Scans

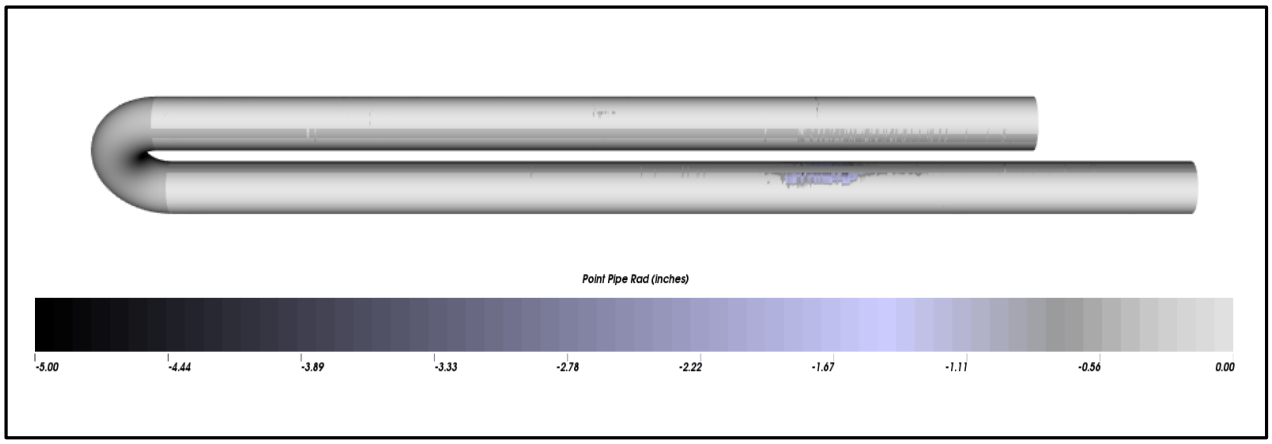
Front View: First Inspection



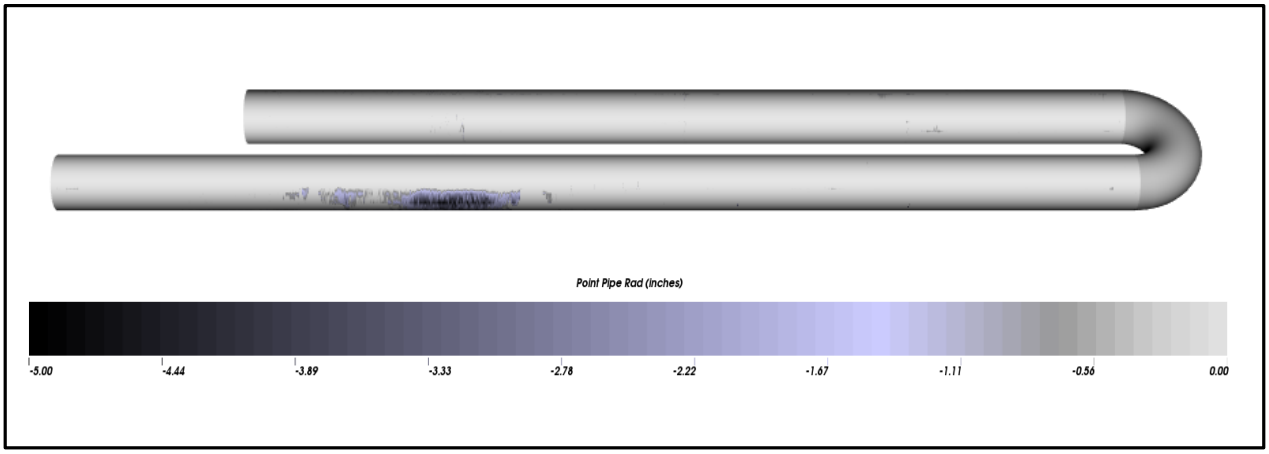
Rear View: First Inspection



Front View: Final Inspection



Rear View: Final Inspection



8 PASS 8 - RADIANT ZONE 1 ANALYSIS

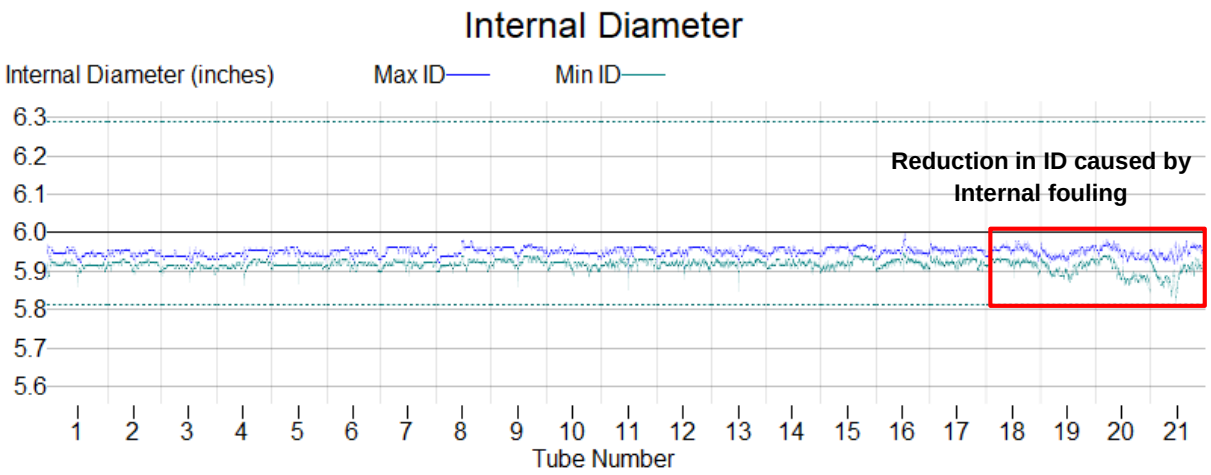
8.1 Pass 8 - Radiant Zone 1: Internal Diameter Data Table

8.1.1 Nominal ID: 5.973inches

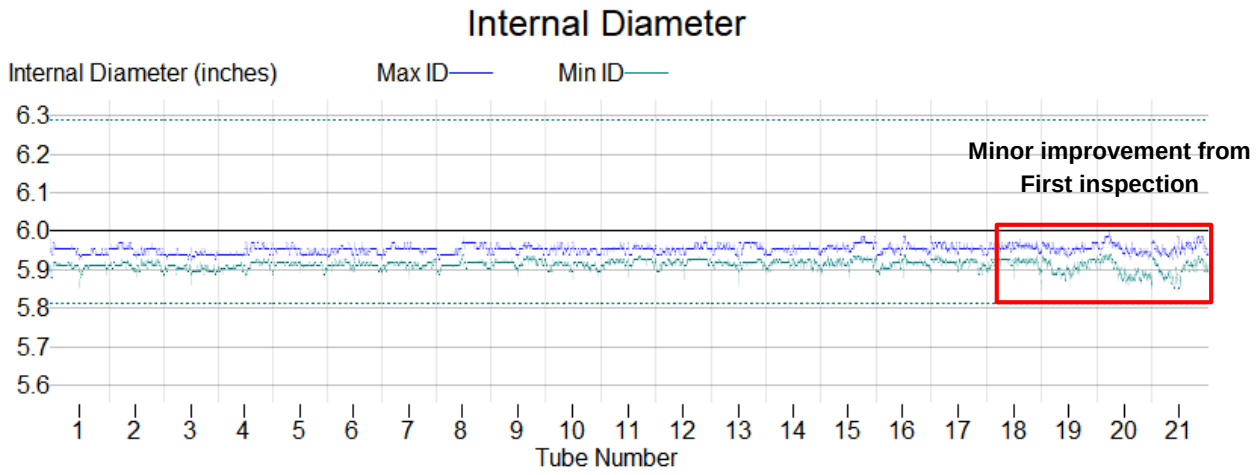
Tube Identity Number	Average ID (inches)	Minimum ID (inches)	Minimum ID Location (x'x")	Comments
1	5.928	5.851	17'12"	No Internal fouling detected
2	5.931	5.881	18'0"	No Internal fouling detected
3	5.924	5.862	18'0"	No Internal fouling detected
4	5.930	5.877	18'1"	No Internal fouling detected
5	5.931	5.886	33'9"	No Internal fouling detected
6	5.932	5.896	Multiple	No Internal fouling detected
7	5.934	5.877	18'1"	No Internal fouling detected
8	5.932	5.888	0'1"	No Internal fouling detected
9	5.938	5.883	18'0"	No Internal fouling detected
10	5.931	5.875	17'12"	No Internal fouling detected
11	5.937	5.876	18'1"	No Internal fouling detected
12	5.937	5.874	18'1"	No Internal fouling detected
13	5.934	5.858	18'1"	No Internal fouling detected
14	5.935	5.886	0'1"	No Internal fouling detected
15	5.940	5.879	18'2"	No Internal fouling detected
16	5.935	5.881	18'1"	No Internal fouling detected
17	5.938	5.888	31'0"	No Internal fouling detected
18	5.940	5.847	35'11"	Approx.. 0.019" thick @ 34'-36'
19	5.931	5.862	18'1"	Approx.. 0.019'-0.039"thick. Patches @ 6'-24'
20	5.929	5.851	35'11"	Approx.. 0.059"-0.078" thick. Patches @ 10'-36'
21	5.928	5.843	16'6"	Approx.. 0.059"-0.078" thick. Patches @ 3'-30'

8.2 Pass 8 - Radiant Zone 1: Summary Graphs

First Inspection

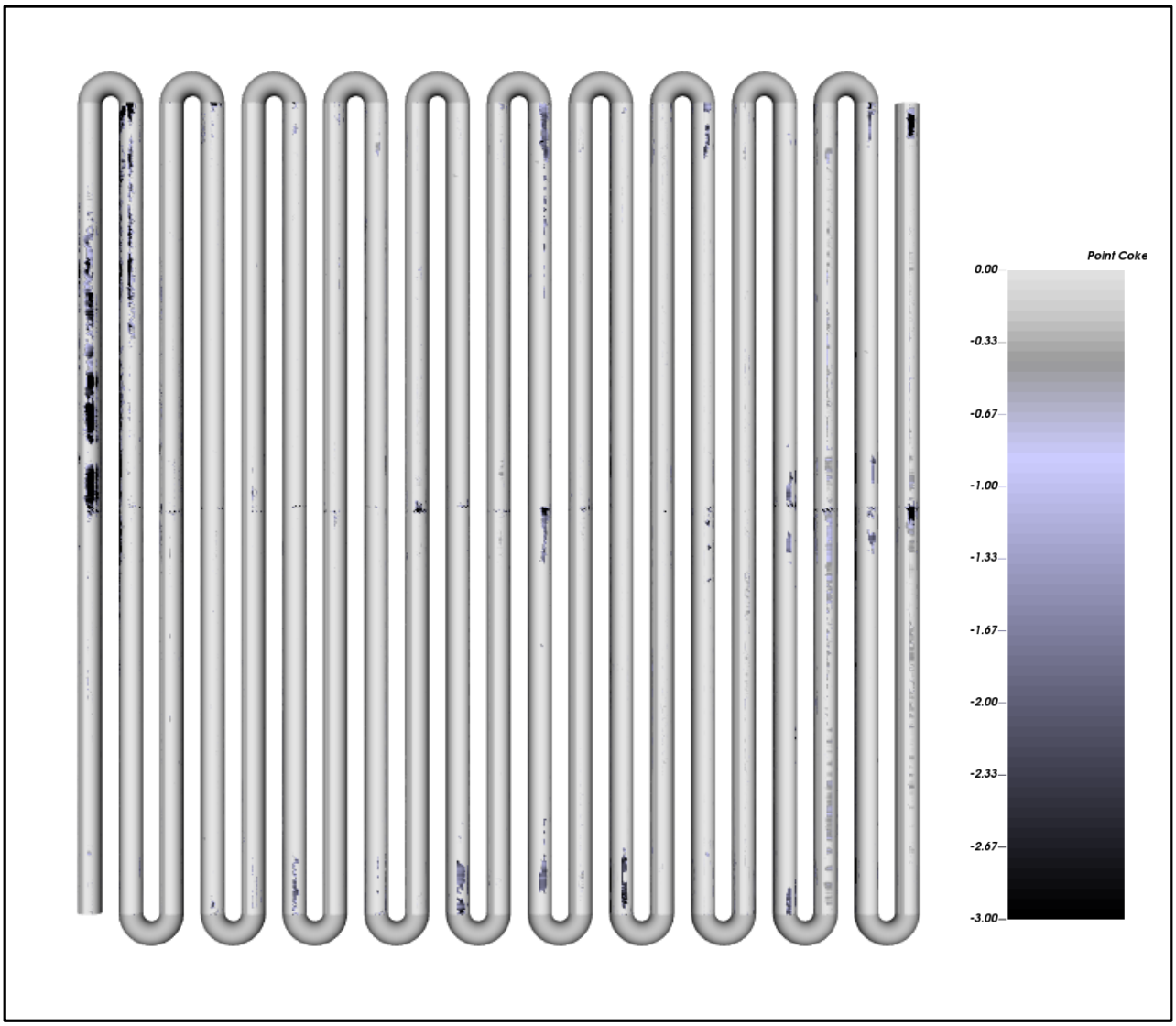


Final Inspection

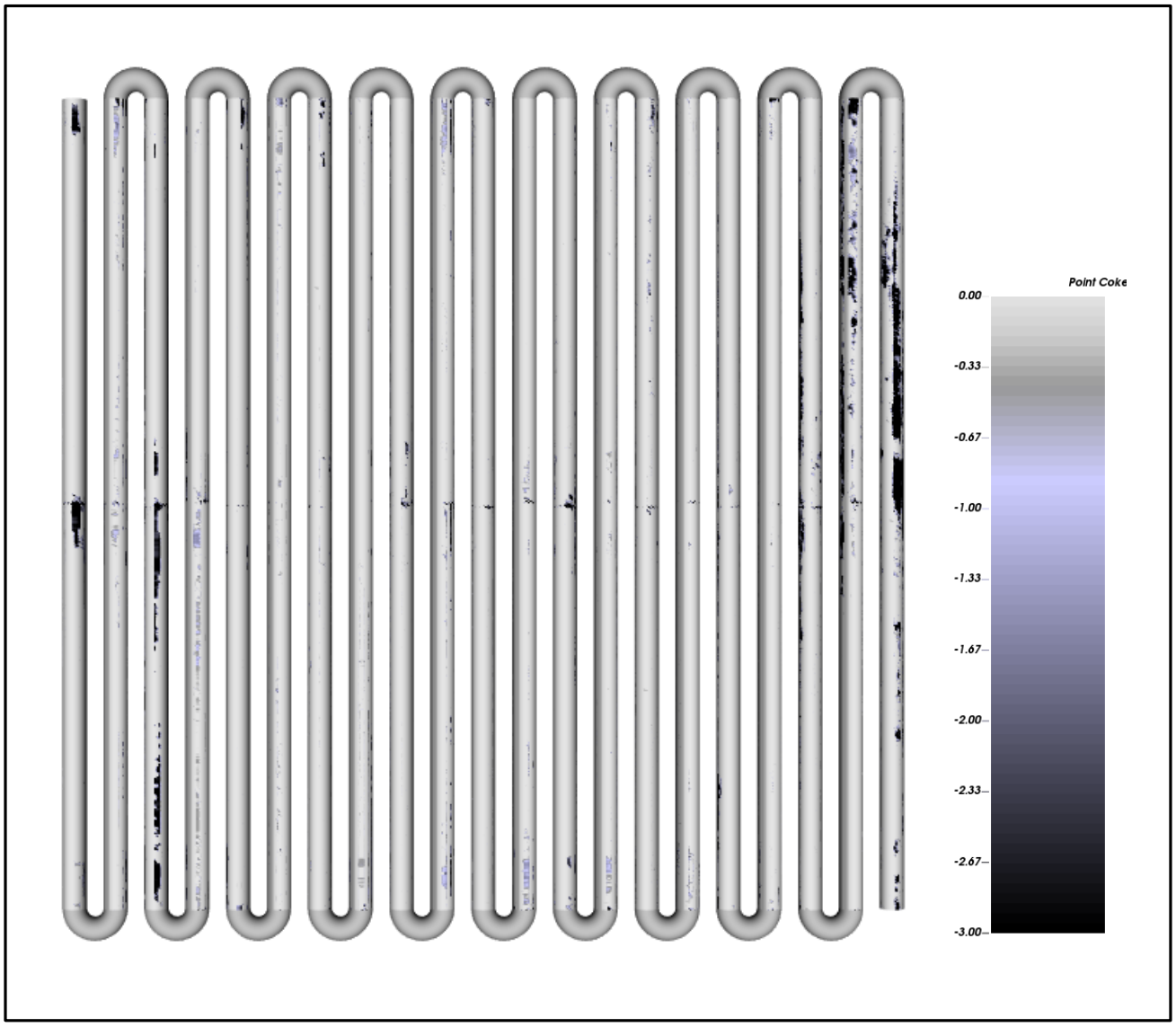


8.3 Pass 8 - Radiant Zone 1: 3D Coke Scans

Front View



Rear View



9 APPENDIX B: EXPLANATION OF COKE REMOVAL ANALYSIS

Results for each pass are split into two sections; Convection tubes and Radiant tubes. Both of these sections include an internal diameter summary table and graph plot. The graphs serve to summarize the measured parameter across the whole of that particular section. For example, a graph for min/max ID in the Pass 1 Convection Tubes section shows the min/max ID along all 12 Convection tubes, beginning at the start of Convection tube 1 and finishing at the end of Convection tube 12. Each vertical gridline within the graph separates each of the tubes. It is emphasized that a full inspection report would include various tube wall thickness graphical and 3D plots.

By careful analysis of wall thickness and internal diameter data, Cokebusters USA inspection technicians are able to identify areas where internal fouling is present within heater tubes. Where Internal fouling is present, internal diameter graphs will show significant drops in the minimum ID as well as the average ID (see Fig. 1).

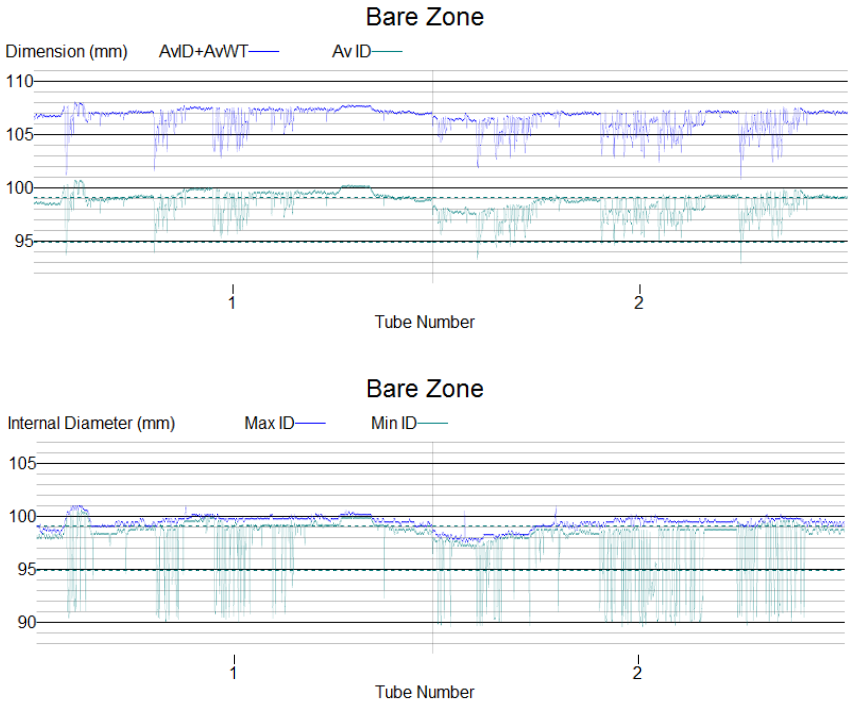
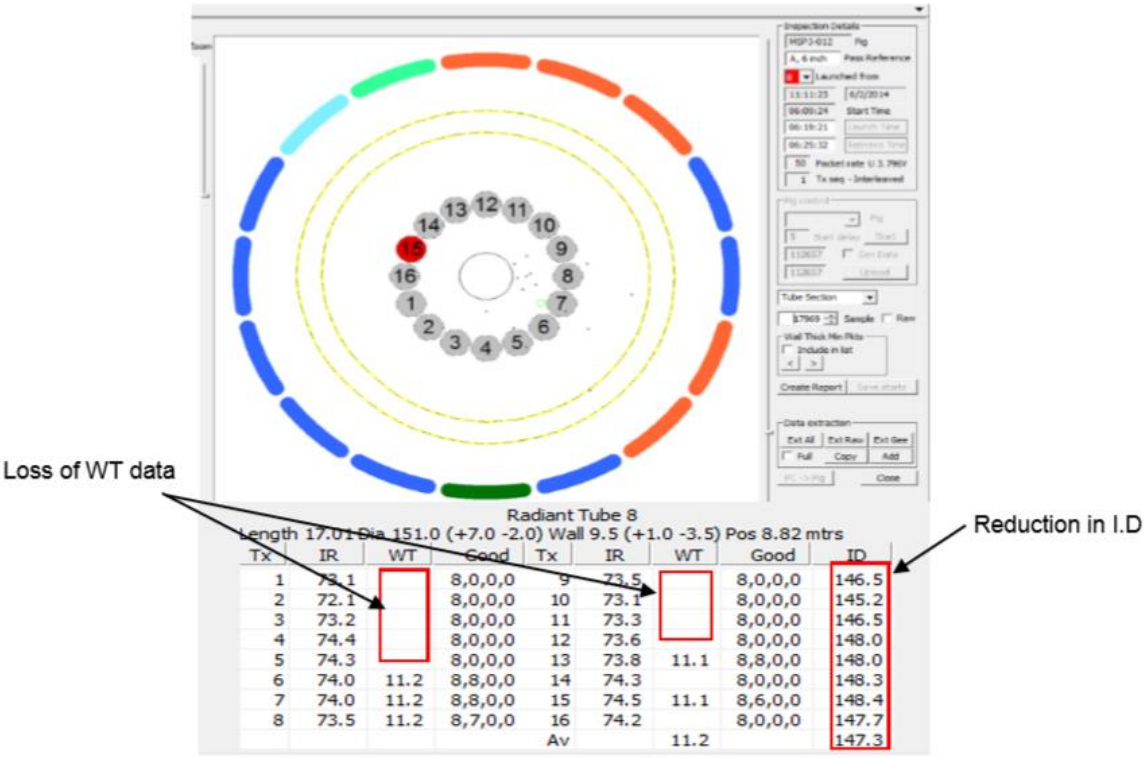


Fig. 1: Internally Fouled Tubes

To verify this, examination of the tube cross sectional view within the Merlin Inspection Data Analysis software at the corresponding areas is carried out. If the reduction in ID is in conjunction with a loss of, or erratic wall thickness measurements, the presence of Internal Fouling is confirmed. (See Fig. 2)



Tx	IR	WT	Good	Tx	IR	WT	Good	ID
1	73.1		8,0,0,0	9	73.5		8,0,0,0	146.5
2	72.1		8,0,0,0	10	73.1		8,0,0,0	145.2
3	73.2		8,0,0,0	11	73.3		8,0,0,0	146.5
4	74.4		8,0,0,0	12	73.6		8,0,0,0	148.0
5	74.3		8,0,0,0	13	73.8	11.1	8,8,0,0	148.0
6	74.0	11.2	8,8,0,0	14	74.3		8,0,0,0	148.3
7	74.0	11.2	8,8,0,0	15	74.5	11.1	8,6,0,0	148.4
8	73.5	11.2	8,7,0,0	16	74.2		8,0,0,0	147.7
				Av		11.2		147.3

Fig. 2: Internally Fouled Tubes

Furthermore, by comparing ID measurements in areas where accurate WT measurements were obtained with that of areas where no WT data was obtained, a good estimate of the thickness of coke remaining on the tube wall can be made.

For comparison purposes Fig. 3 shows how an ID graph should look if the tube were internally clean. As can be seen, the values in these graphs are consistent, non-volatile and there is no significant variation in the Av and Min/Max ID readings.

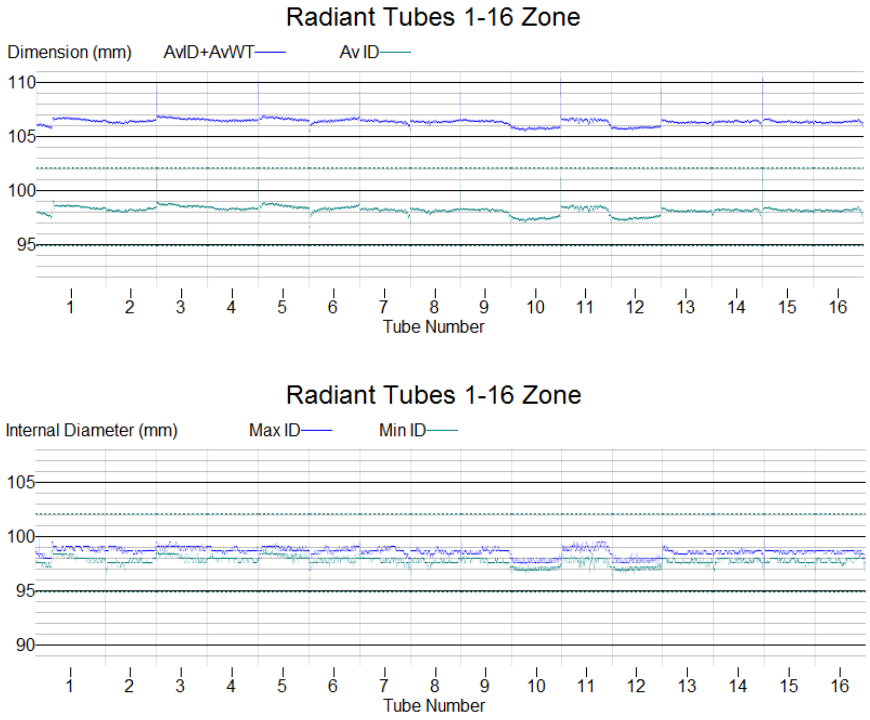


Fig. 3: Internally Clean Tubes

In addition, 3D WT and ID data maps are generated and viewed to clearly identify areas of internal fouling. The reduction in ID will clearly be seen on the ID data map, while areas of grey on the WT data map show where no data wall thickness data was obtained.

10 APPENDIX B: MERLIN MARK IV SPECIFICATION

Inherent static accuracy	±0.1mm / 0.004”
Wall Thickness dynamic accuracy	±0.2mm / 0.008”
Internal Diameter accuracy	±0.75% (full scale)
Axial location accuracy	±60mm / 2.4”
Resolution	0.3” (axial) x 0.5” (circumferential) Typical
Pig speed	0.5ms-1 / 1.6ft/s Typical
Data sampling rate	60Hz
Transducer centre frequency	5MHz
Tube Diameter Range	2.6” – 12”

11 APPENDIX C: INTERPRETING THE DATA

The axial location of each measurement is referenced from the “start” of each tube at the bend/tube weld (0.00m datum). The “end” of each tube is defined as the bend/tube weld farthest away from the process flow. Figures B1, B2 & B3 demonstrate the axial location referencing against three typical process coil arrangement.

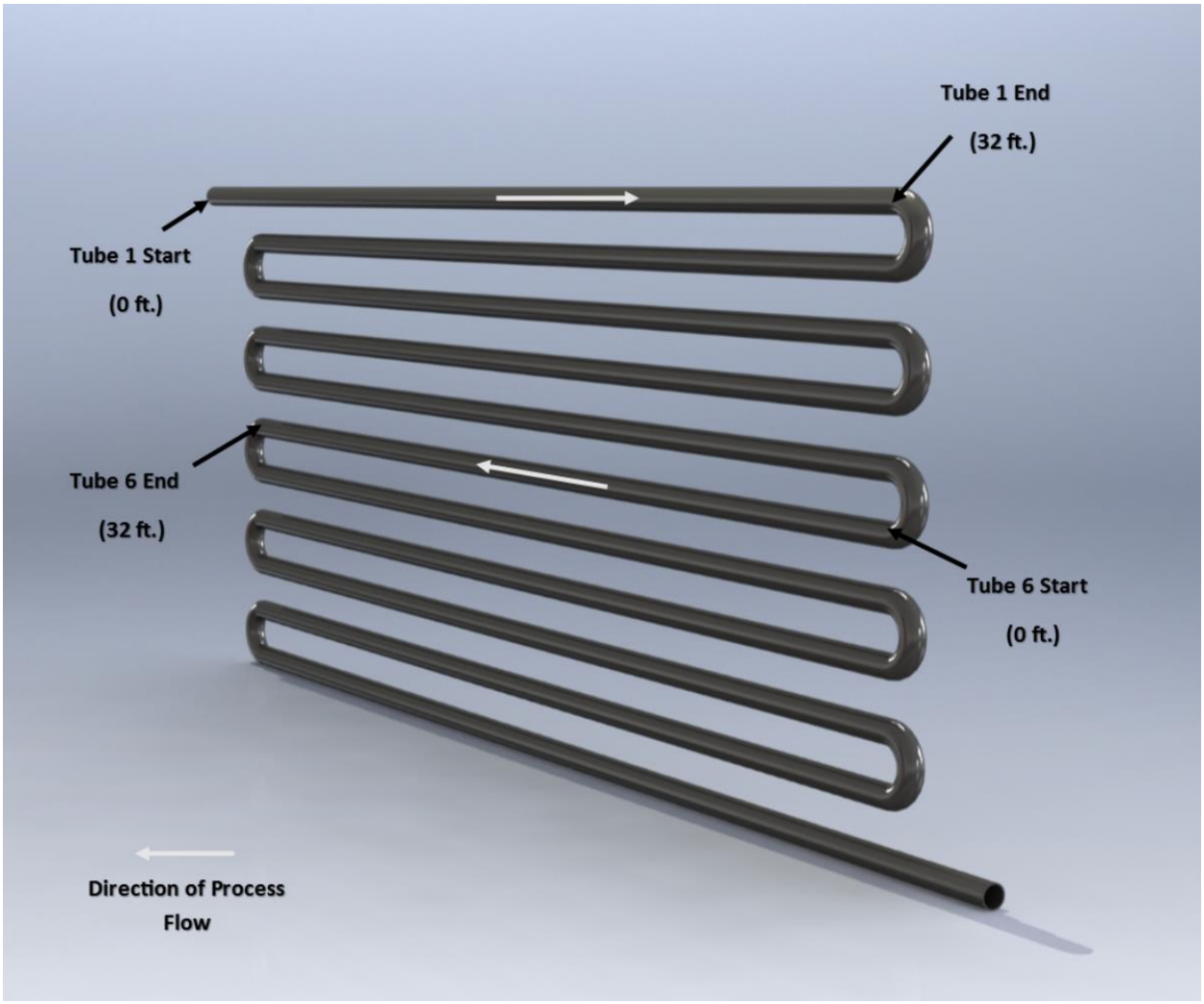


Figure B1: Axial location referencing within a typical horizontal convection coil.

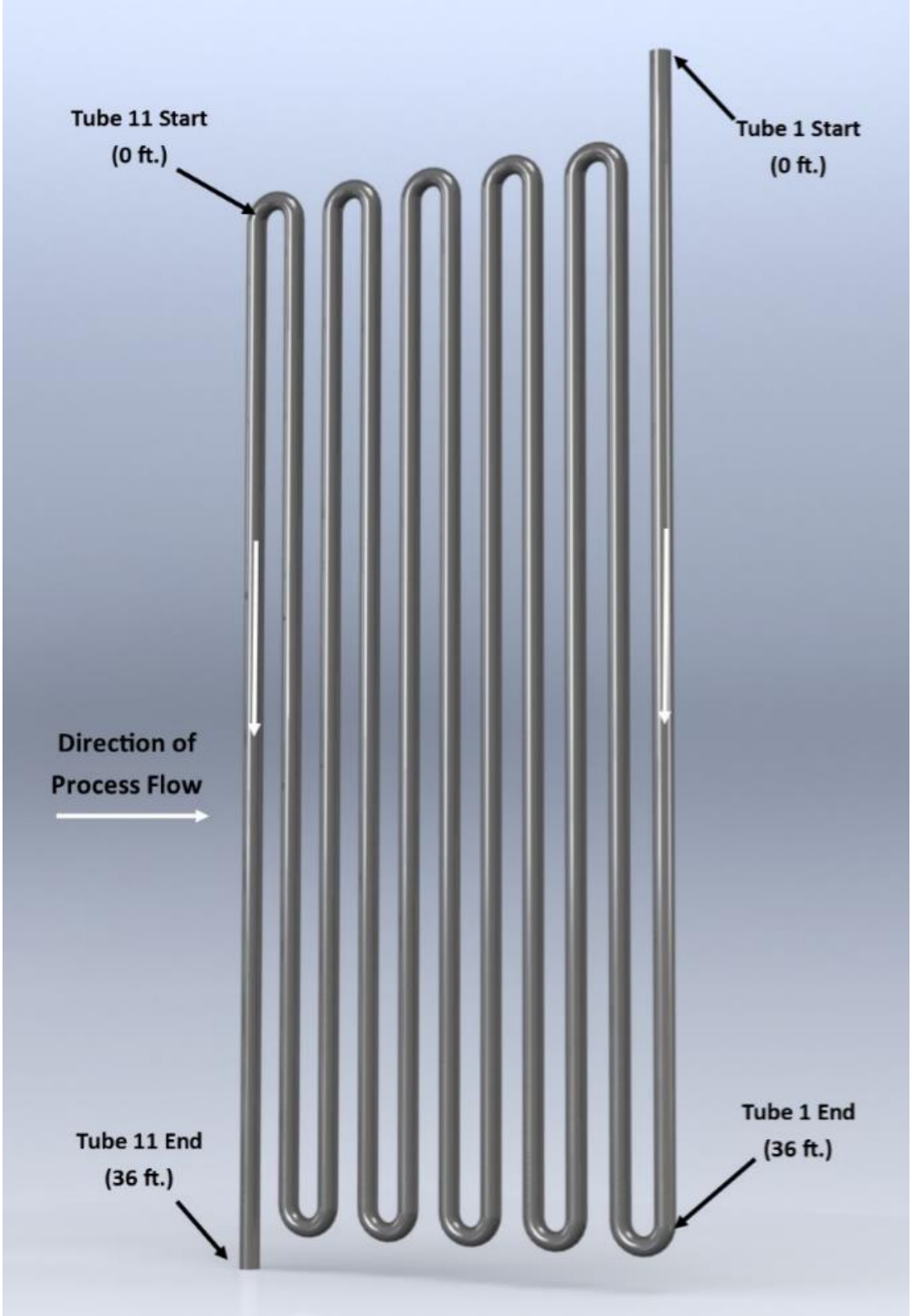


Figure B2: Axial location referencing within a typical vertical radiant coil.

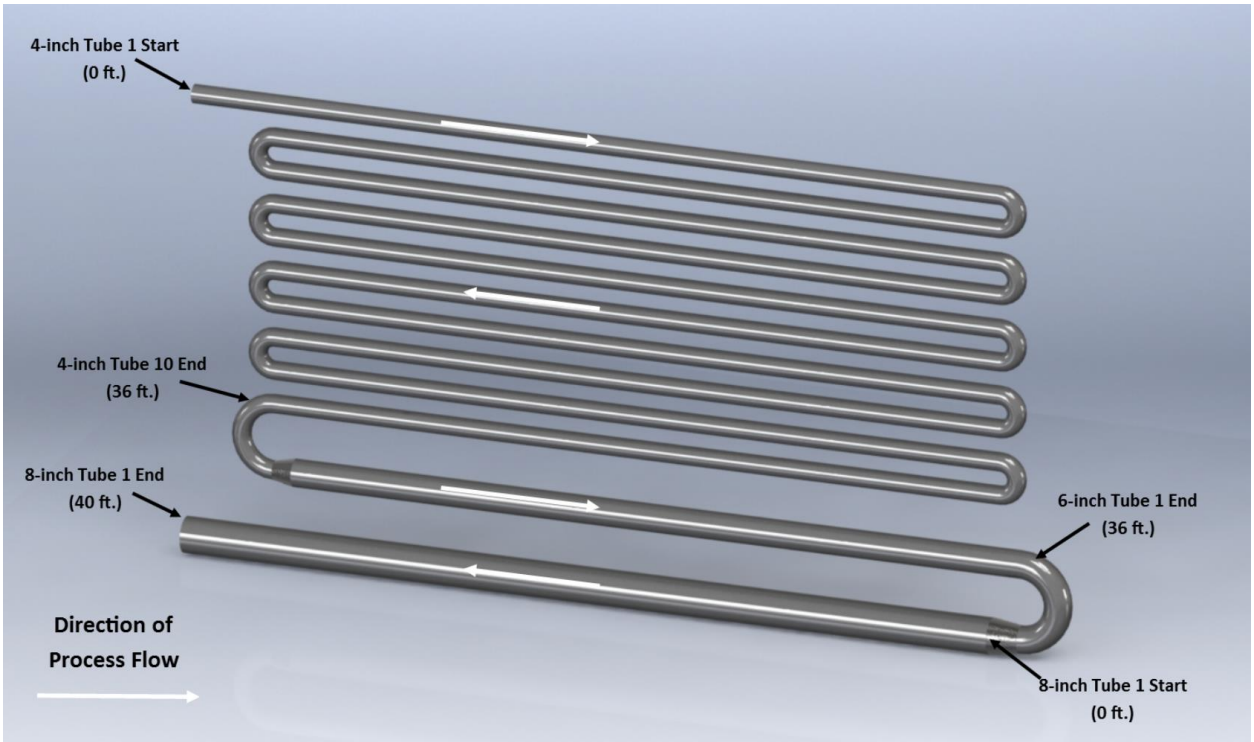
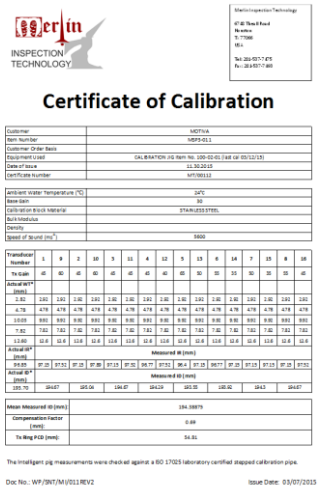


Figure B3: Axial location referencing within a typical radiant coil from a vacuum furnace.

12 APPENDIX D: CALIBRATION

It is standard MERLIN™ procedure that each MIT inspection device is calibrated immediately prior to any MIT inspection operation. The calibration is performed at the COKEBUSTERS Technology Centre, UK, by a PCN/ASNT qualified MIT Technician. During this procedure, each ultrasonic transducer is calibrated independently to a stainless-steel calibration block/step that itself has been measured and certified by a third-party ISO 9001 accredited laboratory. Velocity of sound is then adjusted to the correct value for the furnace tube material that is being inspected and final checks are carried out on a sample that is of equal geometry and material to the furnace tube material. All water temperatures are measured using a Fluke 566 Infrared Thermometer, which has an accuracy of ±1%, to allow for the effect of temperature on the velocity of sound. A calibration block is also available on each Cokebusters pumping unit should technicians need to carry out any further checks whilst on-site. All MIT Technicians are examined and certified to ASNT UT II standards in the Merlin Inspection Procedure and certificates of calibration are available to clients upon request.



INSPECTION TECHNOLOGY

Certificate of Calibration

Customer	MOTIVA
Item Number	MBPS-011
Customer Order Basis	
Equipment Used	CALIBRATION JIG Item No. 100-02-01 (last cal 03/12/15)
Date of Issue	11.30.2015
Certificate Number	MIT/001/15

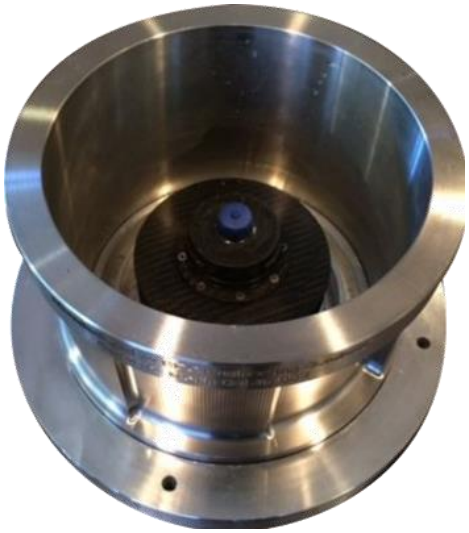
Ambient Water Temperature (°C)	24°C
Base Gain	50
Calibration Block Material	STAINLESS STEEL
Bulk Modulus	
Density	
Speed of Sound (m/s)	5900

Transducer Number	1	9	2	10	3	11	4	12	5	13	6	14	7	15	8	16
Tx Gain	45	60	45	60	45	45	45	60	45	50	55	55	55	55	55	45
Actual WT* (mm)																
2.82	2.81	2.82	2.81	2.81	2.81	2.82	2.82	2.81	2.82	2.82	2.81	2.81	2.82	2.82	2.81
4.78	4.78	4.78	4.78	4.78	4.78	4.78	4.78	4.78	4.78	4.78	4.78	4.78	4.78	4.78	4.78
10.03	9.91	9.91	9.91	9.91	9.91	9.91	9.91	9.91	9.91	9.91	9.91	9.91	9.91	9.91	9.91
7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82	7.82
12.60	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
Actual ID* (mm)	Measured IR (mm)															
94.89	97.15	97.51	97.15	97.89	97.15	97.51	96.77	97.51	96.4	97.15	96.77	97.15	97.15	97.15	97.15	97.51
Actual ID* (mm)	Measured ID (mm)															
185.78	194.87		195.04		194.87		194.04		195.35		195.82		194.5		194.87	

Mean Measured ID (mm):	194.38875
Compensation Factor (mm):	0.69
Tx Ring PCD (mm):	94.81

The intelligent pig measurements were checked against a ISO 17025 laboratory certified stepped calibration pipe.

Doc No.: WP/INT/MI/011REV2 Issue Date: 03/07/2015



13 APPENDIX E: GENERAL CONTRACTUAL CONDITIONS

1.0 The Inspection Contract

In addition to the terms and conditions detailed in the Quotation Template (Document Number: MITUS/IR/205), the following contractual terms which are specific to the Merlin Inspection service shall be adhered to.

The Inspection Company shall during the Contract Period subject to earlier termination provide the Client with an in-line inspection service, referred to as "Intelligent Pigging" or "Smart Pigging". For the avoidance of doubt the Client acknowledges that:

Cokebusters Limited have been requested by the client to undertake an in-line inspection service. The provision of the Inspection Service does not relieve the Client of this responsibility. The Client acknowledges that it is the Client's legal responsibility to have the relevant equipment inspected in accordance with all applicable legislation and the Inspection Company shall have no liability to the Client for any fines or other penalties incurred by the Client in this regard (including without limitation any fees for intervention levied against the Client by the Health and Safety Executive);

The Inspection Service will not include any services not specifically detailed within the Contract including without limitation the following services (although such services may be available subject to additional charges and the conclusion of a separate agreement between the parties):

Neither the Inspection Company nor the Client shall be liable to the other party in contract, tort, negligence or breach of statutory duty or otherwise for any:

- **Loss of profits**
- **Economic loss**
- **Loss of turnover**
- **Loss of business**
- **Loss of data**
- **Loss of goodwill**
- **Indirect, special or consequential losses**

The Inspection Company shall have no liability under the Contract for any failure or delay in the provision of an Inspection to the extent that the same is contributed to by the acts or omissions of the Client (including without limitation where Plant is not made available for Inspection), even if the same results in Plant becoming overdue for Inspection and in such circumstances it shall be the Client's responsibility to rearrange Inspection of such Plant or take it out of service.

Where any Plant is overdue for Inspection at the time it is added to the Contract (including at commencement of the Contract), or where Plant becomes overdue for Inspection as a result of the acts and omissions of the Client, the Inspection Company will seek to agree a timetable with the Client for the Inspection of such Plant. However, the Client acknowledges that the Inspection Company shall have no liability in respect of such overdue Plant and the Client indemnifies and shall keep the Inspection Company indemnified in respect of any claims of any nature made against any and all damages, costs and expenses suffered or incurred by the Inspection Company in connection with such Plant being overdue for Inspection.

Nothing in this Contract shall operate to limit or exclude the liability of either party for fraud, fraudulent misrepresentation, death or personal injury caused by its negligence, or any other liability which cannot be limited or excluded by law.

2.0 Deliverables

Upon completion of the in-line inspection, it is understood that Cokebusters will provide the client with the following within 24-hours of completing the final inspection run:

- **A written Field Report, providing the client with an overview of the process coil(s) metallurgic and geometric condition in tabulated and graphical form.**
- **Details of any metallurgic/geometric flaws contained within the process coil(s). It should be noted that all data contained within the Field Report will not be fully validated until submission of the Final Report.**
- **A close out meeting with the client to discuss the inspection results (if requested).**

Upon completion of the in-line inspection, it is understood that Cokebusters will provide the client with the following within 7 days of completing the final inspection run:

- **A written Final Inspection Report, providing the client with comprehensive details of the process coil(s) condition. In addition to the data tables and graphs provided within the Field Report, the Final Report shall include written evaluations, descriptions and recommendations from a Senior Merlin Inspector (Internal Level III Technician).**
- **Interactive colour coded 3D models of the process coil(s).**
- **A separate document containing individual section graphs for each process tube (If requested)**

It is understood by the client that:

Cokebusters Limited will not accept responsibility for any metallurgic flaw, defect or anomaly contained within the process coil(s) tubing and/or return bends.

Merlin Technology Inspection Service provided by Cokebusters Limited is for advisory purposes only. Cokebusters Limited will not accept responsibility for any geometric anomaly, flaw or defect which may have gone undetected from the inspection procedure. Cokebusters

The accuracy, resolution and technical capabilities of the Merlin Mark IV In-line Inspection Tool are described within Appendix A of the Field and Final Inspection Reports. Cokebusters Limited will not accept responsibility for any misinterpretation of data or reporting.

Cokebusters Limited will not accept responsibility for any process anomalies, accidents or disruptions following the inspection service.

3.0 Confidentiality

Unless otherwise agreed, each party shall keep confidential the terms of the Contract and all information of a confidential nature that it may acquire in relation to the business or affairs of the other party (Confidential Information). Neither party shall use the other party's confidential information for any purpose other than to perform its obligations under this Contract, unless otherwise required by law or the confidential information has entered the public domain other than through the fault of the party which received such Confidential Information. The obligations in this clause shall continue for a period of three (3) years from the date of expiry or termination of the Contract.

The Inspection Company shall be entitled to:

Share Confidential Information with other members of its Group; and

Retain a copy of any Confidential Information as required for regulatory purposes and/or to show evidence of compliance with this.

4.0 Liability

In substitution for all rights which the Client would or might have but for the Contracts, the Inspection Company undertakes that if an Inspection is performed in a defective or erroneous manner then the Inspection Company will at its discretion either credit to the Client the Fee paid by the Client and attributable to the Inspection or re-perform the Inspection (save as to the time of performance).

5.0 Data Protection

The Inspection Company, together with its Group, may use the personal and business details the Client provides (or which are supplied by third parties) including any details of directors, officers, partners and employees (whose consent the Client must obtain) to:

1. Provide the Client with a quotation and to deal with the associated administration of the Contract;

2. Search credit reference, credit scoring and fraud agencies who may keep a record of the search;

3. Support the development of the Inspection Company's business by including the Client's details in customer surveys, for market research and business reviews which may be carried out by third parties acting on the Inspection Company's behalf.

Under the Data Protection Act 1998 individuals are entitled to request a copy of all the personal information the Inspection Company holds about them.

Personal details may be transferred to countries outside the EEA. They will always be held securely and handled with the utmost care in accordance with all principles of English law.

By applying for and/or entering into this Contract the Client is deemed to specifically consent to the use of any personal data supplied by the Client and the Client's contract data in the ways and for the purposes set out.

6.0 Indemnity

The Client indemnifies and shall keep the Inspection Company indemnified in respect of any claims of any nature made against any and all damages, costs and expenses suffered or incurred by the Inspection Company as a result of any third-party claim arising out of the Client's failure to comply with its obligations under the Contract.

7.0 General

Relationship of the parties

Nothing in the Contract is intended to, or shall be deemed to, establish any partnership or joint venture between any of the parties, constitute any party the agent of another party, or authorize any party to make or enter into any commitments for or on behalf of any other party.

Variations to the Contract

No variation of the Contract shall be effective unless it is in writing and signed by the parties (or their authorized representatives).

Notices

Any notice given to a party under or in connection with this Contract shall be in writing and shall be delivered by hand or sent by recorded delivery or pre-paid first-class post or other next working day delivery service to the Cokebusters Head Office address or its principal place of business (in any other case) (and in the case of notices to the Company, a copy shall be required to be sent for the attention of the Company Secretary at the same address).

Entire Agreement

The Contract constitutes the entire agreement between the parties and supersedes and extinguishes all previous agreements, promises, assurances, warranties, representations and understandings between them, whether written or oral, relating to its subject matter.

Each party agrees that it shall have no remedies in respect of any statement, representation, assurance or warranty (whether made innocently or negligently) that is not set out in the Contract. Each party agrees that it shall have no claim for innocent or negligent misrepresentation or negligent misstatement based on any statement in the Contract.

No Waiver

No failure or delay by a party to exercise any right or remedy provided under the Contract or by law shall constitute a waiver of that or any other right or remedy, nor shall it prevent or restrict the further exercise of that or any other right or remedy. No single or partial exercise of such right or remedy shall prevent or restrict the further exercise of that or any other right or remedy.

Rights of Third Parties

No one other than a party to the Contract shall have any right to enforce any of its terms.

Unenforceable Terms

If any provision in the Contract is held by any competent court to be unenforceable in whole or in part, the validity of the other provisions and the remainder of the provision in question shall not be affected.

Language, Governing Law and Jurisdiction

The language of the Contract and all communications relating to it will be in English.

English law shall apply to the Contract and the parties agree to submit to the exclusive jurisdiction of the English Courts in respect of all disputes arising out of or in connection with the Contract (whether of a contractual or tortious nature or otherwise).