## Ultrasonic Inspection Equipment for Seamless Gas Cylinders

**A Paper By** 

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## 1 Introduction

It is necessary to inspect gas cylinders both at the manufacturing stage and on an annual basis as part of a service and maintenance procedure. This ultrasonic inspection should be 100% of the parallel section of the cylinder as detailed in the following inspection standards, BS5045, EN1964 and ISO11439.

The typical flaws found during the ultrasonic inspection of a gas cylinder are:

- 1. Longitudinal scratches both on the internal and external wall of the cylinder.
- 2. Circumferential scratches both on the internal and external wall of the cylinder.
- 3. Thinning of the wall of the cylinder due to a faulty manufacturing process.
- 4. The possibility internal corrosion which would show it's self as a thinning of the wall of the cylinder.

An illustration of these flaws is shown below, where a section through a cylinder has been drawn.



An Illustration of the Typical Flaws Found During the Ultrasonic Inspection of Gas Cylinders

In order to monitor gas cylinder for these flaws each cylinder is inspected on a 100% basis. There are two fundamental techniques for the inspection of gas cylinders with ultrasound.

#### 1.1 The Shear Wave Inspection Technique

With the beam from the probe at an angle to the surface of the gas cylinder, the probe is not directly above the flaw, but some longitudinal distance away. At the surface of the gas cylinder the ultrasonic energy refracts, following Snell's law, and results in a shear wave beam in the cylinder, at an angle to the normal, in this case at an angle of  $45^{\circ}$ . Please refer to the illustration of this technique below, when applied to longitudinal flaws.



An Illustration of the Shear Wave Inspection Technique for Longitudinal Flaws

The flaw will be indicated on the A-Scan of the ultrasonic flaw detector; and its position along the time base of the A-Scan is the distance along the beam, which is the path length to the defect.

If now circumferential flaws are considered, please refer to the illustration of this technique below; again the position along the time base of the A-Scan is the distance along the beam, which is the path to the flaw.



An Illustration of the Shear Wave Inspection Technique for a Circumferential Flaw

#### **1.2 The Compression Wave Inspection Technique**

With the probe normal to the surface of the gas cylinder, a compression wave beam is introduced into the curved surface and is reflected by the inner wall of the cylinder. The inner wall will be indicated on the A-Scan of the flaw detector; and its position along the time base of the A-Scan is the depth from the surface of the cylinder. For accuracy the measuring system measures from the surface signal, the interface echo, to the first repeat of the inner wall signal. Please refer to the following illustration of this technique.



An Illustration of the Compression Wave Inspection Technique

### **1.3 The Water Column Coupled Probe Assembly**

The **WCCP** assembly has been developed to replace existing water jet type probe units and to obtain an inspection signal to noise ratio similar to immersion systems. Units have been supplied for longitudinal shear wave and compression wave inspection

The units are very compact and permit multi-probe heads to be made using a simple modular construction. The latest **WCCP** twin assemblies can configure ten probes in a 100mm length. The index between probes is selected to ensure full interlacing of probe scans. Standard multiple probe configurations have been defined such that full interleaving of probe scans is achieved for detection of a specific minimum flaw length or full ultrasonic coverage.

The **WCCP** assemblies offer the following advantages:

- 1. Units applied to product top surface to give easy access for setting up
- 2. Good signal to noise ratio with performance similar to that of immersion systems
- 3. Minimal adjustment when changing tube diameters
- 4. No immersion tank required
- 5. Inspect within 20mm of the product ends, with instantaneous coupling
- 6. Incorporate end detection facilities using small receiver probes to monitor product position.

In the **WCCP** probe assembly used for gas cylinder inspection there are four shear wave probes, two longitudinal shear wave probes 180° apart, two circumferential probes 180° apart one compression probe, see below for photograph of the WCCP assembly used in gas cylinder inspection.



A Photograph of the Gas Cylinder Inspection WCCP Assembly

## 2 **Principle of Operation**

The use of ultrasound as a non-destructive test method involves transmitting bursts of ultrasonic energy into the gas cylinder and monitoring the reflection from any flaw that may be there. Also at the same time the wall thickness is monitored, using an additional probe.

An electrical impulse, from the flaw detector, transmits ultrasound from the probe into the coupling fluid, at the surface of the gas cylinder the sound beam is refracted, resulting in a beam of sound in the wall of the gas cylinder at 45° to the normal. A flaw such as an internal or external scratch would reflect the sound back along the path it had taken; this flaw would be displayed on the A-Scan of the ultrasonic flaw detector. Monitor gates identify the flaw echo to be processed, and depending on the received signal amplitude, it may be determined as a valid flaw or not.

For a flaw to be determined as a valid flaw, the amplitude of the reflected echo must be greater than the threshold level set for the monitor gate.

For the thickness monitor, the time of flight of the ultrasound, from the interface echo, which is the surface of the gas cylinder, to the reflection from the inner surface of the cylinder is measured. This time of flight measurement is in the form of an analogue voltage proportional to the thickness of the wall measured. Both the flaw digital alarms for each monitor gate and the analogue time of flight signal are connected to the industrial workstation for processing and thickness calculation. All of these operations are synchronised by the rotation of the drive rolls. Please refer to the system block diagram below; each unit being described in detail as follows:



The System Block Diagram

• The Ultrasonic Instrument comprises of a multi-channel transmitter/receiver unit. It provides all the necessary signals to synchronise the transmitter and monitor gates to the rolls when rotating. The monitor gates are provided to allow exclusive monitoring of required flaw signals. The ultrasonic instrument is software controlled and is automatically launched from the gas cylinder Inspection software, on the industrial workstation.

The ultrasonic instrument has two parts; the first for the shear wave channels is a PCI ultrasonic card within the industrial workstation, which is connected to an external eight channel multiplexer, of which only four channels are used. The second for the compression wave wall thickness monitor, which is only a PCI ultrasonic card within the industrial workstation. • The Encoder Interface provides the power for the encoder and also provides the ultrasonic instrument with a synchronising signal even when the rolls are not rotating. Once the rolls start rotating the encoder interface immediately synchronises the ultrasonic instrument to the roll speed. The encoder interface also provides a direct connection of the digital and analogue signals from the ultrasonic instrument, to the data acquisition board in the industrial workstation.

• The Industrial Workstation reads the digital flaw alarms and wall thickness time of flight information from the ultrasonic instrument via the data acquisition board, and stores it in memory. The rate at which this is done and the number of samples taken is dependent on the roller speed, the gas cylinder diameter entered and the length of the scanned area which is set by the position of the scan limit dogs. From this information the flaw lengths and cylinder wall thickness' are calculated and compared with the user selected *Cylinder* file. The results are displayed and the accept/reject decision is made.

• The software to control the test procedure and provide operator interfacing is the Insight NDT Gas Cylinder Inspection Software.

#### 2.1 The Ultrasonic Instrument

The ultrasonic technique is now well established as a method of detecting internal and superficial flaws in a wide range of metallic and non-metallic materials. Not only will the method detect defects but will also provide invaluable information on the location and severity of any flaws detected. The range of applications include, weld testing, crack detection, bond assessment, fatigue and stress damage, metal quality, porosity, thickness



measurement together with many other applications on raw materials, partially and fully finished components and on parts following a period in service.

The transmitter pulse from a transmitter in the ultrasonic instrument in the system excites the transducer connected to that channel. The Channels can fire sequentially, which is a multiplexed system, or they fire at the same time, which is a parallel fire system. The type of system depends on the ultrasonic instrument fitted. The resultant signals from the transducers pass through a tuned amplifier and filter arrangement to be displayed as a A-scan on the computer screen, as the above screen illustration.

#### 2.2 The Gas Cylinder Software

The gas cylinder inspection software is designed to perform several functions critical to the integrity of the overall inspection system. These functions include:

- To provide a user-friendly menu-driven user interface for communication with the gas cylinder testing system.
- To process and analyse ultrasonic inspection data provided to the computer by the ultrasonic instrument.
- To store sets of user definable acceptance parameters, each separate set known as a *Cylinder* file.
- To save the raw inspection data, for future analysis.
- To display the inspection results, after an inspection or when re-loading a saved inspection data file.
- To print the results to a printer or as a bitmap file.

The gas cylinder inspection software collates data provided by the ultrasonic instrument concerning the ultrasonic flaw detection of gas cylinders. This data is stored analysed and displayed following each gas cylinder test, and furthermore,



the software will compare the test results with accept/reject criteria previously entered by the user in the form of a **Cylinder** file, and make an accept/reject decision based upon this data. Finalised test results are displayed following each test and can be saved for future reference.

The main screen of the gas cylinder inspection software is shown above;

The data from an inspection is displayed in a graphical form, and the precise flaw lengths calculated. This inspection data can be loaded from a saved inspection file or the result of a recently completed inspection.

The screen has a number of tab pages, which allow viewing of the data for the desired flaw type as shown below;

• **Longitudinal Flaws** page shows the chart for the ultrasonic channels that are connected to the longitudinal flaw shear wave probes.



In addition to this chart, there are two text controls which display the position and length of flaws found for both internal and external flaws. These controls may be scrolled to view all the flaws found using the scroll bar to the right of the relevant control.

• *Circumferential Flaws* page shows the chart for the ultrasonic channels that are connected to the circumferential flaw shear wave probes.



In addition to this chart, there are two text controls which display the position and length of flaws found for both internal and external flaws. Once again these controls may be scrolled to view all the flaws found using the scroll bar to the right of the relevant control. • *Wall Thickness* page shows the C-Scan chart for the ultrasonic channel which is connected to the wall thickness compression wave probe.



In addition to this chart, there is a single text control which displays the area, position and minimum thickness of the wall thickness flaws found. Again this control may be scrolled to view all the wall thickness flaws found using the scroll bar to the right of the relevant control.

The main screen also has a single button, which allows the user to:

• Exit the Gas Cylinder Inspection Software, by pushing the button, selecting Exit in the File menu or pushing Ctrl+x keys.

## **3** System Configuration

The machine mechanical handling system provides the gas cylinder drive via rubber rolls, the couplant recirculation and filter system and **WCCP** assembly scanning bridge above the cylinder to be inspected. Currently there are three different types of mechanical handling system.

A manual load semi-automatic system, in which the gas cylinder to be inspected is loaded from overhead by the inspector.

A manual load semi-automatic system, in which the gas cylinder to be inspected is loaded from the end being pushed off of a conveyor on to the machine by the inspector.

A custom designed fully automatic system.

#### 3.1 Overhead Loading Semi-Automatic System

The operations involved in the inspection of a gas cylinder on the overhead loading semi-automatic machine, having set up the system, include placing the cylinder to be inspected on the drive rolls, with the neck of the cylinder up against the stop, pressing the inspection start button, and waiting for the verdict, which is displayed on illuminated indicators as either 'accept' or 'reject'.



Parallel horizontal drive rolls that serve to support and rotate the gas cylinder, the rotation is via a three-phase motor and speed controller. An encoder is directly linked to these rolls providing synchronisation of the data acquisition electronics and the ultrasonic instrument. Rubber tyred rollers are used to minimise surface damage to the gas cylinder and prevent slippage.

#### Ultrasonic Inspection Equipment for Seamless Gas Cylinders

Couplant fluid is pumped from an external 55-litre reservoir, via a filter, to the **WCCP** assembly. The term 'couplant' is used to describe the function of the fluid; to provide a coupling medium through which the ultrasound is transmitted between the transducer and the surface of the gas cylinder.

The **WCCP** assembly is attached to a scanning bridge (as shown here) which facilitates correct positioning of the **WCCP** relative to the gas cylinder to be inspected. The **WCCP** has a pneumatic raise lower mechanism and rotary couplant manifold, which allows the **WCCP** traverse the neck or base of a dome ended cylinder, but only in one direction.



The position of the **WCCP** is monitored by the Gas Cylinder Inspection software, it shows the position of the **WCCP** in mm from the reference end of the system and also shows the state of the scan limits, as shown;



Once the inspection start button has been pushed the drive rolls start to rotate. The **WCCP** assembly is then lowered on to the cylinder and the scan started. The scan is stopped on reaching the scan end limit, and the drive rolls stopped. The cylinder is only scanned between the two end limits, and therefore data is only displayed on the software between these limits. When scanning the end of the cylinder the scan will start on the parallel section of the cylinder and move towards the end.

#### 3.2 End Loading Semi-Automatic System

This system is fundamentally the same as the Overhead Loading system above, it only differs in the way that the inspector loads and unloads the gas cylinder. When loading the cylinder, the inspector pushes the cylinder off of the inlet conveyor an on to the inspection system. With the cylinder in place on the inspection system the end stops are raised and the inspection sequence initiated by pressing the inspection start button.

Once the system has made an accept or reject decision, the inspector can lower the end stops and push the cylinder off of the machine and on to the exit conveyor.

The scanning bridge and couplant system are identical to that described in the Overhead Loading system.

#### 3.3 Fully Automatic System

Generally Automatic systems are designed to meet customers' exact requirements; we have supplied a number of different fully automatic systems, an example of which is described and shown below:



The gas cylinders to be inspected are transported on the inlet conveyor. If the inlet of the machine is empty a cylinder is pushed off of the inlet conveyor on to the inlet of the machine. The cylinder on the inlet of the machine is moved by the load eject mechanism to the inspection position, and the cylinder scanned in the same way as the semi-automatic systems.

Once the inspection is complete and an accept or reject decision has been made, the cylinder is ejected, another cylinder will loaded and the inspection cycle for that cylinder started. If the ejected cylinder has been accepted, the cylinder will be ejected off on to the accept conveyor. However if the cylinder was rejected the cylinder will be segregated and put into the reject chute beneath the accept conveyor.

