



CGA C-20—2021

REQUALIFICATION STANDARD FOR METALLIC, DOT AND TC 3-SERIES GAS CYLINDERS AND TUBES USING ULTRASONIC TESTING

THIRD EDITION



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Work Item 17-033
Cylinder Specifications Committee

NOTE—Technical changes from the previous edition are underlined.

NOTE—Appendices A and D (Informative) are for information only.

NOTE—Appendices B and C (Normative) are requirements.

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1 Introduction

This standard is used for the requalification of metallic seamless cylinders and tubes using ultrasonic testing (UT).

UT of cylinders and tubes provides for measurement of wall thickness and detection of both internal and external pits, cracks, and other flaws that cannot be easily discerned by visual inspection or hydrostatic test methods. UT can be performed without removal of the valve and contents.

A cylinder or tube that has been rejected by UT shall not be subsequently requalified for continued service by the use of the hydrostatic test method.

WARNING: *Cylinder requalification can subject the personnel performing examinations to certain hazards such as exposure to containers under pressure and flammable or toxic gases, which can result in death or serious injury.*

2 Scope

This standard identifies and describes the various acceptable UT methods (also known as ultrasonic examination [UE] methods) that may be used in place of internal visual inspection and hydrostatic requalification methods used to examine certain metallic, U.S. Department of Transportation (DOT)/Transport Canada (TC) 3-series gas cylinders and tubes as mandated by Title 49 of the U.S. *Code of Federal Regulations* (49 CFR) and TC's *Transportation of Dangerous Goods Regulations*, and cylinders manufactured under certain DOT special permits or TC equivalency certificates [1, 2].¹ This standard also specifies the allowable flaw acceptance/rejection criteria to be used. This standard may also be applied to other seamless steel and aluminum alloy cylinders and tubes when authorized by the regulatory authority.

Aluminum alloy cylinders susceptible to sustained load cracking such as those manufactured from 6351 aluminum alloy shall also have the shoulder and neck area internally visually inspected and an eddy current examination of neck threads completed in accordance with established regulatory requirements.

This standard does not address any safety, health, or environmental considerations associated with UT or regulations and codes. Operating procedures and processes regarding worker safety precautions and requirements shall be met. See additional references in Section 13.

3 Definitions

For the purpose of this publication, the following definitions apply.

3.1 Publication terminology

3.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

3.1.2 Should

Indicates that a procedure is recommended.

3.1.3 May

Indicate that the procedure is optional.

3.1.4 Will

Is used only to indicate the future, not a degree of requirement.

3.1.5 Can

Indicates a possibility or ability.

¹ References are shown by bracketed numbers and are listed in order of appearance in the reference section.

3.2 Technical definitions

3.2.1 A-scan

Ultrasonic data presentation where the horizontal base line indicates time or distance and vertical deflection from the base line indicates amplitude of reflected and received energy.

3.2.2 Amplitude

Vertical pulse height of a signal, usually base to peak, when indicated by an A-scan presentation.

NOTE—The height of the signal is dependent upon the amount of reflected energy from a surface interface.

3.2.3 Authority having jurisdiction (AHJ)

Organization, office, or individual responsible for enforcing the requirements of a code or standard or responsible for approving equipment, materials, installations, or procedures.

3.2.4 B-scan

Ultrasonic data presentation that displays a cross section of the specimen indicating the length and depth (area) of reflectors and their relative positions.

3.2.5 C-scan

Ultrasonic data presentation that provides a plan view (top view looking down) of the specimen and shows the length, orientation, and location of discontinuities therein and could display amplitude and depth.

3.2.6 Calibration

Process of adjusting UT system parameters using a calibration standard to establish a condition to which cylinders and tubes under test will be compared.

NOTE—Also known as standardization.

3.2.7 Calibration standard

Cylinder or cylinder section possessing similar acoustic properties, surface finish, and metallurgical conditions as cylinders under test that has simulated defects of given dimension representing acceptance/rejection criteria.

NOTE—It is used to produce ultrasonic reflections of known characteristics and calibrate the UT system.

NOTE—Also known as a reference standard.

3.2.8 Condemned cylinder

Cylinder no longer fit for service. A condemned cylinder is required to be removed from service.

3.2.9 Couplant

Substance used between the transducer and test surface to eliminate the presence of air and facilitate transmission of ultrasonic energy.

3.2.10 Cylinder

Pressure vessel designed to standards or regulations to contain pressure 40 psi or greater and having a circular cross section.

NOTE—It does not include a portable tank, multi-unit tank car tank, cargo tank, or tank car.

NOTE—Also described by TC's *Transportation of Dangerous Goods Regulations* as a container with a water capacity not greater than 450 L, in a cylindrical shape, and capable of withstanding an internal absolute pressure greater than 275 kPa [2].²

NOTE—For purposes of this standard, cylinder(s) also means tubes and tons unless otherwise stated.

3.2.11 Defect

Flaw that exceeds the established acceptance criteria.

² kPa shall indicate gauge pressure unless otherwise noted as (kPa, abs) for absolute pressure or (kPa, differential) for differential pressure. All kPa values are rounded off per CGA P-11, *Guideline for Metric Practice in the Compressed Gas Industry* [3].

3.2.12 Discontinuity

Interruption in the normal configuration of a cylinder due to a flaw, geometry (for example, sidewall-to-base transition area), or an imperfection (for example, draw marks).

3.2.13 Flaw

Imperfection or discontinuity that may or may not be acceptable based upon established acceptance/rejection criteria (for example, corrosion, scratches, cracks, cuts, gouges, or pits).

3.2.14 Gain

Ultrasonic equipment control that when adjusted, increases or decreases the sensitivity of the UT system to detect discontinuities.

NOTE—Gain is normally measured in decibels (dB), which is a logarithmic measure of amplification.

3.2.15 Indication

Signal shown on the ultrasonic instrument display.

3.2.16 Isolated pit

Small hole in metal created by localized corrosion.

3.2.17 Lack-of-expected response (LER)

Absence or significant reduction of the indication of the back surface signal of the cylinder being inspected.

NOTE—Also known as loss-of-back wall echo.

3.2.18 Laminar flaw

Subsurface void, crack, or delamination-type discontinuity lying parallel to the surface of the test piece typically resulting from the application of primary manufacturing processes such as rolling or extrusion.

3.2.19 Longitudinal wave

Wave in which the particle motion of the material is essentially in the same direction as the wave propagation.

NOTE—Typically used to conduct straight-beam testing to measure wall thickness or detect potential laminar reflectors.

NOTE—Also known as a compression wave.

3.2.20 Minimum design wall thickness (t_d)

Minimum wall thickness required by the specification at the time the cylinder was manufactured.

3.2.21 Minimum wall thickness (t_{min})

Minimum wall thickness permitted for cylinders while in service in accordance with this standard. t_{min} is less than minimum design wall thickness (t_d).

NOTE—Also known as minimum allowable in-service wall thickness (t_{is}).

3.2.22 Mode

Type of ultrasonic wave propagating in the materials as characterized by the particle motion (for example, longitudinal, transverse, etc.)

3.2.23 Nondestructive testing (NDT)

Test methodologies that detect flaws without destroying or altering the materials.

NOTE—Also known as nondestructive evaluation (NDE).

3.2.24 Nonrelevant indications

Signal generated by a condition or type of discontinuity that is not rejectable.

3.2.25 Pulse-echo method

UT technique in which discontinuities are detected from return echoes from transmitted pulses thus enabling full volumetric examination by accessing only one side of the object being examined.

3.2.26 Rejected cylinder

Cylinder deemed unacceptable and removed from service.

NOTE—Any rejected cylinder may be condemned, further evaluated, or returned to service after repair, rebuild, or requalification by UT.

3.2.27 Shear wave

Wave in which the particle motion is perpendicular to the direction of propagation.

NOTE—Used to perform angle beam testing to detect discontinuities orientated in a planar direction.

NOTE—Also known as a transverse wave.

3.2.28 Sidewall-to-base transition (SBT) area

Area between where the wall of the cylinder begins to thicken (where the inside wall of the cylinder departs from the parallel relation with the outside wall of the cylinder) and where the cylinder sidewall transition meets the base of the cylinder.

3.2.29 Simulated defects

Machined defects of a given dimension in the calibration standard representing acceptance/rejection criteria used for UT system calibration.

3.2.30 Straight beam

Vibrating pulse wave train traveling perpendicular to the test surface.

NOTE—Used to measure wall thickness and detect laminar orientated discontinuities.

NOTE—Also known as zero degrees or normal incident angle.

3.2.31 Transducer

Electro-acoustic device comprised of piezoelectric element, damping material, and electrical leads enclosed in a housing that is used to transmit and receive electrical and mechanical energy.

NOTE—Also known as a search unit.

3.2.32 Tube

Seamless container of cylindrical shape with openings at both ends and a water capacity greater than 450 L.

NOTE—Also described by TC's *Transportation of Dangerous Goods Regulations* as a container with a water capacity greater than 450 L, in a seamless cylindrical form, and capable of withstanding an internal service pressure of at least 12.4 MPa [2].

NOTE—For purposes of this standard, cylinder(s) also means tubes unless otherwise stated.

3.2.33 Ultrasonic testing (UT)

Nondestructive method that uses high frequency sound waves to examine material.

NOTE—Also known as ultrasonic examination (UE).

4 Personnel qualification and responsibilities

An individual in the process of becoming qualified and/or certified shall be a trainee. This individual shall not independently conduct any UT. A trainee shall work under the on-site supervision of a certified Level II or III.

Level I, Level II, and Level III personnel shall be trained, qualified, and certified in accordance with The American Society for Nondestructive Testing (ASNT) SNT-TC-1A, *Personnel Qualification and Certification in Nondestructive Testing*, CAN/CGSB-48.9712-2014/ISO 9712:2012, IDT, *Non-destructive Testing – Qualification and Certification of NDT Personnel (ISO 9712:2012, IDT)*, or any other national standard, as authorized and requirements of this section [4, 5].

Personnel certified as a Level I may independently start up the UT equipment, confirm calibration (excluding configuration of calibration parameters), perform UT, and record results in accordance with written instructions.

These testing activities shall be performed under the on-site supervision of a certified Level II or III. A Level I shall not independently evaluate UT results.

Level I operators shall receive a minimum of 20 hours of sufficiently organized training and shall have a minimum of 80 hours experience on UT equipment.

Personnel certified as a Level II may set up and calibrate the test equipment, conduct tests, and interpret/evaluate results in accordance with approved procedures in accordance with this standard. The individual shall be thoroughly knowledgeable with the scope and limitations of the method (for example, automated UT, manual UT, phased array UT), and be able to conduct on-the-job training and supervision of lesser certified personnel.

Level II operators shall receive a minimum of 40 hours of sufficiently organized training and shall have a minimum of 160 hours experience on UT equipment.

A Responsible Level III is a person who oversees the NDT/UT program, provides written UT procedures, training, qualification, certification of company Level I, II, and III employees, technical guidance to operators, and reviews and verifies UT results. The Responsible Level III shall have a thorough understanding of DOT/TC regulations pertaining to the requalification and reuse of DOT/TC cylinders. A Responsible Level III may be an employee of the company or a contracted consultant.

Responsible Level III personnel shall be designated and certified by the employer after meeting the requirements of a Level III as defined in SNT-TC-1A, CAN/CGSB-48.9712-2014/ISO 9712:2012, IDT, or any other national standard, as authorized by the regulatory authority, and possessing at least one of the following [4, 5]:

- Level III certification from ASNT or from Natural Resources Canada (NRCAN) National Non-Destructive Testing Certification Body (NDTCB) in UT, as authorized by the regulatory authority; or
- Professional Engineer (P.E. or P.Eng) License with a minimum of 2 years documented experience in NDT of pressure vessels, pipelines, or other structures using the UT technique; or
- Ph.D. degree in a discipline of Engineering or Physics with a minimum of 1 year documented experience in NDT of pressure vessels, pipeline, or other structures using the UT technique or research/thesis work and authoring/co-authoring of technical papers published in recognized technical journals.

The employer is responsible for compliance with regulatory requirements and ensuring that each operator and Responsible Level III maintains the required certification described in this standard.

5 Ultrasonic testing equipment

The UT equipment shall repeatedly detect simulated defects and measure the specified thickness of the machined thin area on the calibration standard in accordance with this standard.

The UT equipment shall introduce ultrasonic waves via contact or immersion methods using the pulse-echo technique.

The equipment shall be capable of:

- performing complete examination of 100% of the cylinder's sidewall using straight beam for thickness measurement and using angle beam for defect detection;
- introducing sound in longitudinal (forward and reverse) and circumferential (clockwise and counterclockwise) directions;
- examining the entire sidewall-to-base transition (SBT) area;
- repeatedly detecting and locating simulated defects;
- continuously monitoring for lack-of-expected response (LER) independent of operator actions;

- displaying and recording examination results; and
- remote access to assist with oversight, equipment troubleshooting, and set up.

An example of UT equipment features is shown in Figure 1. Examples of UT equipment are shown in Figures 2, 3, and 4.

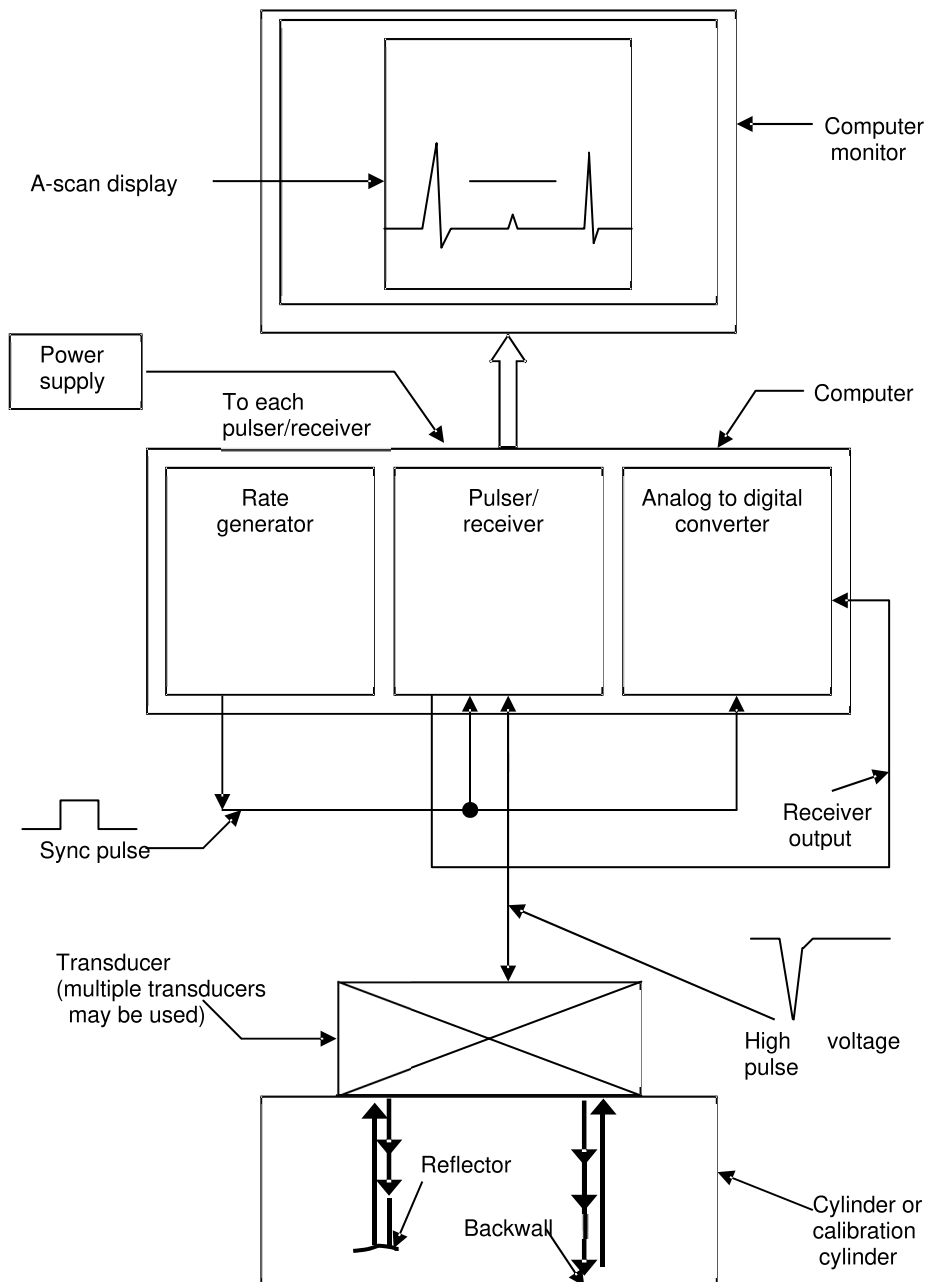


Figure 1—Example of a pulse-echo unit, block diagram



Figure 2—Example of ultrasonic testing equipment (cylinders)



Figure 3—Example of ultrasonic testing equipment (tubes)

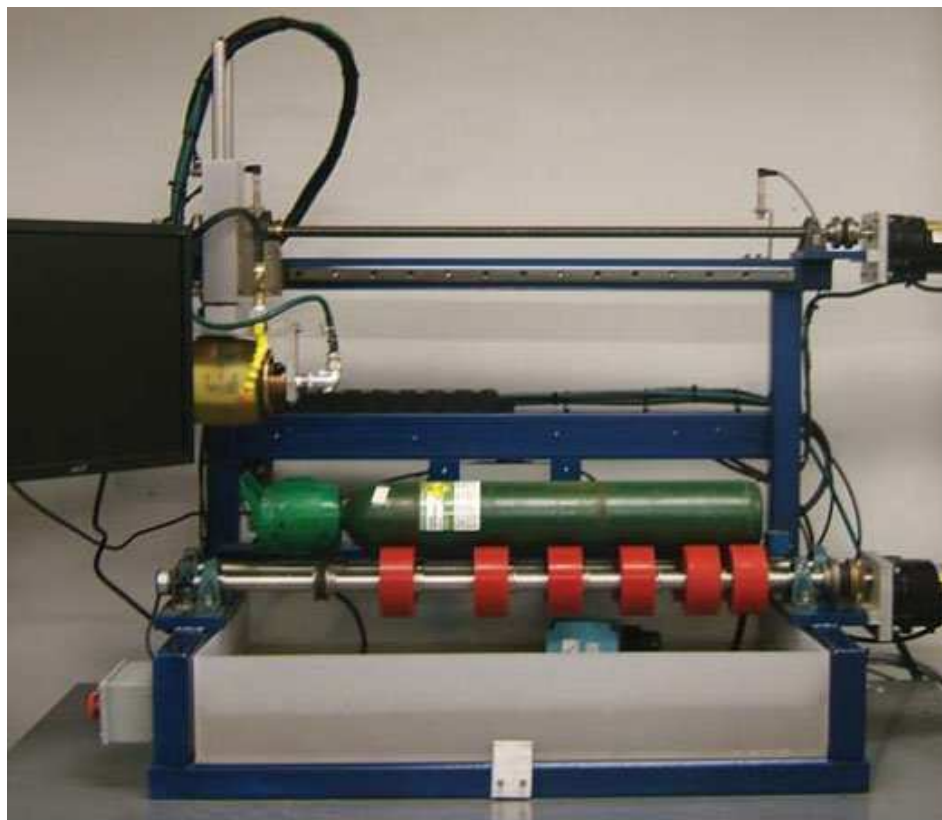


Figure 4—Example of ultrasonic testing equipment (cylinders)

The following components shall be a part of the UT equipment.

5.1 Power supply

AC/DC electrical circuits shall be used to supply the necessary current to provide power to operate basic functions of the UT equipment.

5.2 Analog-to-digital converter

An analog-to-digital converter (ADC) is used to convert returning signals into a digital format. The following factors are important when choosing the digitizer for the system: sample rate, bandwidth, vertical resolution, triggering features, and bus and memory type.

5.3 Pulser/receiver

This device provides high voltage pulses required to activate the ultrasonic transducer and provide signal conditioning before the analog signal is passed to the ADC. The device is initialized prior to testing to set the pulse voltage level, pulse repetition frequency, damping, and band pass filtering settings. The motion controller, digitizer, and pulser/receiver operate as one collective unit during the test to ensure accuracy of results and brevity of test time. The pulser/receiver shall have a frequency range compatible with the transducer(s) employed.

5.4 Rate generator

The rate generator triggers the pulser/receiver and provides a synchronized signal to the ADC where transmitted bursts of acoustic energy are received to measure time or distance on the display.

5.5 Transducer

The UT equipment shall use a single transducer or a probe containing multiple transducers. Transducers of 2.0 MHz to 20.0 MHz nominal frequency and 0.125 in to 2.000 in diameter shall be used. Alternative frequencies, sizes, and shapes may be allowed per approval of the regulatory authority. Focusing of the transducer beam is permitted.

A transducer emits short evenly timed pulses of ultrasonic waves that are transmitted into the material being tested to locate discontinuities and measure cylinder wall thickness. These pulses are generated by high voltage electrical energy that is applied to a piezoelectric crystal within the transducer. The piezoelectric crystal converts these electrical pulses to mechanical vibrations and converts mechanical energy back to electrical energy. A transducer can both send and receive energy. The size (diameter), frequency, and material of a transducer influence the sound beam, resolution, and sensitivity.

5.6 Software (automated systems)

UT application software combines multiple types of inputs and outputs, analysis algorithms, and presentation techniques. The application software comprises three basic parts: acquisition/control, analysis, and presentation. Acquisition/control refers to the interface between the application software and the physically moving hardware.

Software shall be designed such that the following functions can be performed:

- prevent testing unless an acceptable system calibration is performed;
- alert the operator when defects or potential defects are detected and prevent further testing until the alert is acknowledged by the operator;
- provide presentation of location, type, and orientation of defects;
- provide required reports, see Section 10; and
- control movement of transducers and/or cylinders and simultaneous data acquisition.

5.7 Display

The UT system shall have the capability of displaying an A-scan presentation or an alternative method of verifying system performance. In addition, a display is required to show the location and type of flaws such as a B-scan and/or C-scan presentation. Alternative type displays may be used depending upon the type of ultrasonic testing technology employed such as the phased array technique.

Figures 5a, 5b, 6, and 7 provide examples of A-, B- and C-scan displays.

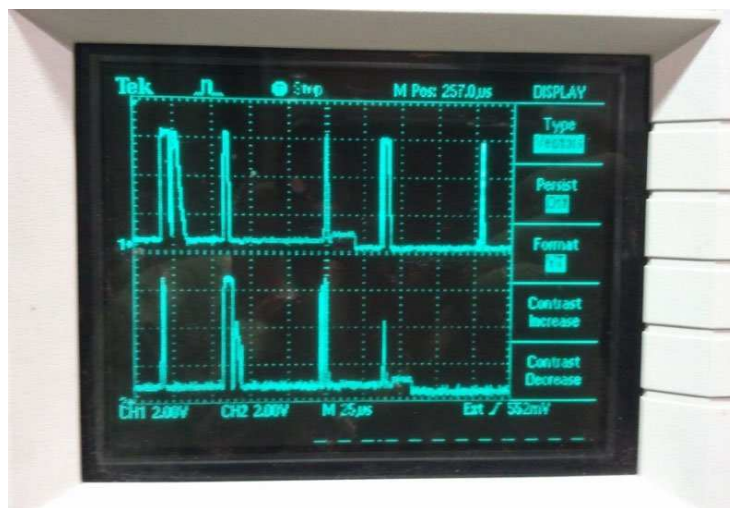


Figure 5a—Example of an analog A-scan display

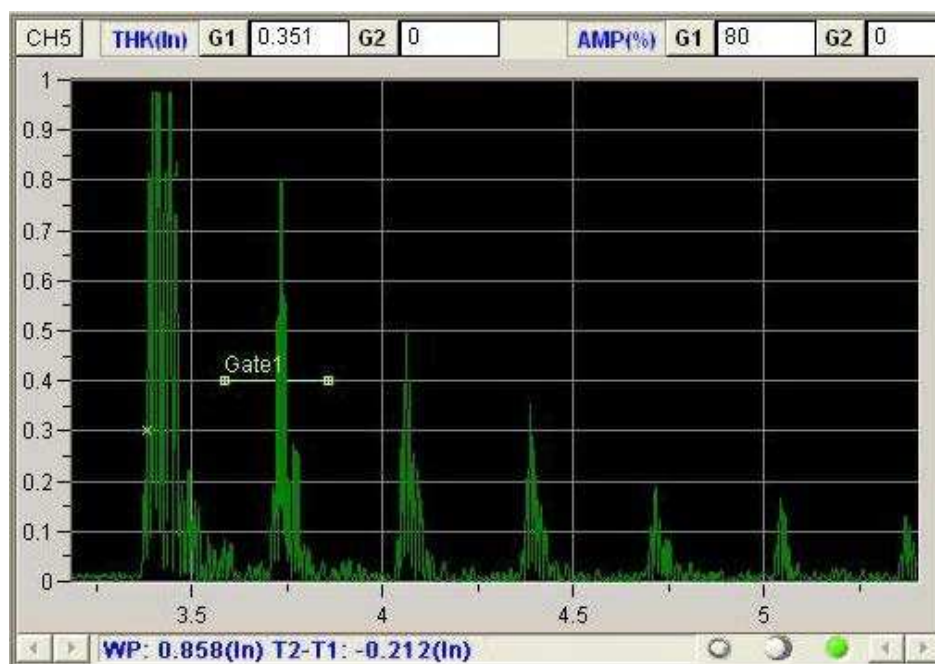


Figure 5b—Example of a digital A-scan display

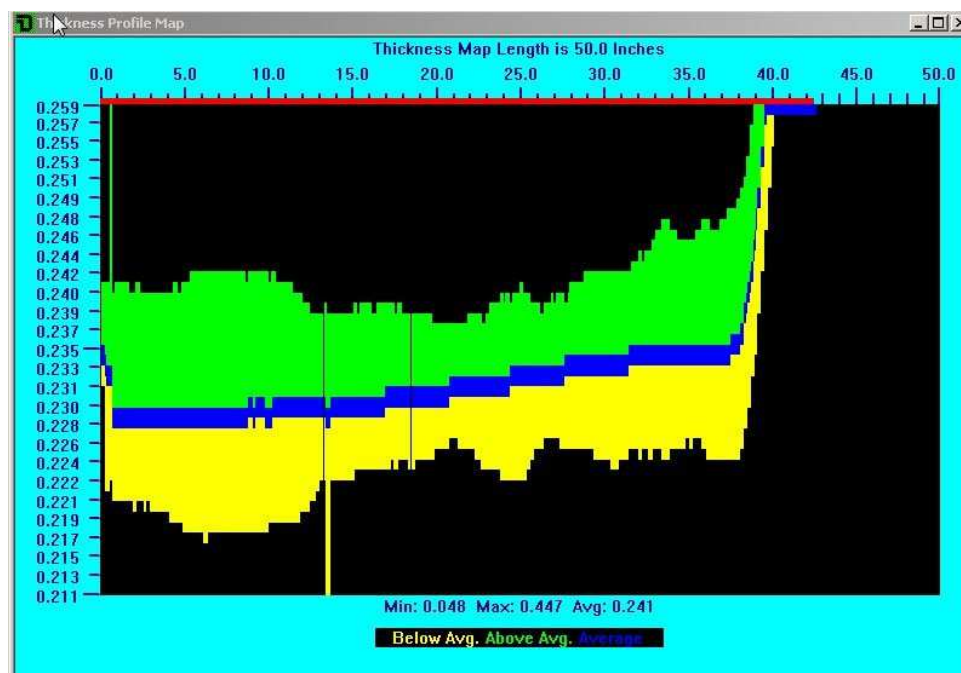


Figure 6—Example of a B-scan display

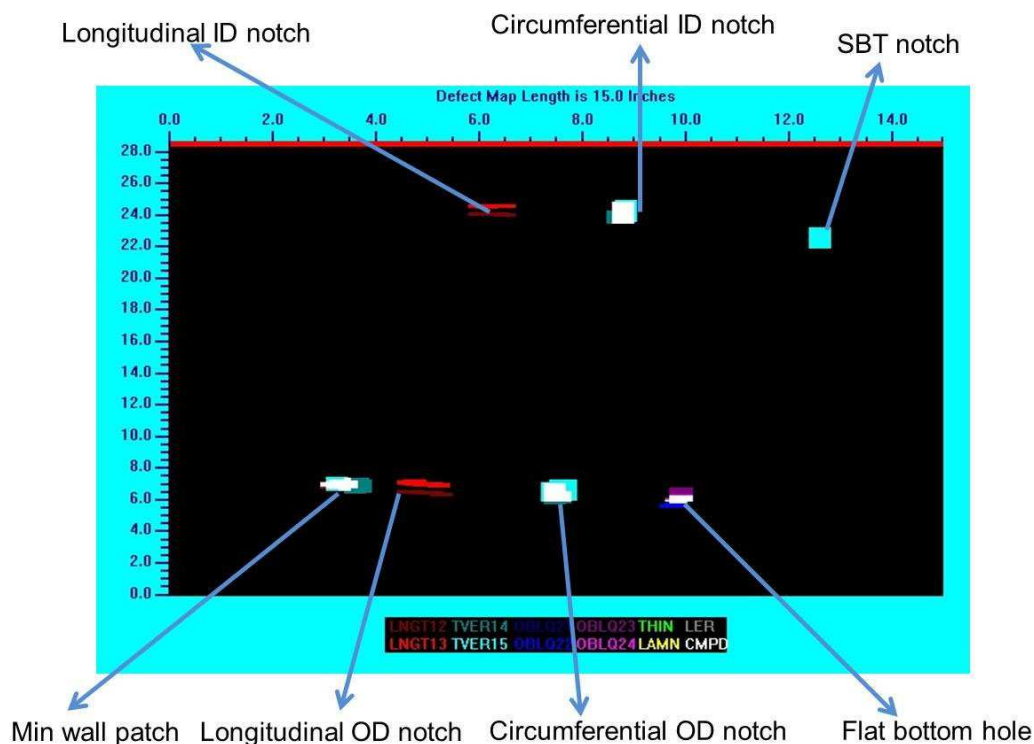


Figure 7—Example of a C-scan display

5.8 Instrument controls

Instrument controls are used to perform UT system calibration and ensure display of signal responses obtained from the calibration standard. Precise adjustments of these controls are used to position and enhance the visual image of the signals received from the cylinder or calibration standard being tested. The following instrument controls are required, as a minimum:

- gain (sensitivity)—adjustment of this control amplifies signal responses received from calibration standard simulated defects;
- gate—adjustment of these controls (start, width, and threshold) establishes the desired height of signal responses and range (beginning and end) where signals are recorded; and
- pulse repetition rate and helix—adjustment of these controls ensures appropriate calibration and examination coverage.

5.9 Motion controls

Automated ultrasonic test systems shall control cylinder rotation and transducer movement to collect multiple data points. The combined control of the transducer(s) position and orientation, cylinder surface scanning speed, and pulse repetition rate is required to ensure the test is accurate and repeatable.

5.10 Data storage

Equipment shall contain or be connected to a data storage device such as hard drives, rewriteable disks or drives, or printed hard copy to store processed data for replay, documentation, and/or archiving.

5.11 Ultrasonic testing equipment maintenance

UT equipment shall be maintained to ensure accuracy and repeatability of results.