Designation: E2479 – 16

Standard Practice for Measuring the Ultrasonic Velocity in Polyethylene Tank Walls Using Lateral Longitudinal (L_{CR}) Waves[1]

This standard is issued under the fixed designation E2479; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice covers a procedure for measuring the ultrasonic velocities in the outer wall of polyethylene storage tanks. An angle beam lateral longitudinal (L_{CR}) wave is excited with wedges along a circumferential chord of the tank wall. A digital ultrasonic flaw detector is used with sending-receiving search units in through transmission mode. The observed velocity is temperature corrected and compared to the expected velocity for a new, unexposed sample of material which is the same as the material being evaluated. The difference between the observed and temperature corrected velocities determines the degree of UV exposure of the tank.

1.2 The practice is intended for application to the outer surfaces of the wall of polyethylene tanks. Degradation typically occurs in an outer layer approximately 3.2 mm (0.125 in.) thick. Since the technique does not interrogate the inside wall of the tank, wall thickness is not a consideration other than to be aware of possible guided (Lamb) wave effects or reflections off of the inner tank wall. No special surface preparation is necessary beyond wiping the area with a clean rag. Inside wall properties are not important since the longitudinal wave does not strike this surface. The excitation of Lamb waves must be avoided by choosing an excitation frequency such that the ratio of wavelength to wall thickness is one fifth or less.

1.3 UV degradation on the outer surface causes a stiffening of the material and an increase in Young's modulus and the longitudinal wave velocity.

1.4 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not considered standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E494 Practice for Measuring Ultrasonic Velocity in Materials

E543 Specification for Agencies Performing Nondestructive Testing

E1316 Terminology for Nondestructive Examinations

E2373 Practice for Use of the Ultrasonic Time of Flight Diffraction (TOFD) Technique

2.2 *ASNT Documents:*[3]

SNT-TC-1A Recommended Practice for Nondestructive Testing Personnel Qualification and Certification

ANSI/ASNT CP-189 ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel

2.3 *AIA Document:*[4]

AIA/NAS-410 Nondestructive Testing Personnel Certification and Qualification

2.4 *ISO Standard*[5]

ISO 9712 Non-Destructive Testing—Qualification and Certification of NDT Personnel

3. Terminology

3.1 *Definitions*—For definitions of terms used in this practice, see Terminology E1316.

4. Summary of Practice

4.1 The lateral longitudinal wave (henceforth called the L_{CR} wave) used in this practice is selected because it is the fastest wave in the tank wall, and, therefore its arrival at the receiver

[1] This practice is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.06 on Ultrasonic Method.

Current edition approved June 1, 2016. Published June 2016. Originally approved in 2006. Last previous edition approved in 2011 as E2479 - 11. DOI: 10.1520/E2479-16.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.

[4] Available from Aerospace Industries Association of America, Inc. (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209-3928, http://www.aia-aerospace.org.

[5] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

***A Summary of Changes section appears at the end of this standard**

location is free from surrounding spurious indications coming through the tank wall. The typical setup is shown in Fig. 1 where the sending and receiving transducers are connected with a link through a pivot joint. The frequency selected is such that the wavelength is short compared to the wall thickness, assuring bulk wave velocity. Moreover, since it is a bulk wave the propagation is not affected by variations in the inside tank wall. Therefore, the velocity measured in the outer tank wall is indicative of the material properties of that region, and not affected by the inner tank wall conditions.

5. Significance and Use

5.1 Measuring the velocity of ultrasound in materials is a unique method for determining nondestructively the physical properties, which can vary due to both manufacturing processes and environmental attack. Velocity is directly related to the elastic moduli, which can vary based on environmental exposure and manufacturing process, The L_{CR} method described herein is able to measure the velocity between two adjacent points on a surface and therefore is independent of the conditions on the opposite wall. Applications of the method beyond polymer tanks will undoubtedly be developed and examination may occur in the production line as well as in the in-service mode.

6. Basis of Application

6.1 The following items are subject to contractual agreement between the parties using or referencing this standard.

6.1.1 *Personnel Qualification*—Personnel performing examinations to this standard shall be qualified in accordance with a nationally or internationally recognized NDT personnel qualification practice or standard such as ANSI/ASNT CP-189, SNT-TC-1A, ISO 9712, NAS-410, or a similar document and certified by the employer or certifying agency, as applicable. The examination should be supervised by a person holding Level III ASNT certification, or equivalent. The practice or standard used and its applicable revision shall be identified in the contractual agreement between the using parties.

6.2 *Qualification of Nondestructive Agencies*—If specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in E543. The applicable edition of E543 shall be specified in the contractual agreement.

6.3 *Practices and Techniques*—The practices and techniques to be utilized shall be as specified in the contractual agreement.

7. Apparatus

7.1 The ultrasonic system to be used in this practice shall include the following:

7.1.1 *Test Instrument*—An ultrasonic instrument comprising a time base, pulser and receiver and A-scan display showing full wave (RF) signals with gates such that arrival times can be determined with a resolution of 10 ns or better. A required feature is the ability to freeze the signal and manipulate and zoom the gate so that the appropriate peak or zero crossing may be identified with satisfactory resolution. The proper arrival time is either the first significant peak or the preceding positive (upward) zero crossing. Zero offset is used to standardize the observed velocity with the expected velocity in a reference standard. Further, the instrument must be capable of communicating with a laptop computer or other digital signal-processing device and sending arrival waveforms as well as other pertinent data for processing and storage. The ultrasonic and computer functions may be incorporated in a single unit. The receiving amplifier must be capable of displaying at full screen height the signals arriving at the receiver search unit for all tank conditions.

7.1.2 *Search Unit*—The dual longitudinal angle beam (L_{CR}) search unit propagates waves across the chord of the tank wall. The L_{CR} wave is excited at an incident angle slightly past the first critical angle. A typical transducer has a 25-mm (1-in.) diameter element, with low damping and narrow bandwidth in order to maximize the signal strength. The wedge has a low speed material column for energy transmission to provide a Snell's law match with the polyethylene tank wall. Typical transducer frequencies range from 0.5 MHz to 2.25 MHz, The frequency must be high enough to assure that no Lamb waves are excited in the tank wall. Search unit separation must be greater than the near field estimated experimentally using the standardization block and must be such that the longitudinal

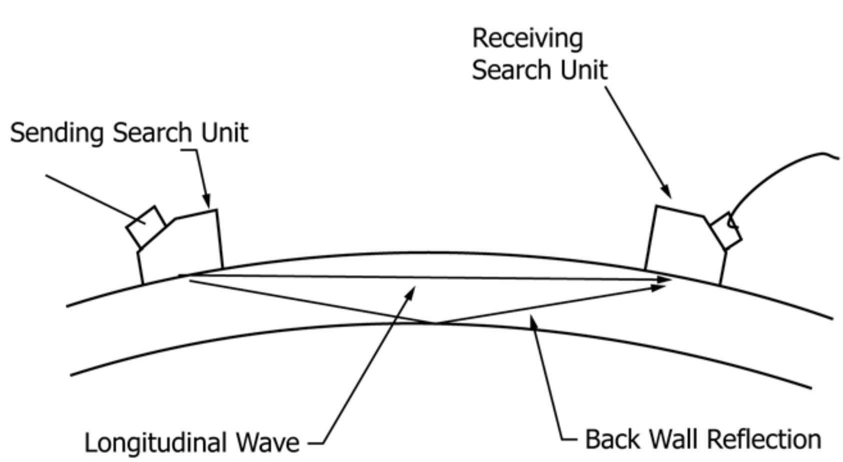


FIG. 1 Dual Search Unit Examination Setup Using L_{CR} Waves on Tank Wall

wave travels across the chord of the tank wall and does not strike the inside wall. A typical distance is 47 mm (1.85 in.), but may be adjusted to other spacing to accommodate examination in moderate and low loss polymers and different tank wall thicknesses.

7.1.3 *Couplant*—Standard ultrasonic gel type couplants are preferred. The couplant must adhere to the sidewall of the tank and not run off, yet it must be easily wiped off when the examinations are completed, leaving no significant residue. It must be fully compatible with the polyethylene tank material.

7.1.4 *Computer*—The computer supporting this examination should be able to store full site and tank detail information. Further, it should be able to calculate the true travel path based on probe separation and tank curvature. It should be able to calculate expected velocity at the wall temperature during the test. The difference between the expected speed for new material at the test temperature and the observed speed is the parameter used to evaluate tank wall condition. Manual data entry in a spreadsheet must be possible if the computer is not available, or its use is inconvenient. The calculations described above may be accomplished in the spreadsheet or by hand calculations.

7.1.5 *Reference Blocks*—A small section of material is used for standardization. This section should be the same type material as the tank being examined, and should be flat. Initially, it should have experienced no significant UV exposure and it should be protected from long-term exposure during its use. First, the search units need to be checked to assure the integrity of the travel path in the wedge, and that a strong L_{CR} signal is being generated. Secondly, the standardization of the zero offset on the ultrasonic unit requires that the arrival time be adjusted to give an observed velocity equal to the expected velocity for the sample being examined. The procedure for standardization is given in more detail in the following and in Appendix X2.

8. Practice

8.1 Standard practice is to take readings at locations approximately 30 cm (1 ft) and 90 cm (3 ft) from the base (bottom) of the tank. These readings should be taken at a minimum of two different N-E-S-W directions on the tank. Their relation to some notable location on the tank, for example, the tank manhole, should be recorded since tanks may be moved and turned during their life. The surface should be clean and not have undue surface fluctuations. The important thing is that a spot gives good readings and that the same location is investigated from year to year. The location should be marked on the tank or designated on the record so that future data are collected at the same place.

8.1.1 For a typical examination, connect the sending transducer to the BNC OUT terminal and the receiving transducer to the BNC IN terminal.

8.1.2 Place a generous amount of couplant on both of the search unit faces (a dollop about 25 mm (1 in.) in diameter). It is required since there is some initial priming of the surface needed for full transmission into the material. Place the search unit on the area of the tank to be examined. When looking at the dual search unit, the two search units should be in a circumferential arrangement. The dual search unit assembly is spring loaded. Manipulate the search unit assembly until a good signal is visible on the screen. Repeat couplant application if needed for additional surface priming. Once a good signal has been found, the signal should be frozen with the ultrasonic unit for further analysis. The gate may be moved to the appropriate point on the wave as discussed above. The tank wall velocity may then be calculated.

8.1.3 For maximum confidence, the practice of full removal, wiping and reapplication of the couplant should be repeated several times at each search unit position. Since there will always be some scatter in the data, a minimum of three values should be obtained at each location of interest.

8.1.4 The L_{CR} wave traversing the chord of the tank wall should appear as the first arriving signal on the flaw detector screen after the initial pulse. A short gate (time less than one wavelength) is used to identify the arrival time of the L_{CR} wave. Fig. 2 shows a typical signal identified by the gate setting. Here the cursor is on the first peak of the wave. The ultrasonic unit should be set to display the time associated with

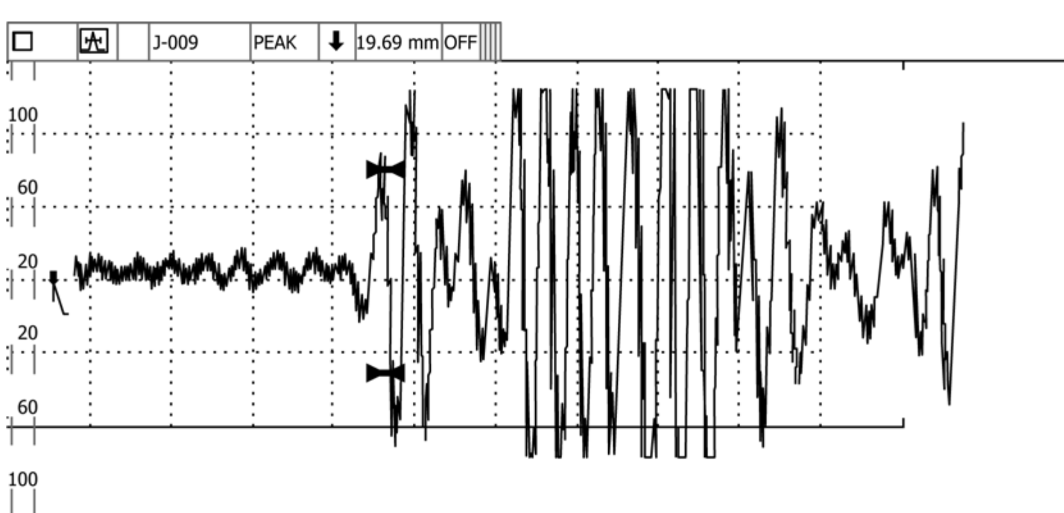


FIG. 2 Typical Signal with L_{CR} Peak Located Within the Gate

the zero crossing of the earliest peak in the gate. It is easily distinguishable from the preceding portions and from the following wave that goes through the interior of the material. Since the refracted beams of the two search units are approximately parallel to the surface of the tank wall, there is no beam intersection point as defined by Practice E2373.

8.1.5 Velocity values based on previously measured tanks in the field are available as an aid in isolating the L_{CR} wave (Appendix X3). Using the prediction curve based on the years of service for the tank being examined can narrow down the approximate location of the L_{CR} wave arrival.

8.1.6 Occasionally, a complex waveform will occur making the L_{CR} difficult to isolate. This is often due to a combination of conditions such as incomplete contact, high instrument gain used in these highly attenuative materials and the parallel sound paths (crosstalk) that occur in the search units and in the air. In the wave shown in Fig. 3, the L_{CR} wave is less distinguishable. This arrival was taken from the same location as the wave in Fig. 2. There appears to be a wave that looks similar to the L_{CR} wave in front of the cursor. This, however, comes from parallel signal transmission in the higher speed wedge material and should not be evaluated. In addition, the wave behind the L_{CR} wave is commingled. Without experience and the predicted velocity table, one could easily take the wrong reading in this case.

8.1.7 The characteristics to look for in finding the L_{CR} waves are: a sharply rising peak immediately after a significant trough and a slight separation between the wave and the following wave. This appearance may depend on the specific transducer properties. The height of the wave may be similar to the amplitude of the following wave. The cross talk waveform is usually smaller than the following waves. Most importantly, the operator should use the predicted velocities for tanks of that age group value as a guide to narrow down a region of interest.

8.1.8 Temperature for establishing the temperature corrected velocity may be added to the data set either manually from an external device such as an infrared indicator, or, directly into the computer through an input device.

8.2 *Consistency of Data*—The predicted values may be affected by the frequency of the dual search units as well as the spacing since this may affect the travel path or region in the tank wall the wave encounters. For newer tanks an adept technician can use experience to find the correct waveform. For older tanks, the attenuation is likely to be very high, and the prediction values will be necessary.

8.3 *Standardization*—Standardizing the ultrasonic system and the search unit assembly is extremely important, for several reasons. First, the working condition of the search unit must be assured before beginning a test. Secondly, the operator must reassure that the instrument settings are correct. The search unit standardization block shown in the appendix should be used to assure that the search unit is properly designed and constructed and that the L_{CR} wave is properly excited. The system is standardized using the system standardization blocks also described in the appendix. Both blocks should be made from polyethylene material as used in the tanks being examined. For the system standardization, the technician should use the system standardization block and find the correct peak on the L_{CR} wave and adjust the zero offset until the laptop computer reads a difference in predicted and measured wave speed that is close to zero. A close value is desired, but ±3 µs should suffice. The zero offset is a function of the delay in the search unit, and is a function of temperature as well as travel path in the wedge. A nominal zero offset of 14 to 15 µs is used provided that the standardization and corrected velocities are calculated later. The exact value is dependent on the wedge and transmission column of the sender and receiver.

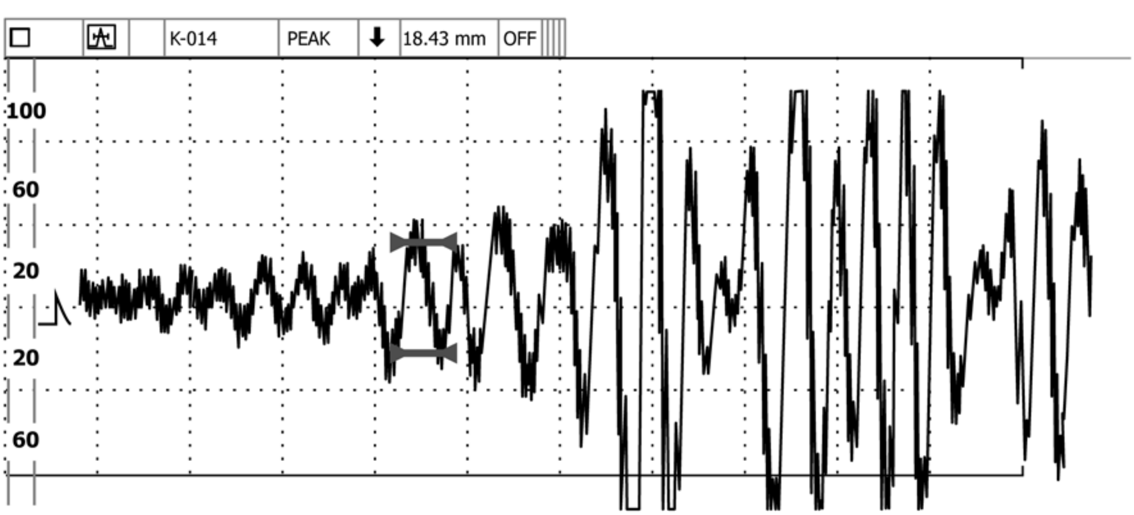


FIG. 3 Arrival Where L_{CR} Wave is Difficult to Isolate (see 8.1.6 for explanation)

APPENDIXES

(Nonmandatory Information)

X1. WAVE SPEEDS

X1.1 Ultrasonic wave speeds in new polyethylene materials are usually very consistent from one sample to the next. Though made at different times, very good agreement will be found in the speeds for the same material. For example, Table X1.1 shows typical speeds for new Linear and Cross Linked samples at 21°C (70°F). Ultraviolet (UV) aging significantly increases the ultrasonic wave speeds in the tank walls. Some variations could be expected due to manufacturing process. Velocities over 3000 m/s (118,100 in./s) have been measured in field tanks 20 years of age and older.

TABLE X1.1 Summary of Typical Longitudinal Wave Speeds (V_e) for New Polyethylene Samples at 21°C (70°F)

Sample		Velocity (V_e)	
		m/s	in./s
Cross Linked Natural	CLN	2226	87 640
Cross Linked Black	CLB	2217	87 280
Linear Natural	LN	2222	87 480
Linear Green	LG	2179	85 790

X1.2 In addition to aging, the ambient temperature also affects the wave speed. Expected velocities (V_e) based on the known material properties and the measured temperature in °C is given by the following formulae at a reference temperature of 21°C (70°F):

$$V_e = 2436.6 - 3.005*T_{tank}\,(CLN) \qquad (X1.1)$$

$$Ve = 2442.1 - 3.222*T_{tank}(CLB) \qquad (X1.2)$$

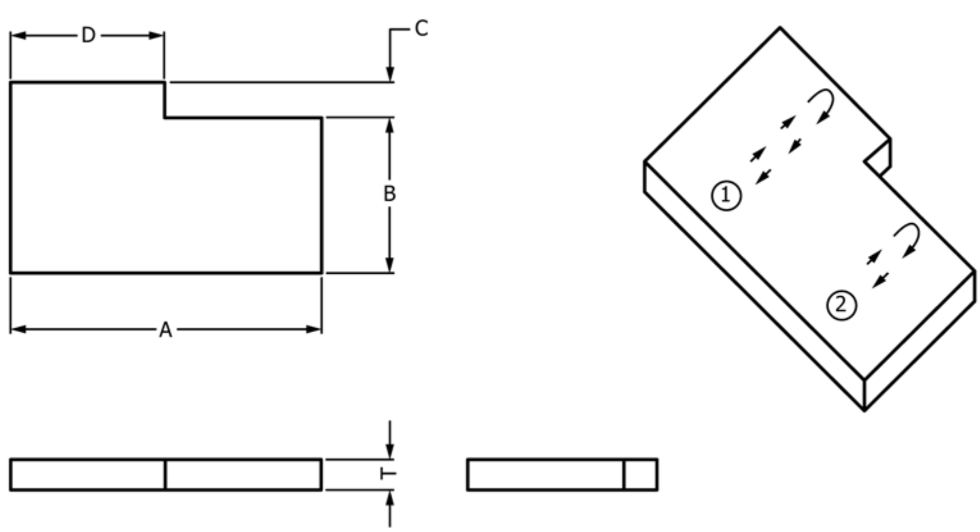
$$V_e = 2449.1 - 3.2424*T_{tank}\,(LN) \qquad (X1.3)$$

$$Ve = 2438.5 - 3.7111*T_{tank}\,(LG) \qquad (X1.4)$$

where T_{tank} is the measured tank temperature in °F. These linear relationships are valid for temperatures both above and below the reference temperature.

X2. STANDARDIZATION BLOCKS

X2.1 Search unit design, construction and performance are checked using the search unit standardization block shown in Fig. X2.1, To use the block, first apply sufficient couplant and place the search unit at position 1 with the ultrasonic beam aimed along the long path of the block. The back of the search unit should be aligned with the back of the block during standardization. Using the ultrasonic instrument, measure the arrival time for the L_{CR} wave. Repeat for the search unit at position 2. If an L_{CR} wave is excited, the travel time difference between the two arrivals should be 20 µs. The operator can also tap at the end of the piece with a couplant-coated finger and observe the effect on the amplitude of the L_{CR} wave. If the



Standardization Block Dimensions		
	mm	in.
A	200	7.87
B	100	3.9
C	22.3	0.88
T	19	0.75

FIG. X2.1 Search Unit Standardization Block

search unit passes these two tests, then the design and construction is correct for exciting the L_{CR} wave.

X2.2 The near field for the L_{CR} search unit may be estimated using the standardization block. With the search unit at position 1 and aimed at the long path, move the search unit toward the end and observe the arrival time and amplitude of the reflected L_{CR} signal. In the far field the amplitude will vary uniformly and the arrival time will coincide with the longitudinal wave velocity. As the search unit approaches the end of the path, and irregular amplitude and arrival time pattern will be observed. This will designate the end of the near field.

X2.3 A system standardization block made from a flat sample of the material to be examined should be available for on-site verification of the search unit performance. It should be not less than 200 mm (7.87 in.) long, 122.3 mm (4.81 in.) wide and 19 mm (0.75 in.) thick. The block should not have received significant UV exposure and care must be exercised to prevent UV damage during use of the block. The date that each block was placed into service should be inscribed on the edge of the block, and the block should be replaced every 5 years. Velocity of the material should be established in accordance with E494.

X2.4 Normal instrument standardization for linearity and gain should be performed on a regular basis.

X3. PREDICTION CURVES

X3.1 The velocity prediction curve shown in Fig. X3.1 is useful for identifying the approximate velocity or time settings where the L_{CR} wave will be expected. The comparison of expected and actual velocity curve may be accomplished with the computer or with manual calculations.

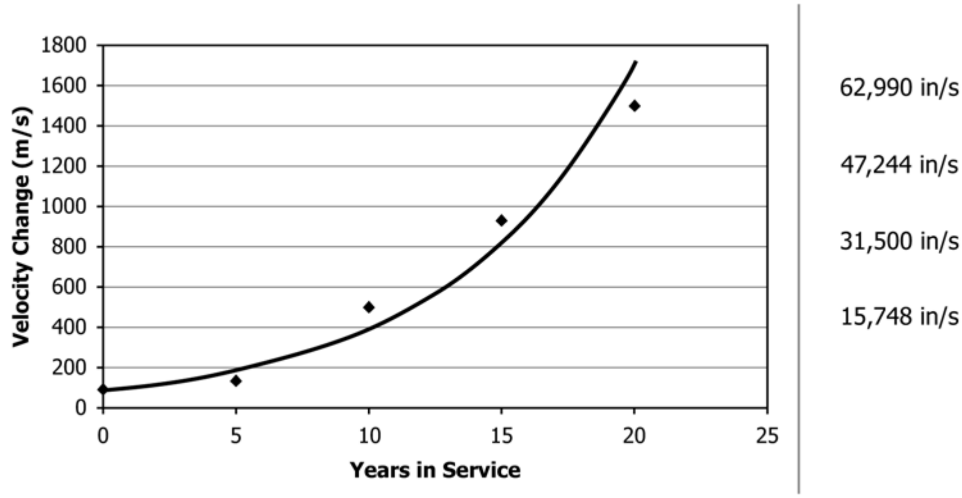


FIG. X3.1 Velocity Prediction Curve for Locating L_{CR} Arrival

SUMMARY OF CHANGES

Committee E07 has identified the location of selected changes to this standard since the last issue (E2479 - 11) that may impact the use of this standard. (Approved June 1, 2016.)

(1) Added ISO Standard ISO 9712 in 2.4 and 6.1.1.

(2) Replaced "lossy" with "highly attenuative" in 8.1.6.