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ULTRASONICS. VOLUME III: APPLICATIONS

Convair/Astronautics
A Division of General Dynamics Corporation
San Diego, California

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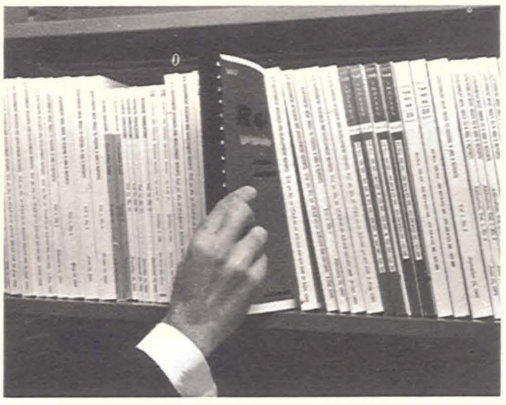
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INTRODUCTION

This is the third and final volume of the series ~~of programmed instruction handbooks~~ on ultrasonic testing. Before proceeding, it is assumed that you have completed Volumes I and II and their prerequisites.

The preceding volumes on ultrasonic testing were devoted to teaching the basic theory and principles of ultrasonics and describing the various types of test equipment and accessories used. Now, in Volume III, you will learn the procedures that are followed in the selection of ultrasonic test equipment, methods, and techniques. You are taught the advantages and limitations of the different test methods and the conditions governing the selection of the equipment, transducers, test frequency, and couplants. You are taught how to "standardize" the equipment and test different materials, e.g., plate, forgings, and castings . . . using both the contact and immersion test methods. You'll learn several specialized techniques, e.g., the testing of weldments, piping, and tubing. And finally you will learn how to use resonance equipment in thickness measuring, corrosion testing, and in locating large laminar discontinuities or lack of bond.

INSTRUCTIONS

The pages in this book should not be read consecutively as in a conventional book. You will be guided through the book as you read. For example, after reading page 3-12, you may find an instruction similar to one of the following at the bottom of the page —

- Turn to the next page
- Turn to page 3-15
- Return to page 3-10

On many pages you will be faced with a choice. For instance, you may find a statement or question at the bottom of the page together with two or more possible answers. Each answer will indicate a page number. You should choose the answer you think is correct and turn to the indicated page. That page will contain further instructions.

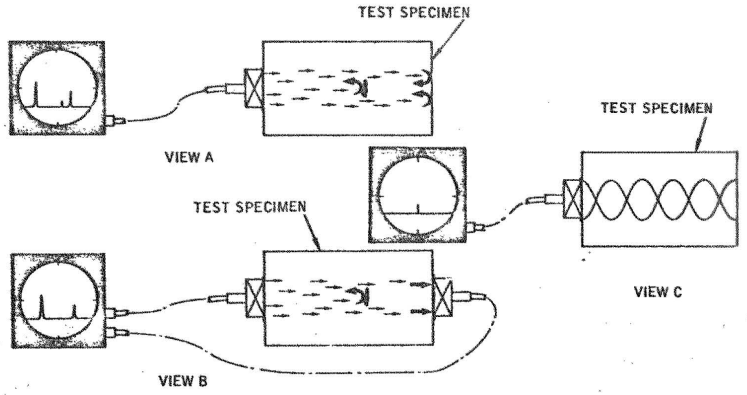
As you progress through the book, ignore the back of each page, they are printed upside down. You will be instructed when to turn the book around and read the upside down printed pages.

As you will soon see, it's very simple — just follow instructions.

Turn to the next page.

So far in your study of ultrasonic testing you have learned the basic principles of ultrasonic sound, its generation, and how it can be used to detect discontinuities in materials of various types and composition. You are also familiar with the equipment and methods of presenting ultrasonic testing results.

Before going into the application of ultrasonics, it would be well to review the systems, methods, and techniques that are available. You'll recall that ultrasonic equipment may be placed into 3 general classes. These are (1) pulse-echo, (2) through transmission, and (3) resonance.



The views above illustrate the 3 general classes of ultrasonic test systems. Which view best illustrates the principles of pulse-echo testing?

View A ..... Page 1-2

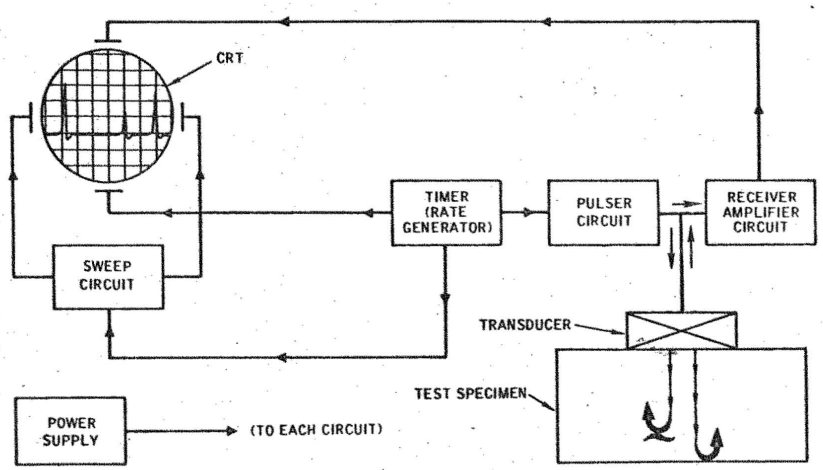
View B ..... Page 1-3

View C ..... Page 1-4

From page 1-1

Right. View A best illustrates the principles of pulse-echo testing.

Now, let's recall what is meant by the term "pulse-echo." We found that in pulse-echo testing pulses of ultrasonic sound are generated by the test instrument and introduced into a material, usually by a single transducer. The sound travels through the material and is reflected from the opposite side back to the transducer. The transducer converts the sound vibrations to electrical vibrations and the reflected pulse is displayed on a cathode-ray tube (CRT).



A-SCAN PULSE-ECHO SYSTEM - BLOCK DIAGRAM

Select the statement below which most nearly describes the nature of the sound generated.

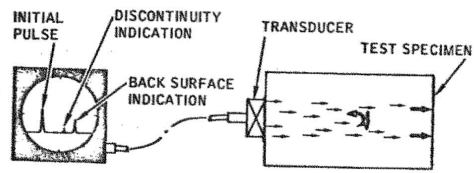
Short pulses of ultrasonic sound . . . . . Page 1-5

Continuous ultrasonic sound. . . . . Page 1-7

From page 1-1

Your selection of View B as the best illustration of pulse-echo testing is incorrect. View B shows the through transmission system using 2 transducers, one as a transmitter and one as a receiver . . . more about through transmission later.

First let's take another look at View A.



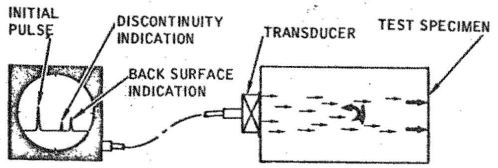
VIEW A

Didn't we learn in Volume I that the pulse-echo system uses reflected energy to determine the presence of discontinuities? Yes. Now, doesn't View A best illustrate this principle? Of course.

Turn to page 1-2.

Your selection of View C as the best illustration of pulse-echo testing is incorrect. View C shows a resonance system setting up standing waves within the test specimen.

You'll recall from Volume I that the pulse-echo system uses reflected energy to determine the presence of discontinuities. Now, doesn't View A best illustrate this principle? Yes.

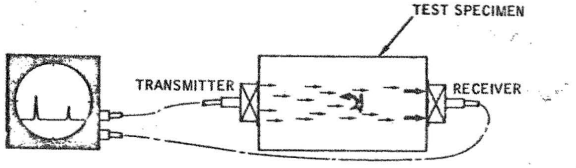


VIEW A

Turn to page 1-2.

Good. You remembered that when using pulse-echo equipment short pulses of ultrasonic energy are introduced into the test specimen.

The through transmission system operates on the principle of transmitting sound waves through a test specimen with one transducer and receiving on a second transducer, as shown below.



The transmitted sound can be either continuous or pulsed. And the presence of a discontinuity is indicated by a reduction in the magnitude of sound energy reaching the receiving transducer.

Select the best completion for the following statement.

Through transmission ultrasonic testing . . .

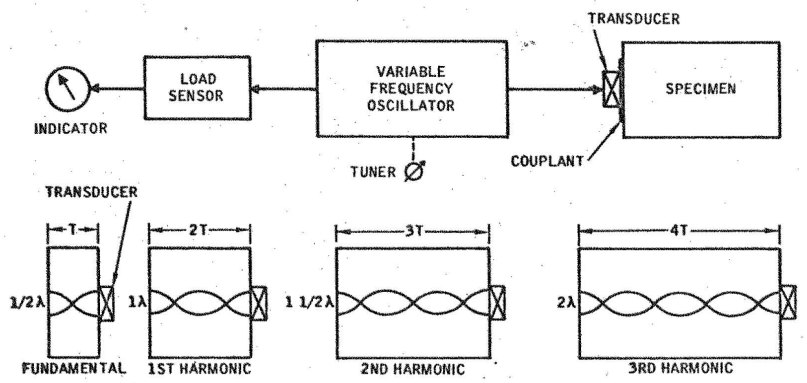
always uses separate transmitting and receiving transducers . . . . . Page 1-6

receives sound reflections on the transmitting transducer. . . . . Page 1-8

From page 1-5

Correct again. The through transmission system always uses separate transducers for transmitting and receiving ultrasonic sound.

Let us move on now to a brief review of resonance testing. The basic equipment elements are shown below along with a representation of the way the sound waves look in the test specimen.



T = THICKNESS
λ = WAVELENGTH

The resonance system makes use of the phenomena of resonance, or stationary waves that are produced when continuous longitudinal waves are introduced into a test specimen of the correct thickness. When the thickness T, shown above, is exactly equal to one-half or multiples of the wavelength of the ultrasonic energy, the test specimen will resonate and cause a loading effect on the transducer. And it is this loading effect that's used to tell us something about the specimen under test.

Select the best completion for the following statement.

The resonance method of ultrasonic testing uses the principle of . . .

recording echoes from the opposite surface . . . . . Page 1-9

standing waves of sound energy. . . . . Page 1-10

From page 1-2

Incorrect. Your selection of continuous ultrasonic sound as best describing the nature of the sound generated by a pulse-echo instrument indicates that you do not understand the meaning of the term "pulse-echo".

As the name implies, "pulse-echo" means the generation of a short pulse of energy and observing the nature of the echo received from the test specimen to determine if there are any discontinuities present.

Remember, it is necessary that a lapse of time be present between pulses in pulse-echo testing if discontinuities are to be distinguishable. If you are generating continuous sound energy, you will not be able to distinguish the reflections from the generated sound, or gain any intelligence that will help in determining if there are discontinuities in the test specimen.

Turn to page 1-5.

Your selection indicates you did not get the point that two transducers are used in through transmission testing. Two separate transducers are used, one for transmitting sound energy into a test specimen and one for receiving sound energy which may or may not have been modified by the internal characteristics of the test specimen.

Remember. Sound reflections are not used in through transmission testing. The presence of a discontinuity is indicated only by a reduction in transmitted sound magnitude.

Turn to page 1-6.

By turning to this page you have indicated that you think the resonance system is based on the principle of recording echoes from the opposite surface of a test specimen. This is not the best selection as an answer.

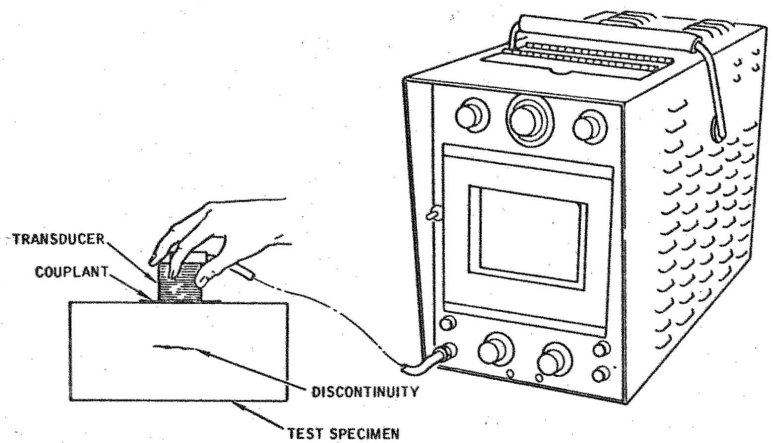
Granted, the resonance system is dependent upon sound waves being reflected from the opposite surface, however the reflection is not recorded on any sort of readout device to give an indication of material thickness or presence of a discontinuity.

The condition of resonance must be satisfied in the test specimen to give a reflection back into the test instrument in order that an indication be present. If the frequency of the sound being transmitted into the test specimen is such that the thickness of the material is not one-half a wavelength or a multiple thereof, reflections of sound waves from the opposite surface will not cause a resonance condition to be indicated on the test instrument.

Turn to page 1-10.

Good. You are correct in stating that the resonance system uses the principle of standing waves of sound energy in the test specimen.

You'll recall that ultrasonic testing may be further classified as either contact or immersion testing. Whether a test is to be contact or immersion depends on many factors, all of which you will learn in this volume. Right now let us take a look at contact testing as illustrated below.



In contact testing using the pulse-echo system, 3 things are required: (1) a test instrument, (2) suitable couplant, and (3) a test specimen. In this case, the transducer is brought into contact with the test specimen with the sound being coupled from the transducer to the specimen by the couplant.

Select the best completion for the following statement.

Contact testing means the . . .

transducer is placed directly in contact with the test specimen. . . . . Page 1-11

transducer is coupled through a thin layer of couplant to the test specimen. Page 1-12

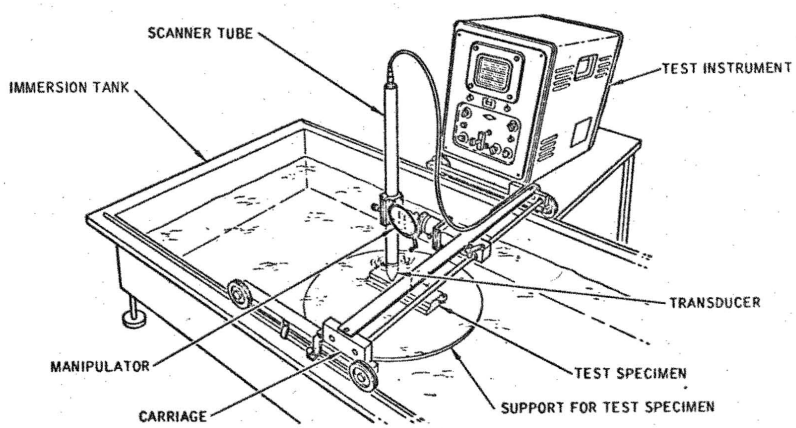
By turning to this page you have indicated that you think contact testing means placing the transducer in direct contact with the test specimen.

Remember what you learned in Volume I about acoustic impedance and the effect of a large ratio of acoustic impedance in the transfer of sound energy from one medium to another? If the transducer is placed directly in contact with the test specimen there is a layer of air between the two surfaces. This air will effectively cause all the sound energy to be reflected back to the transducer since it is such a poor conductor of sound energy. Now, if you place a couplant between the two surfaces a good transfer of sound energy takes place. A couplant, remember, is any substance such as oil, glycerine and water, etc., which fills the space between the transducer and test specimen and provides a good impedance match between the two.

Turn to page 1-12.

Fine. By contact testing, we mean the transducer is coupled to the test specimen through a thin layer of couplant.

Now that you have reviewed and understand the basic elements required in contact testing, let us continue to the immersion testing method which is widely used in industry. In immersion testing, the test specimen and transducer are placed in a liquid, usually water, and this liquid acts as the couplant in the transfer of sound energy from the transducer to the test specimen. Under normal testing conditions, a large tank accommodates the test specimen and the transducer is attached to an overhead fixture as indicated in the illustration below.



There are many advantages to the immersion method as compared to contact testing as you will learn in this handbook. For the moment though, the important difference to remember is that both the transducer and test specimen are immersed in the couplant.

Select the best completion for the following statement.

In immersion testing, an oil couplant . . .

is not required . . . . . Page 1-13
is required . . . . . Page 1-14

That's right. An oil couplant is not required as the liquid in the immersion tank acts as the couplant. There are many other significant differences between contact and immersion testing. However, for the purpose of this brief review, as long as you understand that the primary difference is the couplant, you are ready to proceed to the application of the techniques that have been developed for testing materials of various composition and shape.

Ultrasonic testing is particularly adaptable to the determination of the structural integrity of materials used in aerospace vehicles and related ground support equipment. Major applications are in the detection of discontinuities in raw stock and finished articles, and in thickness measurement. The desirable features of ultrasonic testing include . . .

- High sensitivity permitting detection of small defects.
- Great penetrating power allowing examination of very thick materials.
- Accuracy in determination of discontinuity position and size.
- Fast response permitting rapid and automated testing.
- Requires access to only one surface of the test specimen.

From the above listing of desirable features of ultrasonic testing it is apparent that this is a testing method that has a potential for very wide application. You could say that ultrasonic testing . . .

replaces most other nondestructive testing methods . . . . . Page 1-15

is another nondestructive testing method that may be selected depending upon the requirements of the test to be performed . . . . . Page 1-16

From page 1-12

No. In immersion testing, with the test specimen and transducer both immersed in a tank of liquid, it is not necessary to apply a couplant material to the face of the transducer. The liquid provides the necessary coupling and impedance match between the transducer and test specimen to afford an easy path for the sound waves to travel into the test specimen. The purpose of a couplant is to exclude air from the space between the transducer and face of the test specimen. This affords a better match of acoustic impedance and allows sound waves to travel into the test specimen. The liquid in an immersion testing tank performs this function very nicely.

Turn to page 1-13.

From page 1-13

Wrong. Ultrasonic testing does not replace other nondestructive testing methods even though it is a very versatile method and has capabilities that may not be found in other methods.

The discussion on the limitations of ultrasonic testing which follows will clear up this point.

Turn to page 1-16.

From page 1-13

Good. You have readily determined that ultrasonic testing is only one of a number of nondestructive testing methods that may be selected depending upon the requirements of the test to be performed.

As with all nondestructive testing methods, there are also certain limitations to the use of ultrasonics. Test conditions that may limit the application of ultrasonic methods are . . .

- Unfavorable geometry of the test specimen, i.e., size, contour, complexity, and orientation of defects.
- Undesirable internal structure, i.e., grain size, porosity, inclusion content, or fine dispersed precipitates.

These factors affect the "defect detectibility" of the testing method. And "defect detectibility" is determined largely by the "sensitivity" and "resolution" of the test instrument in use.

You will recall from Volume II that "sensitivity" is the ability of the instrument to detect a minute amount of sound energy reflected from a discontinuity in a test specimen. And "resolution" is the ability of the test instrument to produce separate indications from discontinuities that occur close together in depth in the test specimen.

Given 2 pulse-echo test instruments. Instrument number 1 is capable of clearly showing reflections from discontinuities that are 1/4 inch apart in a specimen while instrument number 2 can only distinguish reflections from discontinuities that are 1/2 inch apart. Instrument number 1 can be said to have the best . . .

sensitivity. . . . . Page 1-17

resolution. . . . . Page 1-18

From page 1-16

Incorrect. Instrument number 1 has the best resolution. You missed the distinguishing features of the differences in definition of "resolution" and "sensitivity".

Again, "sensitivity" is the ability of the instrument to detect the minute amount of sound energy reflected from a discontinuity in a test specimen.

"Resolution" is the ability of the test instrument to produce separate indications from discontinuities that occur close together in depth in the test specimen.

Turn to page 1-18.

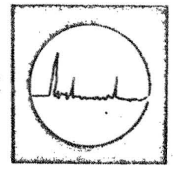
An excellent choice. The "resolution" of instrument number 1 is the better of the two since it can detect discontinuities that are closer together than can instrument number 2.

Another important factor affecting "defect detectibility" is the "noise discrimination" of the test instrument in use. Noise discrimination is defined as the capability of the test instrument to discriminate between signals from discontinuities and unwanted signals of either electrical or acoustical nature. These unwanted signals could be the result of unfavorable geometry of the test specimen or its internal structure, i.e., grain size, porosity, and inclusion content. Signals appear as spurious indications, "grass", "hash", or "metal noise".

Which of the following CRT patterns indicates another form of nondestructive testing should be used?



VIEW A



VIEW B

View A . . . . . Page 1-19

View B . . . . . Page 1-20

Right. The CRT pattern shown in View A indicates another form of nondestructive testing should be used. Any discontinuities that might be in the test specimen would not be distinguishable because of the excessive "metal noise" or "grass" shown on the screen. High attenuation and rough surface conditions are also factors that can limit the use of ultrasonic test equipment.

With respect to ultrasonic testing, we find the pulse-echo system to be the most widely used. An important advantage of the pulse-echo system is that we do not have the problem of orientation between separate transducers as in through transmission testing. One transducer acts as both the transmitter and receiver of the sound energy. And the reflections from discontinuities provide specific information as to discontinuity size and distance from the surface of the test specimen.

The through transmission system also has certain advantages. Its main advantage is a better near surface resolution as a result of using separate transducers for the transmission and reception of sound energy. This allows us to detect discontinuities just below the surface of a test specimen that would be impossible to find otherwise. Attenuation is a lesser problem in through transmission as the sound energy has to travel in only one direction through the test specimen. This makes it possible for us to test thicker specimens than if we were using pulse-echo. The principle disadvantage of through transmission testing is the requirement that the transmitting and receiving transducers have to be precisely oriented or aligned on the test specimen for proper results. Also, the use of separate transducers doubles the problems of surface roughness and couplant.

Which of the following systems would you select to test a specimen if you needed to know the depth and size of any discontinuities found?

Through transmission . . . . . Page 1-21

Pulse-echo . . . . . Page 1-22

Incorrect. The CRT pattern shown in View A indicates another form of nondestructive testing should be used, e.g., radiography or magnetic particle, etc. View B represents a favorable response from a test specimen.

You'll recall that spurious indications and metal noise were briefly discussed in Volume I. And the various CRT screen patterns were presented. We found from these patterns it was easy to have a discontinuity go undetected because of the many multiple reflections appearing on the screen. Spurious indications could also be mistaken for discontinuities. Therefore, in cases where these conditions are present, another form of nondestructive testing should be used.

Turn to page 1-19.

You selected the incorrect answer. The through transmission system will not give you the depth or specific size of a discontinuity. For this reasons the pulse-echo system would be the best.

Turn to page 1-22.

Excellent. You selected the correct answer. The pulse-echo system would be the best system to use if you needed to know the depth and size of any discontinuities found. You remember it is impossible to determine a discontinuity's depth when using the through transmission system.

The resonance system is used primarily to measure material thicknesses however it can also be used to detect large discontinuities, delamination, and lack of bond. The chief advantages of resonance testing are that most of the equipment is simple to operate and portable. However, a limitation of resonance testing is that as material thickness increases, accuracy decreases. Surface taper may also reduce resonance amplitude to the point where resonance indications are difficult to obtain. And we find the pulse-echo system to be the more accurate in measuring thicker materials.

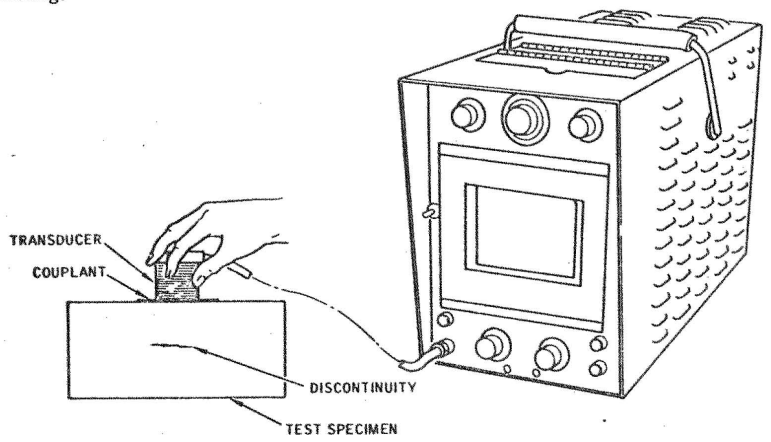
Which of the following systems would you use to measure the thickness of a thin specimen with parallel surfaces?

Resonance. . . . . Page 1-23

Pulse-echo . . . . . Page 1-25

Right. You would use the resonance system to measure the thickness of a thin specimen having parallel surfaces. The pulse-echo system would be better on thick test specimens.

Let us now take a look at some of the advantages of the contact method of ultrasonic testing.



One of the main advantages is flexibility of location. This portability allows the test equipment to be taken to the material or products to be tested. Other advantages of contact testing include . . .

- A minimum of test instrumentation and accessories are required.
- Capability for surface wave testing.
- Deeper penetration power.
- Ability to test very large specimens.

From a review of the advantages of contact testing, it is obvious that this method in general does not lend itself to automatic scanning and recording such as might be required in production line testing.

True . . . . . Page 1-24

False. . . . . Page 1-26

Correct. In the contact testing method, the transducer must be scanned over the specimen usually by hand, or spot readings taken depending on the thoroughness of the test. This method, then, does not lend itself generally to automatic scanning and recording such as might be used in production line testing. We can say that this is a disadvantage of contact testing.

Other limitations of contact testing are . . .

- Difficulty in maintaining uniform acoustical coupling between the test surface and transducer. This contributes to loss of sensitivity in the testing system and test results are not uniform.
- Reasonably smooth surfaces are required in order that there be a maximum transfer of ultrasonic sound energy to the test specimen.
- The use of heavy couplants leaves a coating of oil or grease on test specimens that will need to be removed later.
- Contact testing has a greater "dead zone" at the entrance to the test specimen than immersion testing due to CRT saturation by the initial pulse. This limits the near surface detection or resolution of discontinuities.
- Transducer angulation cannot be varied continuously as is possible in immersion testing except under special conditions when a variable angle transducer is used.

Analysis of the limitations to the contact testing method indicates the greatest disadvantage is . . .

lack of near surface resolution . . . . . Page 1-27
difficulty in maintaining uniform acoustical coupling. . . . . Page 1-28

Incorrect. For measuring the thickness of a relatively thin specimen with parallel surfaces, you would use the resonance system. These are ideal conditions for using the resonance system. The resonance system is extremely accurate for measuring thin materials while the pulse-echo system is better for thicker materials.

Turn to page 1-23.

From your selection of a "false" answer it is apparent you think that contact testing does lend itself to automatic scanning and recording such as might be required in production line testing. Sorry. Your selection is incorrect. In this method the transducer must be scanned over the test specimen usually by hand, or spot readings taken depending upon the thoroughness of the test being performed.

Turn to page 1-24.

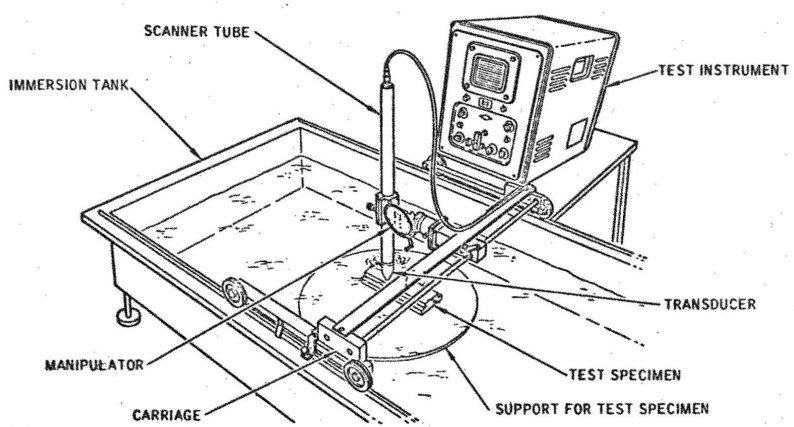
One of the disadvantages of contact testing is lack of near surface resolution which means that discontinuities cannot be detected on the surface or just beneath the surface. This area of the test specimen is obscured by the initial pulse of the test instrument.

However, the main disadvantage is the difficulty in maintaining uniform acoustical coupling between the face of the transducer and the surface of the test specimen. The sensitivity of the testing system will vary as will the test results if the operator does not maintain uniform pressure on the transducer when holding it in contact with the test specimen.

Turn to page 1-28.

Excellent. You have correctly selected as the main disadvantage of contact testing the difficulty encountered in maintaining uniform acoustical coupling between the surface of the test specimen and transducer. This reduces the sensitivity of the testing system and does not give uniform test results. The lack of uniform acoustical coupling is caused primarily by the operator not being able to maintain a constant pressure on the transducer as he tests different spots on the test specimen, or as he makes tests on several test specimens in a lot.

Now let's take a look at the advantages and disadvantages of immersion testing.



The principle advantages of immersion testing are . . .

- Higher test frequencies can be used which leads to high scanning speeds and higher sensitivity to small discontinuities.
- Ease at which transducer angulation can be varied.
- Ability to scan irregular-shaped test specimens.
- Better near surface resolution of discontinuities.

Does the immersion method lend itself to automatic scanning and recording?

Yes . . . . . Page 1-29

No. . . . . Page 1-30

Right. The immersion test method does lend itself to automatic scanning and recording. Automatic scanning and recording would simple require the addition of a motor-driven carriage with an automatic indexing mechanism for scanning the specimen, and a C-scan recorder to make the recording.

We also find that immersion testing has certain limitations or disadvantages. These limitations or disadvantages are . . .

- A large number of accessories are required.
- A large amount of sound energy is reflected at the water/test specimen interface thus reducing indication amplitude.
- The size of some specimens will not permit immersion in a tank.

Suppose we had a specimen at some field location that we wanted to test ultrasonically. Which method would you most likely use?

Contact method . . . . . Page 1-31

Immersion method . . . . . Page 1-32

From page 1-28

You are incorrect when you say the immersion method does not lend itself to automatic scanning and recording. It does. In fact, most automated ultrasonic systems use the immersion method or a variation thereof.

Let's recall the typical test setup used in immersion testing. It includes the test instrument, immersion tank, and a manipulator supported by the carriage. The transducer is mounted in the lower end of a scanner tube in the manipulator. Now, by using a motor-driven carriage with an automatic indexing mechanism in place of a manually operated unit, can not a transducer be set up to automatically scan a test specimen? Yes. And a recording can be made of the scanning operation using a C-scan recorder.

Turn to page 1-29.

From page 1-29

Very good. Contact testing would most likely be the best method to use when testing in the field. The immersion method would be better in the shop or on a production line, depending on the test requirements.

As you can see from the preceding discussions, there are many variables to be considered in ultrasonic testing, some of which are controlled by the operator and some by the inspection problem itself.

In the selection of equipment the operator determines the type of instrument to be used and the type and size of transducer to be employed. Once the equipment has been selected, the operator controls all the variables of equipment operation. And the equipment operation variables can be classed as those relating to technique and control settings.

Variables in "technique" are the selections that are possible in relation to coupling method, sequence of scanning the test specimen, and procedures used for peaking the test instrument.

Variables in "control settings" relate to the test instrument and the selection of operating frequency, pulse length, and sensitivity. Improper selection of any of the operator-controlled variables can affect the results obtained from the test.

Variables controlled by the ultrasonic operator are . . .

equipment selection and operation . . . . . Page 1-33

test specimen and transducer to be used . . . . . Page 1-34

Incorrect. The immersion method does not lend itself very well to field testing. This is due largely to the number of accessories required and bulky equipment ... not very portable.

On the other hand we find the contact method well suited for field testing. We do not have to contend with the immersion tank, carriage, and manipulator, etc. Remember, portability is one of the main advantages of contact testing.

Turn to page 1-31.

You are correct. The operator controls the selection of equipment and equipment operation. As you will see later in the discussion of ultrasonic acceptance standards, we will have some help in this selection, but still a lot of responsibility for success or failure of the tests depends on the operator.

The second set of variables in any ultrasonic testing situation are those controlled by the inspection problem. These variables are the properties of the test specimen and discontinuity conditions that may exist.

Properties of a test specimen that may affect a particular ultrasonic test are . . .

- Sound velocity within the specimen.
- Acoustic impedance of the material.
- Shape of the specimen and surface condition.
- Sound attenuation within the specimen and "noise" level.

Discontinuity conditions that may exist in a test specimen vary over a wide range. Their effect on a test situation depends on . . .

- Depth of discontinuity in the test specimen.
- Size and shape of discontinuity.
- Acoustic impedance of discontinuity in relation to that of the test specimen.
- Orientation of discontinuity with respect to the specimen front surface.

Given a particular test specimen, which of the following may be modified by the operator?

Shape of the specimen . . . . . Page 1-35

Adjustment of the test instrument . . . . . Page 1-36

From page 1-31

1-34

Wrong. The operator does control selection of the transducer to be used but does not have any control over the test specimen. His assignment to perform an ultrasonic test on a particular specimen or group of specimens is a fixed quantity and cannot be controlled by him.

Turn to page 1-33.

From page 1-33

1-35

Incorrect. A test specimen may be of an infinite number of shapes and sizes. If you were the ultrasonic test operator and modified the shape of the specimen before making a test, you would be approaching the field of destructive testing, rather than nondestructive testing.

No, the operator cannot modify the shape of a specimen. He can, however, adjust the test instrument controls to reduce undesirable effects. In Volume II you learned that most ultrasonic test instruments are provided with internal electronic control circuits that enable the operator to vary the CRT presentation or instrument indication to obtain a desired response.

Turn to page 1-36.

From page 1-33

Excellent. You have correctly deduced that an ultrasonic test operator can adjust only the test instrument controls to obtain a better response or CRT presentation. About the only modification an operator can make to a test specimen is its surface condition. With proper authorization, you may sometimes smooth the specimen surface if it is so rough that testing is impractical.

Now that you understand there are many variables that must be considered in performing ultrasonic testing successfully, let us take a look at some of the general requirements for successful testing. These are. . .

- A clear definition of the test to be performed.
- Well-trained operators, properly supervised.
- Adequate standard reference blocks or reference specimens for comparison to test specimens.
- A good test procedure.
- Realistic acceptance standards.

The most important of the general requirements for successful ultrasonic testing are to have well-trained operators and provide these operators with a test procedure and acceptance standards that clearly define the extent of discontinuities that may be tolerated in a test specimen.

From an analysis of the above general requirements of successful ultrasonic testing, what would you say determines the type of standard reference block or reference specimen to be used in evaluating discontinuity indications in the test specimen?

Determined by operator judgment . . . . . .Page 1-37
Stated in acceptance standards . . . . . .Page 1-38

From page 1-36

Your analysis was faulty this time. The type of reference to be used is not determined by operator judgement.

You'll recall from Volume II that standard reference blocks are used to establish discontinuity size. We will find that the type of test block, material, etc., is prescribed in the acceptance standard. And it is the responsibility of the operator to evaluate indications from the test specimen with reference to the artificial discontinuity indications provided by the standard reference blocks or reference specimen prescribed.

Turn to page 1-38.

Excellent. You haven't been told anything about acceptance standards yet but you have correctly determined that the type of standard reference block or reference specimen to be used to evaluate discontinuity indications in test specimens will be prescribed in the acceptance standard.

The test procedure and acceptance standard are important documents and must be used together. General requirements are...

- Instrumentation - General statement specifying end results.
- Testing Technique - Immersion or contact testing specified as well as the scanning technique to be used.
- Reference Standards - A requirement that discontinuities be compared to reflections returned from equipment calibrated previously with ultrasonic reference blocks.
- Acceptance Limits - Ultrasonic quality levels are provided by acceptance standards.

It appears that a good test procedure and acceptance standard provides a lot of detail about an ultrasonic test to be performed. Would you say that this test documentation reduces the need for operator training, or has no effect on the need for training?

Reduces need for operator training . . . . . Page 1-39

Has no effect on operator training requirements. . . . . Page 1-40

By turning to this page you indicate that you think that good test documentation will serve as a crutch and reduce the need for training of operators of ultrasonic equipment. Look at the requirements again - it merely serves as a starting point, sets up the general requirements for the test, and provides a reference point for evaluating discontinuity indications from the test specimen.

One of the most important requirements of an operator of ultrasonic equipment is evaluation of the indications received from a discontinuity. This can only come from training and experience.

Turn to page 1-40.

That is right. Regardless of how good the test documentation is, we still have a need for thorough operator training. No written detail will substitute for the judgment required in evaluating the discontinuity indications that may be expected when submitting test specimens to ultrasonic testing.

Once a determination has been made of the correct method of conducting the test (contact or immersion), and the equipment selected (pulse-echo, through transmission or resonance) it is necessary to assure that the test instrument is calibrated against standard ultrasonic test blocks before proceeding with the test.

When acceptance of material is based on rigid ultrasonic test standards, very close attention must be paid to the calibration of test instruments to assure that accurate test results will be obtained.

Calibration or standardization of ultrasonic instruments is based on reflections from...

the opposite surface of a test block of known precise dimension . . . . Page 1-41

precisely machined holes in test blocks providing an air interface . . . Page 1-42

Your selection is not correct. If we were to base the calibration or standardization of ultrasonic instruments on reflections from the opposite surface of test blocks of known precise dimensions, we would be merely assuring that a back surface reflection is received and would be able to determine the transit time of the ultrasonic beam and thus measure the thickness of the block.

What is <u>really desired</u> during standardization is to determine the magnitude of the reflection obtained from a simulated discontinuity in the test block. These simulated discontinuities are in the nature of precisely-machined holes in test blocks of known size and distance from the test surface.

Turn to page 1-42.

Excellent. The principle method for calibration or standardization of test instruments is based on reflections received from precisely-machined holes in standard reference (test) blocks.

In Volume II you learned that test blocks are provided in sets with precisely-machined holes of varying dimensions and depths. In this volume you have learned that test blocks are prescribed as standards against which to compare discontinuities in test specimens.

Ultrasonic test standards for various tests will prescribe the size of hole and depth in the test block that is to be used as a reference. Since test holes have ideal geometry and surface condition, all discontinuities in the test specimen whose reflection amplitude is equal to the reflection from the test hole will tend to be larger than the dimensions of the ideal test hole.

Test blocks used for standardization should be similar to the test specimen in the following respects:

- Alloy content.
- Heat treatment.
- Degree of hot or cold working due to forging, rolling, or extruding.

It may be necessary at times to fabricate test blocks when standard reference test blocks are not available in the same material as that of the test specimen. In some cases, a portion of the test specimen is removed and artificial discontinuities introduced by drilling carefully-machined, flat-bottom holes at certain depths to produce artificial discontinuity indications.

Is the following statement true or false? Test blocks made from extruded aluminum bar stock would be suitable for standardizing the test instrument for performing tests on aluminum castings.

True . . . . . Page 1-43
False. . . . . Page 1-44

By selecting a "true" answer you are indicating that you think discontinuity echoes from aluminum bar stock and aluminum castings would be very nearly the same so that if the equipment is standardized using test blocks of extruded bar stock, discontinuity indications from the casting could be correctly interpreted.

This answer could be considered correct under certain conditions, but usually there will be large errors in evaluating discontinuity indications from the casting. The selection must be considered wrong because under practical test conditions you could not be sure that the comparison in discontinuity indications is correct.

Turn to page 1-44.

Right. If test blocks of extruded aluminum bar stock are used for standardizing the test instrument and tests are performed on aluminum castings, the echo indications from discontinuities in the test specimen may have no relationship in size to the indications received from simulated discontinuities in the test blocks. This is due to differences in internal structure of the 2 materials.

Consider now a practical example of the use of test blocks and standardization. Suppose the ultrasonic test requires that discontinuity indications in excess of the response from a 3/64-inch flat-bottom hole at the estimated depth of discontinuity be cause for rejection of the material.

Assume that while testing a specimen ultrasonically, we obtained a discontinuity indication which showed a discontinuity at a depth of 2 inches in the test specimen. The height of the indication was 1 inch on the CRT.

First we would select a test block of similar alloy as the test specimen with a 3/64-inch flat-bottom hole at a depth approximately 2 inches from the face of the block.

Then we would adjust the response from the test block using the instrument sensitivity control to display an indication 1 inch in height on the CRT.

Next the test specimen discontinuity is rechecked and its amplitude compared with the reflection from the test block. If the discontinuity signal height is equal to or greater than 1 inch, the discontinuity would be larger than the acceptance standard. The test specimen would not be acceptable to the standard.

Is the following statement true or false? A discontinuity indication from a test specimen that is equal in height to an indication from a test block indicates the discontinuity is actually larger than the flat-bottom hole.

True . . . . . Page 1-45

False . . . . . Page 1-46

Excellent. A discontinuity indication from a test specimen that is equal in height to an indication from a flat-bottom hole in a test block can always be considered as indicating a discontinuity that is larger in size than the flat-bottom hole. This is due largely to the fact that discontinuity surfaces are always uneven and this causes scattering of the sound beam.

In summation, you have learned in this chapter that in ultrasonic test system and method selection . . .

- Ultrasonic testing has both its advantages and limitations with respect to other forms of nondestructive testing.
- System and method selection depends largely on environment and the test results required.
- Many variables must be considered, some of which are operator controlled and some by the inspection problem itself.
- The particular requirements of a test are set forth in the test procedure.
- Standard reference (test) blocks are used to determine and evaluate discontinuities.
- Standardization is a must in evaluating discontinuity indications.

One more thing. The calibration and alignment of electronic circuits within an ultrasonic test instrument is beyond the scope of this handbook. However, as a last consideration, an instrument must bear a currently valid calibration sticker before it can be considered adequate for performance of a test.

Turn to page 1-47 for a review of what you have learned in this chapter.

Your selection "false" is not correct.

A flat-bottom hole is carefully machined and there are no rough surfaces while a discontinuity in the test specimen will always have an uneven surface. An uneven surface will cause scattering of the sound beam, thus reducing the energy in the reflected portion of the sound. The net result is that a discontinuity signal of equal amplitude to a signal from a flat-bottom hole will always indicate a discontinuity that is larger in size than the flat-bottom hole. Therefore, your answer should have been "true".

Turn to page 1-45.

From page 1-45

1. The next few pages are different from the ones which you have been reading. There are_____arrows on this entire page. (Write in the correct number of arrows.) Do not read the frames below. FOLLOW THE ARROW and turn to the TOP of the next page. There you will find the correct word for the blank line above.

8. standing

9. The most widely used ultrasonic test system is p_____-e_____.

16. through transmission

17. Attenuation is a (greater)(lesser) _____ problem in through transmission testing than in pulse-echo testing.

24. immersion

25. Variables in an ultrasonic testing system that are controlled by the operator are equipment s_____ and o_____.

This is the answer to the blank in Frame number 1.

1. four — Frame 2 is next

2. These sections will provide a review of the material you have covered to this point. There will be one or more blanks in each f_____.

9. pulse-echo

10. The method of ultrasonic testing where the transducer is placed on the test specimen with a thin couplant separating them is called _____ testing.

17. lesser

18. The chief advantages of resonance testing are sim_____ and p_____.

25. selection, operation

26. Given a test specimen of certain size, shape, acoustic impedance, surface condition, and discontinuity properties, only the sur_____ c_____ (with proper authorization) can be modified by the ultrasonic operator.

2. frame

3. By following the arrows or instructions you will be directed to the section which follows in sequence. Each section presents information and requires the filling in of _____.

10. contact

11. The method of ultrasonic testing where the test specimen and transducer are placed in water is called _____ testing.

18. simplicity, portability

19. With reference to the resonance system, pulse-echo is the better system for measuring thicknesses in (thinner) (thicker)_____ materials.

26. surface condition

27. Assume you are performing an ultrasonic test. The t_____ s_____ prescribes the type of standard reference (test) block or reference specimen that will be used to compare with discontinuity indications in the test specimen.

3. blanks (or spaces or words)

4. In pulse-echo ultrasonic testing _____ pulses of sound energy are transmitted into a test specimen.

11. immersion

12. The most widely used applications of ultrasonic techniques in the aerospace industry are in th_____ measurement and d_____ detection.

19. thicker

20. Compared to the contact method, the immersion method has a (higher) (lower)_____ sensitivity to small discontinuities.

27. test standard

28. Standardization of ultrasonic instruments is based on reflections from flat-bottom _____ in standard reference (test) blocks.

4. short

5. The pulse-echo system provides specific information as to a discontinuity's s_____ and d_____ from the test specimen front surface.

12. thickness, discontinuity

13. Defect detectibility is largely dependent on the se_____, res_____, and noise d_____ factors of the test instrument in use.

20. higher

21. Difficulty in maintaining a uniform acoustical coupling between the test specimen and transducer is a disadvantage of (contact) (immersion) _____ testing.

28. holes

29. If a steel plate is being tested by ultrasonics, the reference blocks used for standardizing the test instrument should be made of _____.

5. size, depth

6. The system in which discontinuities are indicated by a reduction or loss of transmitted energy in the test specimen is called t_____ t_____.

13. sensitivity, resolution, discrimination

14. The best near surface resolution can be obtained using the (pulse-echo) (through transmission)_____ system.

21. contact

22. Better near surface resolution of discontinuities can be obtained using the (contact) (immersion)_____ method.

29. steel

30. Assume a discontinuity indication 1" in height from a test specimen. The magnitude of the indication from a 5/64" flat-bottom hole at the same approximate depth is also 1". It can be assumed that the size of the actual discontinuity is _____ than the flat-bottom hole.

6. through transmission

7. Through transmission testing uses _____ transducers.

14. through transmission

15. To determine the depth and specific size of a discontinuity, we would use the (pulse-echo) (through transmission)_____ system.

22. immersion

23. Transducer angulation is easier using the _____ method.

30. larger

31. Turn to page 2-1 and continue.

7. two

8. The ultrasonic resonance system uses the principle of st_____ waves of sound energy in the test specimen.

Return to page 1-47, frame 9.

15. pulse-echo

16. The problem of transducer alignment is a principle disadvantage of _____ testing.

Return to page 1-47, frame 17.

23. immersion

24. Test specimen size is a limiting factor in _____ testing.

Return to page 1-47, frame 25.

CHAPTER 2 - PULSE-ECHO/THROUGH TRANSMISSION TESTING USING THE CONTACT METHOD

In Chapter 1 you reviewed the basic systems and methods used in ultrasonic testing and learned each has its advantages and limitations depending on the test conditions that exist. You learned of many variables that must be contended with and the importance and use of test documentation. At this point in your study of ultrasonic testing you should have a "feel" for selecting the most logical test system and method required to perform a particular test you have at hand.

Let's take a look now at some of the considerations in selecting test equipment for contact testing. We'll assume that you have a wide variety of instruments with varying characteristics to select from, and many possibilities in the selection of transducers and display devices. In actual practice this ideal condition in which a wide selection of equipment is available will not often be realized. But, since we should consider all the ways that test specimens affect the selection of test system components, it is necessary also to consider the capabilities of the equipment that may be available to obtain the best test results.

This chapter covers the application of 2 basic systems used in contact testing. These are . . .

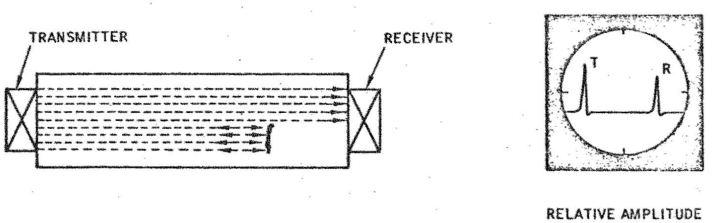
- Pulse-echo using one transducer as both a transmitter and receiver of sound energy, or separate transducers for each function.
- Through transmission using separate transducers for transmitting and receiving the sound beam.

Turn to page 2-2.

From page 2-1

From the discussions in Chapter 1 on the advantages and disadvantages of pulse-echo and through transmission testing, you learned the pulse-echo system is the most widely used. This is true for several reasons. There is no orientation problem of separate transducers for transmission and reception since these 2 functions are combined into 1 transducer. And reflections from discontinuities provide specific information as to the relative size of a discontinuity and its distance from the surface of the test specimen.

Shown below is an illustration of through transmission testing.



When using through transmission, are discontinuity indications proportional to the amount of sound energy reflected by the discontinuity?

Yes . . . . . Page 2-3

No . . . . . Page 2-4

From page 2-2

You have indicated you think the CRT indication in test situations using through transmission would be proportional to the amount of sound energy reflected by a discontinuity. Your selection is not correct.

You'll remember that in this type of testing the transmitting and receiving transducers are placed on opposite sides of the discontinuity. The receiving transducer will receive only that portion of the sound energy that is not reflected by the discontinuity, thus no indication will indicate sound energy is not getting through the specimen. A smaller amplitude CRT indication will signify that there is partial reflection and not all the sound is getting through.

If the received pulse and the transmitted pulse are of the same relative height on the CRT, the test specimen is sound.

Turn to page 2-4.

From page 2-2

That is right. The CRT indication when using through transmission is inversely proportional to the amount of sound energy reflected by a discontinuity. Total reflection of the sound energy will result in no energy being received by the receiving transducer. If there are no discontinuities in the test specimen, the amplitude of the sound energy received by the receiving transducer will be maximum.

We also learned in Chapter 2 that through transmission testing has certain advantages over pulse-echo testing. These were better near surface resolution and the capability for testing thicker test specimens.

In through transmission testing, the receiving transducer does not "see" the reflection from the front surface of the test specimen. At what depth in the test specimen do you think discontinuities can be detected?

A few thousandths of an inch . . . . . Page 2-5

About 1/4 inch . . . . . Page 2-6

From page 2-4

Very good. When the through transmission system is used there is no longer any problem with near surface resolution and discontinuities just below the surface of the test specimen can be detected. However, due to the disadvantages we've previously discussed, through transmission is not widely used for detection of discontinuities except in special applications.

In contact testing it is possible to use a sound beam that is perpendicular to the test surface, that goes into the specimen at an angle, that goes along the surface of the specimen, or that goes through the material from one side to the other. Determination of the proper equipment to be used depends on the following factors:

- Nature, size, orientation, distribution, and number of discontinuities that may be expected in the test specimen.
- Shape, dimensions, and critical areas of the test specimen will determine type of transducer to be used.
- Surface condition, such as smooth or rough, flat or wavy, forged, cast, or rough machined will determine selection of couplant and test frequency.
- Specimen internal structure may be fine or coarse-grained. This will affect attenuation and scattering of the sound beam and will determine the test frequency to be selected.

Turn to page 2-7.

From page 2-4

You can do better than 1/4 inch. Since the initial pulse is not obscuring part of the specimen immediately beneath the surface, it is possible to detect discontinuities that lie a few thousandths of an inch from the surface when using separate transmitting and receiving transducers.

Turn to page 2-5.

From page 2-5

Consideration also should be given to the following performance requirements of an ultrasonic test instrument when making a selection for a particular contact test situation.

- The frequency range capability of the instrument.
- Instrument resolution.
- Linearity of the instrument (the capability of an instrument to display signal amplitude in proportion to amount of reflection from a discontinuity).
- Instrument penetration power (Is sufficient power available to penetrate the test specimen?).
- Instrument sensitivity to give the required amplitude indications.
- When necessary, a capability for measuring distance (marker circuit).
- Capability for both 1- and 2-transducer applications is required.

Select the best completion for the following statement.

Ultrasonic equipment selection is dependent on . . .

test specimen characteristics only . . . . . Page 2-8

the test situation . . . . . Page 2-9

You did not select the best answer. It is true that the test specimen plays an important part in the selection of ultrasonic test equipment; however, are not the test results we wish to obtain also an important consideration? Of course. We should know the test requirements as well as the characteristics of the test specimen, i.e., shape, size, surface condition, and internal structure when selecting ultrasonic equipment.

Turn to page 2-9.

Excellent. You correctly determined that the selection of ultrasonic test equipment is largely dependent on the test situation and not just the test specimen alone.

Once the test situation is established and the basic test instrument selected, it is important to select the proper frequency to test the material in the test specimen to meet the requirements of the test. It is usually desirable to test at the lowest frequency that will locate specified minimum sizes and types of discontinuities consistently. Because of variations in the structure of materials, it is not possible to specify a frequency for all ultrasonic tests of a given material type. Listed below are the frequency ranges and test applications generally used.

FREQUENCY RANGE	TEST APPLICATIONS
200 KC - 1 MC	CASTINGS: GRAY IRON, NODULAR IRON, AND RELATIVELY COARSE-GRAINED MATERIALS, SUCH AS COPPER AND STAINLESS STEELS.
400 KC - 5 MC	CASTINGS: STEEL, ALUMINUM, BRASS, AND OTHER MATERIALS WITH REFINED GRAIN SIZE.
200 KC - 2.25 MC	PLASTICS AND PLASTIC-LIKE MATERIALS, SUCH AS SOLID ROCKET PROPELLANTS AND POWDER GRAINS.
1 - 5 MC	ROLLED PRODUCTS: METALLIC SHEET, PLATE, BARS, AND BILLETS.
2.25 - 10 MC	DRAWN AND EXTRUDED PRODUCTS: BARS, TUBES, AND SHAPES
1 - 10 MC	FORGINGS
2.25 - 10 MC	GLASS AND CERAMICS.
1 - 2.25 MC	WELDS
1 - 10 MC	MAINTENANCE INSPECTION, ESPECIALLY FATIGUE CRACKS.

As in Volumes I and II, it should be noted the term Hertz (Hz) is now the universally accepted designation for the measure of frequency in place of cycles per second (cps). But to avoid possible confusion by using the newer term, the more common phrase cycles per second (cps) is retained in this handbook. It should also be noted that megaHertz (mHz) means the same thing as megacycles (mc) and kiloHertz (kHz) is the same as kilocycles (kc).

A coarse-grained internal structure in a test specimen will require the selection of a:

high test frequency . . . . . Page 2-10

low test frequency . . . . . Page 2-11

From page 2-9

2-10

Your selection is not correct. A high test frequency will be scattered by the coarse grain structure of the test specimen. If the frequency is high enough, the reflections will probably be such that it will appear that the specimen is defective when a lower frequency will not indicate a rejectable discontinuity. When in doubt about the internal structure of a specimen, the operator should experiment to determine the correct frequency to be used for the test.

Turn to page 2-11.

From page 2-9

2-11

That is correct. A low test frequency is required to test a specimen that has a coarse-grained internal structure. A high frequency will be scattered and can lead to an interpretation that the specimen is bad when a lower frequency will indicate a sound specimen.

The surface finish of a test specimen often affects the selection of test frequency. A surface that is rough or pitted with corrosion will require lower test frequencies to give proper sensitivity to the test system.

Under many test conditions, with proper authorization, the operator may do a certain amount of surface conditioning before a satisfactory test can be conducted. Rust, heat-treating scale, and corrosion should be removed with a power disc sander or brush. However, paint that adheres firmly to the metal need not be removed. A surface that has been rough machined may not be smooth enough to allow testing. In this case smoothing should be accomplished with a disc sander.

What is the effect of a rough test surface when testing with a high frequency?

Refraction of sound beam . . . . . Page 2-12

Scatter of sound beam . . . . . Page 2-13

Your choice of a possible answer is not correct. You seem to have forgotten for the moment that "refraction" is bending of a sound beam when it passes from one medium to another. In this case, the sound beam does not enter the medium of the test specimen but is scattered by the uneven surface of the test specimen.

Turn to page 2-13.

Correct. A rough surface on a test specimen will cause higher frequencies of ultrasonic sound to scatter with very little of the energy entering the test surface. "Refraction", of course, does not occur at the surface since this phenomena occurs only when sound beams pass from one media to another.

As stated before, test conditions are also affected by the internal structure of the test specimen. Not all pieces of steel are the same internally. Forgings, castings, extrusions, plate, and rolls all have their own peculiarities of internal grain structure. Some are coarse; others are fine. The characteristics of the internal structure are significant when selecting the proper test frequency. For fine-grained materials, a high frequency should be used; otherwise the lower frequency beam will not "see" the discontinuities. Just the reverse is true for coarse-grained specimens - a lower frequency must be used to avoid having reflections from the coarse grains appear as discontinuity indications on the CRT.

You'll recall from Volume I that when ultrasonic sound passes through a material it does so by successive particle displacements. The ease of particle displacement is determined to a certain extent by the wavelength of the sound energy. At high frequencies the wavelength is short in relation to the size of the grain in the material and a large amount of the energy is expended as heat since the mass of the grains does not move to permit the sound to travel through the specimen. Also, some of the sound energy is reflected back to the transducer giving false indications of discontinuities.

Which material has the finer grain structure, an aluminum casting or aluminum plate?

Aluminum casting . . . . . Page 2-14

Aluminum plate . . . . . Page 2-15

Your selection of a casting is not correct. A casting will usually have a coarser grain structure than a plate which has been rolled and formed. Grain structure of materials becomes more refined as they go through additional forming processes.

Turn to page 2-15.

Correct. An aluminum plate will have a finer grain structure than an aluminum casting. You, therefore, would select a lower frequency if a test was to be made on an aluminum casting.

Before proceeding to the factors that should be considered in the selection of the proper transducer to do the job, let us briefly review the principles that must be considered in selecting the test frequency. These are . . .

- The highest test frequency will provide the greatest sensitivity for detection of small defects.
- The lowest test frequency will give the power that is necessary to penetrate more deeply into the specimen being tested.

The ability of a testing system to detect discontinuities close to the surface depends on frequency among other factors. Which of the following will afford the best "near surface" discontinuity detection?

Low test frequencies. . . . . Page 2-16
High test frequencies . . . . . Page 2-17

From page 2-15

Your selection would not give the best "near surface resolution" in the detection of discontinuities. You need a high frequency for the best system sensitivity and resolution.

Low test frequencies are the best where increased power is required to penetrate thick test specimens.

Turn to page 2-17.

From page 2-15

Excellent. When you have a choice of low and high test frequencies and want to detect discontinuities close to the surface, the high test frequency is the best selection. Combine this with a short pulse length and you will have a combination of factors that will give you the best "near surface" detection of discontinuities.

Now that the problems to be faced in selection of a test frequency are understood, let us proceed to factors to be considered in the selection of transducers. The following factors must be taken into consideration:

- A large-diameter transducer is required when testing through greater distances.
- Available contact surface limits the size of the transducer.
- Beam spread is often desired to detect randomly-oriented discontinuities. Other applications require the straightest beam possible to minimize reflections from surfaces of the test specimen.
- A straight beam is useful for tracing the edges of a large discontinuity.
- At any frequency, the larger the crystal, the straighter the beam; the smaller the crystal, the greater the beam spread.
- For a transducer of given diameter, there is less beam spread at higher frequencies than at low frequencies.

Turn to page 2-18.

Suppose now that the material to be tested is large and flat. To test such a specimen you would choose a transducer that covers a large area, either a large single transducer, or a mosaic of smaller crystals such as could be found in a paint-brush transducer which you learned about in Volume II.

If the test is to be made through ridges, shoulders or other restricted areas on the test specimen, you would select a small diameter transducer. For a curved surface a flat transducer would provide best line contact (point penetration), or to obtain maximum contact surface between the transducer and test specimen, a transducer with a curved surface (curved shoe) will provide the best results.

At a given ultrasonic test frequency which will give the largest beam spread?

A large transducer. . . . . Page 2-19

A small transducer. . . . . Page 2-20

The size of the beam coming from an ultrasonic transducer is <u>not</u> to be considered as proportional to the size of the transducer. Quite to the contrary, the <u>larger</u> the transducer the <u>smaller</u> the beam spread. Just keep in mind that the relationship of beam spread to transducer size is an inverse proportion.

You should have selected "small transducer" as the answer to the question since, at a given frequency, a small transducer will give the largest beam spread.

Turn to page 2-20.

Good. You have correctly selected as your answer the fact that a small transducer has a larger beam spread at a given ultrasonic frequency.

Now, let us concern ourselves with the type of defect that the test is expected to detect. The size of the expected defect, its orientation to the test surface, distribution in the test specimen, and distance from the surface are important considerations in planning the test.

You'll recall high frequencies are required to locate the smallest defects and for testing near the surface of the specimen. Testing for defects that are a great distance from the test surface will usually require larger transducers than those used for testing for defects closer to the surface.

Suppose you are testing a long specimen over 10 feet in length from the end. The area of a suspected discontinuity is 10 feet from the test surface. You have selected 2.25 mc as the frequency most likely to give the best test results. With a choice of a 1/2-inch or 1-inch diameter transducer, which should be selected to penetrate to and beyond the suspected discontinuity?

1/2-inch transducer . . . . . Page 2-21

1-inch transducer. . . . . Page 2-22

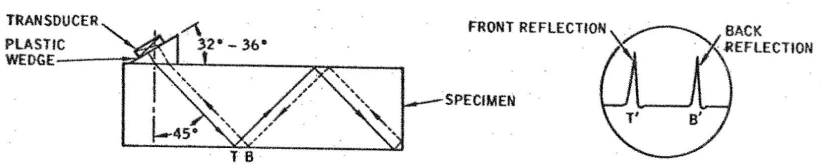
Did you guess on this one? If so, you guessed wrong. The 1-inch transducer should have been selected. It will produce a higher intensity beam over the 10-foot distance for detecting a discontinuity in the suspected area. The 1/2-inch transducer would produce a lower intensity beam that quite likely would not have sufficient power after traveling the 10 feet, to return a measurable reflection.

Turn to page 2-22.

From page 2-20

An excellent choice. The 1-inch transducer is the best selection for the example given. It would have a higher beam intensity at the 10-foot distance which would more likely return a reflection from a discontinuity if one existed in the suspected area.

The technique to be used in performing the ultrasonic test also has an effect on the selection of the proper transducer. It may be desired that the ultrasonic beam look into the test specimen at an angle. In this case, a transducer with a plastic wedge will be selected. The illustration below shows what happens to the sound beam when it enters the test specimen at an angle due to the law of refraction (Snell's Law) which you learned about in Volume I.



Sound is caused to bounce through the test specimen and reflect back to the transducer along the same path.

You'll recall from Volume II that angle beam transducers for contact testing are available in any desired angle from manufacturers of transducers. The common angles available without special order are for 45, 60, and 90 degrees of refraction in steel.

If an angle transducer will produce an angle of 45° in steel and you are to use this transducer for testing aluminum, will the angle of the sound beam in aluminum be greater or less than 45°? Assume shear velocity of sound in aluminum is less than in steel.

Less than 45° . . . . . Page 2-23

More than 45° . . . . . Page 2-24

From page 2-22

Excellent. Congratulations on correctly deducing that the refraction angle of the ultrasonic wave in aluminum will be less than in steel. This is due of course to the application of Snell's Law.

Now for a review of the considerations to be made in the selection of a transducer for making the test. These are . . .

- Larger-sized crystals should be used for general testing and when the least beam spread and maximum power is required.
- Smaller-sized crystals should be used on uneven surfaces, or when the test surface is too small to permit use of large units.
- Selection of an angle beam or straight beam transducer should conform to the testing technique to be used.
- Special, curved contact shoes should be used when testing curved or irregular surfaces.
- If available, a paint-brush transducer should be selected for the maximum scanning area in testing large flat specimens.

Turn to page 2-25.

It looks like you guessed on this one and guessed wrong. Actually, the refracted angle in aluminum will be slightly less at 43° when compared with a 45° angle of refraction in steel, assuming that the angle of incidence remains the same. In this case, the angle of incidence is fixed by the plastic wedge in which the transducer is mounted.

This is due to the relationships between the angles and velocities of sound in the two materials as related by Snell's Law. Snell's Law, expressed by the formula $\frac{\sin \phi_1}{\sin \phi_2} = \frac{V_1}{V_2}$, tells us that the sine of the angle of refraction is in direct proportion to the value of shear velocity when the formula is rearranged and written as $\sin \phi_2 = \frac{(\sin \phi_1)\ (V_2)}{V_1}$. The shear wave velocity is less in aluminum than in steel. Since this factor is reduced, the angle of refraction will also be reduced.

Turn to page 2-23.

A satisfactory contact test cannot be conducted without use of a suitable couplant between the transducer and test surface. A couplant you'll remember is a substance that "wets" the surface and acts to exclude air between the 2 surfaces.

You learned in Volume II that for most contact testing applications, a thin film of couplant should be used and thickness between the 2 surfaces should be uniform. In some applications, where it is not possible to use a liquid couplant, a thin sheet of rubber or plastic may be used. Examples of couplants that may be used are . . .

- Light machine oil.
- SAE-10 or SAE-20 motor oil.
- Water with a wetting agent (common detergent).
- Water and glycerine with a wetting agent.
- Special couplants available from instrument manufacturers for certain applications.

And you learned in Volume II that a couplant should . . .

- Be easy to apply.
- Not run off the surface too fast.
- Be free of bubbles or solid particles.
- Be noncorrosive and nontoxic.
- Have an acoustic impedance as near as possible to the acoustic impedance of the test specimen (between that of the specimen and transducer).
- Not affect the fabrication operations to follow.

Suppose you are conducting a test on a vertical surface. Which would be the most suitable couplant?

Oil . . . . . Page 2-26

Water with wetting agent . . . . . Page 2-27

From page 2-25

Very good. A good selection. If testing on a vertical surface with the selection of couplant limited to oil or water with a wetting agent, oil is the best couplant to select.

Once the proper test instrument has been selected, it will be necessary that the operator check the operating efficiency of the instrument.

Operating efficiency is checked using standard ultrasonic test blocks. To do this, the instrument is connected to the power source, power is turned on, and the equipment allowed to warm up for the period specified in the manufacturer's instruction book. After warm-up, tests are made on test blocks of varying thickness to determine that adequate artificial discontinuity indications are received from the flat-bottom holes and that discontinuity indications from flat-bottom holes at varying distances from the test surface give CRT indications of varying amplitudes.

This procedure is not to be confused with "standardization" of the instrument — it is merely to assure that the instrument is in operating order before proceeding with the test in accordance with the test documentation.

Is the following statement true or false? A couplant will not be required when making the above check for test instrument operating efficiency since the test blocks are very precisely machined and the test surface smooth enough that good contact will be made between the transducer and test surface.

False . . . . . Page 2-28

True . . . . . Page 2-29

From page 2-25

Your selection is not the best. Water with a wetting agent will provide coupling qualities but will have a tendency to run off the vertical surface too rapidly. Oil would be the best of the 2 couplants in this application. It will provide a film that adheres to the surface long enough for the test to be complete.

Turn to page 2-26.

That is correct. A couplant is required at all times between a transducer and test surface, regardless of how smooth the surface is. A very thin couplant will be adequate for the smooth surface involved.

Before conducting a test you should have a clear idea of the kind and quantity of discontinuities you expect to find. This will determine the number of test points to be used and the care to be used in evaluating suspected discontinuities.

A discontinuity indication should not be considered as a discontinuity until its origin is determined by making tests at as many angles as is possible. This ensures it is a discontinuity and not a result of a reflection from an irregular shape in the specimen or due to metallurgical structure.

If the initial test is made using a straight beam, a discontinuity indication should be examined at various angles using angle beam techniques. In many cases, where irregular-shaped specimens are being examined, the beam should be plotted on a drawing of the specimen to determine the angle to be chosen for an angle test.

Suppose the rear surface of a test specimen lies at an angle of 20° to the front surface. What will be the effect on a normal A-scan display considering the basic elements of the display always include front and back surface indications under normal conditions?

No effect. . . . . Page 2-30

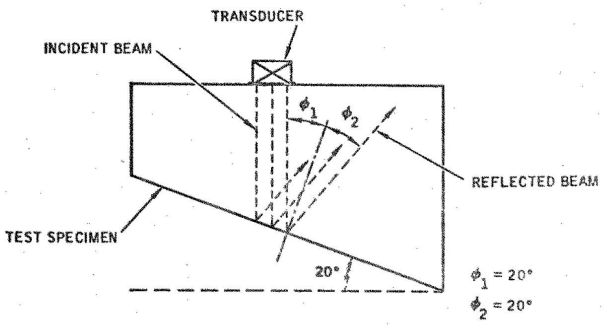
Loss of back reflection . . . . . Page 2-31

You sure guessed on this one, didn't you? It doesn't matter how smooth a surface is, a couplant is still required in contact testing.

A thin film of couplant, such as a light oil, will be adequate in the case cited, but is still needed to exclude air and allow the ultrasonic sound beam to penetrate the test block.

Turn to page 2-28.

You selected the wrong answer. Look at the illustration below. You can see what will happen to the sound beam when it strikes the angled rear surface. You learned in Volume I that the beam will reflect at an angle that is equal to the angle of incidence. Since the rear surface is at an angle of 20° to the incident beam, the reflection will be at an angle of 20° and there will be no reflection returning to the transducer for display on the CRT.

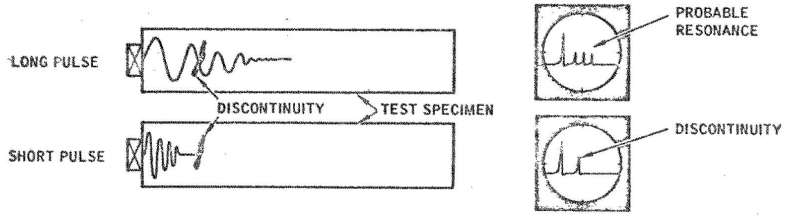


Turn to page 2-31.

That is right. If the rear surface lies at an angle of 20° with relation to the front surface there will be a loss of back reflection since the sound beam will be reflected from the angled surface at an angle of 20° within the test specimen.

You learned in Volume II that with most pulse-echo/through transmission test instruments, you can control the length of the ultrasonic pulse generated by the test instrument. And by adjusting pulse length, you can control the number of cycles of sound energy applied to the transducer.

The illustration below shows how the pulse length will affect the ability of the test instrument to locate discontinuities near the surface.



A long pulse blocks the receiver during the period of transmission of sound and covers up reflections from the discontinuity. The example shown indicates that the reflection may be interpreted as a resonant condition between the front surface and the discontinuity. There is no back reflection since the large discontinuity causes total reflection of the sound energy.

When the pulse length is shortened, less energy is transmitted into the test specimen, and it flows for a shorter interval. Reflected sound energy is not blanked out by the incoming pulse and discontinuity indication appears where none was detectable with the longer pulse.

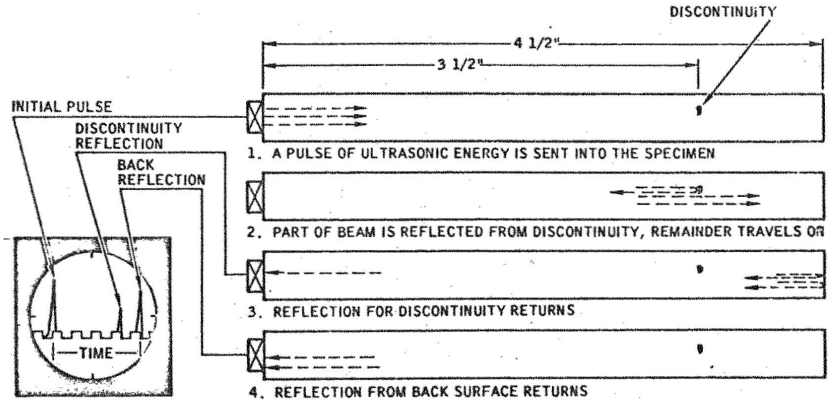
Should the test instrument be adjusted for a long or short pulse when testing a thick specimen with a suspected discontinuity about 10 inches below the surface?

Long Pulse . . . . . Page 2-32
Short Pulse . . . . . Page 2-33

Correct. Any time you are checking for discontinuities that are suspected to lie several inches from the test surface, a longer pulse will give better penetrating power.

Let us now go into the techniques used in transmitting ultrasonic sound beams into a test specimen.

First, what is straight beam testing? As the name implies, the ultrasonic beam is caused to enter the test specimen at a 90° angle to the test surface by placing the transducer in a plane parallel to the test surface. The following illustration shows transmission of a signal into a test specimen, reflection from a discontinuity, and display on an A-scan device.



Are longitudinal or shear waves produced in the test specimen in the above illustration?

Shear waves ..... Page 2-34

Longitudinal waves ..... Page 2-35

Your selection was not the correct one. Testing at a depth of 10 inches can be considered relatively deep and the pulse length should be adjusted to give the best penetrating power at that depth.

A short pulse provides only a few cycles of sound energy transmitted by the transducer. There is less ultrasonic power in this pulse than one where there are more cycles of energy transmitted by the transducer. Therefore, to test at a depth of 10 inches, the test instrument should be adjusted to give a long pulse.

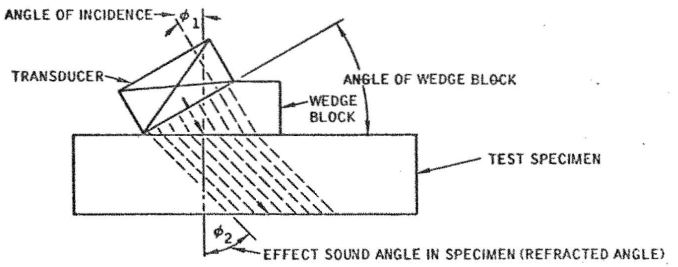
Turn to page 2-32.

It looks like you have forgotten the difference between longitudinal and shear waves. In longitudinal waves, the particle motion is in the direction of sound wave travel. That is the type wave produced in a test specimen when the sound beam is directed at right angles to the test surface. Shear waves are normally produced only by refraction when the sound beam travels at an angle from a medium of one velocity to a medium of a different velocity.

Turn to page 2-35.

Correct. Longitudinal waves only are produced in the test specimen. The beam is being transmitted into the specimen at right angles to the test surface and there is no refraction at the interface to produce shear waves.

In angle beam testing, the sound beam is transmitted into the test specimen at an angle to the test surface. To accomplish this, the transducer is placed behind a wedge of material, usually Lucite, so that the sound will be introduced at an angle. The other edge of the wedge is placed on the test surface as shown below.



The angle of incidence of the sound beam at the surface of the test specimen is determined by the fixed angle of the Lucite wedge. Which of the following characteristics determines the angle of the sound beam in the test specimen?

Acoustic impedance . . . . . Page 2-36

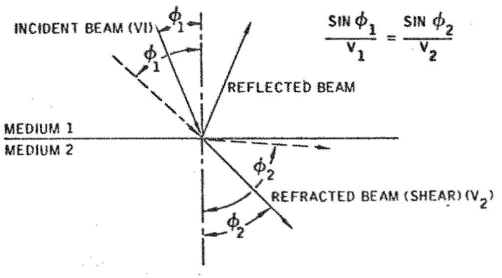
Velocity of sound . . . . . Page 2-37

Your selection is incorrect. "Acoustic impedance" is the product of longitudinal wave velocity in the material and its density. Recall what you learned about velocities in Volume I. The angle of the sound beam in the test specimen is determined by the velocity of sound in that particular material as compared to the velocity of sound in the Lucite wedge.

Turn to page 2-37.

Correct. You remembered the angle of the sound beam in a test specimen is determined by the relationship of the velocity of sound in the test specimen and the velocity of sound in the Lucite wedge - "Snell's Law".

You learned in Volume I that a refracted longitudinal wave and a shear wave component will be produced when the angle of incidence of the entering sound beam is other than 0°, or perpendicular to the surface (normal). As the incident angle increases, refraction of the longitudinal wave increases until there comes a point where total reflection of this wave occurs (refraction exceeds 90°) and all that is left is a shear wave. You'll recall this is the 1st critical angle of incidence (φ_2).



In practice, the effective angle in the test specimen is usually the critical factor. A wedge should be selected that will produce a certain angle based on the velocity of sound in the wedge and the test specimen. There can be either shear or longitudinal waves in the test specimen, so the actual type desired must be known. With the 3 known factors (1) the desired angle in the test specimen, (2) the velocity in the wedge, and (3) velocity in the material, it is easy to calculate the required wedge angle.

Will the amount of refraction in the test specimen be greater or less as the relative velocities in the wedge and test specimen become more nearly equal?

Greater . . . . . Page 2-38

Less . . . . . Page 2-39

Your answer is not correct. The relationships stated in Snell's Law apply in this case. If you rearrange the basic formula you find that the sine of the angle of refraction is equal to the velocity of sound in the second medium (test specimen) times the sine of the angle of incidence (wedge angle) divided by the velocity of sound in the wedge as follows:

$$\sin \varphi_2 = \frac{V_2 \sin \varphi_1}{V_1}$$

This relationship indicates that the nearer the velocities are to the same value, the more nearly the sines of the 2 angles will be equal. Thus, the angle of refraction in the test specimen will be less. On the other hand, if there is a wide difference between the velocities in the 2 mediums, the angle of refraction will be greater.

Turn to page 2-39.

That's right. The angle of refraction becomes less as the relative velocities of sound in the wedge and test specimen become more nearly equal. This is shown by rearrangement of the basic Snell's Law formula as follows:

$$\sin \varphi_2 = \frac{V_2 \sin \varphi_1}{V_1}$$

The angle of refraction is directly proportional to the ratio of velocity of sound in the test specimen to the velocity in the wedge. As this ratio approaches 1, the sines of the 2 angles, and therefore the size of the angles, become more nearly equal.

The following table shows the velocity of sound and resultant wavelength of longitudinal waves in some of the more common materials.

MATERIAL	VELOCITY	WAVELENGTH AT FREQUENCIES INDICATED		
	INS PER SEC	1 MC	2-1/4 MC	5 MC
ALUMINUM	245,000	0.245 IN.	0.109 IN.	0.049 IN.
STEEL	229,000	.229	.102	.046
NICKEL	219,000	.219	.097	.044
MAGNESIUM	210,000	.210	.093	.042
COPPER	182,000	.182	.081	.036
BRASS	174,000	.174	.077	.035
LEAD	84,000	.084	.037	.017
GLASS	205,000	.205	.091	.041
LUCITE	105,000	.105	.047	.021
WATER	57,000	.057	.025	.011
AIR	13,900	.014	.006	.003

Using the above table and your knowledge of Snell's Law, determine which test specimen will provide the greatest angle of refraction, aluminum or copper, assuming a constant Lucite wedge angle of 30°.

Copper . . . . . Page 2-40

Aluminum . . . . . Page 2-41

Did you guess on this one? You either guessed or failed to substitute the proper values in the equation. We aren't interested in the size of the angle of refraction, therefore you do not need to refer to a trigonometry table. All that is needed here is to refer to the table and obtain the constants that will give the ratio of sound velocity in the two mediums.

The sound velocity in Lucite is 105,000 inches per second which remains constant. The velocity of sound in copper is 182,000 inches per second, and in aluminum 245,000 inches per second. The ratio of V_2 to V_1 in copper is 1.73 and in aluminum is 2.33. This indicates that the sine of the angle of refraction is greater for aluminum than for copper, since this is determined by multiplying the ratio of velocities by the sine of the angle of incidence, given as 30°.

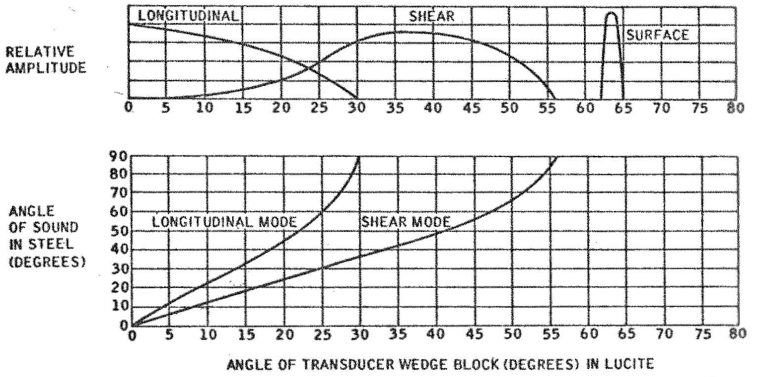
In the question you were to determine which of the 2 specimens would provide the greater angle of refraction. From the above analysis, you can see that the greater angle will be provided by the aluminum specimen.

Turn to page 2-41.

Excellent. You will have the largest angle of refraction in aluminim, since the velocity of sound is greater in aluminum than copper, which gives a larger ratio when the values are applied to the formula for Snell's Law.

Longitudinal waves will ordinarily be produced in the wedge, but it is possible to have either longitudinal or shear waves in the test specimen. Both may be present at the same time, depending upon the angle of the wedge.

The following chart shows the relative effective angle for both longitudinal and shear waves in a steel specimen for given wedge angles in Lucite. It also shows that the 2 modes will exist in different amplitudes depending on the wedge angle and other factors.



When choosing a wedge, it is desirable to avoid angles that produce both longitudinal and shear waves at the same time and at similar intensities. Imagine the difficulty in trying to interpret indications that would appear on the CRT screen when 2 waves are traveling through the test specimen at different velocities and at different angles. The problem of trying to determine which wave is providing a reflection from a particular discontinuity would be almost impossible to solve. Let us look at a practical example of the problems you might encounter.

Turn to page 2-42.

Assume that you want a 45° angle in the test specimen (steel) and have decided that a 45° longitudinal wave is to be generated. Reference to the chart (page 2-41) shows that if you read up the left to 45° and across to the longitudinal mode curve you find that a wedge angle of 20° is required. Note also in reading up from the 20° mark on the lower edge of the chart that a shear wave exists at the same time at an angle of about 25° from the normal. The upper part of the chart shows that the intensity of the shear wave will be approximately 40% that of the longitudinal wave. This will not provide satisfactory results since you receive reflections from both wave modes.

For a 45° angle in the test specimen it will be more satisfactory to select a wedge angle of 36° and produce a 45° shear wave. At this wedge angle there will be no longitudinal wave as shown by the chart.

For practical purposes, if the angle in the test specimen is to be less than about 40°, you will use longitudinal waves since the shear waves will be weak and create no problems. If the angle in the test specimen is to be greater than 45°, shear waves should be used. As stated above, at these angles the longitudinal mode is not present and there is no confusion.

Assume you have a Lucite wedge with an angle of 45°. Referring to the chart on page 2-41, what will be the angle of the shear wave in the test specimen?

57° . . . . . Page 2-43

63° . . . . . Page 2-44

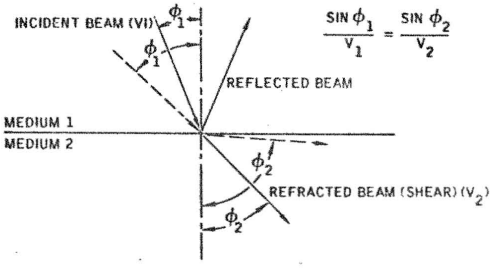
Very good. By reading the chart you very readily can determine that a 45° wedge angle will produce a 57° angle in the shear mode in a steel test specimen.

Typical applications of shear waves in ultrasonic testing are . . .

- Inspection of welds.
- Inspection of plate.
- Inspection of pipe and tubing.

Now, let's see what happens as the wedge angle is increased further beyond the first critical angle.

The angular relationships of the incident and refracted beams is shown in the following illustration:



You'll recall from Volume I that as the wedge angle is increased further to the point that φ_2 (shear wave) is equal to 90°, we have what is known as the second critical angle and no shear wave energy enters the test specimen. A component of sound energy still exists parallel to the interface however and this component of energy is known as "surface waves", also known as "Rayleigh waves".

Refer back to the illustration on page 2-41. Which of the following wedge angles will produce surface waves of the greatest amplitude in steel?

63° . . . . . Page 2-45

65° . . . . . Page 2-46

From page 2-42

Your selection is incorrect which indicates you did not read the chart correctly. Refer again to the chart on page 2-41. Read across the bottom of the lower chart to where a 45° wedge angle is indicated as stated in the question. Now read up until you come to the shear mode curve. Read across to the vertical line at the left where the angles in the test specimen are indicated. This is shown to be between 50° and 60°, or very nearly 57°, rather than 63° as you selected.

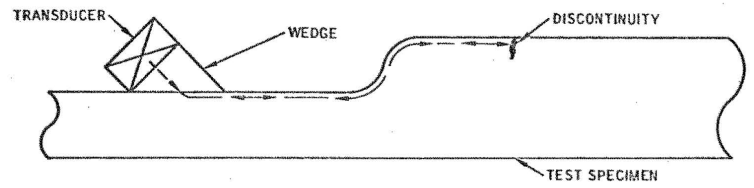
Turn to page 2-43.

From page 2-43

Very good. A wedge angle of 63° will produce surface waves of greater amplitude in steel than will a wedge angle of 65°.

A surface wave penetrates the test surface to a depth of only about one wavelength and is therefore only adaptable for detection of surface or near-surface discontinuities. Since the wave travels on the surface it will be damped by a liquid so it is only adaptable for contact testing.

A unique feature of surface waves is that they will follow the contour of a test specimen around radii, fillets, and other irregular features provided the contours are large in comparison to the wavelength of the sound wave, as shown in the following illustration.



Typical applications for the use of surface waves are . . .

- Inspection of surfaces of test specimens for cracks caused by fatigue, heat treating, etc.
- Detection of tool marks or other stress risers not visible to the eye.

Suppose you are testing a specimen with a test surface having a sharp 90° angle. What effect will the angle have on the surface wave?

No effect. . . . . Page 2-47

Reflection of sound wave . . . . . Page 2-48

It looks as if you guessed on this one. Reference to the chart indicates the amplitude of surface waves is greater at wedge angles between 63° and 64°. In this case your selection should have been 63° for a practical value.

Look at the chart again to see the relationship of the point where the shear mode ceases to exist and the surface wave mode is effective with relation to the angle of the wedge.

Turn to page 2-45.

Your answer is not correct. A surface wave will go around a contour that is long with respect to one wavelength, but a sharp 90° angle is too short with respect to a wavelength. The result will be reflection of the sound wave. The thing to keep in mind is it's the radius around a turn that makes the difference between a wave following a contour or being reflected. Unless the ultrasonic operator correctly interprets the reasons for a reflection, it may be incorrectly assumed that the indication of the CRT shows a crack on the test surface, or immediately beneath the surface.

Turn to page 2-48.

From page 2-45

That's right. A sharp 90° angle on a test surface will cause reflection of a surface wave since this angle will be short with respect to one wavelength of the sound energy.

When the material to be tested is very thin, one surface wavelength or less, a special type of wave mode can exist in the sheet. You'll recall this is a "plate wave" or "Lamb wave" and is produced by angular incidence of the sound beam and mode conversion at the interface.

Plate waves do not have a single velocity in one material as with the other wave modes. There is a whole family of plate waves, any one of which, or combinations, may exist depending on the 5 factors of (1) frequency, (2) thickness of the sheet, (3) sound velocity in the wedge, (4) incident angle of the wedge, and (5) type of material. The relationship of these factors is shown in the following illustration. It can be seen that by changing one or more of these factors, it is possible to produce conditions where plate waves of various velocities will, or will not, propagate.

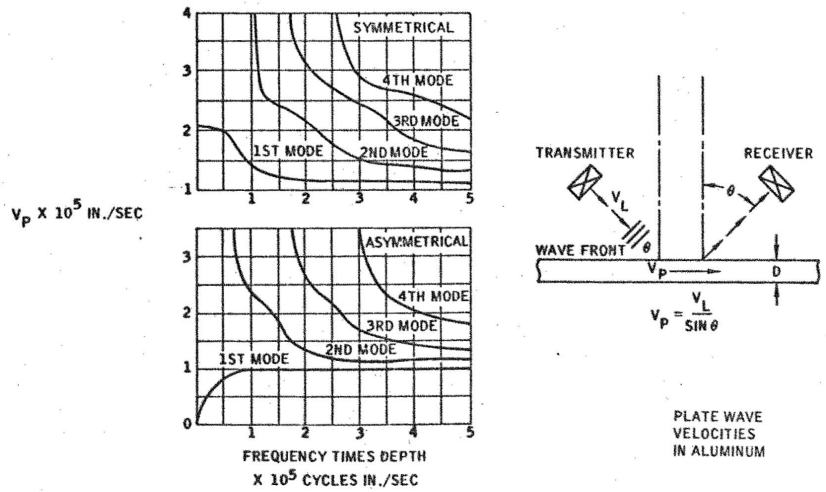


PLATE WAVE VELOCITIES IN ALUMINUM

Turn to page 2-49.

From page 2-48

The same general rules that are used for other wave modes are used in interpretation of reflections when using plate waves. Sound is transmitted into the test specimen by a transducer and is reflected by a discontinuity or corner of the specimen. The reflection appears on the CRT in the normal manner.

The choice of a particular plate wave is not critical. The main problem is to cause sound energy to propagate through the specimen and reflect back from a discontinuity. In many practical cases, a transducer that is designed to produce shear or surface waves in a larger or heavier test specimen will produce plate waves in relatively thin materials.

Plate waves are extremely useful in detecting laminations in thin materials. The lamination appears as a change in thickness to the wave and a portion will be reflected back for display on the CRT. Another application is detecting lack of bond in thin laminar constructions, such as multiple sheets that are cemented or brazed together.

Is the following statement true or false? The propagation of plate (Lamb) waves is not dependent on the material properties of the test specimen.

True . . . . . Page 2-50

False . . . . . Page 2-51

You seem to have forgotten the factors that determine the existence of plate waves. Plate waves are dependent on 5 factors: (1) frequency, (2) thickness of test specimen, (3) velocity of sound in the wedge, (4) incident angle of the wedge, and (5) type of material. Now you can see from a review of these factors that material properties of the test specimen <u>are</u> one of the determining factors in the generation of plate waves.

Turn to page 2-51.

Correct. The propagation of plate (Lamb) waves is dependent on the material properties of the test specimen among other factors. These include frequency, thickness of the specimen, angle of incidence of the wedge, and sound velocity in the wedge.

Let us now consider the use of 2 transducers in contact testing. Throughout these first chapters there have been references to the use of 2 transducers, principally in the discussions of through transmission testing. Although not extensively used in practical testing applications, there are certain applications where 2 transducers will provide more satisfactory test results in <u>pulse-echo</u> testing.

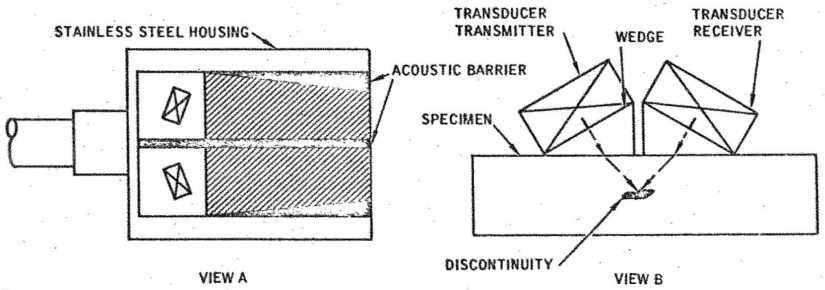
You learned that the through transmission system operates on the principle of transmitting sound waves through a test specimen with one transducer and receiving on a second transducer, a discontinuity being indicated by a reduction in the magnitude of sound energy available at the receiving transducer. In 2-transducer pulse-echo testing, sound waves are transmitted by a transmitting transducer and discontinuity <u>reflections</u> are picked up at a receiving transducer.

Turn to page 2-52.

From page 3-51

Transducer combinations in 2-transducer testing systems may be classified into 2 groups as follows:

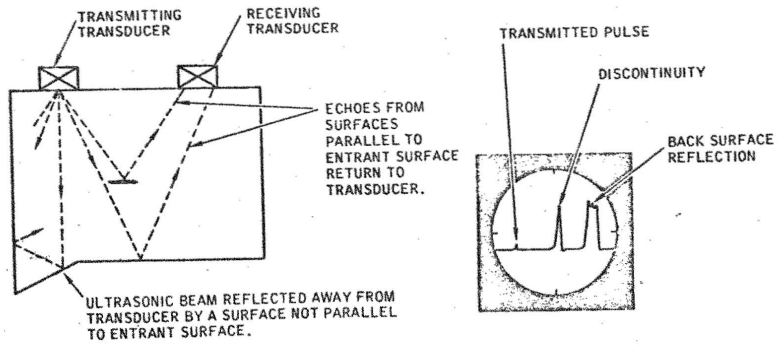
- Combined transmit-receive search units with 2 transducers mounted in a single housing and acoustically insulated from each other. Each transducer is connected separately to the transmitter and receiver-amplifier units. This combination is illustrated in View A below.
- Separate transmitting and receiving transducers with separate electrical connections to the transmitter and receiver-amplifier units. This principle is illustrated in View B.



Turn to page 2-53.

From page 2-52

The principle of 2-transducer pulse-echo testing is illustrated below with a typical view of the indication received on the CRT screen. Note that there is no large pulse corresponding to the front surface of the test specimen such as is obtained when using one transducer. This is the most important difference between single- and 2-transducer pulse-echo systems. A single transducer used for both transmitting and receiving cannot detect discontinuities until its function as a transmitter is complete, which results in a zone near the surface the instrument cannot "see". A 2-transducer system can detect discontinuities before the transmission of the pulse is complete since there is no direct linkage between the transmitting transducer and amplifier in the test instrument. Also the amplifier is not saturated by the transmitted pulse as in single-transducer systems.



Would you say that a 2-transducer pulse-echo system is more sensitive to the detection of more discontinuities than a single-transducer system?

Yes . . . . . Page 2-54

No . . . . . Page 2-55

From page 2-53

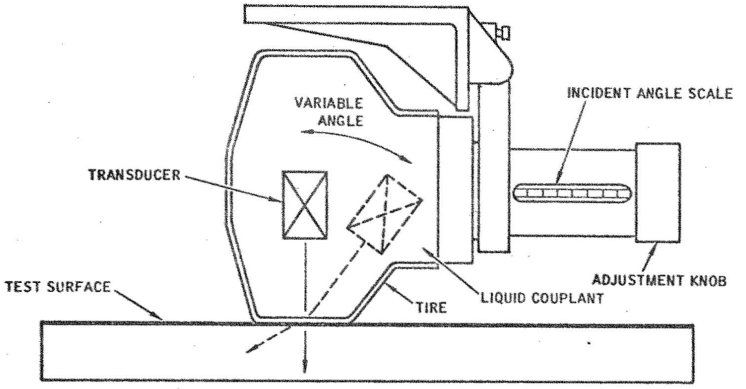
You're not correct. A 2-transducer pulse-echo system is more sensitive to the detection of discontinuities close to the surface of the test specimen only. For all practical purposes, sensitivity is the same for both single- and 2-transducer pulse-echo testing in that portion of the test specimen between the areas normally occupied by the front and back surface reflections.

Turn to page 2-55.

From page 2-53

That's right. A 2-transducer pulse-echo system is not more sensitive to the detection of all discontinuities. It is more sensitive only in detecting discontinuities very near to the surface. Sensitivity is about the same in the area of the specimen between the normal location of the front and back surface reflections.

A special adaptation of contact testing is the transducer wheel of which a "variable angle" version is shown below.

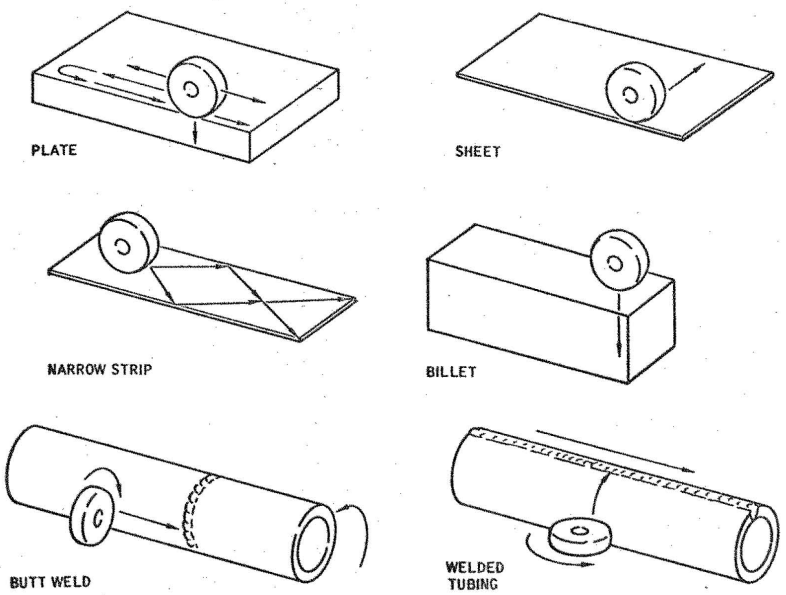


You'll recall that transducer wheels were discussed in Volume II. In this test method the sound is propagated through a liquid couplant while within the confines of the wheel and, after entry into the test specimen, acts the same as waves produced in conventional contact testing. The transducer wheel is the only version of contact testing that can be adapted to automatic scanning and recording. And it is especially good for high speed testing of welded steel tubing, steel sheet, and testing large contoured surfaces.

Turn to page 2-56.

From page 2-55

Some of the possible applications of transducer wheels are shown below.



Is the following statement true or false? The transducer wheel can be used to produce sound waves in any of the modes of propagation.

True ..... Page 2-57

False ..... Page 2-58

From page 2-56

Right. The statement is <u>true.</u> The transducer wheel can be used to produce sound waves in any of the modes of propagation. This is done simply by varying the transducer incidence angle inside the tire and changing the test frequency when required.

Before proceeding to the application of contact testing to the various materials and processes that may be inspected, let's first review the more important points you have learned in this chapter.

Turn to page 2-59.

From page 2-56

Your answer is incorrect. By turning to this page you have indicated you do not think the transducer wheel can be used to produce longitudinal, shear, surface, and plate waves.

Take another look at the variable angle transducer wheel shown on page 2-55. It shows that the transducer angle of incidence can be readily changed. By positioning the transducer normal to the test surface, longitudinal waves can be produced. If we angulate the transducer with reference to the test surface, shear and surface waves can be produced depending on the angle of incidence. And by varying the frequency in addition to angulating the transducer, we can create plate waves. Therefore, the statement is true that the transducer wheel can be used to produce sound waves in any of the modes of propagation.

Turn to page 2-57.

From page 2-57

1. The selection of ultrasonic test equipment for contact testing depends largely on the test sit_____ and test doc_____.

5. heavy

6. A rough test surface will cause the sound beam to s_____ when testing is attempted at a high frequency.

10. angle beam

11. The ability of an ultrasonic testing system to detect discontinuities close to the test surface depends on pulse length and frequency, among other factors. A combination of _____ pulse length and _____ frequency will give the best "near surface" discontinuity detection.

15. velocity

16. Both shear and longitudinal wave components are present to a significant degree when using certain angles for angle beam testing. For practical applications, the _____ wave should be eliminated.

1. situation, documentation

2. The greatest disadvantage of contact testing is the difficulty in maintaining uniform acoustical _____ between the transducer and test specimen.

6. scatter

7. At a given ultrasonic test frequency, a _____ transducer will produce the least beam spread.

11. short, high

12. A test is to be made on a vertical surface. With a choice to be made between oil and water with a wetting agent as couplant, _____ is the best selection.

16. longitudinal

17. When the angle of refraction of the shear waves is equal to 90 degrees, surface waves are produced. A unique feature of surface waves is that they will follow the contour of a test specimen provided its contour is large in comparison to the _____ of the wave.

2. coupling

3. The substance that must be placed between the transducer and test surface during contact testing is called a _____.

7. large

8. Assume a test is being made on a 10-foot long specimen. Transducers are available in 1/2- and 1-inch diameters. The _____ transducer would be selected to give the best penetrating power at the test frequency of 2.25 mc.

12. oil

13. Any mode of wave propagation can be produced when using a t_____ w_____ or a variable angle _____.

17. wavelength

18. Plate (Lamb) waves, which can be produced in very _____ materials, are extremely useful in detecting l_____ and _____ of bond.

3. couplant

4. A test specimen with a coarse-grained internal structure will require selection of a _____ frequency for testing.

8. 1-inch

9. Pulse length in ultrasonic test instruments is variable. When a test is to be conducted on a thick specimen, a _____ pulse will give the best results.

13. transducer wheel, transducer

14. In straight beam testing, the wave mode is l_____.

18. thin, laminations, lack

19. Contact testing can be accomplished using either one or two transducers. To detect discontinuities close to the surface of the test specimen, a _____-transducer setup is the best.

4. low

5. When testing a specimen with a rough surface, a _____(heavy) (light) oil should be used as a couplant.

Return to page 2-59, frame 6.

9. long

10. Plastic wedge transducers are used in _____ _____ testing.

Return to page 2-59, frame 11.

14. longitudinal

15. In angle beam testing, the angle of incidence at the surface of the test specimen is determined by the angle of the Lucite wedge. The v_____ of sound in the test specimen is another factor that helps to determine the angle that the sound will travel in the specimen.

Return to page 2-59, frame 16.

19. two

20. Turn to page 3-1 for a continuation of your study of contact testing.

Let us now consider the application of contact testing to materials of varying shapes, sizes, composition, and internal structure. The first application will be the testing of castings.

The lower range of test frequencies is generally used to test castings due to the coarse-grained internal structure. Many of the very coarse-grained castings are not practical to test ultrasonically due to extreme scattering of the sound beam by the grain structure. Examples are alloys of brass, stainless steel, titanium, and cast iron.

In most tests, when the back surface echo is visible, there will be several heavily damped stray echoes immediately following the front surface echo that are due to the internal structure.

If you have a choice of a 1.0- and 2.25-megacycle transducer for testing a casting, which would be the most practical to select?

2.25 mc ..... Page 3-2

1.0 mc ..... Page 3-3

From page 3-1

The selection of 2.25 mc in preference to 1.0 mc for testing a casting is not the best of the 2 choices available. The large grain structure inherent in most castings dictates that the lowest frequency be used to reduce disturbing echoes from the coarse grains. A frequency of 1.0 mc will provide better penetrating power and better evaluation of actual discontinuities than if a higher frequency is selected.

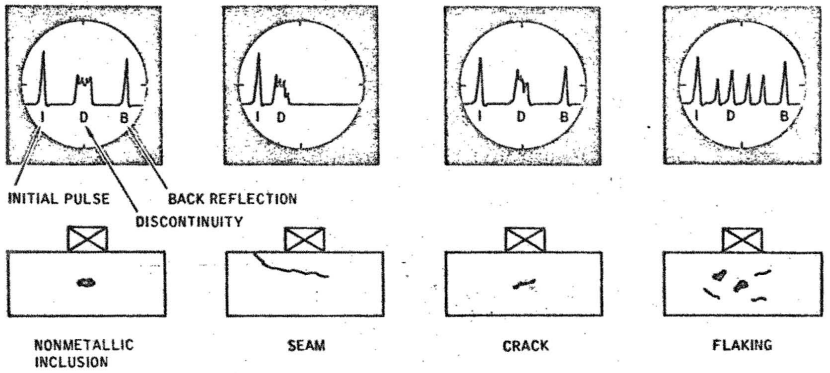
Turn to page 3-3.

From page 3-1

That is correct. The best results will be obtained if a 1.0 mc transducer is used to test a casting in comparison to those that would be obtained from using a 2.25 mc transducer.

Most forgings of uniform size and shape are good objects for ultrasonic testing. This applies to most of the metals and alloys. Testing of forgings is normally accomplished at frequencies of 1.0 to 5.0 mc with the sound beam normal to the surface and at 90° to the direction of maximum working. Discontinuities are usually flattened out and parallel to the test surface, thus presenting the best orientation for reflecting the sound beam.

Discontinuities that may be detected in forgings are nonmetallic inclusions, seams, forging bursts, cracks, and flaking. Typical indications are illustrated below.



In which direction should the inspection be made in order that you will be most likely to detect discontinuities in a forging?

Parallel to direction of metal flow during working . . . . . Page 3-4

Transverse (at right angle) to direction of metal flow during working . . . . Page 3-5

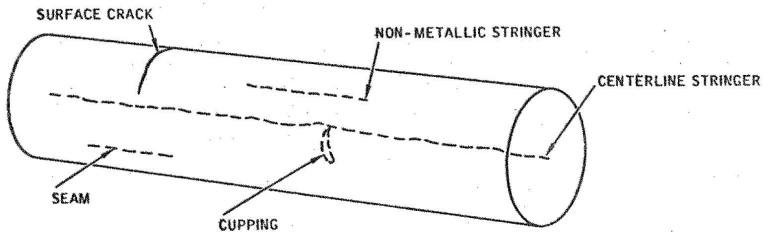
From page 3-3

Incorrect. If the beam is transmitted into the specimen in the direction of metal flow during working you won't be able to obtain many reflections from discontinuities since the discontinuities are most likely to be oriented in the direction of metal flow during working. It would be much better to test the specimen at right angles to the direction of metal flow during working.

Turn to page 3-5.

Correct. You will be most likely to detect discontinuities in a forging if the inspection is made at right angles to the direction of metal flow during working. Working will orient discontinuities in this direction in the same manner that the grain of the metal is oriented in this direction.

The problems of testing bar stock are similar to those encountered in tests of forgings. If an ingot, similar to the forging previously discussed, is rolled or stretched into a long configuration, round, square, or octagonal, it is now classed as bar stock. Shrinkage, inclusions, or porosity are now changed into seams, laps, centerline piping, or some other form of elongated defect as shown in the following illustration.



A bar may be tested from the end so the sound beam is transmitted through its length. If access to both ends is possible, it should be tested from both ends. This will allow use of lower gain settings on the test instrument and use of markers will enable accurate determination of location of discontinuities. If a good back reflection can be obtained by sending the sound beam through the entire length with no significant discontinuity indications, the bar can be considered free of gross discontinuities. There is not likely to be seriously elongated piping or seams present in the specimen if a strong back reflection is obtained.

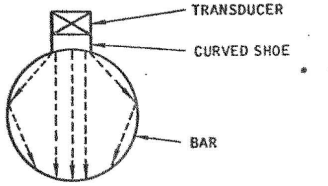
Will an end-to-end test of a 10-foot bar that results in a large back reflection and no large discontinuity indications mean the bar has no discontinuities?

No ..... Page 3-6
Yes ..... Page 3-7

That's right. An end-to-end test that results in a large back reflection with no large discontinuity indications does not mean the bar is completely free of discontinuities. There may be discontinuities oriented parallel to the length of the bar that are not detected by this method. Whether or not additional testing is required will depend on the requirements of the test.

Further testing of bar stock can be made by the diametrical method. In this method the transducer is applied to the side of the bar so that the sound is transmitted through and reflected by the opposite side. Depending on the diameter of the bar, this method may not be very efficient in transmitting sound into the bar due to the lack of sufficient contact surface between the transducer and entry surface. The coupling of sound from the transducer to the entry surface of the bar may be improved by using a curved shoe that is contoured to the radius of the bar as shown below.

A compromise when complete diametrical testing is not practical is to scan the bar diametrically from 2 or 4 sides, approximately 90° apart, around the diameter along the length of the bar. Any elongated piping, seams, or elongated porosity can be easily located using this method.



The idealized illustration above shows the sound beam entering the bar as longitudinal waves. Under actual test conditions, what wave modes will be present in the bar?

Longitudinal waves ..... Page 3-8
Longitudinal and shear waves ..... Page 3-9

Your analysis in this case is not correct. End testing resulting in a strong back reflection and no large discontinuity indications will indicate merely that there are no large discontinuities. There may be small discontinuities, oriented parallel to the direction the sound beam, that are not detected. Depending upon the test requirements and the ultimate use of the specimen, the discontinuities that cannot be detected by end testing may be sufficiently large to cause rejection of the specimen if the test is made transverse to the length of the bar.

Turn to page 3-6.

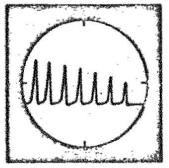
Don't be fooled by the illustration which shows most of the sound entering straight into the specimen. Actually the curved surface of the bar will create a varying angle of incidence across the width of the sound beam that will cause refraction to varying degrees. The refracted beams will have both longitudinal and shear components. This should have been your selection of a correct answer.

Turn to page 3-9.

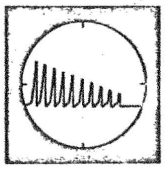
Excellent. You correctly determined that the curved surface of the bar will cause varying angles of incidence across the width of the sound beam, resulting in refraction within the specimen and production of both longitudinal and shear waves.

Rolled sheet and plate materials may be tested with either a straight beam or angle beam. Straight beam testing has the advantages of being able to pick up signals from laminations readily, discontinuities can be pinpointed quickly and accurately, and outlines or limits of discontinuities can be easily and accurately determined. Straight beam testing, however, cannot be used on a sheet that is too thin to allow the first back reflection to clear the initial pulse. Another disadvantage is that straight beam testing is very time consuming if 100% testing is required.

When the plate is sufficiently thick that the first back reflection is distinct from the initial pulse on the CRT, a multiple reflection pattern as shown in View A, below, is displayed on the CRT. A reduction in the multiple reflection pattern as shown in View B indicates the presence of discontinuities. View A assumes a plate with no discontinuities and the distance between each pulse is the sheet thickness. Note that in View B the horizontal distance between pulses is less than in View A due to reflection from a lamination.



VIEW A



VIEW B

If a 100% test is to be made of a sheet of steel 5' x 5', would it be more practical to select a straight or angle beam technique?

Straight beam . . . . . Page 3-10

Angle beam . . . . . Page 3-11

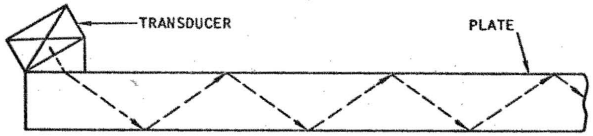
It will be possible to complete a 100% testing of a sheet of steel of the dimensions given using a straight beam technique but it won't be very practical due to the large amount of time required. Consider the number of different test points that would be required to get the job done. Wouldn't it be better to use a technique that will allow a much larger area to be tested at one time? Of course; the answer is to use an angle beam technique.

Turn to page 3-11.

From page 3-9

Correct. An angle beam technique is the only way to go if you want to get the job done in a reasonable time and with best results.

The advantage of angle beam testing is that it is a very fast method of inspecting plate material. It is sometimes possible to inspect an entire plate in a few minutes by angling the sound across to the opposite side of the plate from one edge as shown in the following illustration. Most types of discontinuities that will be found in plates can be located in this manner. Little trouble should be experienced in locating or detecting rough laminations, laps, flaking, and inclusions.



A disadvantage of angle beam testing with shear wave techniques is that smooth laminations parallel to the surface are difficult to detect. As the sound wave bounces across the plate between the top and bottom, it is difficult to detect the difference between a signal from the top of the plate and a lamination near the top.

Should an ultrasonic test of a plate by angle beam techniques be attempted with no knowledge of the general acceptability of the plate, or should some method of gross checking for discontinuities be accomplished first?

Angle beam test . . . . . Page 3-12

Gross check . . . . . Page 3-13

From page 3-11

Your answer is not the best selection. Before going to the trouble of setting up and scanning the plate by angle beam techniques it would be best to do a gross check to determine if the plate has large discontinuities that are sufficient to cause immediate rejection of the plate. If a large number of sheets are to be tested, considerable time can be saved by using this method.

Turn to page 3-13.

You're right. Why waste time setting up and scanning a plate with an angle beam if the plate contains large discontinuities that make it obviously unacceptable. Gross discontinuities can be detected rapidly by a sampling of straight beam tests. If these tests are satisfactory, then the operator can proceed with the angle beam test.

In setting up an angle beam test, let's assume that a plate 5' x 5' x 1/2" is to be tested. The plate should first be divided into a vertical and horizontal grid with approximately 6" between grid lines. (It is not necessary to actually draw grid lines on the plate - imaginary grid lines are sufficient). The plate should be spot checked in each of the grid squares with a straight beam transducer. This type of random sampling will give the operator an idea of the amount of laminations present in the plate. If any are found, more detailed examination of the outline of the defective areas can be made at the time. If the grid check doesn't show any gross laminations in the plate, the angle beam transducer can then be used for a more thorough scanning of the entire plate area.

How are discontinuities in a rolled plate likely to be oriented?

Parallel to surface . . . . . Page 3-14

At an angle to the surface . . . . . Page 3-16

That's correct. Discontinuities in a rolled plate are more likely to be oriented parallel to the surface rather than at an angle to the surface. This is due to working the metal which orients the grain structure and discontinuities in the direction of rolling.

Before using an angle beam transducer for inspection of the plate, it is necessary to set up a reference notch so that the amplitude of the reflected sound from a known size discontinuity will be known. Unless otherwise specified the notch should be either 3% of the plate thickness, or 0.005" deep. Locate and use the notch as follows:

1. Place the notch approximately 12" from one end of the test plate so that back reflections from the edge of the plate will not interfere with interpretation of signals from the reference notch.
2. Using a suitable couplant, place the transducer approximately 4" from the notch and adjust the gain of the instrument so that the signal from the notch is full scale on the CRT screen.
3. Move the transducer back about 8" from the notch and note the amplitude of the signal on the CRT. Mark the height with a grease pencil for future reference.
4. Repeat this operation at 1 ft., 2 ft. and 4 ft. from the notch. Reference marks on the CRT indicate the amplitude of the reflected signal that may be expected from the manufactured notch at any of several different distances from the notch.

Assume you are testing a plate in accordance with an ultrasonic acceptance standard Would you normally expect to find the dimensions of the reference notch to be used for comparison with discontinuities in the plate prescribed by the standard?

No . . . . . Page 3-15

Yes . . . . . Page 3-17

From page 3-14

The ultrasonic test operator is expected to be capable of locating discontinuities in a test specimen, compare them with a certain prescribed standard, and, from this comparison, make a determination if the specimen should or should not be rejected.

The use to which a specimen is to be put will, in most cases, determine the size and number of discontinuities that can be tolerated. The size of the reference notch and distribution of discontinuities that are acceptable should be available to the operator in the acceptance standard.

Turn to page 3-17.

From page 3-13

Your selection was not correct. Discontinuities are most likely to be oriented parallel to the surface in a rolled plate.

A billet, as poured, has random grain structure with discontinuities scattered in a random fashion. The rolling process will refine the grain structure and align the grain in the direction of rolling. Discontinuities will likewise be aligned in the direction of rolling which will make them parallel to the surface.

Turn to page 3-14.

That is right. You can normally expect that the acceptance standard for testing the plate will specify the dimensions of the reference notch.

Scanning of the plate should be done by moving the transducer along each of the 4 edges of the plate. It may be done under certain conditions from 2 adjacent edges or perhaps only one edge. However, it should normally be done from at least 2 adjacent edges so that any defects present will be scanned by the sound beam from 2 different angles. Since there is a certain amount of "skip distance" in angle beam testing, it is possible for the sound beam to go across the plate and not strike a discontinuity. If the second sound beam approaches the discontinuity at 90° to the direction of the beam from the other edge, the discontinuity is more likely to be detected.

A discontinuity indication that appears during scanning is easy to locate by either using markers on the CRT to measure the distance or by moving the fingers along the plate in front of the transducer toward the discontinuity. Movement of the fingers along the plate will cause a small signal on the CRT that will move in the direction of the discontinuity. When directly over the discontinuity the signal will be damped. Once the distance to the discontinuity is known it is a simple matter to move the transducer to a point equal to one of the distances measured from the reference notch. The amplitude of the signal from the discontinuity can then be compared with the signal from the reference notch.

Discontinuity indications that are equal to or greater than the amplitude of reflections from the reference notch should be marked and, when scanning is complete, these should be further evaluated by testing at different angles. It is possible the signal amplitude may be greater at another angle than that obtained during scanning.

If you receive a stronger signal at one angle than another, does this mean an error was made during scanning?

Yes . . . . . Page 3-18
No . . . . . Page 3-19

Your selection is not correct. When scanning, the sound beam is subject to skipping certain areas of the material as the sound beam bounces between the top and bottom surfaces in traveling across the plate. There are probably some discontinuities that will not be "seen" by the sound beam at all and others that will not be struck by the beam at such an angle that the reflected sound energy reflects the true size of the defect. Testing at various angles will determine whether the indication received during the initial scan correctly detected the extent of the discontinuity. There definitely was no error made in scanning; it is just one of the characteristics of angle beam testing that must be understood.

Turn to page 3-19.

From page 3-17

Right. During initial scanning the sound beam may completely miss some discontinuities and be only partially reflected by others when the sound beam does not strike them at an angle of 90°. It is for the first possibility that scanning should be done from a second edge, and for the second possibility that it is necessary to examine the discontinuity at various angles to determine the extent and seriousness of the discontinuity.

The previous discussion of angle beam testing of plate materials has assumed that discontinuities are located in the interior of the plate at such a depth that they could be detected by the use of shear waves.

Suppose now that you want to determine if there are cracks on the surface or just beneath the surface. You will use the same scanning techniques, and use the reference notch in the same manner as you did for shear waves. But this time you will generate surface waves. And to generate surface waves you need an angle transducer with a wedge angle that lies beyond the second critical angle for generating shear waves in that particular type of specimen.

In surface wave testing it is extremely important that the surface of the test specimen be free of dirt, oil, and any excess couplant. You'll recall from Volume I that any of these foreign elements will cause reflection of surface waves or dampen them, and the test will not be satisfactory.

Assume you have the task of testing a rolled plate for surface defects. How many surfaces should you have access to?

One surface. . . . . Page 3-20

Two surfaces . . . . . Page 3-21

From page 3-19

Have you forgotten the characteristics of surface waves? These travel only on the surface and below the surface to a depth of about one wavelength. This isn't very deep when you consider that one surface wavelength is 0.002" in both steel and aluminum at 5 mc.

It will be necessary to scan <u>both</u> of the surfaces to detect any surface discontinuities. These are just as bad if they occur on the bottom as well as on the top of the plate.

Turn to page 3-21.

From page 3-19

Correct. Of course you have to test both surfaces. Surface waves penetrate only to a depth of about one wavelength. One scan will only tell you if there are any surface discontinuities on that one side. Then, you have to turn it over and test the other side using the same techniques.

There is one more technique that may have to be used under certain conditions when you are testing very thin materials using an angle beam. This is the "plate wave" technique. In materials with a thickness approximately equal to one-half wavelength of the surface wave sound beam, it is not possible to generate shear or surface waves. However, plate waves can be produced in these thin materials if any ultrasonic transmission at all is possible.

It is often difficult to generate plate waves with the fixed angle transducers; therefore, it is desirable to use an angle beam transducer that is variable so it can be adjusted to the point that waves are generated in the test sheet.

To generate plate waves using a variable-angle transducer, you place the transducer on the test specimen with suitable couplant and adjust the incident angle of the sound beam to the point that reflections are observed on the CRT screen. Then you scan the sheet with the transducer set at this angle. Changing the angle of the transducer will result in loss of indications on the CRT indicating that plate waves are no longer being produced.

Suppose you do not have a variable-angle transducer available. You do have several fixed-angle transducers at various frequencies. Do you think it will be possible to generate plate waves in the test plate?

Yes . . . . . Page 3-22

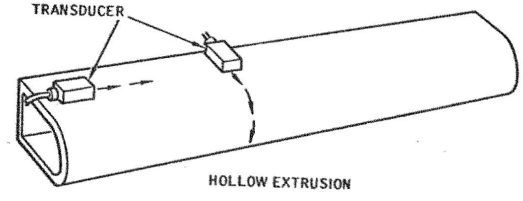
No . . . . . Page 3-24

From page 3-21

Excellent. It is quite possible you will be able to generate plate waves in a sheet even though you do not have a variable-angle transducer available. If you have a variety of fixed-angle transducers at various frequencies available to you, you most likely can find a combination that will result in generation of plate waves by experimentation. If the selection of fixed angles and frequencies is limited, it is unlikely that these waves can be produced.

Discontinuities in extrusions usually extend lengthwise in the specimen because of elongation in the direction of extension. Straight beam techniques and interpretation of discontinuity indications for solid specimens are the same as those given for bar stock.

Where hollow extrusions are to be tested, it may be more practical to use surface wave techniques as illustrated below.



The sample shown is curved. It is possible with such a shape to get complete coverage of the specimen by scanning the length and then scanning transversely. The surface waves will follow the curvature of the specimen and be reflected by the sharp edge on the opposite side. Of course, this technique will only detect surface discontinuities.

Suppose the extrusion shown in the illustration is aluminum and you do not have an angle transudcer that will allow you to produce surface waves in the specimen. You do have available an angle transducer that will allow you to produce shear waves. Can the same scanning techniques be used for shear waves as those shown for surface waves?

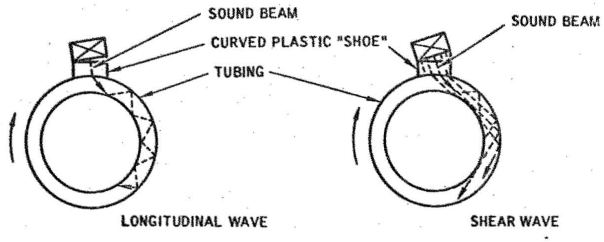
No . . . . . Page 3-23

Yes . . . . . Page 3-25

From page 3-22

Very good. You can't use the same technique for shear wave scanning as used for surface waves since shear waves will not follow the curvature of the test specimen. The specimen can be tested using shear waves but it will be necessary to do additional scanning to obtain ultrasonic coverage of both the upper and lower surfaces of this hollow specimen.

Consider now the techniques to be used in testing pipe and tubing by ultrasonic means. The illustration below shows what happens to a sound beam that strikes the surface at an angle other than perpendicular. The refracted sound beam is transmitted around the wall of the tubular specimen.



Sound propagates around the wall in a zigzag pattern as either longitudinal or shear waves. Due to the undesirability of reflections from the shear component if longitudinal waves are used, most testing on specimens of tubular shape is accomplished with shear waves.

What type of transducer would you select to conduct an ultrasonic test on a section of pipe with an outside diameter of 6"?

Curved shoe, straight beam . . . . . Page 3-26
Curved shoe, angle beam . . . . . Page 3-27

From page 3-21

Your answer is not the best selection. It was stated that you have available a number of fixed-angle transducers at various frequencies. The thickness of the sheet is a fixed quantity as is the velocity of sound in the angle wedge. However, two of the variables that are a determining factor in generation of plate waves can be adjusted. It will be necessary to experiment by selecting different angles and frequencies and observe the CRT for an indication that sound waves are being generated. Your answer should have been "yes" to the test question although in practical applications the range of angles and transducer frequencies available to you may not give the correct combination for generation of plate waves.

Turn to page 3-22.

From page 3-22

Did you consider the behavior of shear waves when you made your selection? Apparently not, since you should recall that shear waves will not travel around a curved surface such as is shown.

In the example shown, you will get reflections from the far edge of the specimen and will only be able to test one surface at a time.

Depending on the thickness of the wall of the specimen, you may be able to test the length of the specimen with shear waves. It will be necessary to test both the upper and lower surfaces of the hollow specimen with shear waves to get complete coverage. The result is twice as much work to do the job with shear waves, compared with the effort required to test with surface waves. Why twice? You will have to test lengthwise twice and crosswise twice, once each on the upper and lower surfaces. For these reasons your answer is wrong.

Turn to page 3-23.

From page 3-23

Your answer isn't the best one. A straight beam transducer will not produce a wave that will travel around the wall of the pipe. Due to the curvature of the test surface, a portion of the sound beam will strike the surface at an angle and some refraction of the beam will result. But, the main portion of the beam will enter the test surface perpendicularly, travel to the opposite wall and be reflected back to the transducer, providing an ultrasonic test of only a small area of the pipe's circumference. It will be more practical to use an angle beam transducer which will cause the sound to enter the specimen at an angle and travel around the tube.

Turn to page 3-27.

Right. An angle beam transducer will project sound into the pipe wall at an angle and the sound beam will travel around the circumference of the pipe in a zigzag manner.

There are certain disadvantages to use of contact testing methods for testing pipe and tubing although this technique may be used to transmit shear waves around the circumference of pipe as small as 1-3/4" outside diameter. There are lower limitations to the diameter of pipe that can be tested by this technique as you will learn later, but no practical limits on largeness.

In addition to the size limitations, there are serious limitations to the speed with which the length of a specimen can be scanned using a curved contact shoe.

If you are selecting a material for constructing a contact shoe for use in testing a pipe, which of the following materials will you select?

Same as pipe ..... Page 3-28
Same as angle wedge ..... Page 3-29

It won't work. Think now what will happen if you try to use a contact shoe that is the same material as the pipe. You will get a false entry surface indication when the sound beam travels from the Lucite angle to the contact shoe.

The sound will undergo refraction when passing into the second medium, even before it enters the wall of the pipe. Results will be anything but satisfactory. You also will receive a reflection from the interface between the contact shoe and pipe surface - not complete reflection due to the presence of a good couplant (supposedly), but with all these spurious reflections, it will be difficult to identify any reflections from discontinuities. Use a Lucite shoe - the same material as the angle wedge and avoid these difficulties.

Turn to page 3-29.

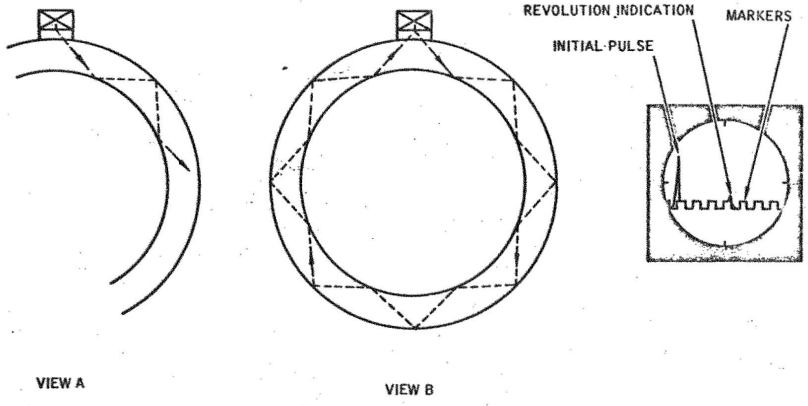
From page 3-27

Correct. The contact shoe should be made of the same material as the angle wedge used to produce the angle beam.

Assume now a practical application of testing a steel pipe 6" in diameter with a 3/4" wall. Use of the contact method utilizing shear wave techniques is assumed with a test frequency of 1.0 mc.

Very little cleaning of the outside surface of the pipe is necessary. The main requirement is that it be free of loose material. Once cleaned, you apply a couplant of SAE 40 oil, or equivalent viscosity.

A 45° angle beam transducer with a Lucite contact shoe, cut to fit the contour of the pipe, is used to propagate shear waves which are directed around the circumference of the pipe as shown in View A, below. The shear waves bounce off the outer and inner surfaces of the pipe wall as they travel around the circumference. The waves travel completely around the pipe and pass under the transducer where they are picked up and displayed on the CRT as shown in View B.

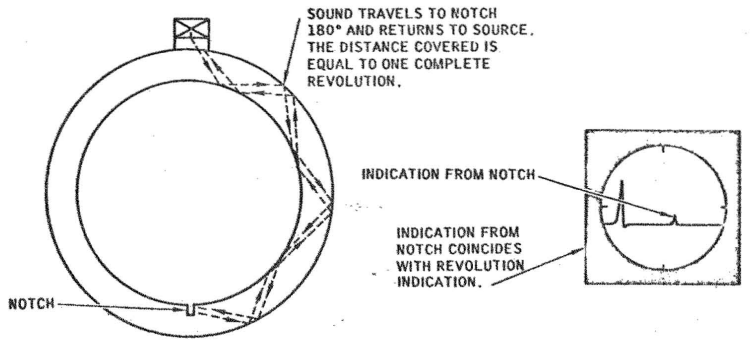


Turn to page 3-30.

From page 3-29

The position of the indication received on the CRT after the sound wave travels around the pipe will remain constant, regardless of movement of the transducer around the outer surface of the pipe. This pip on the CRT represents 360° of sound travel and is called the "revolution indication". For measurement purposes though it is referred to as being 180° rather than 360° around the circumference of the pipe.

Why? This is brought about by the fact that there is no end to the sound path in this circular specimen, therefore no end reflection. Sound continues to travel around the pipe until completely attenuated. Suppose now that a notch is cut in the pipe directly opposite the position of the transducer as shown in the below illustration. The reflection from this notch will coincide with the revolution indication previously displayed since the reflected sound wave is still traveling a total of 360°.



Assume a shear wave is being transmitted into a pipe in a clockwise direction. A discontinuity exists at a point 220° around the circumference from the point of entry of the sound beam. Will this discontinuity indication appear to the left or right of the revolution indication?

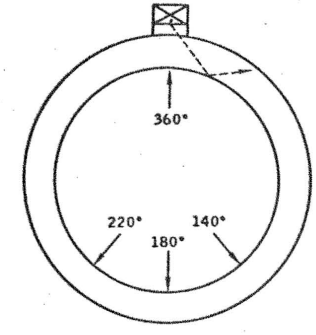
Left . . . . . Page 3-31
Right . . . . . Page 3-32

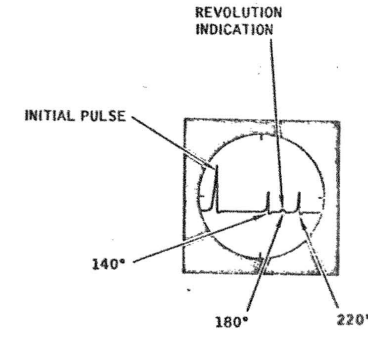
Tilt. You missed on this one. Remember that even though the revolution indication represents 360° of sound travel around the circumference, it also represents the distance the beam travels to a 180° discontinuity and return. Now if a discontinuity exists at 220° with respect to the transducer, the sound will travel 220° to the discontinuity and 220° in returning to the transducer or 440° total. The indication will therefore be to the right of the revolution indication (360°).

Turn to page 3-32.

Excellent. The sound travels 360° around the pipe to produce a revolution indication, but for measurement purposes the revolution indication is considered to be at 180° with respect to the location of the transducer.

Indications from discontinuities that exist less than 180° from the transducer will appear to the left of the revolution indication as shown in the below illustration. Discontinuities that exist more than 180° from the transducer will appear to the right of the revolution indication.





Turn to page 3-33.

From page 3-32

Reference standards for pipe and tubing are not available as a commercial item. Therefore, it is necessary to prepare a standard for comparison with the actual discontinuity. This standard usually consists of reference notches, longitudinally machined into a sample of the test specimen of the same ultrasonic qualities. A notch is placed in both the inside and outside diameters of the pipe or tube. Unless otherwise specified, each notch should be approximately 1-1/2 inches long and a depth that approximates 3 to 5% of the wall thickness.

The transducer is placed on the reference specimen and reflections obtained from each of the artificial discontinuities at 90°, 180°, and 270°. You then mark the amplitude of the indications from the varying distances on the face of the CRT with a grease pencil.

During testing, discontinuity indication amplitude should be compared with the amplitude received from the artificial discontinuities at the indicated distance around the circumference of the specimen.

Is the following statement true or false? The inner and outer reference notches in a sample piece of pipe should be cut at the same location on the circumference of the pipe.

True . . . . . Page 3-34

False . . . . . Page 3-35

From page 3-33

What sort of artificial discontinuity reference indication would you receive under these conditions? How can you determine if your indication is from the inner or outer surface notch? You can't. You're likely to receive an indication that is a combination of the reflections from each of the notches. It is preferable to place one notch at each end of a reference sample. If, for some reason or other it is necessary to place both notches at the same end of a reference sample, separate them by 180°.

Turn to page 3-35.

From page 3-33

That's right. The reference notches on the inner and outer diameters of the reference samples should not be cut at the same location on the circumference of the pipe. They need to be separated so that separate and distinct artificial discontinuity indications can be received for reference purposes. It is preferable that the inner and outer diameter reference notches be placed at opposite ends of a reference sample. If it is necessary that the two notches be placed on the same end of a sample, they should be separated by 180°.

So far in the study of ultrasonic techniques for testing of materials of various types, sizes, structure, and shape we have considered how we may go about testing castings, forgings, rolled sheet and plate, and pipe and tubing. There is a lot of application coming up on finding discontinuities in welds - but first let's have another short review.

Turn to page 3-36.

From page 3-35

1. Given a choice of a 1.0 or 2.25 mc transducer for testing a casting, the most practical selection is the _____ mc transducer.

5. angle

6. Discontinuities in rolled plate are likely to be oriented _____ to the surface.

10. straight

11. An _____ _____ transducer should be selected to conduct an ultrasonic test on a section of 6" pipe.

15. marker

16. Standards are prepared for pipe and tubing by machining reference _____ on the inside and outside diameters of a sample of either the test specimen or other specimen of the same ultrasonic qualities.

1. 1.0

2. Knowledge of probable orientation of discontinuities in test specimens is important to the ultrasonic operator. Discontinuities in forgings are likely to be oriented p_____to the direction of working.

6. parallel

7. When testing plate materials, the discontinuities are sometimes compared with reflections received from a r_____ n_____ of given dimensions called out in the acceptance standard.

11. angle beam

12. For generating surface waves, the ultrasonic operator needs an angle beam transducer with a wedge angle that lies beyond the_____ _____ _____.

16. notches

17. Turn to page 3-41.

2. parallel

3. In testing bar stock from the end, discontinuities can still exist in the bar and not cause reflections if they are oriented_____to the length of the bar.

7. reference notch

8. A plate should be scanned from at least_____adjacent edges to reduce the effect of "skip distance" overlooking some discontinuities.

12. second critical angle

13. With a transducer in a fixed position during ultrasonic testing of a pipe, some discontinuities may be overlooked by the sound beam as it travels around the pipe's circumference due to skip distance. This can be overcome by_____ the pipe from end to end.

3. parallel

4. In a diametrical inspection of bar stock, sound transmission can be improv using a transducer having a c_____ s_____ that fits the radius of the bar.

8. two

9. The best transducer to select for generation of plate waves in a thin plate i one that has a v_____ angle.

13. scanning

14. Assume a shear wave is being transmitted into a pipe in a clockwise direc A discontinuity exists at a point 220 degrees around the circumference fro the point of entry of the sound beam. With respect to the revolution indica on the CRT, the discontinuity will be to the_____.

4. curved shoc

5. With a choice of straight and angle beam transducers, the_____ beam transducer is the quickest for testing a large plate.

Return to page 3-36, frame 6.

9. variable

10. A_____ beam transducer is extremely valuable in pinpointing discontinuities in rolled sheet and plate, and for making gross checks.

Return to page 3-36, frame 11.

14. right

15. During pipe testing, distance from the transducer to a discontinuity can be measured on the CRT by utilizing the_____circuit in the test instrument.

Return to page 3-36, frame 16.

From page 3-37

Let us proceed now to the consideration of contact testing in locating discontinuities in welds.

Welds may contain discontinuities of varying types such as porosity, cracks, lack of fusion, incomplete pentration, and slag inclusions. The acceptable quality of a weld is a function of the total quantity of discontinuties in some linear distance of the weld as well as being a function of the thickness of the material being welded.

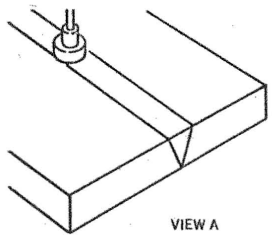
And welds are usually inspected using a test frequency of 1.0, 2.25, or 5 mc depending on the nature of the weld defects anticipated and on the material joined by the welding process.

Turn to page 3-42.

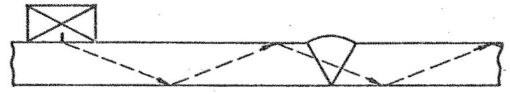
From page 3-41

Welds may be ultrasonically tested by either straight beam or angle beam techniques although the angle beam technique is in much wider use.

Straight beam testing of welds requires that the surface of the weld be ground smooth as shown in View A, below, while the weld bead may extend above the surfaces joined by the weld when angle beam techniques are used as shown in View B.



VIEW A



VIEW B

The couplant used in testing welds may either be oil or water with a wetting agent (detergent). If the surface is flat, water with a wetting agent will be more satisfactory since it will leave the surface cleaner and will not soil the specimen, the equipment, and the operator. Of course if the test surface is not smooth it will be necessary to use a more viscous couplant.

When testing a weld do you think you will receive any reflections from the weld area even if there are no discontinuities present?

No . . . . . Page 3-43

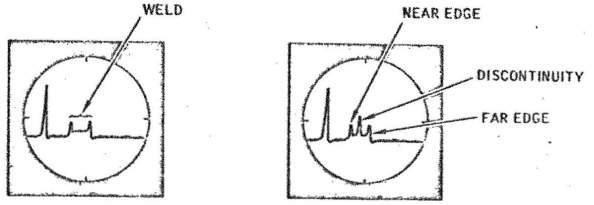
Yes . . . . . Page 3-44

Sorry. You will receive a reflection from the weld area even if there are no discontinuities present. Remember, there is a fusion zone on each side of the weld where it joins the base metal. These will cause a small reflection and the weld itself contains metal with a randomly-oriented grain structure as compared with the grain structure of the material joined together which is oriented in the direction of working. Some typical CRT indications are coming up very shortly.

Turn to page 3-44.

Correct. The fusion zones between the base metal being joined and the weld area will cause small indications due to reflection.

Illustrated below are some typical indications from welds. In View A a satisfactory weld area is shown with the fusion zones clearly indicated. View B shows the same reflections for the fusion zones but in this illustration there is a discontinuity in the center of the weld.

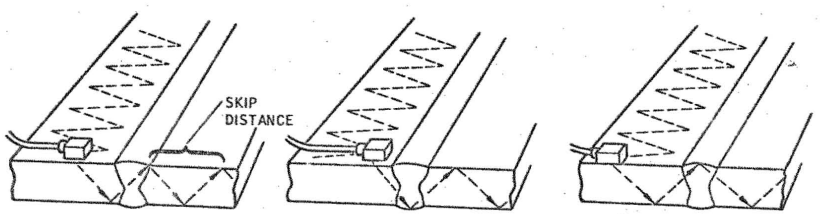


Suppose the indication on the CRT does not show the fusion zones. Which of the following problems do you think exists?

Sound beam does not penetrate weld. . . . . Page 3-45
Excessive porosity absorbs the sound beam . . . . . Page 3-46

That is right. If the indication on the CRT does not show the fusion zones it is an indication that the sound beam has not penetrated the weld. And failure of penetration is not an uncommon occurrence. When it happens, you simply change the frequency and try again or change the position of the transducer.

In order to scan the welded seam over its whole cross section at one particular spot, you move the transducer forward and backward, alternately approaching and moving away from the weld a distance of 1/2 to 1 "skip distance" from the center of the welded seam as shown in View A, below. At 1/2 the "skip distance" the beam axis strikes the center of the welded seam at the bottom, and at 1 "skip distance", the beam will strike the center of the seam at the top as shown in Views B and C.



A reflection will be received from a discontinuity in the weld even when the center of the beam does not strike it. The maximum reflection, however, will be received when the discontinuity is struck by the center of the beam.

False . . . . . Page 3-47

True . . . . . Page 3-48

Your selection is not correct. If you fail to receive indications that show the sound beam has penetrated through the weld, there will be no reflections from the fusion zones.

Excessive porosity would not be the cause since there would be a reflection from the nearest fusion zone and reflections from the center of the weld where the porosity occurs.

Turn to page 3-45.

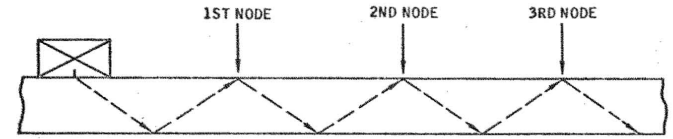
Your selection is not correct. A sound beam is strongest in the center and grows progressively weaker as distance from the center increases. The reflection from a discontinuity will be strongest when the discontinuity is struck by the center of the beam even though a small reflection will occur when it is struck by the weaker portion of the beam.

Turn to page 3-48.

Correct. A sound beam is strongest in the center. Maximum reflection from a discontinuity is received when it is struck by the center of the sound beam.

It is necessary to understand skip distance and the means for finding it to use the proper scanning technique for welds.

The path of a shear wave from an angle transducer showing the nodes of the beam is illustrated below.



The location of the nodes can be determined by rubbing the material by hand or with an oiled brush away from or toward the transducer along the sound path. This will interfere with reflections of sound at the nodes and the indications on the CRT will be dampened at the point of interference so that the point the sound strikes the surface is readily apparent.

Skip distance, or the distance between 2 nodes, can be determined by measuring the distance between 2 adjacent points that show reduced indications on the CRT. When the finger touches a point on the surface between 2 nodes there will be no dampening of the sound wave.

Skip distance is a function of which of the following factors?

Frequency . . . . . Page 3-49
Wedge angle . . . . . Page 3-50

From page 3-48

If you have turned to this page it indicates you think skip distance is a function of the frequency of the sound wave being transmitted into the test specimen.

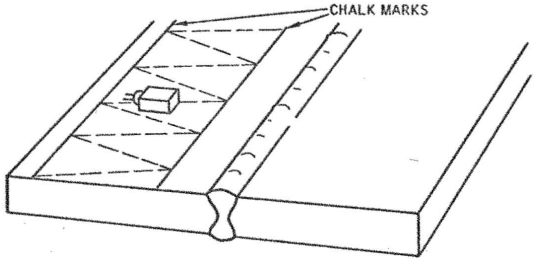
Consider now what determines the angle of sound in a material. Isn't this due to the angle of incidence of the sound beam on the test surface and the ratio of the velocity of sound in the wedge to that in the test specimen? It is! Since frequency isn't a factor in consideration of the angle of refraction from Snell's Law, it is apparent that frequency is not the correct answer. The angle of incidence, as determined by the angle of the Lucite wedge, is the factor that determines skip distance.

Turn to page 3-50.

From page 3-48

That's right. Skip distance is determined by the angle that sound enters the test specimen, which, in turn, is determined by the angle of the Lucite wedge.

Once the skip distance is known, the area over which the transducer is to be moved in scanning the weld can be determined by drawing 2 chalk marks parallel to the weld seam, one at 1/2 the skip distance and one at the whole skip distance from the center of the seam. With the aid of the centerline on the probe, you can then move the transducer in a zigzag path from one chalk mark to the other, progressing along the test specimen to completely scan the weld. Contact between the transducer and test surface must remain uniform throughout the scanning path as spurious indications will be received if good contact is not maintained.



Serious discontinuities in the weld seams, such as cracks and slag streaks usually extend longitudinally along the seam and give particularly clear echoes when the sound beam strikes the joint at right angles.

Will skip distance increase or decrease as thickness of the test specimen is increased, assuming the same wedge is used and the same material properties are maintained?

Decrease . . . . . Page 3-51

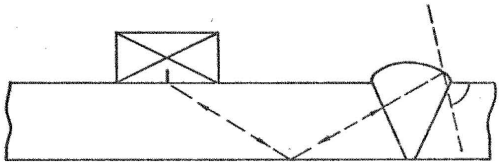
Increase . . . . . Page 3-52

"Skip distance" will not decrease as the thickness of the test specimen is increased. The angle of refraction in the specimen will remain the same and the angles of reflection at the nodes will remain the same, however as the thickness increases the sound must travel further between nodes to the surface. The correct answer is that the skip distance will increase as thickness of the test specimen is increased.

Turn to page 3-52.

Correct. Skip distance will increase as the thickness of the test specimen is increased. The angle of refraction in the test specimen and the angles of reflection within the specimen will remain the same but, as the thickness is increased, the distance between nodes will increase.

Generally, the angle of sound beam incidence selected should be as large as practical when testing welds so that the incidence is as flat as possible. At steep beam angles, small spurious echoes will be returned from the weld bead and these are difficult to distinguish from real discontinuities. Smaller angles, however, must be used on thick sheets to reduce skip distance as too great a skip distance will cause a reduction in the sensitivity of the test instrument.



Judgment must be used in selecting a large angle of incidence for the generation of shear waves. What will happen if the angle selected is so large that the angle of refraction is 90°?

Skip distance too great . . . . . Page 3-53

Surface waves produced. . . . . Page 3-54

Your selection is not the best of the two available. As beam angle is increased, skip distance increases. The question poses the problem that the angle of refraction in the test specimen is 90°. This is the second critical angle and will result in no shear waves being produced in the test specimen. Surface waves will be produced that will flow on the surface of the specimen but these will not penetrate far enough below the surface to locate discontinuities in the weld.

Turn to page 3-54.

Excellent. If the angle of incidence becomes so great that the angle of refraction in the test specimen is 90°, shear waves will no longer be produced; surface waves will result and it is not possible to thoroughly test a weld with surface waves.

The following table provides a comparison of the most favorable beam angle for testing welds in materials of varying thickness with the weld bead ground down flush with the material surface and also with the weld bead not removed.

WELD BEAD GROUND ON BOTH SIDES		
SHEET THICKNESS (INCHES)	BEAM ANGLE (DEGREES)	SKIP DISTANCE (INCHES)
0.2 - 0.6	80	2.2 - 6.6
0.6 - 1.2	70	3.2 - 6.6
1.2 - 2.4	60	4.2 - 8.4
OVER 2.4	45	4.8 AND UP
WELD BEAD NOT REMOVED		
0.2 - 0.8	80	2.2 - 8.8
0.8 - 1.6	70	4.4 - 8.8
OVER 1.6	60	5.6 AND UP

Is the following statement true or false? As sheet thickness is increased, beam angle should be increased.

True . . . . . Page 3-55

False . . . . . Page 3-56

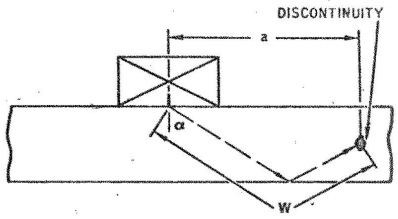
The statement on the preceding page is "false". As the thickness of the material is increased, the beam angle should be decreased. If not, the skip distance will increase and this creates problems in the sensitivity of the testing system. Remember, as the skip distance becomes greater, sensitivity decreases. Therefore, in selecting an optimum beam angle in relation to material thickness, skip distance must be taken into consideration.

Turn to page 3-56.

Good. You determined the statement was false and you're correct. As sheet thickness increases, beam angle should be decreased, not increased. Otherwise skip distance will increase and this is undesirable as it reduces instrument sensitivity.

Let's go on now and learn how the physical location of a discontinuity can be determined in angle beam weld testing. Here we find the distance shown on a CRT screen represents the angle beam path distance in the test specimen plus the apparent distance the sound beam traveled through the transducer wedge. The wedge travel distance must be compensated for before any calculations can be made as to discontinuity location. As an example, the velocity of sound in Lucite is less than 1/2 that of steel, which would make the thickness of the average transducer wedge equivalent to 1" of steel. This 1" would have to be subtracted from the CRT indicated distance to obtain the true beam path distance in the test specimen.

The true beam path can then be calculated according to the formula $a = w (\sin \alpha)$ where α is the angle of beam incidence, as shown below.



The factor, $\sin \alpha$, indicates difference in relative length of beam path "w" and actual distance "a" between the transducer and discontinuity. Its value for representative angles is 0.985 for 80°, 0.939 for 70°, 0.866 for 60°, and 0.707 for 45°. At 80° you can see that the beam path and actual distance are almost equal with the beam path becoming progressively longer as the angle decreases.

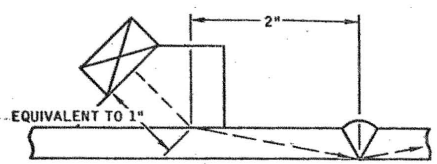
In a practical test situation, assume you are testing a weld in a steel specimen at an angle of 60°. The distance "w" as measured on the CRT screen is 7.9 inches. What is the distance "a" from the centerline of the wedge angle to the discontinuity?

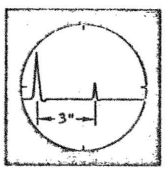
6 inches . . . . . Page 3-57

7 inches . . . . . Page 3-59

Excellent. The correct answer is 6 inches. "w" is found by subtracting length of sound travel in the wedge (1") from apparent distance (7.9"). The answer is then obtained by multiplying the distance "w", 6.9 inches, by the sine of 60°, given as 0.866. The resultant distance "a" tells you the distance from the centerline of the wedge angle to a point directly above the discontinuity.

Assume you are testing a weld in a steel specimen at an angle of 80°. One half the skip distance has been determined to be 2 inches. With the transducer in this position, a discontinuity indication appears on the CRT screen 3 inches after the initial pulse. This will indicate that the discontinuity is at the root of the weld, since at one-half the skip distance the sound beam strikes the root of the weld seam. If the equivalent distance of 1 inch of steel is added to compensate for sound beam travel in the angle wedge, the resultant is a total of 3 inches, the distance indicated on the CRT.





Now, assume that while scanning the weld, a discontinuity indication appears when the transducer is at a distance of 3 inches from the center of the weld seam. The CRT indication shows the discontinuity to be 3 inches from the initial pulse.

From the above assumption, where would you say the discontinuity is located?

Center of weld seam . . . . . Page 3-58

Between the transducer and weld seam . . . . . Page 3-60

Your selection is not correct. You were shown that when the transducer is 2 inches from the weld seam center, the CRT indicates the discontinuity is 3 inches from the initial pulse. The discontinuity is located at the root of the weld when you add the distance that is represented by the time of sound beam travel in the angle wedge.

When the transducer is moved to a distance of 3 inches from the center of the weld seam, the CRT indicates that a discontinuity is 3 inches from the initial pulse.

At a distance of 2 inches from the center of the weld the sound beam reaches the root of the weld; at a distance of 3 inches from the center, the sound beam will be reflected between the transducer and weld seam. The discontinuity therefore is located between the transducer and weld seam.

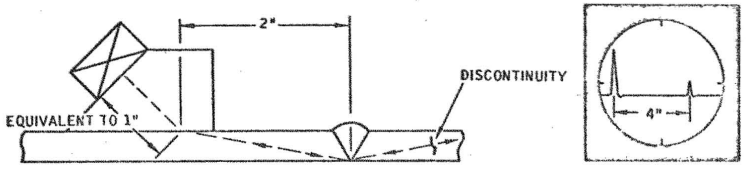
Turn to page 3-60.

You guessed on this one, didn't you? You were given values of $\sin\alpha$ for various beam angles. The value given for a 60° degree angle was 0.866. Now, if "w" equals 6.9 inches (7.9 inches less 1 inch in wedge), you multiply 6.9 by 0.866 and obtain an answer of 6 inches as the distance from the centerline of the wedge angle to the discontinuity.

Turn to page 3-57.

Good. If one-half the skip distance is 2 inches and we have the transducer at a position 3 inches from the center of the weld seam, a discontinuity indication on the CRT showing that the discontinuity is 3 inches from the initial pulse will mean that the discontinuity is between the transducer and the weld.

Next, assume that the transducer is at a point 2 inches from the center of the weld (1/2-skip distance). A discontinuity indication on the CRT appears 4 inches after the initial pulse. This will indicate that the discontinuity is in the plate beyond the weld as shown in the below illustration.



Assume again that the skip distance at an angle of 80° is 4 inches. During scanning, the center line of the angle wedge on the transducer is at the whole skip distance line when a discontinuity indication appears on the CRT 5 inches from the initial pulse. The discontinuity is . . .

Beyond the weld . . . . . Page 3-61
In the weld . . . . . Page 3-62

From page 3-60

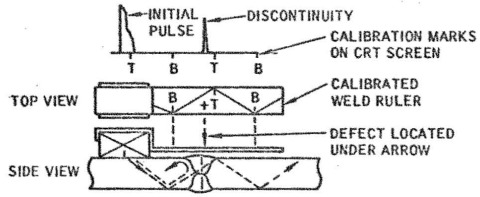
No. The discontinuity is in the weld. By turning to this page you have indicated that you forgot to consider the effect of travel of the sound wave in the angle wedge. This is equivalent to 1 inch of steel that must be added to the distance in the material to obtain the actual distance of sound travel following the initial pulse. Remember, too, that at an angle of 80° the angular path of the sound beam is considered to be the same as the distance measured parallel to the surface. These considerations mean that the reflection from the discontinuity occurs in the weld.

Turn to page 3-62.

From page 3-60

An excellent choice. The discontinuity is in the weld. At 80° the angular path of the sound beam is considered the same as the distance measured parallel to the surface. You took this into consideration as well as adding the distance required for sound wave travel in the angle wedge.

The location of discontinuities in welds thus far has been accomplished by manual means through application of the mathematical relationship between the distance traversed by the angle beam and actual distance measured parallel to the test surface. In addition, discontinuities may be located by use of accessories such as the weld testing ruler illustrated below.



A full explanation of the use of the weld testing ruler will not be given since this device must be calibrated against the thickness of the plate, the angle of the Lucite wedge to be used, and the material composition of the test specimen. Calibration marks on the ruler must correspond to calibration marks on the face of the CRT. This scale will vary for different test instruments according to the manufacturer.

Use of a weld testing ruler that has been properly calibrated for the angle of sound in the test specimen, specimen thickness, and the test instrument will enable you to directly determine the location of the discontinuity with respect to horizontal distance from the centerline of the transducer wedge angle and depth below the surface of the weld.

A weld testing ruler that is designed for locating discontinuities in a weld in 1/2-inch steel plate should not be used to locate discontinuities in a weld in a 1/2-inch aluminum plate. Which of the following reasons would explain this?

Different reflection angles . . . . . **Page 3-63**
Different refraction angles . . . . . **Page 3-64**

From page 3-62

Looks as if you have forgotten the difference between "refraction" and "reflection". When a sound beam passes from one medium to another, as from the Lucite wedge used in angle beam testing to the test specimen, it will be caused to bend. This is refraction. The amount of bending is dependent on the ratio of velocity of sound in the 2 mediums.

The amount of refraction in going from Lucite to steel will be a certain fixed amount and will result in a fixed angle of propagation within the test specimen. The angle of reflection at sound wave nodes will be a fixed value depending upon the initial angle of propagation.

The initial angle of propagation in aluminum will differ from that in steel assuming the same angle of incidence because of the difference of sound wave velocity in the 2 mediums. Again, the angle of reflection as the sound wave travels in a zigzag pattern through the test specimen will be determined by the initial angle of propagation in the test specimen.

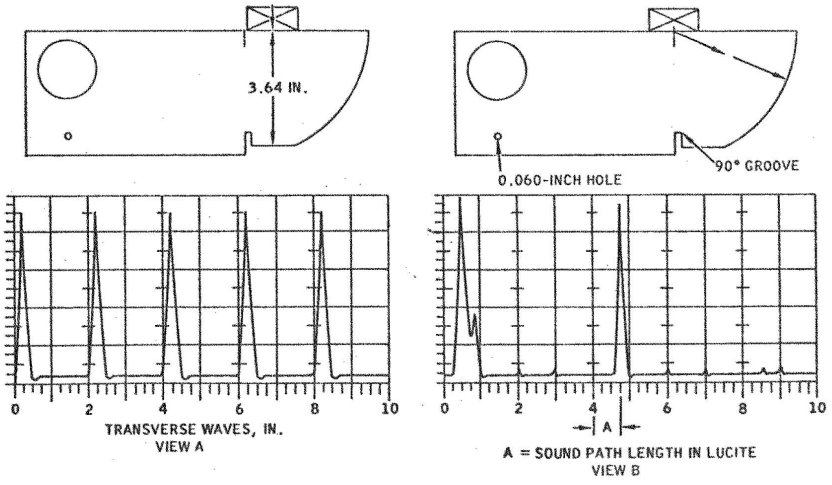
Turn to page 3-64.

From page 3-62

That's right. A weld testing ruler that is suitable for locating a discontinuity in steel will not be adequate for use with an aluminum specimen due to differences in refraction. When testing aluminum, it is necessary to use a ruler that is calibrated for aluminum.

Assume now that you have available an International Institute of Welding (IIW) ultrasonic reference block for use in standardizing the test instrument for testing welds in steel. You'll recall the IIW block was described in detail in Volume II. In general, instrument standardization for angle beam testing of welds in steel using the IIW block is accomplished as follows:

1. A 5 mc straight beam transducer is first connected to the test instrument to make the initial adjustment. This transducer is placed on the IIW block as shown in View A, below, and the test instrument sweep is adjusted to obtain 5 reflections spaced as shown across the face of the CRT.



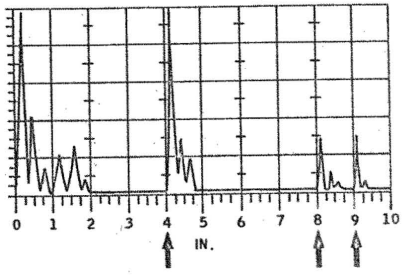
2. We then change to the proper angle beam transducer to be used in the test and this transducer is placed on the IIW block as shown in View B, above.

Turn to page 3-65.

From page 3-64

The CRT pattern you obtain will be similar to that shown in View B on the preceding page. Note the position of the first back reflection and its distance from the 4-inch mark. We find this distance (A) represents the sound beam travel time in the Lucite wedge.

3. At this point we again adjust the instrument sweep so the back reflection occurs exactly at the 4-inch mark as shown below.

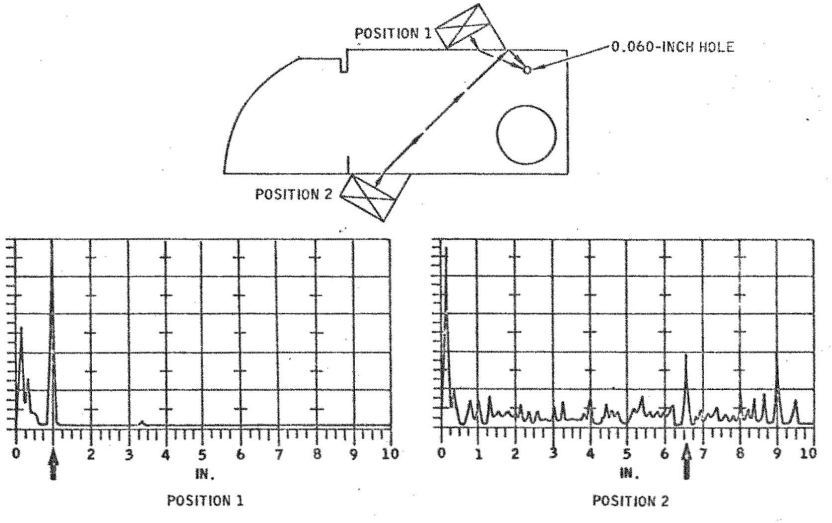


4. Instrument sensitivity is then adjusted to such a level that reflections from the 0.060-inch hole and the 90° groove in the IIW block can be recognized. These reflections will occur at the 8- and 9-inch marks on the CRT screen and the resulting CRT pattern should be similar to that shown above.

Turn to page 3-66.

From page 3-65

5. Finally the transducer is placed in each position shown below, and moved back and forth on the block's surface until maximum reflections are obtained from the 0.060-inch hole. Sensitivity is adjusted until the amplitude of the reflections in the 2 positions is exactly as given in the acceptance standard. And the CRT patterns should be similar to those shown.



What is the purpose of adjusting the instrument so that the reflection from the IIW block arc occurs at precisely the 4-inch mark on the CRT?

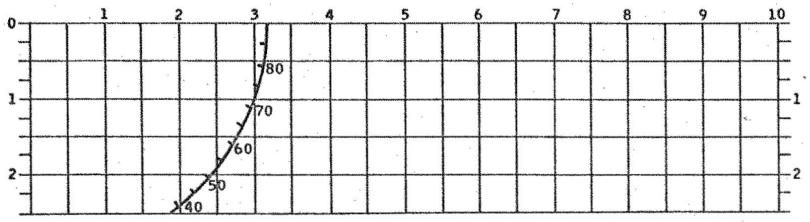
CRT distance accurately represents sound travel distance in test material . . . . . Page 3-67

Unwanted indications from initial pulse are eliminated . . . . . Page 3-68

From page 3-66

Correct. The adjustment of the reflection is for the purpose of calibration. The CRT can then be used to accurately indicate distance of sound travel in a test specimen.

This brings us now to the use of the direct reading ultrasonic calculator for weld testing when the plate thickness of the test specimen and angle of the transducer are known. Cards similar to that shown below are available commercially and are quite handy to use.



The horizontal scale across the top of the card represents the number of inches between the transducer and the weld. The vertical scale represents specimen thickness and the numbers adjacent to the arc show the degrees incidence of the sound beam. A transparent plastic slide fits over the card and is used to identify the weld and show its location in the specimen. A typical example using this form of calculator follows.

Turn to page 3-69.

From page 3-66

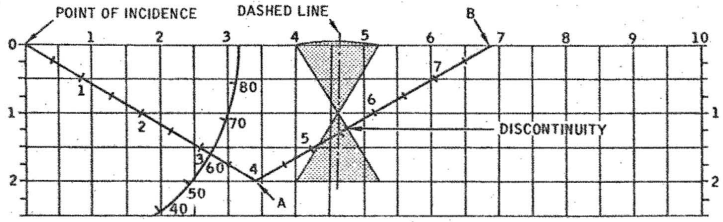
It is true that by adjusting the instrument so that the reflection from the arc occurs at the 4-inch mark on the CRT, the initial pulse will move off the CRT to the left. However, this is not the purpose of the adjustment - the purpose is to calibrate the CRT sweep so that it can be used to accurately measure distance of sound travel in the test specimen.

Turn to page 3-67.

From page 3-67

Assume now that we are testing an X-weld with an opening of 30° in a 2-inch steel plate. The transducer we're using has a 60° incidence angle in steel.

1. First we draw a line representing the sound path from the upper left corner of the card (representing point of incidence in the specimen) through the 60° mark on the arc as shown below. The line should extend to the 2-inch line (point A) representing plate thickness. We now have the sound beam incidence angle recorded on the card. The angled line also represents one-half the skip distance as measured on the surface — approximately 3-7/16 inches.



2. For full skip distance, we double the 3-7/16 inches and mark that point at approximately 6-7/8 inches (point B). We then draw a line between point A and point B and mark off the 2 angles in inches, as shown above. Scale should be the same as the horizontal and vertical lines on the card.

3. We next sketch the 30- X-weld on the plastic slide with the dashed line representing the exact center of the weld and place the card in the slide.

4. Let's assume now the test instrument CRT shows a discontinuity at 5.5 inches when the centerline of the transducer (point of incidence) is 4-5/8 inches from the weld centerline. First we locate the plastic slide weld centerline over the 4-5/8 inch mark on the card. Then the discontinuity location is read directly by reading along the sound path to a point 5.5 inches from the point of incidence. We find the discontinuity is 1-1/4 inches from the surface and 1/8 inch from the center of the weld on the far side of the weld.

Which of the following discontinuities is apparent in the above example?

Lack of penetration . . . . . **Page 3-70**

Lack of fusion . . . . . **Page 3-71**

From page 3-69

Your answer is incorrect. Note the location of the discontinuity. It is at the boundary between the specimen and the weld metal. In this case the discontinuity is caused by a lack of fusion between the specimen and the weld which will cause the weld to be weakened. Lack of penetration is caused by molten weld material not flowing throughout the area to be filled.

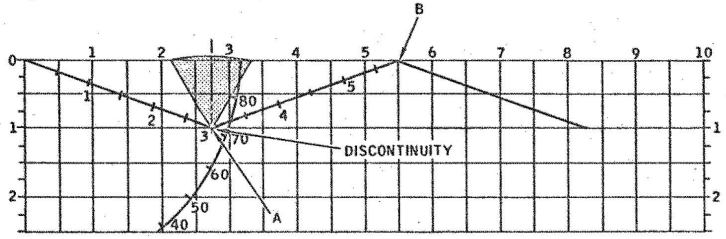
Turn to page 3-71.

From page 3-69

That's right. The indicated discontinuity is caused by a lack of fusion between the edge of the specimen and the weld.

Assume now we're testing a V-weld with an opening of 30° in a 1-inch steel specimen. The transducer angle of incidence is 70°.

1. The sound path is drawn on the card from the upper left corner toward the 70° mark on the arc and down to the horizontal line at one inch (point A) as shown below. For the full skip distance we double the length of this line and place a mark at approximately 5-1/2 inches (point B). The second half of the sound path is then drawn in.



2. We add the inch scale to the sound path as we did in the previous example, sketch the weld on the transparent plastic slide, and place the prepared card in the slide.

3. Let's now assume a discontinuity indication at 3 inches on the CRT screen when the transducer point of incidence is 2-3/4 inches from the weld centerline. We adjust the weld centerline on the plastic slide over the 2-3/4 mark on the card and read the location of the discontinuity directly by reading along the sound path to a point 3 inches from the point of incidence. The discontinuity occurs one inch below the surface and in the center of the weld.

Which of the following discontinuities is apparent in the above examples?

Lack of fusion . . . . . Page 3-72

Lack of penetration. . . . . . Page 3-73

From page 3-71

Incorrect. In this example the discontinuity is located at the lower part of the V-weld where the 2 sections of the specimen are joined. The discontinuity is caused by lack of penetration of the molten weld material into this space and not by lack of fusion between the weld material and specimen.

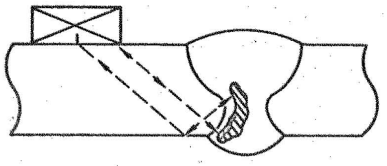
Turn to page 3-73.

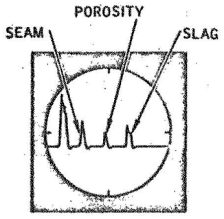
From page 3-71

Very good. The indicated discontinuity is caused by lack of penetration of molten material at the root of the weld.

The experienced ultrasonic operator can determine the type of discontinuity from the type of indication on the CRT. Typical indications from the most common discontinuities are as follows:

- Cracks and bonding discontinuities in the direction of the weld seam will produce a sharply defined indication when the beam strikes at right angles as shown below.
- Porosity that is spherical in shape will produce a sharp echo even when the beam strikes at an angle to the weld seam.
- Slag streaks produce a stepped indication that is maximum at right angles to the weld seam. This discontinuity differs but little from cracks with flat surfaces.
- A large inclusion such as the one shown in the illustration below can produce multiple reflections with interference by reflections from the surface of the plate.





If a multiple reflection is received from a discontinuity such as the one shown in the illustration above, what would be the best way to isolate its location?

Test from other side of weld seam . . . . . Page 3-74

Test at different angle . . . . . Page 3-75

From page 3-73

Excellent. The most practical solution to the problem is to test from the other side of the weld seam.

Ideally, the reference or standard to use for comparison in weld inspection is a welded sample specimen of the same type and size as that being tested. And it should contain known discontinuities of the same size and type as those suspected as being contained in the test specimen. However, this type of comparative standard is hard to obtain in practical test situations. As an alternative, it is common practice to drill a hole in the test specimen, or in a separate piece of material of the same general size, and compare reflections from this hole with reflections received from discontinuities in the test specimen.

The hole size commonly used is 1/16-inch in diameter by 1/2-inch deep. The actual size of the hole to be used as a reference standard will be prescribed by the acceptance standard.

If you are determining the magnitude of the reflection that will be received from the reference hole, at what distance should the transducer be placed from the hole?

Minimum and maximum for weld scanning . . . . . Page 3-76

Mid-point of area of scan. . . . . Page 3-77

From page 3-73

Your answer is not the most practical solution to the problem. It will be much better to test from the other side of the weld seam and avoid unfavorable multiple reflections. It may require the selection of several different angles before one can be found that will give the proper discontinuity indication. In the event that testing from the other side of the seam also results in multiple reflections, it may then be necessary to experiment and use different angles in an attempt to obtain a defineable discontinuity indication.

Turn to page 3-74.

From page 3-74

Good. The transducer should be placed at the minimum and maximum points in distance from the center of the reference hole that will be used later in scanning the test specimen. These 2 points are 1/2 and whole skip distance from the hole and represent the 2 extremes that are covered in scanning.

Turn to page 3-78.

From page 3-74

Your answer is incorrect. The magnitude of the reflections obtained from the reference hole should be determined from the minimum and maximum points to be included in the scanning path when actually testing the weld. This will be 1/2 and full skip distance from the center of the hole. Skip distance, of course, is a function of the angle of the sound beam incidence on the test surface, thickness of the test specimen, and material properties of the specimen.

To obtain the magnitude of reflection only from the mid-point of the area of scan would not provide adequate reference information since this is only one of a very large number of test points between the 1/2 and whole skip distance points.

Turn to page 3-76.

From page 3-76

1. The f_____ z_____ in a weld between base metal and weld material will cause reflections on the CRT even though there are no discontinuities present.

4. incidence

5. Skip distance will _____ (increase or decrease) as the thickness of the test specimen is increased, assuming the same material properties and test conditions are maintained.

8. greater

9. During weld scanning at 60°, a discontinuity indication appears when the transducer is 3 inches from the center of the weld seam. The CRT indication shows the discontinuity to be 3 inches from the initial pulse. Is the discontinuity located in the weld seam or in the plate. (weld or plate - select one) _____.

12. steel

13. A test hole in the test specimen is to be used as a reference standard for comparison with discontinuity indications from a weld. In establishing reference indications from the test hole, the transducer should be moved within the limits that will be used in s_____ the weld.

1. Fusion zone

2. During testing of a weld using angle-beam techniques, only the front surface reflection appears on the CRT. This is an indication of lack of p_____ of the sound beam.

2. penetration

3. The maximum reflection from a discontinuity is received when the discontinuity is struck by the _____ of the sound beam.

5. increase

6. It is desirable to use large angles of incidence for the generation of shear waves. Judgement must be used though, since surface waves may be produced when the angle of refraction of shear waves in the test specimen exceeds _____ degrees.

6. 90

7. A relationship exists between the thickness of a test specimen and the most desirable sound beam angle in the specimen. As the thickness of the test specimen is increased, the sound beam angle should be _____.

9. plate

10. Assume you have angle beam transducers available that will produce angles of 60, 70, and 80 degrees in a test specimen. One of these, the _____degree transducer, will produce a beam that travels very nearly the same distance in the material as distance measured on the surface.

10. 80

11. A weld testing ruler is suitable for locating discontinuities in welds in steel will not be suitable for use with aluminum specimens because of differences in r_____ angles in aluminum.

13. scanning

14. Turn to page 3-82.

3. center

4. Skip distance in a test specimen will change as the angle of _____ is changed.

Return to page 3-78, frame 5.

7. decreased

8. Assume you are testing a weld at an angle of 60 degrees. A discontinuity appears on the CRT 6.9 inches after the initial pulse. This distance is _____ (greater) (less) than the distance between the wedge centerline and a point on the surface directly above the discontinuity?

Return to page 3-78, frame 9.

11. refraction

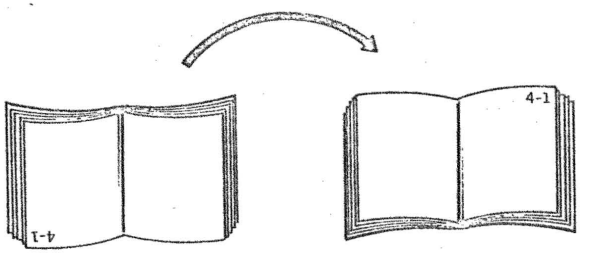
12. International Institute of Welding (IIW) reference blocks can be used for standardizing ultrasonic instruments for testing welds in _____ only.

Return to page 3-78, frame 13.

From page 3-79

Now you are ready to start back through the book and read those upside-down pages.

TURN OR ROTATE THE BOOK 180° — LIKE THIS



READ PAGE 4-1 AND CONTINUE AS BEFORE.

CHAPTER 4 — PULSE-ECHO/THROUGH TRANSMISSION TESTING USING THE IMMERSION METHOD

In Chapters 2 and 3 you learned the application of contact testing and the various techniques used to properly evaluate discontinuity indications. Many of these applications and techniques are also used in immersion testing. Therefore, this chapter on immersion testing will cover only the equipment and techniques peculiar to immersion testing and the indications that may be expected when conducting tests. Little additional discussion will be given when the principles of the techniques are similar or identical to those discussed in contact testing.

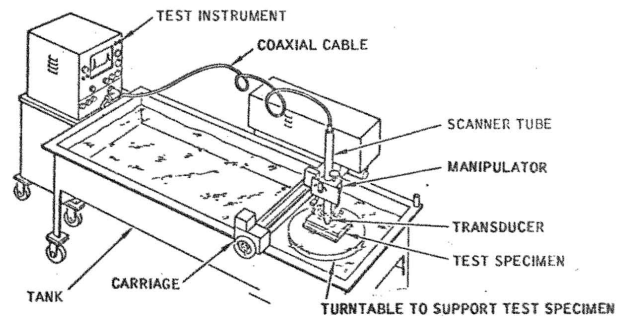
You recall that in immersion testing the transducer is separated from the test surface of the test specimen by a liquid, usually water with a wetting agent and rust inhibitor added. And under normal testing applications both the test specimen and transducer are immersed in a tank and the sound must traverse a short distance of liquid (usually water with a wetting agent) before reaching the surface of the test specimen.

Turn to page 4-2.

From page 4-1

The equipment required in immersion testing depends upon the particular testing problem or application. A typical installation will include the following items:

- Ultrasonic test instrument.
- Test tank to hold coupling medium (water) and test specimen.
- Scanner tube for holding transducer.
- Manipulator for positioning transducer.
- Carriage to support manipulator and permit movement of transducer back and forth and across the test tank in any direction.
- For automatic scanning, a C-scan recorder and a turn table to permit rotation of symmetrically-shaped specimens for automatic scanning.



Water used in test tanks as a couplant usually requires the addition of a wetting agent. The wetting agent serves the purpose of . . .

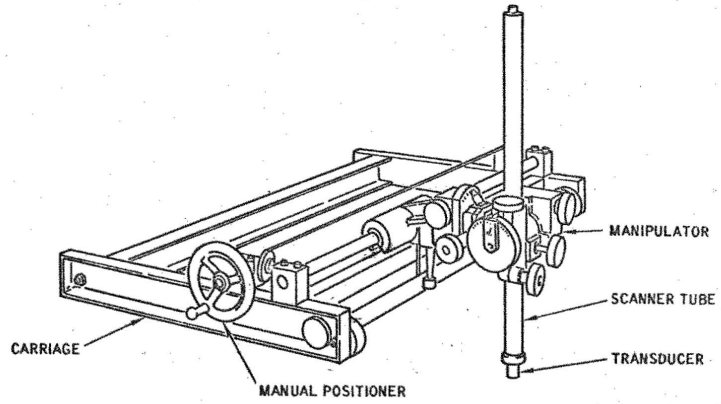
elimination of air bubbles . . . . . Page 4-3

aerating the water . . . . . Page 4-5

Good. The "wetting agent" added to the water in the test tank is for the purpose of eliminating air bubbles. We can expect the maximum transfer of sound energy into the test specimen when there are the fewest obstructions - air bubbles are a definite obstruction.

Before considering the test frequencies that can be used in immersion testing, let us briefly review some of the basic equipment used in immersion testing.

The carriage assembly we learned in Volume II mounts on the immersion test tank and provides a means of moving the transducer in both longitudinal and transverse directions relative to the surface of the test specimen. And the unit may be either manual or automatic, a manual unit being illustrated below.



Automatically operated carriage units include a motor and drive mechanism for moving the transducer across the width of the tank and indexing in small increments in the opposite direction to scan the entire surface. Speed of scanning is variable and controlled by the operator.

Which of the following items should you adjust if you want to determine the extent of the area of a large discontinuity?

Manipulator. . . . . Page 4-4

Manual positioner. . . . . Page 4-6

Your answer is incorrect. Under practical test conditions, if you want to move the transducer to determine the extent of the area of a large discontinuity, you will have to move the manual positioner on the carriage. Movement of the manipulator will cause the angle of incidence of the sound beam to change - this we do not want.

Turn to page 4-6.

From page 4-2

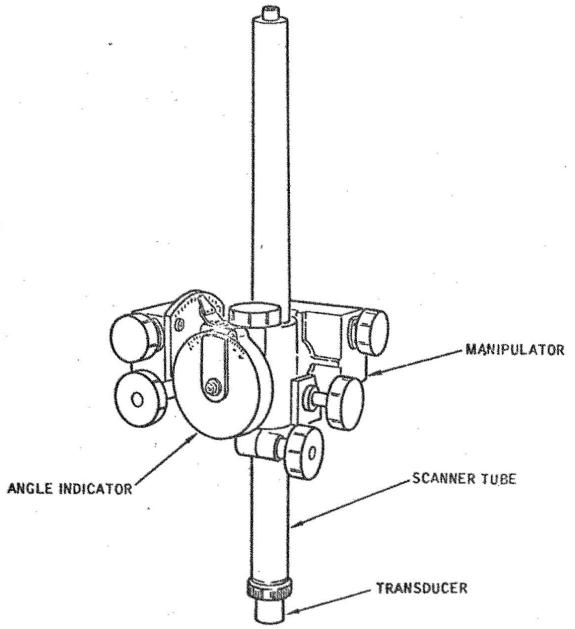
When we add a wetting agent it is for the purpose of getting rid of air rather than adding it. If you were to "aerate" the water it would reduce its effectiveness as a couplant since ultrasonic sound has just as much trouble getting through an air bubble in water as it has in getting through free air. Your selection should have been "elimination of air bubbles." When there are no air bubbles in the water that surrounds a test specimen the water "wets" the surface better and we have a better transfer of sound from the water to the test specimen.

Turn to page 4-3.

From page 4-3

Fine. You are quite right in stating that the manual positioner is used when you want to adjust the position of the transducer parallel to the test surface.

The "manipulator", you'll recall, is used to precisely raise, lower, or change the angle of the transducer with reference to the test surface of a specimen. The unit is so designed that the preset transducer position will be accurately maintained during all speeds in automatic scanning.



In contact testing you learned that the angle imprinted on a Lucite wedge used in angle beam testing is often the angle of refraction in a given test material, not the angle of incidence. Which of the following angles do you think is shown by the angle indicator on the manipulator?

Angle of incidence at test surface . . . . . Page 4-7

Angle of refraction in test specimen . . . . . Page 4-8

Correct. The angle shown by the angle indicator in the manipulator is the angle of incidence at the surface of the test specimen.

The scanner tube, shown on the previous page with the manipulator, provides a rigid coaxial connection with a watertight mount for the transducer on one end and a standard coaxial connector on the other end. Scanner tubes are provided in varying lengths as dictated by test requirements.

Which element of the immersion testing system is raised or lowered to adjust water distance between the transducer and test specimen?

Scanner tube . . . . . Page 4-9

Manipulator . . . . . Page 4-10

Incorrect. The angle shown on the angle indicator portion of the manipulator is the angle of the sound beam in the water medium, or angle of incidence at the test surface. It is then necessary to apply Snell's Law and calculate the angle of refraction in the test specimen or use a calculating device. If the angle indicator showed the angle of refraction in the test specimen, it would be necessary to change indicators each time a specimen of a different material was tested.

Turn to page 4-7.

That's right. The scanner tube is moved vertically by the manipulator to change the water distance between the transducer and test specimen.

Now let us consider the test frequencies that may be used in immersion testing.

Since the transducer does not come into contact with the test specimen in immersion testing, it is possible to use thinner crystals and thus test at the higher ultrasonic frequencies.

As in contact testing, the nature of the internal structure of the test specimen and the size of the discontinuity expected will be major factors in determining the frequency to be used. Where the test situation permits, it is possible to use frequencies as high as 15, 20, or 25 mc. The frequency range of test instruments used in immersion testing is usually from 2.25 to 25 mc.

Suppose the purpose of an ultrasonic test is to detect very small discontinuities. You have a choice of 10 mc or 20 mc as a test frequency. Which should be selected for the best resolution of small discontinuities?

10 mc. . . . . Page 4-11

20 mc . . . . . Page 4-12

No. The manipulator is not raised and lowered to adjust the water distance. We raise and lower the scanner tube using the manipulator to perform this function.

Remember. It is the manipulator we adjust to raise, lower, or change the angle of the scanner tube. And it is the scanner tube that holds the transducer.

Turn to page 4-9.

You picked the wrong one. If you want to detect the smallest discontinuity, select the highest frequency available. This, in turn, will provide a sound beam of the shortest wavelength - the shorter the wavelength, the smaller the discontinuity that the beam can "see."

You can "see" a much smaller discontinuity at 20 mc than at 10 mc.

Turn to page 4-12.

Very good. If you want to detect very small discontinuities and you have a choice between a test frequency of 10 mc and 20 mc, the 20 mc frequency will give you the best results.

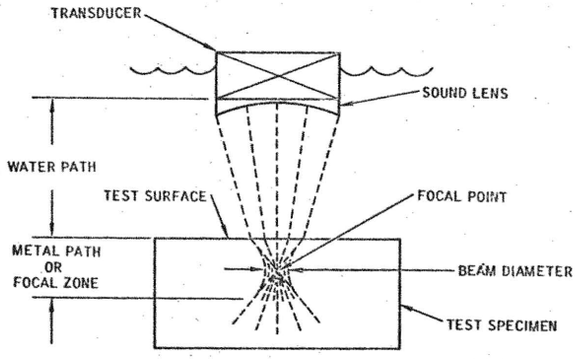
You learned in Volume II that transducers used in immersion testing differ from those used in contact testing mainly in the manner of construction. Since the transducer is immersed in water during testing, it follows that it must be watertight. You have already learned that it is possible to make the transducer crystal much thinner for immersion testing since the transducer does not come into contact with the test specimen and therefore is not as susceptible to mechanical damage. The thinner crystal is what makes the higher test frequencies possible.

Turn to page 4-13.

From page 4-12

For immersion testing applications where a sharper than normal sound beam is required, a focused transducer should be used. Focusing the sound beam will give better resolution for small discontinuities at a given frequency and will enable you to look for discontinuities at a given depth below the test surface. This type transducer is especially useful in testing an area of bonding between 2 materials.

You learned in Volume II that the focusing effect, illustrated below, is attained by the lens structure on the face of the crystal. It can be seen that the lens focuses the sound energy into a small, well-defined pattern.



Assume you are making a test using a focused transducer with test results displayed on an A-scan device. Sweep delay is adjusted to "erase" the initial pulse. Further assume there are no discontinuities in the focal zone of the transducer. Which of the following indications will be displayed on the CRT?

Front surface only . . . . . Page 4-14

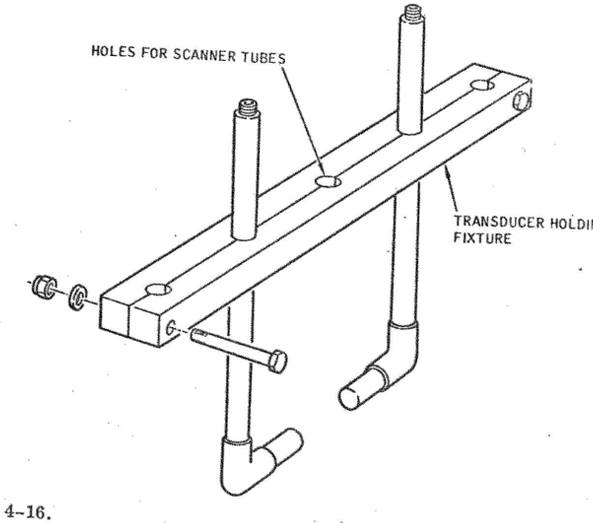
Front surface and back reflection . . . . . Page 4-15

From page 4-13

Very good. When using a focused transducer and no discontinuity exists within the focal zone of the transducer, no reflection will be returned for display on the CRT following the front surface indication.

Through transmission techniques in immersion testing use the same "shadow" effects for detection of discontinuities as through transmission in contact testing. Maximum transmission of sound energy is obtained when there are no discontinuities in the test specimen - discontinuities cause reflection of the sound beam with a corresponding reduction of sound energy that is received by the receiving transducer.

Accessory equipment for through transmission testing is the same as for single-transducer methods with the addition of a holding fixture for the second transducer. This can be either a second manipulator or, if one is not available, a holding fixture similar to the one shown below.



Turn to page 4-16.

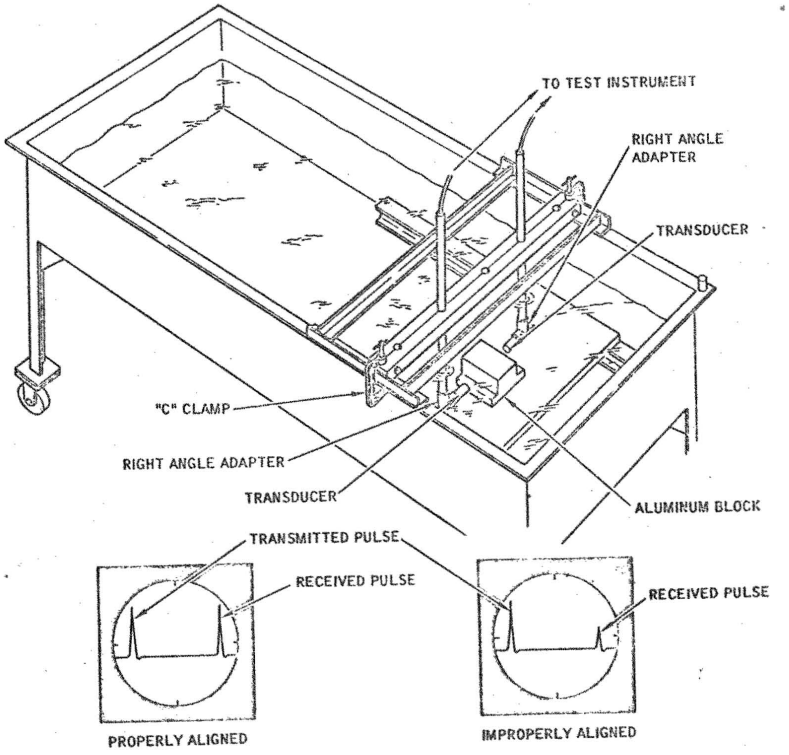
From page 4-13

Sorry. You made an incorrect selection. Under the hypothetical situation stated the sound beam will diverge (scatter) beyond the focal zone of the transducer and there will be considerable scatter at the back surface. There will not be enough sound energy returned from the back surface to cause an indication on the CRT. A test under these conditions will result in only a front surface indication on the CRT.

Turn to page 4-14.

From page 4-14

A partial test setup showing uses of a holding fixture and the expected test instrument readout with proper and improper transducer alignment is shown below.



What is the relationship between size of discontinuity and amplitude of indication on the CRT? Select one of the following:

Small discontinuity - small indication . . . . . Page 4-17

Large discontinuity - small indication . . . . . Page 4-18

From page 4-16

4-17

Your selection is not correct. If the discontinuity is small, more of the sound energy gets past and a larger amount will reach the receiving transducer. The indication on the CRT will be larger with a small discontinuity.

On the other hand, if the discontinuity is large, more of the sound beam will be reflected, and less will pass through the specimen to the receiving transducer.

A good rule to remember in through transmission testing is the larger the discontinuity, the smaller the indication on the CRT.

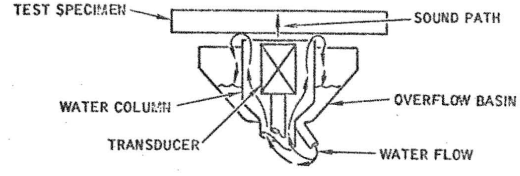
Turn to page 4-18.

From page 4-16

4-18

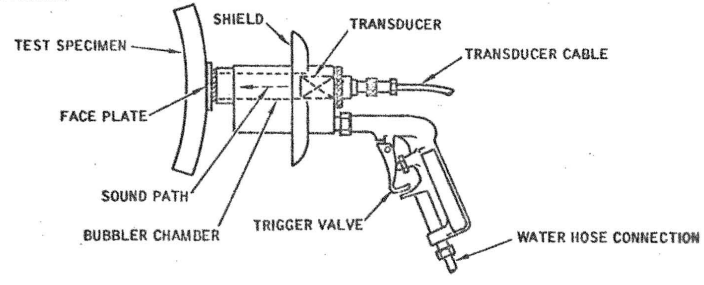
Good. Your analysis is correct. In through transmission testing, as the size of the discontinuity increases, the indication on the CRT will become smaller. This is because more of the sound wave from the transmitting transducer is reflected by the discontinuity and less is able to get to the receiving transducer.

A special application of immersion testing is the "bubbler" or "squirter" illustrated below.



This application is also sometimes referred to as the water column technique. As can be seen a "bubbler" provides the flexibility of immersion testing without the necessity for large test tanks and elaborate positioning equipment. Both straight and angle beam techniques can be used depending on the bubbler design.

A variation of the "bubbler" is the high temperature bubbler shown below that can be used for testing on surfaces that are too hot for standard contact testing. The flowing column of water insulates the transducer against heat and couples the sound beam to the test specimen.



Which of the following can be considered an advantage for using a bubbler?

Both straight and angle beam techniques can be used . . . . . Page 4-19

No immersion test tank is required. . . . . Page 4-20

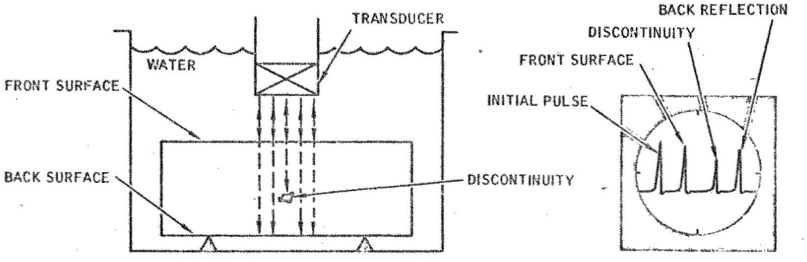
Incorrect. It is true that bubblers can use both the straight and angle beam techniques but this is no special advantage for using a "bubbler". You'll recall that both of these techniques are readily applied to conventional immersion testing.

Now let's take another look at the other selection "no immersion test tank is required" Suppose we had a large specimen which could not be placed in an immersion tank but we needed the sensitivity and resolution capabilities only the immersion method can produce. A logical choice would be a bubbler because no immersion tank is required. Now wouldn't this be an advantage for the bubbler? Of course.

Turn to page 4-20.

Correct. The fact that no immersion tank is required can be considered an advantage of the bubbler application. It allows us to still use the immersion principle when a test specimen may be too large for immersing as in conventional immersion testing.

The following illustration shows immersion testing with a straight beam and the CRT indications that will be received.



The water-path distance from the transducer to the front surface of the test specimen is generally set to be longer in time than the length of scan from the front to rear surface in the test specimen. This is done so that the first multiple of the front surface reflection will appear behind the back reflection on the CRT.

Which of the following will be the result if the transducer is placed too close to the test specimen's front surface?

Spurious indication . . . . . Page 4-21

Loss of back reflection . . . . . Page 4-23

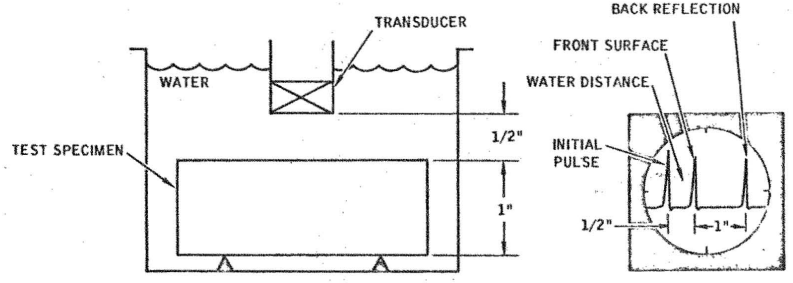
From page 4-20

Good. When the transducer is too close to the front surface of the test specimen the second front surface reflection will appear on the CRT between the first front and back surface reflections. Unless you realize what you are looking at, you may think this is a discontinuity.

The transducer must be positioned so it is further from the front surface with respect to the time for sound travel in water than the time required for the sound beam to travel through the test specimen and be reflected from the back surface. This is especially important when the test area is gated for automatic signalling and recording.

Velocity of sound in water is approximately one-fourth that of aluminum or steel. One inch of water will appear on the CRT presentation in the same time span on the sweep as 4 inches of steel.

A good rule to remember is that the distance from the transducer to the test specimen must be at least equal to 1/4 the thickness of the test specimen plus 1/4 inch as illustrated below.



Assume you are making a setup to test a flat aluminum plate that is 3 inches thick. How much water distance is required between the transducer and top surface of the sheet?

1-1/2 inches ..... Page 4-22

1-inch ..... Page 4-24

From page 4-21

No. You must have guessed at the answer by turning to this page. The water distance must be 1/4 the thickness of the specimen plus 1/4-inch. The thickness of the specimen is given as 3 inches.

1/4 of the thickness is 3/4-inch, add 1/4-inch, and your answer is 1 inch.

Turn to page 4-24.

From page 4-20

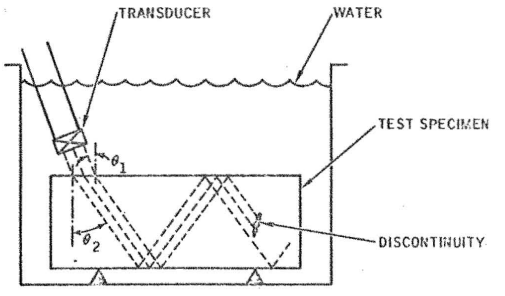
Incorrect. Consider again what will happen if the transducer is placed too close to the front surface of the test specimen. The second reflection from the water-test surface interface will appear on the CRT between the front and rear surface indications. When this happens you are likely to identify it as a discontinuity - your answer to the question should have been "spurious indication." What you think is a discontinuity is really a multiple reflection that will always occur.

Turn to page 4-21.

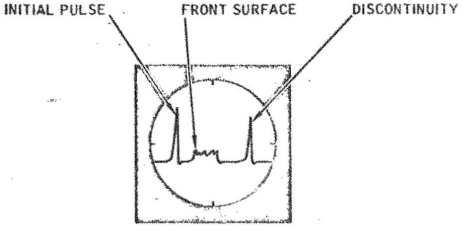
From page 4-21

Good. The correct distance between the transducer and test specimen in this test situation is 1 inch.

Angle beam testing with immersion techniques is illustrated below.



The test setup shown above will produce a CRT indication that differs from that received with straight beam testing due to the angled incidence of the sound beam at the test surface as shown below.



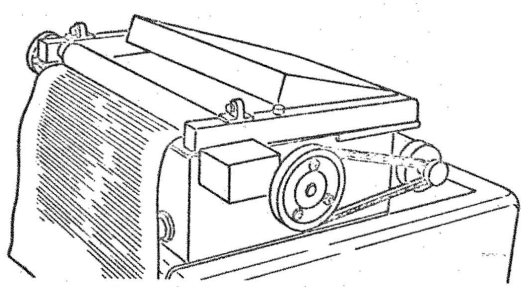
What is the reason for the small front surface indication when using angle beam techniques? Select the answer from the following.

Reflection of sound at test surface . . . . . Page 4-25
Refraction of sound at test surface . . . . . Page 4-26

Fine. You remembered the difference between "reflection" and "refraction." In this case the sound is reflected at the test surface an an angle and does not return to the transducer.

The final item we should consider in the selection of immersion test equipment is the C-scan recorder.

During automatic scanning it is not practical to monitor a CRT for discontinuity indications due to the continuous movement of the transducer and the speed with which reflections from the specimen are obtained. In this case a facsimile-type recording device similar to the one illustrated below is used to obtain a plan view of the test specimen.



As you already know from the discussions in Volume II, a "gating circuit" in the test instrument is activated so that the output of the test instrument to the recorder will only include discontinuity indications that occur in the area of interest. The front and back surface reflections are not recorded. And the recorder can be adjusted to produce a mark from each pulse with no mark from a discontinuity, or marks only from discontinuity indications. Thus, either a positive or negative recording can be made.

Which of the following features of a discontinuity are recorded in C-scan?

Shape and relative size . . . . . Page 4-27

Depth and shape . . . . . Page 4-28

Looks as if you were caught napping on this one. Refraction is what occurs inside the test specimen when the sound beam is bent due to the difference in sound velocity in water and the specimen. In this case the sound is reflected at the surface. It does not return to the transducer due to the angle at which reflection occurs.

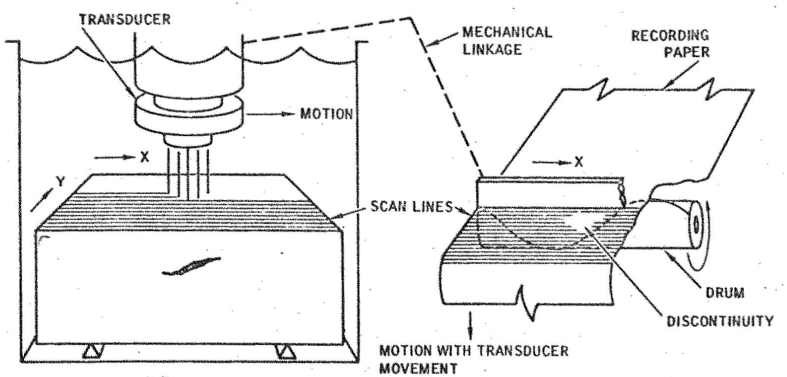
Turn to page 4-25.

From page 4-25

Correct. A C-scan recording will display shape and relative size of a discontinuity but will not tell us how deep it is in the test specimen. We know that it is within the "gated" area - that is all.

After scanning a specimen and obtaining a C-scan readout, it is difficult in most systems to exactly relate the position of the discontinuity as shown on the recording to its actual position with relation to the test surface. This is because there is no mechanical linkage between the recording head and the transducer.

Some automatic systems are equipped with mechanical linkage between the recording head and transducer so that it is possible to accurately locate a discontinuity with respect to the test surface as shown below.



To reposition the transducer directly over a discontinuity in a system such as shown above, it is only necessary to move the recording head to the desired point on the recording and the transducer is automatically repositioned.

Under which of the following conditions would you want to locate a discontinuity with respect to the test surface?

To determine its nature . . . . . Page 4-29

To measure its depth . . . . . Page 4-30

From page 4-25

The shape of a discontinuity is displayed - you are only half-right. The recording does not indicate the depth of the discontinuity. You will know the approximate depth since it will occur somewhere within the "gated" area, but actual depth will be apparent only by manual scanning and using the CRT to measure depth of discontinuity indication. You can say then that a C-scan recording shows shape and relative size of a discontinuity, but not depth.

Turn to page 4-27.

From page 4-27

This was a guess, wasn't it? You won't be able to determine the exact nature of a discontinuity in a specimen unless destructive methods are used. In other words, you will have to use other methods for identification. Both A- and C-scan readouts will show you that a discontinuity exists and you can determine how big it is and where it is - what it is, is another question. It may be a lamination, slag, porosity, or any of the other possibilities.

Once you locate the discontinuity with respect to the test surface, you can then determine how deep it is within the specimen, how it is oriented with respect to the surface, and about how large it is.

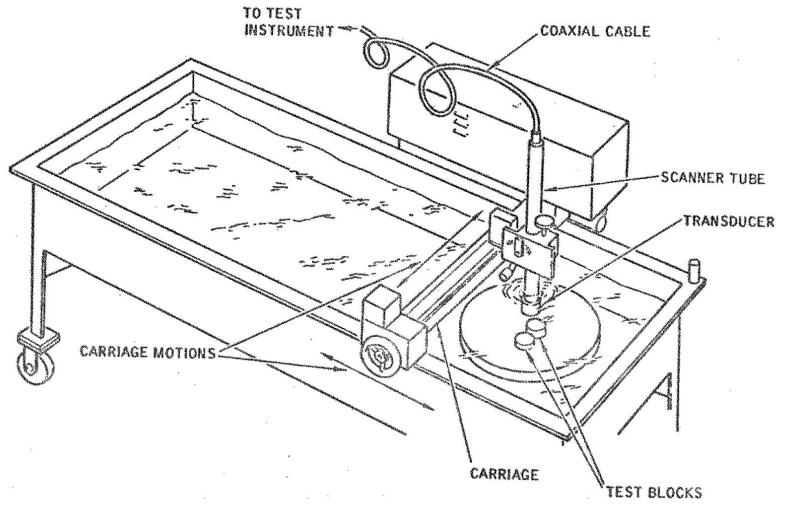
Turn to page 4-30.

From page 4-27

That's right. When you have located a discontinuity with respect to the test surface you can determine how deep it is in the specimen. You also can find out how it is oriented with respect to the surface, and about how big it is. You cannot find out exactly what it is though. This can only be determined by other methods.

Standardization of immersion test equipment, as with contact test equipment, is a check we make to assure that the test instrument will provide proper response to signals from artificial discontinuities in test blocks. This operation is performed before each series of ultrasonic tests.

There are a number of different standardization procedures that are used depending on the test to be conducted or even on personal preference. Following is a typical standardization procedure. First, examine this setup.



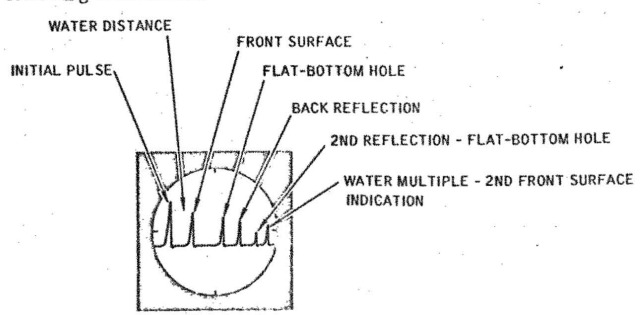
Turn to page 4-31.

From page 4-30

1. First we select 2 distance amplitude test blocks of the same material as that to be tested, or of the material prescribed by the acceptance standard. Each block should contain a 3/64-inch flat-bottom hole, one having a metal distance corresponding to the thickness of the material to be tested; the other having 1/2 inch metal distance. These are placed in the test tank.

2. We then position the transducer over the longest block, slightly off-center and normal to the surface (perpendicular), and observe the reflections on CRT. Water-travel distance is adjusted with the manipulator so that the second front surface reflection occurs after the first back reflection. We can identify the front surface or water-multiple indications by moving the transducer up and down. As this is done, the indications will move across th face of the CRT screen; the front and back surface indications will maintain the same relationship to each other, while the water-multiple reflections will change position relative to the front surface indication.

3. Next we adjust the transducer angle to obtain a maximum-height front surface indication onthe CRT. This will indicate that the sound beam is striking the surface of the test block squarely. Typical CRT indications are shown in the following illustration.



4. The transducer is then moved to obtain the maximum response from the flat-bottom hole.

Turn to page 4-32.

From page 4-31

The test instrument sensitivity (gain) is adjusted to produce a minimum signal strength of one full-height indication from the flat-bottom hole, plus at least a one-half height second reflection from the flat-bottom hole. For example: if the measured height of the first indication is 2 inches, the second indication should be one inch. This relationship is shown in the illustration on page 4-31.

5. Then we position the transducer over the second test block containing a metal distance of 1/2 inch to the flat-bottom hole, and without changing instrument adjustment, we observe whether the minimum display of one and one-half indications from the flat-bottom hole has been maintained. If the combined length of both indications from this block are less than those obtained from the longer block, we increase the instrument sensitivity to obtain this minimum signal strength.

6. Last but not least we measure the water distance between transducer and test block. This distance must be maintained within plus or minus 1/2 inch during testing.

Which of the following statements most nearly describes the reason for selection of the 2 test blocks in the above procedure?

Uniform response over full specimen thickness . . . . . Page 4-33

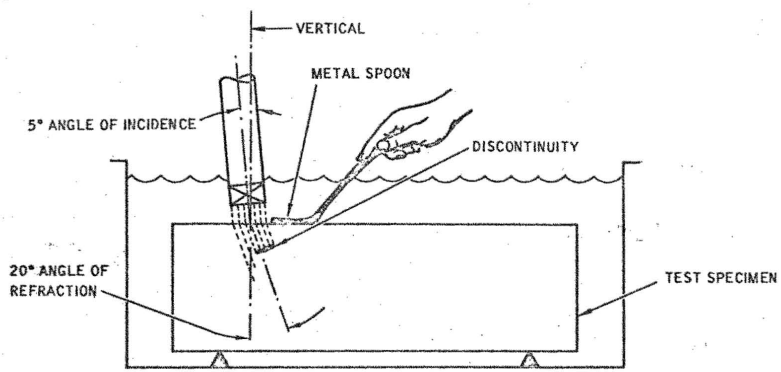
3/64-inch flat-bottom hole is smallest to be used for comparison with actual discontinuities . . . . . Page 4-34

From page 4-32

You're right. The main reason for selecting one block with 1/2-inch metal distance from the front surface to the flat-bottom hole and the other with a metal distance that approximates the thickness of the test specimen is to check and adjust the response of the test instrument so that it is uniform over the full range of test specimen thickness.

Now, let us assume we are checking a specimen manually and a discontinuity indication appears on the CRT. How can the position of the discontinuity in the specimen be determined?

If a straight beam is being used, the discontinuity will be directly below the transducer. If the sound beam is striking the surface at an angle, we have another problem - refraction of the sound beam has to be taken into consideration. Here's how you can locate a discontinuity when the beam hits the surface at an angle. First examine this diagram.



Turn to page 4-35.

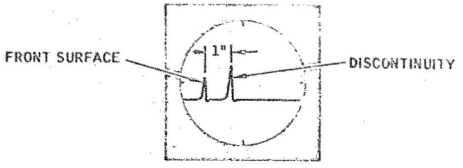
From page 4-32

Your answer is not the best of the two available. It is true that a 3/64-inch flat-bottom hole may be the smallest that will be used for comparison with actual discontinuities, but the main reason for selecting one block with a metal distance the same as the specimen, and the other 1/2-inch from the test surface is to adjust the instrument so that uniform response is obtained over the full specimen thickness.

Turn to page 4-33.

From page 4-33

CRT indications during such a test might look like this.



In our illustration, the discontinuity is about 1 inch below the test surface at an angle of 20° from where the sound beam strikes the surface.

The point at which the sound beam strikes the surface can be determined by placing a straight-edged piece of metal (metal spoon) on the surface of the specimen and moving it toward the area where the sound is entering the test surface.

As soon as the leading edge of the metal enters the sound beam an indication will appear on the CRT. This point is marked on the test surface. The same check is then performed from the other 3 sides of the beam. This locates the area in which the sound beam enters the specimen.

It must be remembered that the discontinuity will be directly beneath the area marked only when a straight beam is being used. Where the beam is entering the surface at an angle, the amount of refraction must be taken into consideration.

Assume now that you have located the discontinuity. You wish to determine if it is at a shallow or steep angle to the surface. If the angle of incidence is increased from 5° to 10° and the discontinuity indication decreases, the discontinuity is . . .

at a steep angle to the surface . . . . . Page 4-36

shallow angle to the surface . . . . . Page 4-37

From page 4-35

Incorrect. The maximum reflection from a discontinuity is received when the sound beam strikes it at a 90° angle. As the angulation changes, the amount of reflection will decrease since a portion of the sound beam will be reflected and not return to the transducer. In this case, you are increasing the angle and the amount of reflection is decreasing, resulting in a smaller indication on the CRT. The discontinuity is at a shallow angle to the surface.

Turn to page 4-37.

From page 4-35

Good. As the angle of sound beam incidence is increased the indication on the CRT decreases indicating that the discontinuity lies at a shallow angle to the test surface. The added angulation causes more of the sound beam to be reflected away from the transducer.

Before going on to the application of immersion testing, we should consider what wave modes can be used in immersion testing.

Here, as in contact testing, straight beam testing involves only the longitudinal wave mode. And again as in contact testing, by using the angle beam technique, sound can be propagated in several different modes depending on the test conditions and requirements. The most common wave mode used other than longitudinal is the shear wave mode.

From what you've learned about the different wave modes and their characteristics, which of the following waves can not be used in immersion testing?

Plate waves ..... Page 4-38

Surface waves ..... Page 4-39

From page 4-37

Your answer is incorrect. Plate waves <u>can</u> be produced in thin sheets using conventional immersion methods, normally using a 2-transducer testing technique. It is <u>surface waves</u> that cannot be produced in immersion testing.

Recall what you learned about surface waves in Volume I and in this volume. You'll remember that a surface wave can be dampened out by water, grease, your finger, or just about anything placed in its path on the surface of a test specimen. Therefore, we find that in immersion testing these waves are dampened so soon after the start of propagation that it is impossible to use them for test purposes.

Turn to page 4-39.

From page 4-37

Good. You remembered that a surface wave will not propagate in water. Water causes a dampening effect and a useful reflection cannot be obtained. Plate waves on the other hand can be produced in thin sheets and used in immersion testing.

Now let's have a short review on what you've learned about immersion testing.

Turn to page 4-40.

From page 4-39

1. In immersion testing, the principal function of water is use as a _____.

4. scanner tube

5. Given a choice of a 10 mc or 20 mc transducer, the_____mc transducer should be chosen for the best resolution of small discontinuities.

8. ahead

9. The distance from the transducer to the test specimen should be at least equal to_____the thickness of the specimen plus_____.

12. metal spoon

13. Assume that you receive a 1-inch high front surface reflection when testing with the sound beam striking the surface at a 90° angle (perpendicular). When the transducer angle is changed to 20°, the front surface indication will become _____.

1. couplant

2. One of the main advantages of immersion testing is use of _____ frequencies so that smaller discontinuities can be detected.

5. 20

6. When using a focused transducer, you can normally expect to receive _____ (no) (reduced) back reflection.

9. 1/4, 1/4-inch

10. S_____ is a check by the operator to assure that the test instrument will provide proper response to reflections from flat-bottom holes in test blocks.

13. smaller

14. Assume a discontinuity returns a 1-inch indication on the CRT when the transducer is at an angle of 5° to the test surface. When the angle of the transducer is increased to 10°, the CRT indication decreases to 1/2-inch. This is an indication that the discontinuity lies at a (steep) (shallow)_____ angle with respect to the surface of the specimen.

2. high

3. The device used to adjust the angle of the transducer so that the sound beam can be transmitted into a test specimen at an angle is the m_____.

6. no

7. A special application of immersion testing in which an immersion tank is not required is referred to as the _____ or _____ _____ technique.

10. Standardization

11. Some automatic scanning systems are equipped with a mechanical linkage between the C-scan recorder and the transducer to facilitate locating a discontinuity with respect to the _____ _____ of the specimen.

14. shallow

15. All wave modes, except _____ waves, can be produced in test specimens with conventional immersion testing techniques.

3. manipulator

4. The s_____ t_____ provides a mounting for the transducer and is raised or lowered to change the water distance between the transducer and test specimen.

Return to page 4-40, frame 5.

7. bubbler (squirter), water column

8. When a transducer is placed too close to the front surface of a test specimen, the second front surface reflection will appear_____(ahead) (behind) the back reflection of the CRT.

Return to page 4-40, frame 9.

11. test (front) surface

12. When testing a specimen manually, a flat m_____ s_____ is used to determine the area in which the sound beam enters the test specimen.

Return to page 4-40, frame 13.

15. surface

16. Turn to page 5-1 for a continuation of your study on immersion testing with emphasis on application.

Before going into a few of the typical applications of immersion testing, let us consider how it can be determined if the discontinuities found will be cause for rejection of the specimen.

The acceptance standard will tell us, for example, that discontinuities providing a reflection greater than that from a flat-bottom hole of certain dimensions will be cause for rejection. Or, in other cases, if the discontinuities are of certain size and closely-spaced, the specimen shall be rejected.

Evaluate the discontinuities as follows:

1. Note depth of discontinuity by measurement on face of CRT.
2. Note magnitude of discontinuity indication on CRT.
3. Select a test block with hole dimension specified in the acceptance standard that has a metal distance very nearly equal to the depth of the discontinuity.
4. Position the transducer above the test block with the same water distance as used in testing the specimen.
5. Obtain an artificial discontinuity indication from the flat-bottom hole in the test block.
6. Compare the height of the discontinuity indication from the flat-bottom hole with the indication from the actual discontinuity.
7. The discontinuity is rejectible if the indication is equal to or greater than the indication from the flat-bottom hole.

Assume a 1-inch indication from a discontinuity and flat-bottom hole. Which is the larger of the two?

Flat-bottom hole . . . . . Page 5-2

Discontinuity . . . . . Page 5-3

From page 5-1

Did you forget? At any time that you receive reflections that are of equal amplitude from a discontinuity and a flat-bottom hole, you can always judge the discontinuity to be the larger. This is because of the nature of the two reflecting surfaces.

A flat-bottom hole has smooth reflecting surfaces and there will be little scattering of the sound beam with the majority returned to the transducer for display on the CRT. On the other hand, discontinuities will always be rougher than a flat-bottom hole, some of the sound beam will scatter and not be returned to the transducer; the resulting indication will be smaller.

Turn to page 5-3.

From page 5-1

Excellent. You remembered that a discontinuity can always be considered to be the larger when equal-magnitude indications are received from a discontinuity and a flat-bottom hole. The acceptance standard takes this fact into account when it specifies a standard for comparison.

Immersion tests of large, flat plate or sheet materials may be conducted by either the straight or angle beam technique. And where facilities exist for automatic scanning and recording, the straight beam technique should be used.

If facilities do not exist for automatic scanning and recording, testing will be accomplished more rapidly by using the angle beam technique and observing discontinuity indications on the CRT.

Assume you are testing a large sheet of aluminum stock by the immersion method. Facilities for automatic scanning and recording are not available. When using shear wave techniques, will you scan from one edge only or from two edges?

Two edges . . . . . Page 5-4

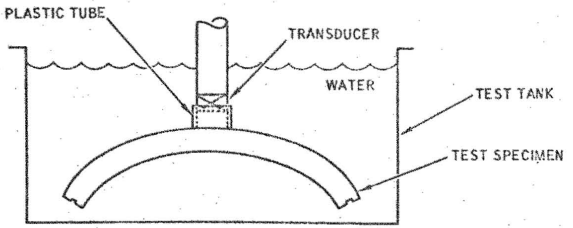
One edge. . . . . Page 5-5

From page 5-3

That is correct. If you are hand-scanning a large, flat aluminum sheet using the angle beam (shear wave) technique, scanning should be done from two edges. Scanning from only one edge will not provide necessary coverage of the specimen due to "skip distance" as the sound beam zigzags across the sheet.

Contoured surfaces can be easily tested by immersion. Some large ultrasonic testing installations have facilities for automatic scanning of complex shapes with the automatic equipment driven by a punched-tape machine to match the contour of the specimen. This assures that the water distance and transducer angulation is automatically corrected to match the change in test surface contour.

Hand scanning of contoured surfaces requires the use of a hollow plastic extension tube on the end of the transducer. The tube is placed in contact with the test surface and thus maintains proper distance between the transducer and specimen at all times. Where the specimen has a constant curvature similar to that shown in the following illustration, the plastic tube is shaped to fit the contour of the specimen to maintain normal incidence of the sound beam.



The plastic tube in the above illustration provides proper spacing between the transducer and test specimen as well as proper shape to follow the contour of the specimen. Which of the following properties of the tube describe the effect on the sound beam?

Contains and directs the sound beam . . . . . Page 5-6

High acoustic impedance . . . . . Page 5-7

From page 5-3

You forgot about "skip distance," didn't you? As the sound wave zigzags across the sheet of aluminum between the upper and lower surfaces, it is going to skip part of the area and you may miss some of the discontinuities. Looking at the sheet ultrasonically from two of the edges will give much better coverage. Of course, it will be better if you can turn the sheet over and check from two edges on the other side. We have assumed in this case though that the sheet is not to be turned. "Two edges" is the correct answer.

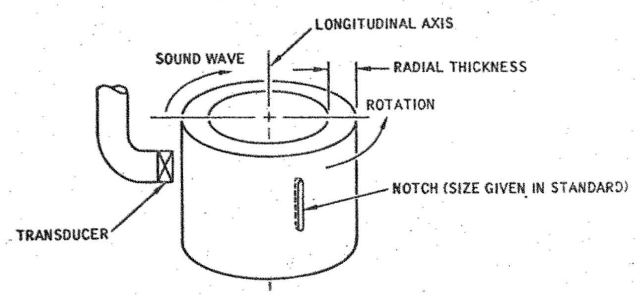
Turn to page 5-4.

From page 5-4

Correct. In addition to the mechanical job of maintaining proper spacing between the transducer and specimen and adjusting to the contour of the specimen, the plastic tube contains and directs the sound beam.

Two different techniques will be discussed for the testing of cylindrical-shaped specimens. As an example of the first technique, we will consider the testing of ring forgings.

A ring forging is positioned with its longitudinal axis perpendicular so as to permit rotation about this axis as shown below. When shear wave techniques are to be used, a notch is cut into the radial thickness of the forging and the test instrument standardized to reflections from the notch.



A right-angle transducer is used to project an angle beam into the forging as it is rotated with the beam entering the specimen opposite to the direction of rotation. And the test instrument is adjusted to obtain a maximum indication from the notch on the CRT. During the test on the forging, any discontinuity indications exceeding the indication from the notch will be cause for rejection.

The ring is scanned from top to bottom, moving the transducer successively downward after each revolution of the ring.

Assume a discontinuity in a ring forging. Which of the following indications will appear on the CRT?

Small front and back surface and discontinuity reflections . . . . . Page 5-8

Small front surface and discontinuity reflections . . . . . Page 5-9

From page 5-4

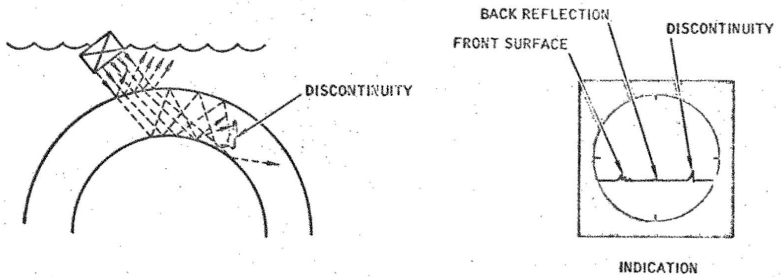
The plastic tube does not offer a high acoustic impedance compared with the water in which immersed. Its impedance is greater than that of most of the metals that will be tested by this method, but it cannot be said that one of its properties is "high acoustic impedance" since it offers only small opposition to the passage of sound waves. In this application the plastic tube "contains and directs" the sound beam.

Turn to page 5-6.

From page 5-6

5-8

Your answer is partially correct. In the test situation under consideration, the sound beam is striking a curved surface at an angle. In the question we assumed a discontinuity, so the following illustration portrays what is observed on the CRT.



Turn to page 5-9.

From page 5-6

5-9

Good. This question is an adaptation of what you studied previously about the effects of an angle beam striking a curved surface. We will receive only a small front surface reflection and a reflection from the discontinuity.

Straight beam testing can also be applied to testing ring forgings. In this case, the instrument is standardized by projecting the sound beam perpendicular to the surface. Instrument sensitivity is adjusted so that the back surface indication is at least 3/4 of the height of the CRT screen. A notch is not used in this case.

During testing, the forging is rotated while the transducer is held in a position perpendicular to the surface. Discontinuity indications will be conventionally displayed on the CRT between the front and back surface indications.

The forging will normally be considered defective if discontinuity indications exceed a percentage of the back surface indication as specified in the acceptance standard.

Select the best completion for the following statement. The process of adjusting a test instrument to provide a controlled response under simulated test conditions is known as . . .

calibration . . . . . Page 5-10

standardization . . . . . Page 5-11

From page 5-9

No. Calibration is the periodic adjustment of an instrument in a laboratory under controlled conditions with the use of precise standards. This process checks the performance of all electronic circuits as well as the capability of the instrument to provide standard CRT indications from calibrated reference blocks similar to the test blocks used for standardization.

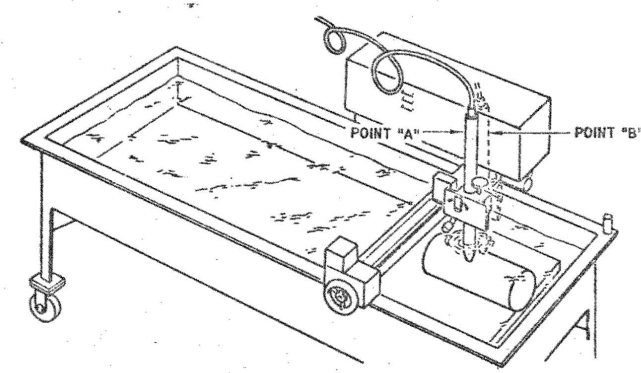
Standardization is adjustment of a test instrument to provide a controlled response under simulated test conditions.

Turn to page 5-11.

From page 5-9

Very good. The process of adjusting a test instrument to provide a controlled response under simulated test conditions is known as standardization.

Round bar stock, tubing, and curved sections of forgings may be tested using "off-center" scanning techniques. In this technique, the transducer is positioned parallel to the vertical diameter of the test specimen but is displaced to one side of the center as shown in the illustration below (point B). With the crystal off-center, the test surface is at an angle other than normal to the sound beam and refraction occurs.



Scanning commences from the center, Point A in the above illustration, where the refracted angle is zero. The transducer is then indexed toward point "B" until a point is reached where the shear wave mode is refracted 90° (second critical angle). This technique will assure that radial discontinuities will be intersected at right angles to the face of the discontinuity so the sound will be reflected in the proper direction for display on the CRT.

When scanning with the above technique, which of the following wave modes will exist in the test specimen?

Shear and surface waves . . . . . Page 5-12

Longitudinal and shear waves . . . . . Page 5-13

From page 5-11

Your answer is incorrect. The initial scanning pass with the transducer in the center of the specimen will result in longitudinal waves. As the transducer moves further from the center, the refracted angle will first cause longitudinal waves to exist in the specimen; then as it moves further away from the center, shear waves will be produced. Scanning ceases at the point shear wave refraction reaches 90° (second critical angle), the angle at which surface waves are produced. Remember, surface waves are dampened out by the water couplant in immersion testing and cannot be used. Therefore, we can say then that only longitudinal and shear waves will exist in the test specimen as scanning progresses from the center of the test specimen outward.

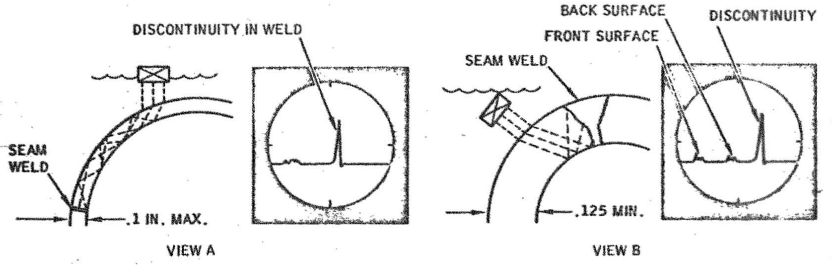
Turn to page 5-13.

From page 5-11

Right. Longitudinal and shear waves will exist in the test specimen as scanning progresses from the center outward, depending upon the angle of incidence at the test surface.

Immersion testing of pipe and tubing can be accomplished on a production line basis using either conventional methods with the transducer immersed in water or by use of a "bubbler" where the sound beam is projected through a water column.

Typical ultrasonic indications that may be obtained on a CRT while testing specimens with different wall thicknesses are shown below. View A shows the behavior of the sound beam when testing thin-wall tubing. Much of the sound is reflected from the surface; that which enters the specimen is trapped in the tube wall and will travel around the circumference until it strikes a discontinuity that will cause a reflection. When no discontinuities are present, only a very small front surface indication will be received.



View B shows the sound beam entering a thicker-walled tube. Again, the sound is trapped in the tube wall, but different reflections will occur due to the difference in wall thickness. In tubes larger than about 0.125" wall thickness, small front and back surface reflections will occur; discontinuity indications will cause a much larger indication and are readily detected.

The only difference in the above test setups and conditions that will cause the different indications is . . .

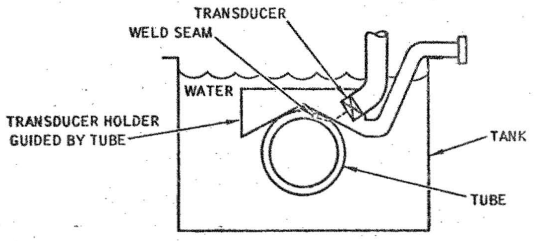
tube wall thickness . . . . . Page 5-14

angle of sound beam incidence . . . . . Page 5-16

That is correct. The only thing that causes the difference in the 2 CRT indications is the thickness of the tube walls.

Let us look now at a method used in high speed scanning of welds in tubing. Tubing, after welding, is passed through an ultrasonic immersion tank; holes in the ends of the tank allow the tube to pass through, being so designed that water is retained in the tank.

The transducer is fastened to a holder that rides on the surface of the tubing as shown in the following illustration. The seam in the tube always occupies the same position with relation to the transducer. The sound beam strikes the surface of the tube at an angle producing a sound wave in the tube wall that travels around the circumference and strikes the welded seam at right angles.



If the weld seam contains no discontinuities, no indication will appear on the CRT, however if there is a discontinuity, an indication will appear that is proportional in height to the reflecting surface. The position of this indication will not change and will be determined by the constant distance between the transducer and seam. It is also possible to equip the testing system with a marking device that will automatically mark the tube when a discontinuity indication is received, or a continuous-strip recorder can be used.

In this type testing the weld area only is inspected. What feature of the test instrument will prevent unwanted discontinuity reflections being recorded?

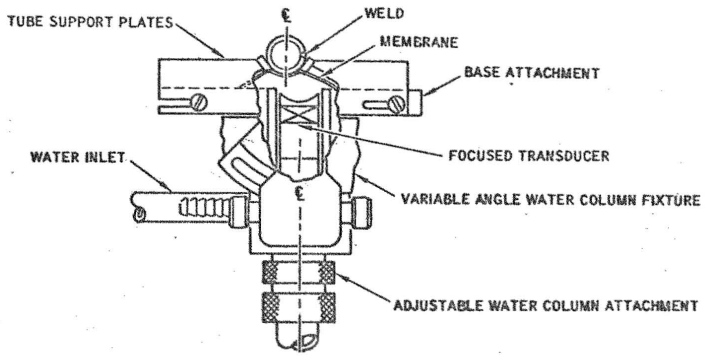
Gate. . . . . Page 5-15

Sweep delay. . . . . Page 5-17

That's right. The use of the electronic gate on the test instrument will allow us to record only those reflections that occur in the area of the gate which will be the weld area. Discontinuity reflections from other areas around the circumference of the tube can be seen on the face of the CRT, but will not be recorded since we are only interested in the weld area.

A variation of the immersion method in testing of tubing using a "bubbler" is shown below. Tubes are drawn across the transducer which is positioned to allow sound energy to enter the tube wall 90° from the welded area.

Discontinuity indications will occur under the same conditions as those described when the transducer and tube are immersed in water. Automatic marking and recording devices may also be used with this system to designate areas of the tube that contain discontinuities.



What sort of standardizing device is used for comparison with discontinuities detected in tubing when tested by the above method?

Test blocks . . . . . Page 5-18

Notches in good section of tubing . . . . . Page 5-19

From page 5-13

Incorrect. The only difference is the thickness of the tube wall. In this case we are considering that the same angle of incidence is used. If the angle of incidence is changed there will be different effects reflected in each of the specimens, but that factor is not to be taken into consideration in this example.

Turn to page 5-14.

From page 5-14

The question asked what feature of the test instrument will permit unwanted discontinuity reflections to be rejected by the test instrument and not recorded. You chose "sweep delay." This is not correct. This feature of the instrument allows us to delay the start of the sweep on the CRT for a certain increment of time following this initial pulse to allow "erasing" the water distance from the face of the CRT. We will see all indications that are due to reflections from discontinuities around the circumference of the tube.

If we want to record only what the sound beam detects in the weld area, we use the electronic gate. Discontinuities occurring outside the gated area will cause reflections that we can see on the face of the CRT but, due to the gate, we will only record indications from discontinuities within the gated area.

Turn to page 5-15.

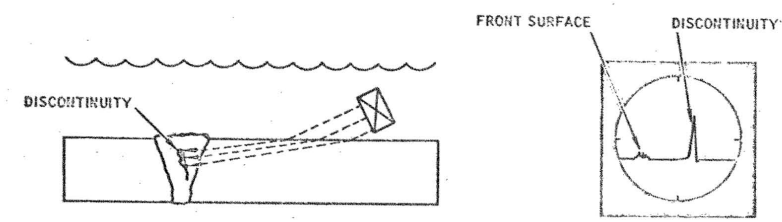
By turning to this page you indicate you think that test blocks are used for standardizing the instrument for comparison with discontinuity indications from tubing. This is not correct. Remember what you learned about ultrasonic testing of tubing in the chapters on contact testing? You learned that standards are prepared by cutting notches in the inner and outer diameter of the tube. Reflections from these notches are the standards against which reflections from discontinuities are compared.

The size of the notches is not important at this time. This will be set forth in acceptance standards.

Turn to page 5-19.

Very good. Indications as a result of reflections from notches in a good section of tubing are used as standards to compare with reflections from discontinuities.

The use of immersion testing techniques to test butt welds in heavy plate is illustrated below.



When the sound beam enters the test surface at an angle, refraction will occur in the test specimen. Small changes in the angle of incidence will cause much larger changes in the refracted angle due to the difference in sound velocity in water and metal. It usually is desirable in weld testing to generate shear waves in the test specimen. To do this the transducer is tilted to an angle of incidence between 15° and 33°.

In shear wave testing, a small and poorly-defined reflection will be returned from the entry surface. A strong reflection will be returned from vertical fissures or cracks in the test specimen.

If the transducer is moved horizontally along the test specimen toward the weld the discontinuity indication will move forward or away from the front surface indication because the path of the sound wave in the specimen is made longer or shorter by moving the transducer.

Which of the following wave modes best describes the particle motion while the sound beam is traveling through the water?

Shear waves . . . . . Page 5-20

Longitudinal waves . . . . . Page 5-21

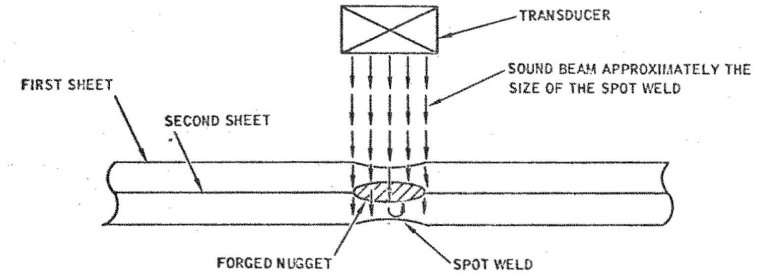
Your answer is wrong. Mode conversion to transform the wave from longitudinal to shear does not occur until the sound beam strikes the entry surface of the test specimen. At that point it is transformed into shear waves. The sound wave travels in the shear mode while in the specimen and is converted to longitudinal mode at the interface before returning to the transducer for display on the CRT.

Turn to page 5-21.

Right. The wave mode is longitudinal during the time the sound beam is traveling through the water between the transducer and test surface.

Several methods of ultrasonic testing of spot welds are in current usage. Only one which uses manual techniques will be discussed in this volume.

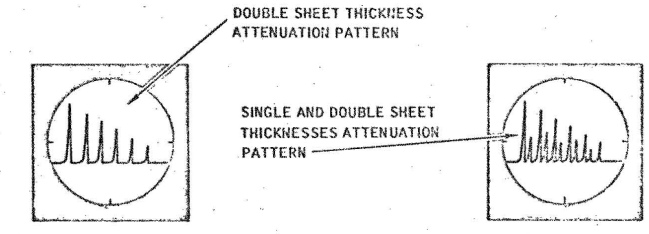
The weld penetration technique shown in the following illustration requires that the sound beam be approximately the same size as the electrode tips used to fabricate the spot welds.

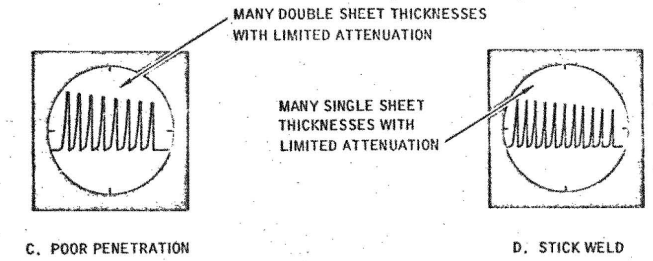


This method of testing spot welds is limited to materials such as carbon steel and aluminum which have a change in grain size in the spot weld nugget. It can be used in testing plate in the range of 0.075 to 0.250 inches thick with a frequency of 10 mc using a focused, closed-water-column transducer.

Turn to page 5-22.

When a good spot weld is tested, the pattern on the CRT will show only the double sheet thickness as illustrated in View A, below. The attenuation of the coarse nature of the forged nugget and the surface condition limit the number of sound reverberations that will occur. As the forged nugget size decreases, the number of double sheet reverberations decreases and the number of reflections from the single sheet thickness increases as shown in View B.





If the spot weld does not create a change in grain size of the nugget area as might be expected in a weld with poor penetration, the number of multiples of the double-sheet thicknesses increases and an indication similar to that shown in View C will be seen.

A stick, or paste weld will show many single sheet thicknesses as shown in View D.

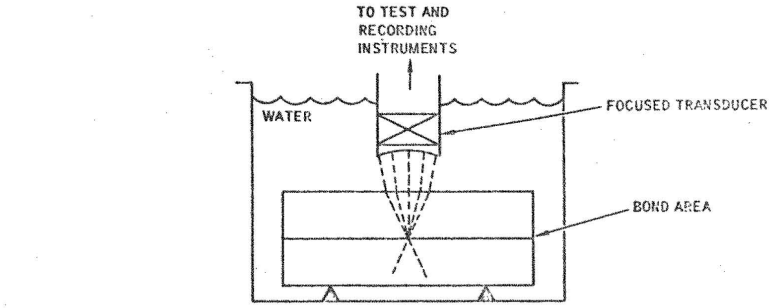
Which of the above CRT patterns will result if the sound beam is larger than the spot weld area?

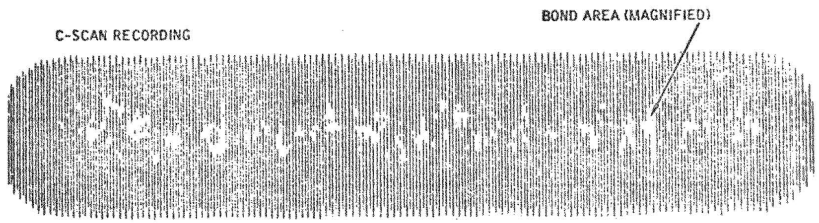
View B ..... Page 5-23

View C ..... Page 5-24

Excellent. If the sound beam is larger than the spot weld area, the CRT pattern will be a combination of single- and double-sheet reflections as shown by View B.

The area of bonding between two materials can be tested ultrasonically with good results. The following illustration shows a technique for use with automatic scanning and recording equipment. A focused transducer with a focal zone at the area of the bond is used to test the area between the two materials. Results are printed out on a C-scan recording similar to the one shown which is greatly magnified.





Assume you are to conduct a test of bonding. Transducers of 10 mc and 20 mc are available for use. Which should you select for the best resolution of lack of bond discontinuities?

10 mc ..... Page 5-25

20 mc ..... Page 5-26

From page 5-22

5-24

Your selection is incorrect. View C shows the indication that will be received when the weld does not penetrate and provide an ultrasonic path between the two plates. The correct answer is "View B" which shows that there are some double sheet reflections mixed in with the single-sheet reflections. This indication is caused by some of the sound energy being reflected at the interface between the two plates, the rest being reflected by the back boundary of the two-plate combination.

Turn to page 5-23.

From page 5-24

5-25

Your selection will not give you the best resolution of very small discontinuities. 20 mc would be the best choice since wavelength will be shorter at the higher frequency. One of the basic rules of ultrasonics is that the shorter the wavelength, the smaller the discontinuity that can be detected.

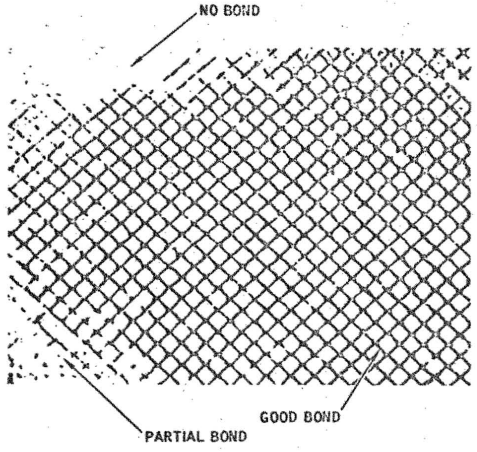
Turn to page 5-26.

From page 5-24

Excellent. The higher frequency will give the best resolution of the very small discontinuities such as you are looking for in checking the degree of bonding between 2 materials.

Metal to honeycomb bonding, commonly known as "honeycomb bond," can likewise be successfully tested with immersion testing techniques. The degree of bonding, as well as the lack of bond, can be detected since the degree of bonding is directly related to the acoustic impedance mismatch at the interface between the two materials.

The amount of sound energy that is reflected from or transmitted through the interface is also directly related to the degree of bonding so that variations in the quality of the bond will be shown as variations in the amplitude of the reflected signal as illustrated below.



Which of the following conditions do the dark areas in the above C-scan recording indicate?

Reflection from interface . . . . . Page 5-27

Reflection from back surface . . . . . Page 5-28

From page 5-26

The dark areas on the C-scan recording indicate points at which the bonding is good. Right? This means that the sound beam has penetrated through the bonded area to the back surface and been reflected. In this case your selection of an answer should have been "reflection from back surface."

Turn to page 5-28.

From page 5-26

Good. You are so right. The dark areas on the C-scan recording indicate the sound beam has penetrated the bond area and traveled to the back surface of the specimen before being reflected. In the areas where there is no bond, the sound beam sees a discontinuity due to the difference in acoustical impedance and is reflected back to the transducer.

Turn to page 5-29 for a review of material contained in this chapter.

From page 5-28

1. When comparing the height of a discontinuity indication with that of an equal magnitude indication from a flat-bottom hole, the discontinuity can always be considered to be_____.

4. longitudinal

5. Assume you are testing a ring forging using an angle beam. Will you normally expect to receive a reflection from the back surface? (Yes) (No)_____

8. No

9. During production-line testing of welds in tubing, the test instrument is adjusted so that reflections from the weld area are the only ones that will cause a recording or marking device to be actuated. The g_____ circuit in the instrument provides this feature.

12. 20

13. When testing bonding between 2 materials, a strong CRT indication will be received from the bond area when the bond is (bad) (good)_____.

1. larger

2. Immersion tests of large, flat plate or sheet materials may be conducted using either straight beam or angle beam techniques. The _____ beam technique is usually preferred when automatic scanning and recording equipment is used, while the _____ beam technique is faster when scanning a test specimen manually.

5. No

6. Angle beam immersion testing, like angle beam contact testing, requires the use of r_____ n_____ to evaluate discontinuities in ring forgings, piping, and tubing.

9. gate (gating)

10. When testing a spot weld with a sound beam that is the same size as the weld nugget, a CRT pattern that shows sheet thickness will be displayed. If the weld is good, will the pattern indicate (double) (single) _____ sheet thickness?

13. bad

14. A C-scan recording of good quality honeycomb bond will provide a "photograph" of the scanned area that shows a series of well-defined patterns where the honeycomb core is bonded to the surface material. An area of good bond is characterized by _____ (reflection) (transmission) at the interface.

2. straight, angle

3. Hand scanning of contoured surfaces using immersion techniques requires use of a plastic extension tube on the end of the transducer. The tube is necessary to assure that the w_____ d_____ is the same at all test points.

6. reference notches

7. When testing a ring forging using the straight beam technique, the forging is considered defective if any discontinuity indication exceeds a specified percentage of the _____ _____ reflection as given in the acceptance standard.

10. double

11. A small and poorly-defined reflection is returned from the entry surface of a test specimen when using _____ beam immersion methods.

14. transmission

15. Now turn to page 6-1 for a discussion on irrelevant indications.

3. water distance

4. Particle motion when the sound beam is traveling through water between the transducer and test specimen is always in the_____mode.

Return to page 5-29, frame 5.

7. back surface

8. Different CRT indications can be expected when testing tubing with thin walls than those obtained from tubing with thick walls. Assume thin-wall tubing is being tested with an angle beam. Will you expect to see a reflection from the back surface? (Yes) (No)_____

Return to page 5-29, frame 9.

11. angle

12. Assume a test of bonding between 2 materials is to be made. A choice of 10 mc and 20 mc transducers is available. The best resolution of lack of bond discontinuities will be obtained if the_____mc transducer is used.

Return to page 5-29, frame 13.

So far in your study of ultrasonic testing we have considered the techniques to be used in testing materials of various shapes and composition and have learned what may be expected in the way of CRT indications when discontinuities are encountered in test specimens. In practice, the indications on the CRT are not as simple as may have been suggested. Many CRT indications are caused from secondary influences from the test instrument and the test specimen. We need to know the existence of these, what they look like on the CRT, and to disregard them in evaluating the results of ultrasonic testing.

The indications that may be caused by secondary influences are divided into 7 classes, as follows:

- Electrical interference.
- Interference from the transducer.
- Interference from the surface of the test specimen.
- Interference caused by refraction of the sound beam.
- Interference caused by the shape of the test specimen.
- Interference caused by material structure.
- Accidental interference.

The first 2 classes are caused by malfunctions in the test instrument; the remainder are inherent in the ultrasonic test method. The type of CRT indications that may be expected from each of the many possible "irrelevant indications" will be explained and illustrated on succeeding pages.

Turn to page 6-2.

From page 6-1

False indications resulting from electrical interference can be due to the effects of noise, power supply, or reverberations in the test specimen.

Noise can be recognized as a vertical broadening of the horizontal sweep line on the CRT. This can be caused by poor electrical contact in the plugs and receptacles that interconnect the transducer and test instrument, poor electrical contact between the coaxial cable and terminating plugs, or poor electrical contact within the amplifier circuits in the test instrument.

The indication from noise effects is much the same as the noise that can result from test specimens with relatively coarse grain structures. You learned in Volume II that this type of noise can be eliminated on instruments with a REJECT control by moving the horizontal sweep line vertically on the face of the CRT.

If the noise indication is caused by electrical interference, moving the sweep line vertically by use of the REJECT control will have no effect in eliminating the noise.

Noise conditions that are due to poor electrical contact in connections exterior to the test instrument case can usually be corrected by cleaning the electrical plugs and receptacles.

Electrical noise effects are similar to noise that can be caused by the test specimen. When noise indications are received, your first step in isolating and correcting the cause of the noise should be . . .

determine if caused by instrument or specimen . . . . . Page 6-3

check and clean the electrical plugs and receptacles . . . . . Page 6-4

From page 6-2

That's right. When you receive noise effects on the CRT, first determine if the source is the specimen or the instrument. If the instrument is so equipped, operate the REJECT control to move the horizontal trace vertically. If in the specimen, the noise indication will disappear; if in the instrument, it will remain. If the instrument does not have reject capability, lift the transducer from the test specimen. The noise indication will disappear if caused by the specimen, but will remain if the instrument is defective.

An apparent discontinuity indication that is moving in a horizontal plane along the CRT trace is caused by the main electrical power supply, probably due to other industrial equipment. This problem can also be caused by a defective thyratron (gas filled) tube in the test instrument. This is the tube that generates the ultrasonic pulse. This indication can be distinguished from a discontinuity since it is irregular and not synchronized with the time base.

Select the best completion for the following statement. The first step in isolating the cause of a moving indication on the CRT trace should be . . .

test the thyratron tube . . . . . Page 6-5

connect to a different electrical power circuit . . . . . Page 6-6

From page 6-2

What if the noise is caused by the test specimen? If so, you might be going to a lot of trouble for nothing.

First, you should determine if the noise is coming from the specimen or the test instrument. This can be isolated in one of two ways (1) if the instrument has a REJECT control, move the CRT trace vertically and if the noise disappears, the instrument is operating satisfactorily, and (2) if there is no REJECT control, lift the transducer off the test specimen. The noise will disappear if the instrument is not defective.

Once the trouble is isolated to the test instrument, proceed to check and clean the electrical plugs and receptacles.

Turn to page 6-3.

From page 6-3

No. The most practical first step to be taken if you encounter a moving indication on the CRT will be to disconnect the test instrument and try it out on a different electrical power circuit. If the problem is caused by industrial equipment that is connected to the first circuit, the indication will disappear when connection is made to a different circuit. If the test instrument is defective, the moving indication will remain regardless of which electrical circuit is used. When this is determined, the trouble can be isolated in the instrument.

Turn to page 6-6.

Right. The first step in isolating the source of electrical interference resulting in a moving indication on the CRT should be to determine if the trouble is in the main electrical power source. If connection to a different electrical circuit has no effect on the indication, then the test instrument can be checked and repaired.

Another cause of electrical interference is "reverberation (re-echo)" in the test specimen. This can be caused when materials with a very low attenuation are being examined. This interference is caused by the test specimen not absorbing the initial sound pulse before the next pulse is transmitted. The result will be apparent discontinuity indications that are synchronized with the sweep line or time base.

These disturbances cannot be omitted completely but can be reduced to the point that correct interpretation of valid discontinuities is possible by reducing the gain of the amplifier in the test instrument.

Interference caused by electrical conditions will interfere with proper evaluation of reflections from discontinuities. The effects of this interference can be controlled by the ultrasonic operator.

False ..... Page 6-7

True ..... Page 6-8

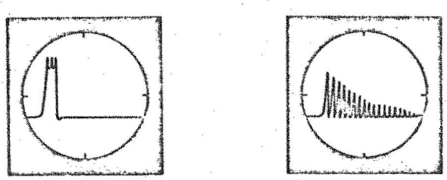
Sorry, but you are wrong. Electrical interference is caused by the ultrasonic test equipment. If it is defective, many of the faults can be corrected by the operator, or he can isolate the trouble to determine that it is definitely in the test instrument.

Turn to page 6-8.

From page 6-C

Correct. The effects of electrical interference can be controlled by the ultrasonic operator.

The next and last irrelevant indication that results from a malfunction in the testing system is due to a loose or defective crystal. This unwanted indication is characterized by a prolonged ringing which widens the initial pulse as shown in the below illustration. View A shows the front surface indication that should be expected from a good transducer; View B shows the type of indication that will result if the crystal should happen to become loose in its holder. The prolonged ringing effect will result in very little capability of the instrument to detect discontinuities.



VIEW A VIEW B

What is the main advantage of a narrow initial pulse?

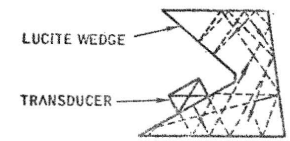
Better "near surface" resolution . . . . . Page 6-9

Better penetrating power . . . . . Page 6-11

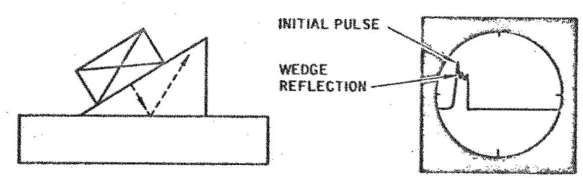
From page 6-8

You're correct. The main advantage of a narrow initial pulse of sound is detection of discontinuities close to the surface of the test specimen.

During angle beam contact testing, using angle wedges, a certain amount of unwanted reflections are received from the wedge. Reflections within a typical wedge are shown in the illustration below.



Ordinarily, a portion of the energy from the transducer is reflected at the interface between the wedge and test specimen, away from the transducer. A small amount of the reflected energy will return to the transducer, and be displayed on the CRT. The use of Lucite for construction, and shaping wedges properly, causes a maximum amount of sound attenuation so that the amount actually displayed on the CRT is negligible immediately following the initial pulse as shown below.



The disturbance due to reflections in the angle wedge can be identified easily by the ultrasonic operator. When the transducer with angle wedge is lifted off the test specimen this unwanted indication will still be present on the CRT.

What can you do to eliminate unwanted reflections from the angle wedge?

Nothing . . . . . Page 6-10

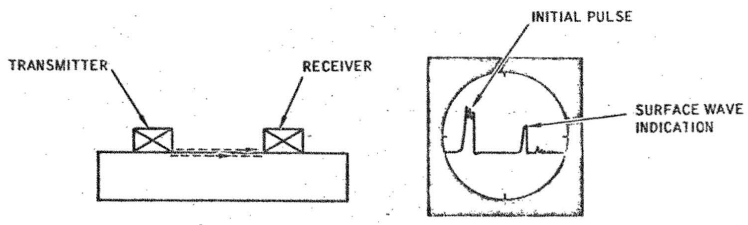
Experiment with different angles of incidence . . . . . Page 6-12

From page 6-9

That is correct. There is nothing you can do to eliminate the small reflections from the interface between the angle wedge and the surface of the test specimen. These reflections are inherent to the angle beam method of contact testing. Once it is understood that they will always be present there will be no difficulty in evaluating reflection from actual discontinuities.

The surface of the test specimen can cause unwanted reflections that must be understood when evaluating indications that appear on the face of the CRT.

When using straight beam test techniques with 2 transducers, one a transmitter and one a receiver, it is possible to have a small surface wave component of the sound beam transmitted to the receiver as shown in the illustration below. This type of unwanted reflection can be recognized easily. When the distance between the transmitting and receiving transducers is increased, the apparent discontinuity indication will move away from the initial pulse on the CRT.



This type of irrelevant surface indication is most likely to occur when the surface of the test specimen is curved. It can be reduced by using rubberized nylon or other plastic-sheet materials as a couplant between the transducers and test specimen.

What is the advantage of using a plastic-type solid material as a couplant?

To provide a smoother surface . . . . . Page 6-13

To provide a better acoustic impedance match . . . . . Page 6-14

From page 6-8

Sorry. You answer is not correct. Penetrating power is proportional to the amount of energy in the transmitted beam, there being more power in a longer pulse than a short one.

Remember. A short pulse will provide better resolution of discontinuities close to the surface of the test specimen. And a short pulse cannot be obtained if the transducer crystal is loose.

Turn to page 6-9.

From page 6-9

Nothing can be gained by experimenting with different angles of incidence - that is, using different wedge angles. The reflections from the interface between the wedge and test specimen will always be present to a certain degree during angle beam testing by the contact method. However, they will create no problems once it is realized that this is an ever-present phenomena.

Turn to page 6-10.

From page 6-10

You seem to have forgotten the purpose of a couplant in contact testing.

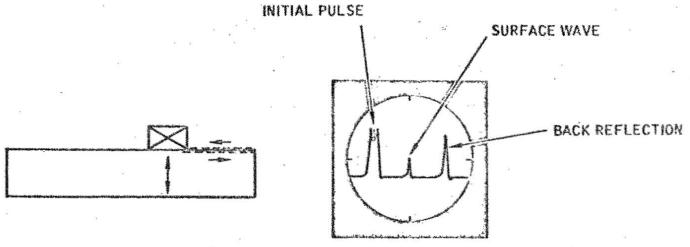
A couplant serves the purpose of excluding air between the transducer and surface of the test specimen so that there will be a maximum transfer of sound energy from one to the other. A liquid couplant is normally used, but in certain specialized applications it is more advantageous to use a solid material such as rubber, plastic, etc. A couplant also serves as a medium to match the acoustic impedance of the transducer and test specimen. Ideally, we can have the maximum transfer of sound energy when the impedances are equal.

Turn to page 6-14.

From page 6-10

That's right. In the application cited, the plastic-type material used as a couplant will provide for a better impedance match between the transducer and test specimen. This reduces the possibility of generating unwanted surface waves.

Surface waves generated during straight beam testing can also cause unwanted irrelevant indications when they reflect from the edge of a test specimen as shown below.



A small surface wave component is transmitted in all directions from the transducer. When the transducer is close to an edge of the specimen a reflection will be obtained that may be interpreted as a discontinuity. This type of irrelevant indication can be detected by moving the transducer. Movement of the transducer will cause a surface wave indication to move across the CRT screen with the movement of the transducer.

Is the following statement true or false? It will not be possible to detect discontinuities if the transducer is close enough to the edge of the test specimen that spurious surface wave indications are received.

True . . . . . Page 6-15

False . . . . . Page 6-16

From page 6-14

Your answer is not correct. It will be possible to detect discontinuities in the presence of unwanted surface wave indications. Once the spurious indication is identified as such, we can disregard it and look only for other indications. There will be many occasions when indications are present on the CRT screen which are meaningless insofar as detection of discontinuities is concerned. The correct answer is "false".

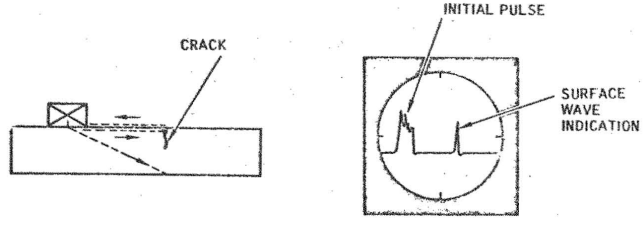
Turn to page 6-16.

From page 6-14

Very good. It will very definitely be possible to locate discontinuities in the presence of these unwanted surface wave indications. Once the indication is identified as coming from the edge of the specimen, you can disregard it and look for discontinuities within the specimen.

You will recall that surface waves may be used to detect surface cracks in test specimens. Not all reflections that are received from these unwanted surface waves are spurious indications. Some will reveal actual discontinuities.

Assume that you are testing with shear waves using angle beam techniques. A small surface wave component will be generated as shown in the illustration below. A surface crack will cause reflection and display of an indication on the CRT screen.



You can determine if the reflection is from a surface wave by running a finger along the surface in front of the transducer. If the reflection is due to surface waves, the wave will be damped by your finger. To determine crack location, move the transducer until the discontinuity indication coincides with the indication from the initial pulse. At that point, the transducer wedge center line is directly over the crack.

Under which of the following conditions of angled sound beam transmission do you think would be more likely to generate a surface wave component?

Small angle of incidence . . . . . Page 6-17

Large angle of incidence . . . . . Page 6-18

From page 6-16

Your answer is not correct. At a small angle of incidence the sound beam will strike the surface of the test specimen closer to the perpendicular and there will be less refraction than if a larger angle is used. When there is least refraction, the small surface wave component will be least. As the angle of incidence is increased, the surface wave component will increase until the second critical angle is reached when the refracted beam is composed entirely of surface waves in the test specimen.

Turn to page 6-18.

From page 6-16

Right. A surface wave component is more likely to be generated during angle beam testing if you are using a large angle of incidence.

Unwanted surface wave components of the sound beam in the test specimen can also cause irrelevant indications on the CRT when the surface is rough. The surface of the test specimen may have been machined, but if surface grooves or machining marks exist and the distance between them happens to correspond to one wavelength of the surface wave component, reflection will occur and result in apparent discontinuity indications on the CRT.

These unwanted surface wave reflections again can be distinguished from valid discontinuity indications by running your finger along the test surface. If the indication is caused by surface waves, the waves will be damped by your finger and the indication reduced or cancelled.

Which of the following actions should be taken when testing a rough-machined specimen and a known irrelevant indication due to surface waves is received? Assume a discernible back reflection is obtained on the CRT.

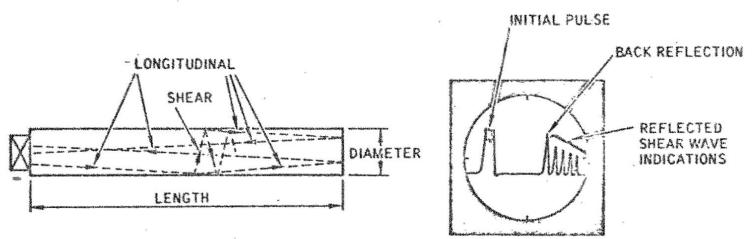
Proceed with the test . . . . . Page 6-19

Grind the surface . . . . . Page 6-20

From page 6-18

Correct. Surface grinding should not be done if sufficient sound energy is being transmitted into the specimen to obtain a back reflection. The surface wave reflection is identified as irrelevant, so it can be disregarded and the specimen tested for valid discontinuities.

Unwanted reflections can occur as a result of "mode conversion" in the test specimen. "Refraction" and "reflection" can occur any time a sound beam strikes an interface between 2 mediums at an angle other than 90°. You learned in Volume I that when this happens, as shown in the following illustration, the reflected beam inside the specimen will have both a longitudinal and shear component. The shear wave component can, at times, cause additional indications on the CRT screen.



In the example shown above a long bar is being tested. The reflected shear waves travel a longer distance than the longitudinal waves and, for this reason, will appear on the screen following the back reflection and at regular intervals. They can be disregarded in evaluating discontinuity indications that occur between the front and back surface indications.

Proper transducer selection will assist in reducing unwanted reflections such as those shown above. Which of the following transducers at a given frequency will give less beam spread?

Small transducer . . . . . Page 6-21

Large transducer . . . . . Page 6-22

From page 6-18

6-20

Your answer is not the best of the 2 possibilities. When a back reflection is received, you know enough sound energy is being transmitted into the specimen to locate a discontinuity if one is present.

The irrelevant indication from the surface wave should be disregarded and the test continued. Under conditions where irrelevant indications clutter the CRT to the extent that valid indications cannot be distinguished, you may have to smooth the surface. However, don't resort to this unless absolutely necessary.

Turn to page 6-19.

From page 6-19

6-21

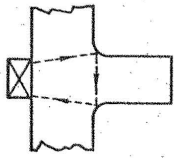
Your selection is wrong. A small transducer produces more beam spread than a large one at a given frequency. In this case, selection of a large transducer will provide a sharper beam and the amount of internal reflection will be reduced.

Turn to page 6-22.

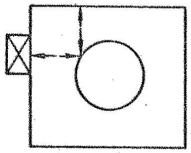
From page 6-19

Correct. A large transducer will give you a sharper beam. With the sharper beam, unwanted internal reflection will be reduced.

Apparent discontinuity indications can be caused by reflection in irregularly shaped test specimens such as are illustrated below.



VIEW A



VIEW B

The possibility of reflections from fillets and corners must be taken into consideration when testing castings such as is shown in View A, above. Specimens with internal bore holes will also provide spurious indications as shown by View B.

When testing specimens such as those illustrated the operator should examine the drawing for the article and select the point for making the test that will give the least amount of unwanted reflections.

Suppose a test of an irregular-shaped specimen is being conducted. Which of the following actions should we take to confirm that an apparent discontinuity is actual or due to a reflection from a corner?

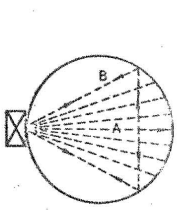
Test from a different part of the surface . . . . . Page 6-23

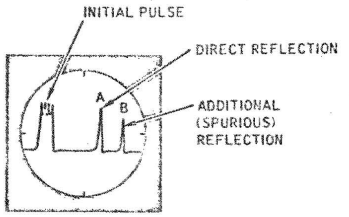
Use shear wave techniques. . . . . Page 6-24

From page 6-22

That's right. The operator should make a test from another location on the surface of the specimen in an effort to evaluate the indication as being either from an actual discontinuity or from a corner of the specimen.

Additional reflections following the back surface echo can occur when tests are being made on cylindrical specimens, especially when the face of the transducer is not curved to fit the form of the specimen as shown in the following illustration.





The beam spread of a sound wave depends on the size of the transmitting area of the transducer. When a flat transducer is placed on a curved surface, the transmitting area is very small and the beam spread will be practically 180°. Additional reflections will occur after the first back reflection. These reflections will occur sooner and more frequently with a smooth test surface. On a rough surface such as a casting, the roughness of the surface will scatter the sound and the additional reflections may not be noticed.

This type of spurious indication can be identified easily since the same type of indication will occur all along the length of the cylindrical specimen. Reflections from discontinuities, on the other hand, will cause a changing indication as the transducer is moved along the cylinder.

Which of the following methods will be best for narrowing the width of the sound beam transmitted into a cylindrical test specimen?

Use a smaller transducer . . . . . Page 6-25

Use a curved plastic shoe that fits the specimen contour . . . . . Page 6-26

From page 6-22

6-24

Your answer is not correct. Use of shear wave techniques would not be an aid in confirming that an indication is from a discontinuity or due to the shape of the specimen. You should make the test from another location on the test surface and try to avoid reflections from a corner.

Turn to page 6-23.

From page 6-23

6-25

A smaller transducer will not help to any great extent. As long as the surface of the transducer is flat there will still be a large spreading of the sound beam. Remember, the smaller the transducer, the greater the beam spread and, in this case, the effective transmitting area of the transducer that touches the test specimen is smaller. You have gained nothing. The best thing to do is to use a plastic shoe that is ground to fit the contour of the cylindrical specimen.

Turn to page 6-26.

Correct. A smaller transducer won't do the job since it will cause more spreading of the sound beam, if anything. The only practical method of narrowing the sound beam will be to use a plastic shoe that is ground to fit the contour of the cylindrical specimen.

Now we will consider the effects of internal grain structure on sound transmission and the types of indications that might be obtained with coarse grain structures.

There are times when sound transmission in a material is impossible even with the strongest possible signal and maximum gain of the amplifier in the test instrument. Under such conditions it may not be possible to receive a reflection from the back surface and system sensitivity for locating discontinuities is practically zero. It may be possible to improve the sound transmission capability of the system by using a lower frequency.

When a situation such as that described above occurs, what type of grain structure is indicated?

Fine . . . . . Page 6-27
Coarse . . . . . Page 6-28

You guessed, didn't you? This particular point has been discussed previously. Coarse grain structure absorbs the sound beam. If coarse enough, the sound beam will be completely absorbed and there will be no reflection back to the transducer. On the other hand, fine grain structure offers little opposition to the passage of the sound beam and maximum transmission efficiency is obtained.

Turn to page 6-28.

Excellent. A coarse grain structure, if sufficiently coarse, will absorb the sound beam and there will be no reflection back to the transducer for display on the test instrument.

Coarse grain structures may also cause reflections that appear across the width of the cathode ray tube if the test is attempted at a high frequency as shown by the following illustration.



It is not difficult to identify these indications due to their irregularity. Identification of discontinuity indications will be very difficult, if not impossible. The only thing that can be done to eliminate or reduce the effect of these unwanted reflections is to lower the frequency and change the direction of the sound beam by using an angle beam transducer.

The relationship of wavelength to size of the grain in a specimen is the factor that causes reflections such as those shown above. The size of the grain in a specimen will remain constant, so we can say that as the frequency is lowered, wavelength . . .

increases . . . . . Page 6-29
decreases . . . . . Page 6-30

Very good. You remembered that wavelength is inversely proportional to frequency so if the frequency is decreased, the wavelength increases.

The last irrelevant indication to be considered is one that will be received accidentally and is caused by use of too much couplant. This type of indication will move slowly along the trace of the CRT or change amplitude as couplant flows along the surface of the test specimen. It is usually encountered when using angle beam techniques in contact testing.

What can we do to assure that this type of irrelevant indication does not occur during testing?

Use the correct frequency . . . . . Page 6-31

Do not use an excessive amount of couplant. . . . . Page 6-32

From page 6-28

6-30

You're not correct. You learned in Volume I that "wavelength" is equal to velocity of sound divided by the frequency, or that wavelength is inversely proportional to frequency. So, in this case, the frequency is being decreased and the wavelength will have to increase to satisfy the mathematicl relationship of wavelength, velocity, and frequency.

Turn to page 6-29.

From page 6-29

6-31

What happened? You shouldn't have turned to this page. You have an indication on the CRT that slowly moves across the face of the tube or changes in amplitude. This is an indication that you are generating a small surface wave component and it is being reflected by an excess of couplant. Changing the frequency will be no help at all - all that has to be done is to remove the excess couplant and the problem will be solved.

Turn to page 6-32.

From page 6-29

That is correct. The operator merely needs to exercise caution in application of couplant and he will have no trouble with an irrelevant indication that moves on the CRT screen or changes in amplitude as the couplant flows on the test surface.

All of the various types of irrelevant indications that have been covered come from the test method itself with the exception of those covered in the beginning of the discussion that are a result of equipment troubles.

These indications will cause no difficulties in interpreting ultrasonic test results so long as it is understood that not all "pips" on the CRT indicate a discontinuity in the test specimen. Also, you need to remember the basic principles of isolation for these apparent discontinuity indications to separate valid from invalid discontinuity displays.

Turn to page 6-33.

From page 6-32

1. The _____ control on a test instrument may be used to move the CRT horizontal trace vertically to eliminate noise.



3. gain

4. Unwanted reflections from the Lucite wedge of an angle beam transducer are minimized by the_____ of the wedge.



6. acoustic impedance

7. During straight beam testing, a small_____wave component is transmitted in all directions from the transducer. If this wave component strikes an edge of the specimen or a crack, reflection will occur and provide a spurious discontinuity indication.



9. narrow

10. A _____ grain structure will absorb ultrasonic energy to the extent that it may not be possible to conduct tests on some specimens.



1. REJECT

2. An apparent discontinuity that broadens the CRT sweep line is caused by _____ interference.

4. design (shape)

5. A loose or defective crystal in the transducer will produce a _____ effect on the screen of the CRT.

7. surface

8. Suppose you are testing a rough-machined surface with 2 transducers, one for receiving, and one for transmitting. The transducers should be oriented p_____ to the grooves.

10. coarse

11. An indication on the CRT that moves slowly with respect to the front surface indication and may change amplitude is caused by use of too much _____ .

2. electrical

3. Reverberation (re-echo) in the test specimen is caused when the specimen does not absorb the sound pulse before a second pulse is transmitted. This spurious indication can be reduced by adjusting the _____ of the amplifier.

Return to page 6-33, frame 4.

5. ringing

6. A plastic-type solid material is required as a couplant under certain testing conditions to provide a better match of a_____ i_____ between the transducer and test specimen.

Return to page 6-33, frame 7.

8. parallel

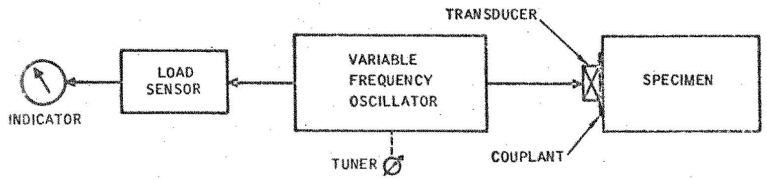
9. A curved plastic shoe that fits the curvature of a cylindrical specimen will cause a n_____ sound beam to be transmitted into the specimen.

Return to page 6-33, frame 10.

11. couplant

12. Turn to page 7-1 for a discussion on resonance testing.

You learned earlier in your study of ultrasonic testing that when a continuous beam of ultrasonic energy (longitudinal wave mode) is introduced into a specimen and reflected in phase with the incoming energy, resonance occurs. Standing waves are set up within the specimen and the specimen vibrates with a considerable increase in amplitude. You learned that resonance occurs when the thickness of the specimen is equal to a half-wavelength, or exact whole number multiples of a half-wavelength, or exact whole number multiples of a half-wavelength. We also found the resonance principle is used primarily as a thickness measuring system, but can also be used to find relatively large discontinuities, delamination, or lack of bond.



Shown above is a schematic diagram of a typical resonance generator/indicator instrument coupled to a specimen. You'll recall that a tunable, variable frequency oscillator is used to excite the transducer, causing the transducer to vibrate over a range of frequencies. When the transducer is coupled to a test specimen, the ultrasonic vibrations generated by the transducer are transmitted into the specimen as continuous longitudinal (compression) waves. The waves reflect from the opposite surface of the specimen and return to the transducer. If the oscillator is tuned to a resonant frequency for the test specimen, the waves transmitted into the specimen will be in phase with previous waves and result in a resonant condition.

Turn to page 7-2.

From page 7-1

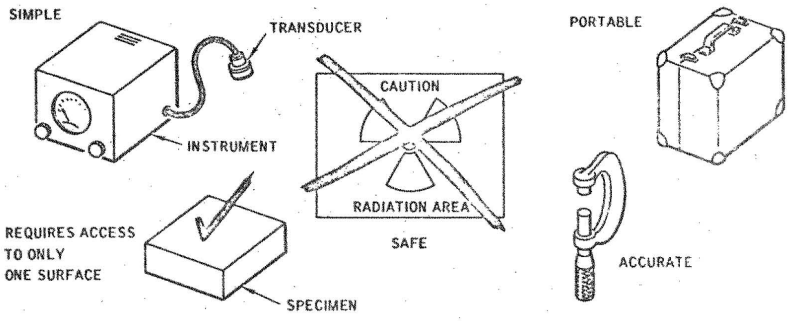
Any frequency which produces a resonant condition in the specimen causes a load change in the oscillator. This load change appears as a pip on a cathode-ray (CRT) screen, a meter deflection, a flashing neon light, or an audible sound change in an earphone.

Most instruments have a direct readout, which means actual thickness measurements can be read from a scale or meter. Others require the use of charts or tables to determine thicknesses. And to use these charts or tables, you must determine the fundamental resonant frequency. You then find this frequency on the chart or table and read off the corresponding thickness.

The application of resonance testing falls into 3 broad classification: (1) gaging, (2) corrosion inspection, and (3) detection of discontinuities. Typical examples of materials which can be tested include extruded, drawn or spun metals; hollow castings; rolled sheet metal; chemically or machine milled articles; piping and tubing; glass; ceramics; and rigid plastics.

Turn to page 7-3.

The chief advantages of resonance testing are that the equipment is usually simple and in most cases portable. It requires access to only one surface of a test specimen and, like pulse-echo/through transmission equipment, is considered to be safe. By safe, we mean there is no radiation hazard, etc. We also find the resonance system extremely accurate when measuring thicknesses of relatively thin materials (within 0.1 to 3 percent of the actual thickness) and in determining lack of bond in bonded materials.



Indications generally are not affected by common variables, e.g., ambient temperature, magnetic properties, small differences in alloy or heat treat, or proximity to an edge or fillet.

Would you say the operation of resonance equipment requires a high degree of training?

Yes . . . . . Page 7-4

No. . . . . Page 7-5

Your selection "yes" is not correct. Resonance equipment in general does not require a high degree of training to operate. Recall that most resonance instruments provide a direct readout or indication. Others require only the use of a simple conversion chart or a table of values.

Turn to page 7-5.

You're right. Resonance equipment in general does not require a high degree of training to operate. The equipment is usually simple and, when properly used, accurate and safe.

The conditions which limit the usefulness of resonance testing are largely determined by the test specimen itself. Specimen limitations include excessively rough front and back surfaces, severe corrosion, lack of parallelism, complicated geometry or shapes, and material structure, e.g., excessive grain size, porosity, and irregular inclusions.

Can we say that, in general, the conditions which limit the usefulness of resonance testing are basically the same as those limiting the use of other ultrasonic test systems?

Yes . . . . . Page 7-6

No . . . . . Page 7-8

Right. The conditions which limit the usefulness of the resonance system are basically the same for all ultrasonic test systems, be it pulse-echo, through transmission, or resonance. Ultrasonic waves are influenced by a test specimen in much the same manner regardless of the test system used.

In resonance thickness measuring, the thickness of a specimen is generally limited to between 0.004 and 12 inches. But sometimes, depending on frequency and equipment selection, thicknesses of several feet can be measured. However, it should be pointed out that as thickness increases, accuracy decreases. We find the pulse-echo system to be the better system for measuring thicker materials. And for accuracy, surface taper should not exceed 2 degrees. Beyond that, surface taper reduces resonance indication amplitude and resonance may not occur.

Both the contact and immersion methods are used in resonance testing . . . the contact method being the most common. In contact testing with resonance equipment, the same basic principles are involved as when contact testing with pulse-echo or through transmission equipment. The transducer is placed directly on the test specimen. And an ultrasonic wave is transmitted into the specimen through a thin layer of couplant. The main difference is that a continuous longitudinal wave is used in resonance testing.

Is the following statement true or false? It is also possible to conduct ultrasonic resonance testing with the test specimen and transducer submerged in water.

True . . . . . Page 7-7

False . . . . . Page 7-9

From page 7-6

7-7

Correct. It is possible to conduct resonance testing with the test specimen and transducer submerged in water. You remembered that this is the basic principle of immersion testing, and that the immersion method is sometimes used in resonance testing.

We have found the immersion method is widely used in ultrasonic pulse-echo and through transmission testing. In these systems, the water path between the transducer and the specimen is used as both a couplant and a time delay medium. By time delay, we mean the transducer is spaced far enough from the test specimen to prevent any multiple echoes from interfering with specimen indications.

In immersed resonance testing, the water path is used not only as a couplant but also as an integral part of the test system. Resonance conditions are set up in both the water path and the specimen. And instead of the test specimen resonances appearing as separate indications which could interfere with or distort the water resonances, the test specimen resonances cause a sharp attenuation of the water resonance at the resonant frequencies of the test specimen. It is this attenuation of the water path resonances which is detected and converted into recognizable information by the test instrument. And as stated before, only continuous longitudinal waves are transmitted into a specimen in resonance testing.

In immersed resonance testing, the test equipment . . .

senses specimen resonance to determine material thicknesses or quality. . Page 7-10

senses water path resonance amplitude changes to determine material thicknesses or quality . . . . . Page 7-11

From page 7-5

7-8

Wrong. The conditions which limit the usefulness of resonance testing can be said to be basically the same as those limiting the usefulness of other ultrasonic test systems.

Doesn't the resonance system rely on the propagation of ultrasonic energy for resonance indications? Of course. We learned earlier how a specimen's characteristics affect ultrasonic energy. We found that rough surfaces and some types of materials tend to scatter or absorb the sound beam. Surfaces which are not parallel reflect the beam in a direction other than back to the transducer. We also learned how unfavorable geometry reduces the effectiveness of ultrasonic testing. Since the resonance, pulse-echo, and through transmission systems all depend on ultrasonic wave propagation, the same general conditions which limit the use of one also limit the others.

Turn to page 7-6.

From page 7-6

7-9

You say it is not possible to conduct ultrasonic resonance testing with the test specimen and transducer submerged in water. Your selection is wrong. It is possible to conduct resonance testing with the test specimen and transducer submerged in water.

Isn't this type of testing known as the immersion method? Yes. Didn't we just learn the immersion method is used in resonance testing too, although not as frequently as the contact method? Yes. Therefore, resonance testing can be conducted with the test specimen and transducer submerged in water.

Turn to page 7-7.

From page 7-7

7-10

Incorrect. In immersed resonance testing, the test equipment senses water path resonance amplitude changes (not specimen resonance) to determine material thicknesses or quality.

Recall that the specimen nulls or attenuates the water resonances at the specimen resonant frequencies. The water path becomes in effect a secondary transducer, and it is the effect of the test specimen on the water resonances which are detected and used by the instrument.

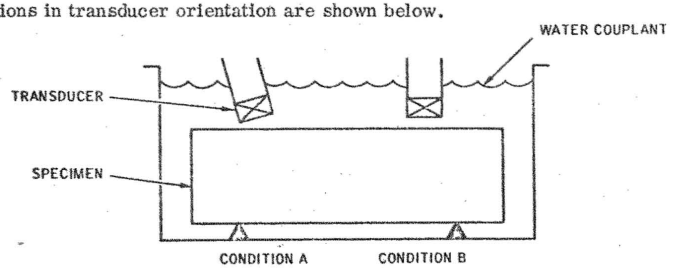
Turn to page 7-11.

From page 7-7

Right. In immersed resonance testing, the test equipment senses water path resonance amplitude changes (not specimen resonance) to determine material thicknesses or quality.

The water distances used in immersed resonance testing range from approximately 1/4-inch to 2-1/2 inches depending on the transducer used. And a spacing can vary approximately 1/4-inch without affecting accuracy. The critical factor here is transducer orientation. We find a nonsymmetrical water path will distort the resonance patterns and result in unreliable instrument indications. Therefore, the transducer must be kept perpendicular (normal) to the specimen front surface in immersed resonance testing.

Variations in transducer orientation are shown below.



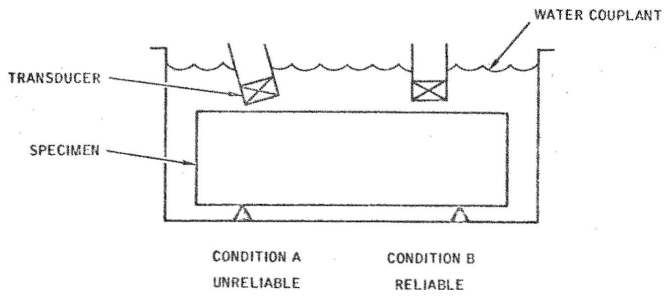
Which condition provides the most accurate resonance indication?

Condition A . . . . . Page 7-12
Condition B . . . . . Page 7-13

From page 7-11

Wrong. Condition A does not produce the most accurate resonance indications. In fact the opposite is true.

Recall that orientation was stated to be a critical factor in immersed resonance testing. You were told that unless the transducer is positioned perpendicular to the specimen front surface, the resonance patterns will be distorted and unreliable.



Now, doesn't condition A show the transducer at an angle to the specimen front surface? Of course. Doesn't condition B show the transducer properly oriented?

Turn to page 7-13.

From page 7-11

Excellent. Condition B does provide the most accurate resonance indications.

The preparation of a specimen's surfaces for resonance testing generally involves the same requirements or conditions as when testing with other types of ultrasonic equipment. For example, dirt, grit, and loose paint or scale should be removed. And any severe surface irregularities should be reworked ... preferably using a disc-type sander. We also should keep in mind that the extent of surface preparation largely depends on the condition of the specimen surface opposite the front surface. If the opposite surface is seriously pitted or scaled, resonance signals will be weak, and it is then necessary to prepare the front surface quite thoroughly. However, it is not necessary, or even desirable, to prepare a polished surface.

Select the best answer to the following statement.

If the surface opposite the front surface of a specimen is smooth, it is . . .

essential that the front surface of the specimen be prepared quite thoroughly . . . . . Page 7-14

usually not necessary to rework the front surface of the specimen except for cleaning and maybe the removal of paint high spots . . . . . Page 7-15

From page 7-13

You are incorrect. It is not necessary to go to any great lengths in preparing a specimen for test if its surface opposite the front surface is relatively smooth. Usually the removal of paint high spots, etc., is adequate. The front surface, however, should be clean and free of loose paint or scale that might reduce resonance amplitude.

Turn to page 7-15.

From page 7-13

Fine. You selected the better answer. Except for cleaning and maybe the removal of paint high spots, it is usually not necessary to rework the front surface of a specimen if its opposite surface is smooth.

When preparing a specimen for thickness measuring, it is best to clean an area considerably larger than the transducer . . . approximately 4 to 6 inches square. This enables you to determine any local variations in metal thickness. And, when local pitting is severe, it is often possible to obtain measurements by moving the transducer slightly from the point where it was first applied to the specimen.

Plates with very deep local pitting should be tested from the pitted side if possible. A measurement should be taken as close to the pitted area as possible to establish the "normal" wall thickness. The depth of the pits is then measured using a mechanical depth gage and subtracted from the wall thickness. It is generally not desirable to grind the specimen down to the depth of the pit as this would reduce the strength of the plate.

Would you say the amount of surface preparation required is dependent on the test specimen?

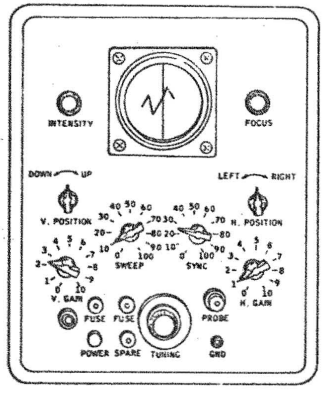
Yes . . . . . Page 7-16

No . . . . . Page 7-17

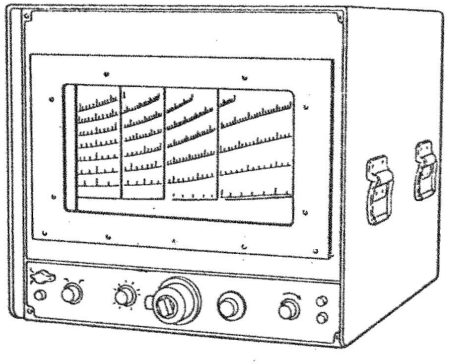
From page 7-15

You're doing fine. The amount of surface preparation required is dependent on the test specimen. Smooth, clean surfaces require little preparation while rough or severely pitted surfaces require extensive rework before resonance testing can be accomplished.

The selection of resonance equipment depends on the task you have at hand. For example, if you're checking laminated materials, you should use resonance equipment specifically designed for checking delamination or lack of bond. If you're measuring material thicknesses, corrosion, or looking for gross discontinuities in solid materials, you should use a thickness tester, etc. Where extreme accuracy is required, you should use the larger instruments. If the job is in the field and doesn't require the extreme accuracy, you should consider a more portable, compact unit that can be carried using a shoulder strap or similar device. The following are typical resonance instruments.



BOND TESTER



CRT-TYPE THICKNESS TESTER

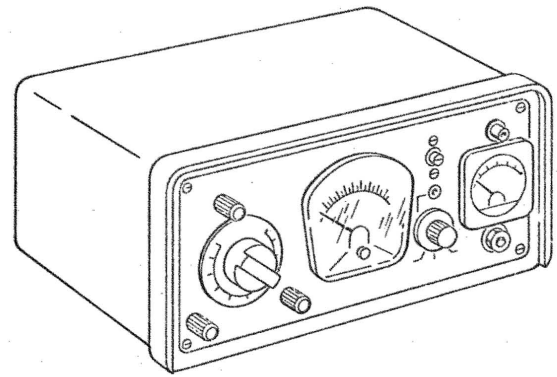
Turn to page 7-18.

You say the amount of surface preparation required for making a resonance test does not depend on the test specimen. You're wrong. Surface preparation does depend on the test specimen.

Recall that if the test specimen has relatively smooth, flat surfaces that are parallel, little preparation other than maybe general cleaning is required. Again, loose "finishes" tend to reduce resonance amplitude. Any loose paint, scale, etc., should be removed. If a surface is excessively rough - it must be reworked by removing the high spots.

Now, isn't the amount of surface preparation required dependent on the test specimen ? Of course.

Turn to page 7-16.



METER-TYPE THICKNESS TESTER

Again - you should remember that as a specimen's thickness increases, resonance measurement accuracy usually decreases. For a specimen that is relatively thick, we should substitute pulse-echo equipment. We find the pulse-echo equipment is generally more accurate when measuring thicker materials.

Now, for example, let's say we're testing a honeycomb panel to determine its soundness or quality. We would use a resonance . . .

thickness tester . . . . . Page 7-19

bond tester . . . . . Page 7-20

From page 7-18

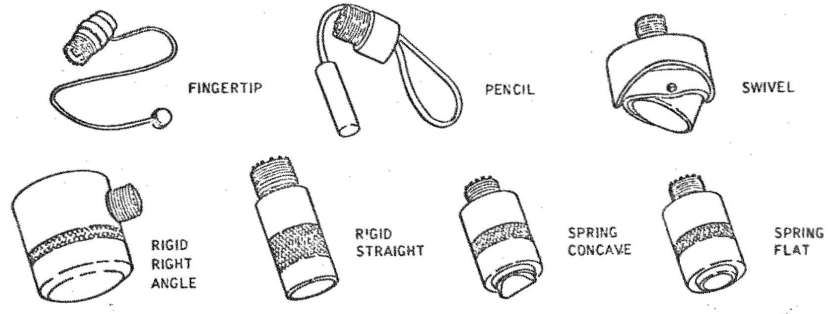
Wrong. For testing the quality or soundness of a honeycomb panel, we would use a bond tester (not thickness). Recall that a honeycomb panel is made up of multiple layers of material bonded together as an integral unit. Now wouldn't a bond tester be the better choice for checking the quality or soundness of this type of specimen? Of course. The thickness tester would be the better choice for gaging materials.

Turn to page 7-20.

From page 7-18

Right. When testing a honeycomb panel to determine its soundness or quality, we would use a bond tester. A bond tester is used to find unbonded areas whereas a thickness tester is used as a measuring device or to find gross discontinuities.

Several different types of transducers are available in a variety of sizes and shapes, depending on the test instrument used and the test situation. The transducer can be a "fingertip" or "pencil" type; spring-loaded; curved or flat faced. It can have a straight mounting or right-angle mounting; some even swivel. Some transducers are designed for immersion testing, others for contact testing.



The main thing to remember is to choose a transducer having a fundamental (minimum) resonant frequency higher than the frequency at which you're inspecting the specimen. This precludes the possibility of interference between transducer resonance and specimen resonances.

A piece of 1/4-inch thick steel plate has a fundamental (minimum) resonant frequency of 0.461 megacycles. And we're going to use its 3rd and 4th harmonics to test the steel. The transducer resonant frequency should be . . .

below 0.461 megacycles . . . . . Page 7-21

above 1.85 megacycles . . . . . Page 7-22

Incorrect. The transducer resonant frequency would have to be above 1.85 megacycles to avoid interference between the specimen and transducer resonances.

Recall that the 1/4-inch steel resonant frequency was 0.461 megacycles. We were using the 3rd and 4th harmonics for testing. The 4th harmonic is FOUR X the FUNDAMENTAL RESONANT FREQUENCY or 1.85 megacycles. Wouldn't the transducer resonant frequency have to be higher than 1.85 megacycles? Yes.

Turn to page 7-22.

You're correct. The transducer resonant frequency should be above 1.85 megacycles. You recognized that the 4th harmonic is approximately 1.85 megacycles (4 x 0.461) and the transducer resonance should be above that to avoid interference.

In most cases, there is a choice of several frequencies that can be used in measuring a given material thickness. These consist of the fundamental resonant frequency and its harmonics. And we find the selection of a test frequency is usually dependent on the characteristics of the test specimen. For example, low frequencies are used for specimens having corroded or pitted surfaces, lack of parallelism, large grain size or irregular inclusions. High frequencies are generally best for testing extremely thin materials, or where high sensitivity is desired. It also is desirable to use the 2nd through 10th harmonics rather than the fundamental resonant frequency. Measurements on fundamental resonant frequencies are somewhat less accurate than their harmonics.

Select the best completion for the following statement.

With material thickness being the determining factor, you would test a thick specimen using a . . .

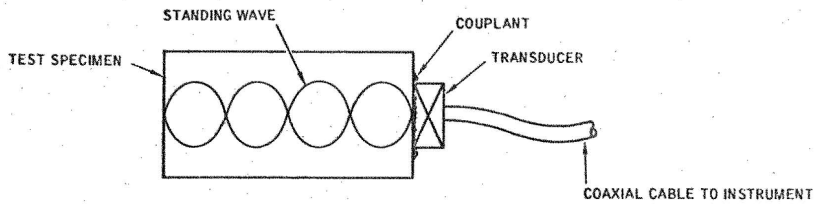
low test frequency. . . . . Page 7-23

high test frequency . . . . . Page 7-25

From page 7-22

Very good. You selected the better answer. Low test frequencies are generally required when testing thick materials. At the same time, we should keep in mind that fundamental resonant frequencies are less accurate than their harmonics. We should use harmonics where possible.

Various oils, greases or liquids can be used as couplants between the transducer and the test specimen in resonance testing. And as you already know, the purpose of a couplant is to exclude air between the transducer and specimen and transmit ultrasonic waves.



Light oils are considered very good for most contact resonance applications. Water with a wetting agent added is usually used in immersed resonance testing.

Couplants also affect the sensitivity of resonance instruments considerably and the selection of a suitable couplant frequently makes it easier to obtain a reliable indication. It is best to use light couplants such as very light oils or water on materials with relatively smooth and parallel surfaces. When thickness resonances are difficult to obtain, due to surface contours, surface roughness or lack of parallelism, glycerin with a wetting agent added is generally the most satisfactory. Greases are generally used on vertical surfaces or where liquid couplants are inconvenient.

Which of the following statements is true?

For the best "all round" testing, grease and glycerin are considered the most suitable couplants. . . . . Page 7-24

For the best "all round" testing, light oils or water are considered the most suitable couplants. . . . . Page 7-26

From page 7-23

Wrong. It is true that glycerin with a wetting agent added has the highest sensitivity and is best where resonance indications are difficult to obtain. However, grease on the other hand applies mostly to situations where liquid couplants run off or are hard to use; e.g., on vertical surfaces. Therefore, you should have selected the other statement as the "true" statement.

For the best "all around" testing, light oils and water are considered the most suitable couplants.

Turn to page 7-26.

From page 7-22

Incorrect. If material thickness is the only determining factor, we would use low frequencies in testing a thick specimen.

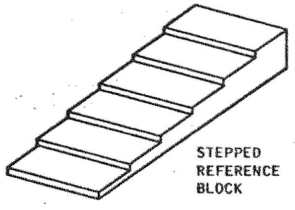
Recall that high frequencies generally apply to extremely thin materials. Let's remember it this way: The thicker the material, the lower the test frequency required; and the thinner the material, the higher the test frequency required.

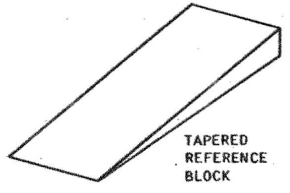
Turn to page 7-23.

From page 7-23

Excellent. Light oils or water are considered the best "all round" couplants for resonance testing. You should also remember that glycerin with a wetting agent added provides the highest sensitivity, particularly where surface conditions are unfavorable.

In the preceding chapters of this volume you learned that the accuracy and reliability of ultrasonic test equipment is largely dependent on the use of reference blocks, or a similar standard. The equipment had to be "standardized" to these blocks, or whatever was being used for comparison purposes, before proceeding with a test. Ultrasonic resonance equipment also require the use of reference standards, both for checking equipment accuracy, and for adjusting the instrument prior to use. Resonance equipment reference standards can be in the form of calibrated blocks, each one accurately ground to a predetermined thickness; stepped blocks; or wedges with a very fine degree of taper at which the thickness at various points is clearly indicated. Some instruments use plug-in "tuned circuits" and calibrated frequency markers to simplify instrument adjustment.





Also, we often find it practical to adjust an instrument directly on the material of interest. By using a point on the material where the thickness can be measured by some other means, e.g., with calipers or a micrometer, the equipment can be set up for the actual working conditions. Standard reference blocks are not required in this case.

Would you say resonance equipment need not be "standardized" to obtain accurate resonance indications?

Yes . . . . . Page 7-27

No . . . . . Page 7-28

Your choice "yes" is not the correct answer. Resonance equipment, like the other forms of ultrasonic test equipment previously discussed, requires the use of some sort of standard to obtain accurate indications.

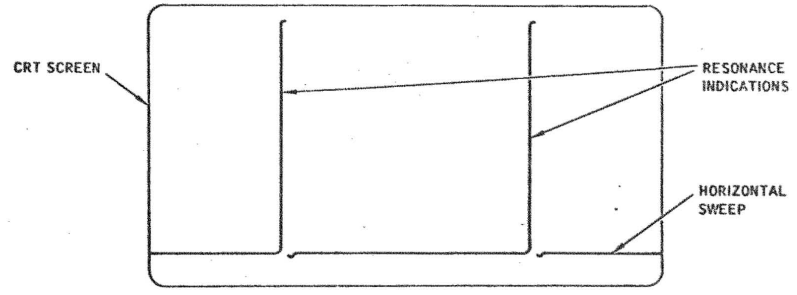
Keep in mind that a reference standard, be it a standard reference block, "tuned circuit," or the test material itself, is a basic requirement of resonance testing. Standards must be used both when setting up a test and later to check instrument accuracy.

Turn to page 7-28.

Good for you. You recognized the statement is wrong. Resonance equipment does require "standardizing" to obtain accurate indications. And by "standardizing", we mean some sort of reference standard must be used in setting up the equipment for a test.

You'll recall that most resonance instruments provide a direct readout. Actual thickness measurements are read from a scale or meter. Others require the use of simple charts or tables to determine thicknesses.

Following is a typical example of resonance indications presented on a cathod-ray tube (CRT) of a direct readout resonance thickness tester.

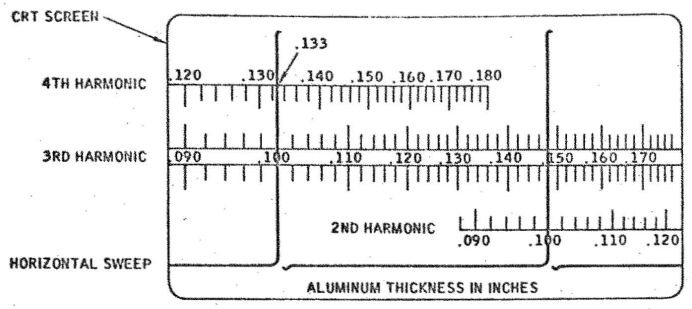


Two resonance indications are shown projecting above the horizontal sweep line. In Volume II you learned that the height of these pips represents signal amplitude or strength. Their position and number along the horizontal sweep line is a function of frequency.

Turn to page 7-29.

From page 7-28

And by placing a transparent thickness scale over the face of the tube, a direct thickness readout can be obtained.



The scale shown above is for aluminum and covers a range of 0.090 to 0.180 inch. The 2nd, 3rd, and 4th harmonics are shown. The left resonance indication is read as 0.100 or 0.133 inch. The right resonance indication is read as 0.100 or 0.148 inch. You'll recall from Volume II that the correct thickness is 0.100 inch, since it lines up on two adjacent harmonic scale lines . . . the left indication being the 3rd harmonic; the right indication being the 2nd harmonic.

Turn to page 7-30.

From page 7-29

Resonance thickness testers measure material thicknesses from one side by transmitting continuous longitudinal (compression) waves into a test specimen. The waves travel through the specimen, reflect at the opposite side, and return to the transducer. Since the velocity of the waves is constant for a given material, thickness is proportional to the elapsed time required for a wave to travel through the specimen and return to the transducer. Resonance thickness testers measure this time interval by mechanically or electronically adjusting the transducer frequency so that wave travel time is equal to the fundamental resonant frequency or whole number multiplies thereof (harmonics). At these points, wave interference occurs and a resonance signal is obtained.

Is the following statement true or false? By comparing resonance indications with those of a known material thickness, accurate thickness measurements can be obtained.

True . . . . . Page 7-31

False . . . . . Page 7-33

From page 7-30

Yes, "true" is the correct answer. By comparing resonance indications with those of a known material thickness, accurate thickness measurements can be obtained.

Material thicknesses can also be determined using simple resonance instruments and what is called a table of constants, or K table. This table lists predetermined constants for different materials, in million inches per second. The following are typical examples.

MATERIAL	CONSTANT K (MILLION INCH/SECOND)
ALUMINUM	0.125 - 0.130
BRASS	0.089
COPPER	0.093
PLASTICS	0.04 - 0.06
STEEL	0.116 - 0.118

Constants will normally give satisfactory accuracy for frequency-thickness conversion, using the formula:

$$T = \frac{K}{F}$$

where T = Thickness of material in inches

K = Constant (longitudinal wave velocity in million inch/second divided by 2)

F = Fundamental resonant frequency in megacycles

Turn to page 7-32.

From page 7-31

For example, let's say we're testing a piece of steel plate and found its fundamental resonant frequency to be 0.461 megacycles.

Using the formula $T = \frac{K}{F}$ and substituting the following values for K and F:

K = 0.116 (steel constant obtained from K table)

F = 0.461 megacycles (fundamental resonant frequency)

$$T \text{ (thickness)} = \frac{0.116 \text{ (constant K)}}{0.461 \text{ (fundamental resonant frequency)}}$$

$$T = 0.25$$

We find the piece of steel is 1/4-inch thick.

Which of the following statements is true?

Constants obtained from a K table are used to determine the velocity of sound in the material being tested . . . . . Page 7-34

Constants obtained from a K table are used to convert frequency to material thickness . . . . . Page 7-35

From page 7-30

You think the statement is "false." You're wrong. We can obtain accurate thickness measurements only be comparing resonance indications with those of a known material thickness.

Recall instrument "standardization." When we standardize an instrument prior to making a test, aren't we adjusting the instrument to a known thickness? Of course. This is the way we obtain accurate indications.

Turn to page 7-31.

From page 7-32

Wrong. Constants (K) are not used to determine the velocity of sound in materials being tested. They are used for frequency-thickness conversion.

A constant (K) is a factor derived by dividing a material's longitudinal wave velocity, in million inches per second, by 2. Since a constant already represents a materials velocity factor, it is not used for velocity measurements. Again, constants are used with the formula:

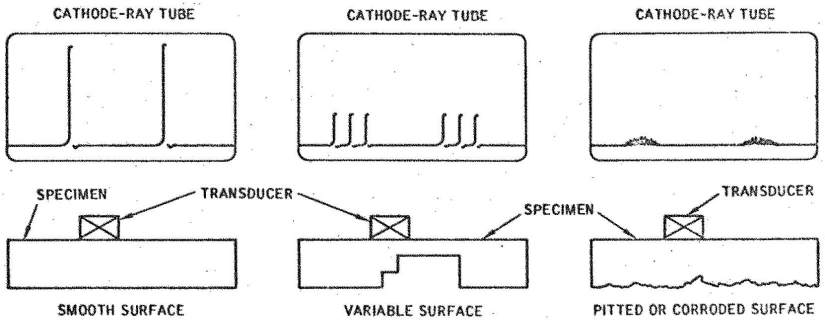
$$T = \frac{K}{F}$$

to convert a material's fundamental resonant frequency to a thickness measurement.

Turn to page 7-35.

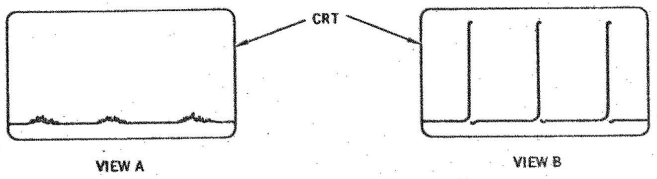
Good. You selected the "true" statement. Constants obtained from a K table are used to convert frequency to material thickness in resonance testing.

In checking for corrosion, we may find it necessary to scan either a large area or small suspect areas to determine if corrosion is present. And corrosion is indicated by a decrease in material thickness, usually accompanied by reduced signal amplitude.



Shown above are 3 different CRT presentations obtained from various surface conditions. Note that smooth surfaces provide sharp, strong indications, whereas variable surfaces produce several indications of varying frequency and reduced amplitude. Corroded surfaces produce a wide band of resonant frequencies and the signals are usually quite weak.

Which of the following CRT patterns indicates the presence of corrosion?

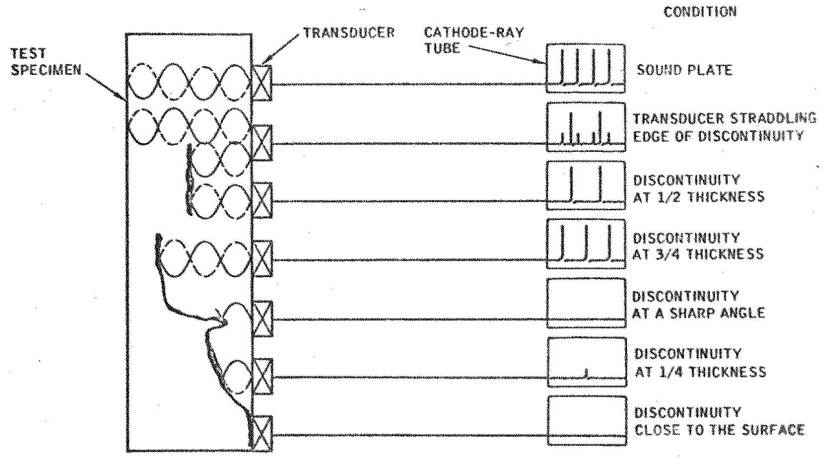


View A ..... Page 7-36

View B ..... Page 7-38

Correct. View A illustrates the presence of corrosion. View B represents an indication obtained from a material having no corrosion.

Gross discontinuities can be detected using ultrasonic resonance instruments by observing changes in the strength or location of the resonance indications.



Shown above are several resonance indications obtained from a specimen containing various types of discontinuities. The instrument is set up to measure specimen thickness, with 3 or 4 resonance indications appearing on the CRT screen. Discontinuities are then indicated by a sudden shifting of the indications or by the appearance or disappearance of all or some of the indications as the specimen is scanned.

Which of the following statements best defines discontinuity indications obtained from resonance instruments?

Discontinuities are indicated as a sudden increase in material thickness or by the disappearance of resonance indications ..... Page 7-37

Discontinuities are indicated as a sudden change in material thickness or by the appearance or disappearance of resonance indications ..... Page 7-39

From page 7-36

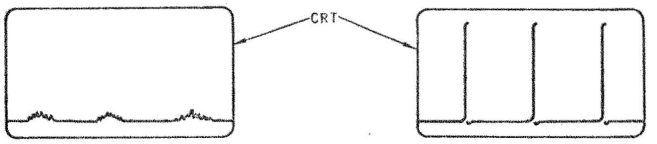
Wrong. Discontinuities are indicated as a change (not increase) in material thickness, or by the appearance or disappearance of resonance indications.

Keep in mind that resonance indications are related to material thickness. And discontinuities act like material boundaries. They reflect ultrasonic energy causing a change in resonant frequency.

Turn to page 7-39.

From page 7-35

You're incorrect. The pattern shown in View B does not indicate the presence of corrosion. View A shows the presence of corrosion.



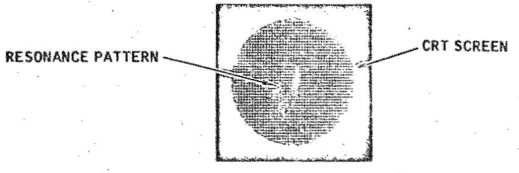
Recall that corrosion produces a wide band of resonant frequencies having very little amplitude. Now doesn't View A best illustrate this condition? Yes.

Turn to page 7-36.

From page 7-36

Right. In resonance testing, discontinuities appear as sudden changes in material thickness or by the appearance or disappearance of resonance indications.

Bond testers use a little different approach for indicating the quality or soundness of a material, their purpose being to detect voids and substandard bond areas. Lack of bond is similar to a laminar discontinuity. Usually it is a void or empty space and has a very high impedance mismatch.



Shown above is a typical CRT pattern from an ultrasonic bond tester. By adjusting the size of the resonance pattern to represent a void of a known size, the pattern can then be compared to the responses obtained from a bonded specimen under test. Its function is similar to a "GO-NO-GO" gage. Indications within a given size may be considered good. Indications over a given size mean the material being tested does not meet minimum requirements. It also should be pointed out here that the reference standards containing the "void" and "non-void" areas must simulate as closely as possible the physical characteristics of the bonded specimen being tested.

Select the best completion for the following statement.

With a bond tester, we can determine the quality or soundness of a test specimen by...

comparing the test specimen resonance pattern with those of known size voids . . . . . Page 7-40

measuring the size of the test specimen resonance pattern . . . . . Page 7-41

From page 7-39

Very good. You selected the better answer. We can determine the quality or soundness of a test specimen, using a bond tester, by comparing the test specimen resonance patterns with those of known size voids.

And again, the physical characteristics of the reference standard used must be as close as possible to those of the test specimen, e.g., the same material, thickness, construction, etc.

Now let's turn to page 7-42 for a short review on resonance testing.

From page 7-39

You didn't select the better answer. It's true we measure the size of the test specimen resonance patterns; but, we also must compare the patterns with those of known standards if we're to be accurate.

Therefore, when using a bond tester, we compare the test specimen resonance patterns with those from known size voids to determine a specimen's quality or soundness.

And again, remember that the physical characteristics of any reference standard used must be as close as possible to those of the test specimen, e.g., the same material, thickness, construction, etc.

Turn to page 7-42 for a short review on resonance testing.

From page 7-40

1. Resonance instruments may be used for thickness me_____g, cor_____n testing, and detection of gross di_____or lack of _____d.

7. orientation, immersed

8. Surface preparation depends on the test specimen. Smooth, clean surfaces require (little) (extensive)_____preparation while rough or severely pitted surfaces require (little) (extensive)_____ rework.

14. High

15. (High) (Low)_____ frequencies are generally best for testing less favorable specimens, e.g., large grain size, rough surfaces, etc.

21. constants

22. Constants (K) are used in the formula T = _____ to determine material thickness.

1. measuring, corrosion, discontinuities, bond

2. Resonance instruments, like pulse-echo equipment, require access to (one) (two) _____ surface(s) of a specimen.

8. little, extensive

9. The extent of surface preparation required is also largely dependent on the condition of the specimen b_____ s _____.

15. Low

16. Fundamental resonant frequencies are (more) (less) _____ accurate than harmonics.

22. $\frac{K}{F}$

23. Corrosion is indicated by a (decrease) (increase) _____ in material thickness and is usually accompanied by a loss in sig_____ am_____e.

2. one

3. Resonance instruments are most accurate when testing relatively (thin) (thick) _____ materials and determining l_____k of b_____d.

9. back surface

10. The preferred power tool for removing severe surface irregularities is a (rotary grinder) (disc sander) _____.

16. less

17. (Grease) (Glycerin) _____ with a wetting agent added is the best couplant for less favorable specimens.

23. decrease, signal amplitude

24. Corrosion indications may appear as "bumps" on the CRT screen hor_____s_____p.

3. thin, lack, bond

4. The measuring of thick materials and locating small discontinuities should be done with (pulse-echo)(resonance)_____ equipment.

10. disc sander

11. Resonance equipment can be separated into 2 basic categories according to use. T_____ testers are used for gaging, corrosion inspection and determining gross discontinuities.

17. Glycerin

18. The best "all round" couplants are (greases) (light oils or water) _____.

24. horizontal sweep

25. Gross discontinuities are indicated by a sudden sh_____ing, or the dis_____ce and app_____ of resonance indications as a specimen is scanned.

4. pulse-echo

5. Both the con_____ and imm _____ techniques may be used in resonance testing, the_____ technique being the most common.

11. Thickness

12. B_____ testers are used for determining lack of bond, etc.

18. light oils or water

19. Resonance testers, like the pulse-echo/through transmission instruments, require the use of ref_____ blocks or st_____ds when setting up the equipment and checking accuracy.

25. shifting, disappearance, appearance

26. Bond testers are used as a "GO-NO-GO" gage to indicate the qu_____y or so_____ss of a material.

5. contact, immersion, contact

6. In immersed resonance testing, instrument indications are based on w_____path resonance am_____e changes

12. Bond

13. A prime factor in the selection of a transducer is that its fundamental (minimum) resonant frequency must be (higher) (lower)_____than the test frequency used.

19. reference, standards

20. Accurate thickness measurements can be obtained by comparing a material's r_____ind_____with those obtained from a known material thickness.

26. quality, soundness

27. In testing for lack of bond, a test specimen is accepted or rejected according to the size of its r_____pat_____s in comparison with those of a known size v_____d.

6. water, amplitude

7. We find a nonsymmetrical water path will distort resonance indications. Therefore, ori_____ion is a critical factor in im_____ed resonance testing.

Return to page 7-42, frame 8.

13. higher

14. (High) (Low)_____frequencies are generally best for testing extremely thin materials.

Return to page 7-42, frame 15.

20. resonance indications

21. Predetermined factors obtained from a table are frequently used for frequency-thickness conversions. These factors are known as con_____(K).

Return to page 7-42, frame 22.

27. resonance patterns, void

28. Turn to page 7-49.

From page 7-48

Congratulations. You have just completed the third and final volume of the programmed instruction course on ultrasonic testing.

You may want to evaluate your knowledge of the material presented in this handbook; therefore, a set of self-test questions are included at the back of the book. The answers can be found at the end of the test.

Again, we want to emphasize that the test is for your own evaluation of your knowledge of the subject. If you elect to take the test, be honest with yourself - don't refer to the answers till you have finished. Then you will have a meaningful measure of your knowledge.

Since it is a self evaluation, there is no grade - no passing score. If you find that you have trouble in some part of the test, it is up to you to review the material till you are satisfied that you know it.

Turn or rotate the book 180° and flip to page T-1 at the back of the book.

ULTRASONIC TESTING - VOLUME III - APPLICATIONS

Self-Test

1. What is the name of the test system which relies on reflected energy to find discontinuities?

   a. Through transmission
   b. Pulse-echo
   c. Longitudinal wave
   d. Continuous wave

2. The test system that uses either pulsed or continuous sound and indicates discontinuities as a reduction in received energy magnitude is called:

   a. Contact testing
   b. Longitudinal wave testing
   c. Pulse-echo testing
   d. Through transmission testing

3. The test system which makes use of stationary waves to tell us something about a test specimen is called:

   a. Continuous wave testing
   b. Pulse-echo testing
   c. Through transmission testing
   d. Resonance testing

4. The test method where the transducer is coupled to the test specimen through a thin layer of couplant is called:

   a. Continuous wave testing
   b. Contact testing
   c. Coupled wave testing
   d. Through transmission

5. The test method where both the transducer and the test specimen are placed in a tank filled with a liquid (water) is called:

   a. Surface wave testing
   b. Immersion testing
   c. Submerged testing
   d. Through transmission

6. The ability of an ultrasonic test instrument to detect discontinuities is not affected by the surface condition, shape, or metallurgical characteristics of a specimen to be tested. (True - False) _____.

7. Pulse-echo testing provides specific data on the relative size of discontinuity and its distance from the surface of the test specimen. (True - False)

   _____.

8. With reference to through transmission testing, attenuation is a lesser problem in pulse-echo testing. (True - False) _____.

9. The requirement that the transmitting and receiving transducers have to be precisely aligned on the test specimen is a disadvantage of:

   a. Contact testing
   b. Longitudinal wave testing
   c. Pulse-echo testing
   d. Through transmission testing

10. The test system which is used primarily to measure material thicknesses and detect lack of bond or large discontinuties is called:

   a. Through transmission testing
   b. Surface wave testing
   c. Resonance testing
   d. Longitudinal wave testing

11. Which of the following are advantages of resonance testing? (Choose two)

   a. Portability
   b. Greater beam penetration
   c. Lower frequencies
   d. Simplicity

12. Which of the following factors is an advantage of contact testing over immersion? (Choose two)

   a. Greater beam penetration
   b. Higher frequencies may be used
   c. Better resolution
   d. Portability

13. Which of the following factors is a disadvantage of contact testing?

   a. Decreased beam penetration power
   b. Portability
   c. Difficulty in maintaining a uniform acoustical coupling
   d. Confined to high frequency testing only

14. Which of the following factors is an advantage of immersion testing over the contact method?

   a. Greater beam penetration power
   b. Portability
   c. Lower test frequencies may be used
   d. Angulation for unfavorably oriented discontinuities

15. Which of the following is not an advantage of immersion testing?

   a. Portability
   b. Better resolution
   c. Reduced transducer wear
   d. Angulation ability

16. Equipment selection and operation are parameters of the ultrasonic test system that are controlled by the operator. (True - False) _____.

17. To improve the ultrasonic test of a given specimen, which of the following may be modified? (Choose two)

   a. Specimen shape
   b. Adjustment of instrument controls
   c. Specimen surface condition
   d. Specimen heat treat

18. The requirements of an ultrasonic test are:

   a. Determined by operator judgement
   b. Established by the reference standard block used
   c. Outlined in the acceptance standard

19. Standardization of ultrasonic test instruments is based on reflections from reference standards containing known size simulated discontinuities. (True - False) _____.

20. Any precisely machined reference standard block may be used in standardizing a test instrument for testing a given test specimen. (True - False) _____.

21. Pulse-echo testing is more widely used than transmission testing. (True - False) _____.

22. A particular advantage of through transmission testing is:

   a. No couplant is required
   b. The depth of a discontinuity can be easily determined
   c. Only one transducer is required

23. Proper test equipment selection is dependent on the:

   a. Overall test situation
   b. Metallurgical structure of the specimen
   c. Test specimen geometry
   d. Surface condition of the test specimen

24. Which of the following frequencies would probably result in the greatest attenuation loss?

   a. 1.0 mc
   b. 10.0 mc
   c. 25 kc
   d. 25 mc

25. Paint must be removed from a test specimen since it prevents good coupling between the transducer and specimen surface. (True - False)_____.

26. Before testing a specimen whose surface is covered with thin scale:

a. Clean off any loose scale
b. Remove all scale
c. Rough-machine the surface
d. Paint the surface

27. In order to find the smallest discontinuities during a test:

a. Use the lowest frequency possible
b. Use the highest frequency possible
c. Use through transmission testing
d. Use a small transducer

28. Transducers incorporating a plastic wedge frontal member are commonly used in straight beam testing. (True - False)_____.

29. The acoustical impedance of an ideal couplant should be between that of the transducer and the test specimen. (True - False)_____.

30. The choice of a couplant is largely dependent on the surface condition of the test specimen. (True - False)_____.

31. Loss of back reflection is evidence that sound is not being returned to the:

a. Discontinuity
b. Transducer
c. Test specimen
d. Back surface

32. An ultrasonic instrument operator can control the number of cycles of sound energy transmitted into a test specimen by adjusting pulse length. A short pulse length results in: (Choose two)

a. Less instrument sensitivity
b. Less penetration power
c. Better near surface resolution
d. Increased penetration power

33. In contact testing, shear waves may be produced in a test specimen by:

a. Placing an X-cut quartz crystal on the specimen and coupling with oil
b. Using two transducers, one on each side of the specimen
c. Using a shear-cut lens on the transducer
d. Using an angle beam transducer on a Lucite wedge

34. The critical incident angle for longitudinal waves is the point at which:

a. The reflected angle is zero degrees
b. The refracted angle of the longitudinal wave mode is parallel to the surface
c. The longitudinal wave mode is totally reflected
d. Both longitudinal and shear waves are transmitted into the specimen

35. What is the waveform developed when the shear wave mode is refracted 90 degrees?

a. Longitudinal wave
b. Surface wave
c. Transverse wave
d. Transitional wave

36. Ultrasonic waves which travel around a gradual curve with little or no reflection from the curve are called:

a. Longitudinal waves
b. Shear waves
c. Surface waves
d. Transverse waves

37. Plate waves may be used to test:

a. Thin sheet
b. Forgings
c. Bar stock
d. a, b, and c

38. With reference to single-transducer pulse-echo testing, two-transducer pulse-echo testing has better:

a. Near surface resolution
b. Specimen penetration power
c. Resolution at all depths
d. Sensitivity at all depths

39. Ultrasonic testing of castings is often not possible because of:

a. Rough surfaces
b. Small grain structure
c. Coarse grain structure
d. Irregular shape

40. Which of the following materials is most likely to produce the greatest amount of sound attenuation over a given distance?

a. Hand forging
b. Coarse-grained casting
c. Extrusion
d. Fine-grained material

41. It is normal practice in testing bar stock to use both axial and radial tests (test through both the length and width of specimen. (True - False)_____.

42. In straight beam contact testing, with sound beam entering a flat specimen such as a plate from one of the surfaces, the following type of discontinuity will probably be detected:

a. Laminations with major dimensions parallel to surface
b. Transverse-type discontinuities at an angle to the surface
c. Radial-type discontinuities with major dimension along length but radially oriented to the surface
d. Porosity

43. Thin sheet materials may be tested with the beam perpendicular to the surface by observing the:

a. Front surface reflection
b. Multiple reflection pattern
c. All surface reflections
d. Second back surface reflection

44. A gross check of plate or sheet consists of marking off a grid pattern on the material, either real or imaginary, and then testing each grid square using:

a. Transducer wheel
b. Focused transducer
c. Angle beam transducer
d. Straight beam transducer

45. Before using an angle beam transducer for testing plate, a reference notch must be set up to determine the size of any discontinuities that might be found. (True - False)_____.

46. The most common application of ultrasonic tests using shear waves is:

a. Detection of discontinuities in pipe, tubing, and welds
b. Determining elastic properties of materials
c. Detection of laminations in rolled plate
d. Testing large round specimens

47. The resolution indication found on a CRT screen when testing pipe represents:

a. 180 degrees of sound travel in specimen
b. 360 degrees of sound travel in specimen
c. The rotating of the pipe past the transducer
d. The diameter of the pipe

48. A notch-type reference standard for testing of tubing should be machined on:

a. Both inner and outer surfaces
b. Inner surface only
c. Outer surface only

49. During weld testing, the fusion zone may return a reflection that is similar to reflections from discontinuities. (True - False) _____.

50. The term "skip distance" refers to the bouncing of a sound beam between opposite material boundaries in angle beam testing. This distance will change as material thickness changes. (True - False)_____ .

51. Skip distance is determined by:

a. The angle of reflection
b. The test frequency used
c. Pulse width used
d. Incidence angle

52. Generally, the best ultrasonic testing method for detecting discontinuities oriented along the fusion zone in a welded plate is:

a. Contact method using surface waves
b. Straight beam method using longitudinal waves
c. Angle beam method using shear waves
d. Straight beam method using plate waves

53. When using the formula $a = w (\sin \alpha)$ to determine a discontinuity's physical location, the transducer wedge sound travel distance must be first determined before any calculations can be made as to discontinuity location. (True - False) _____.

54. A weld test ruler can be used to locate discontinuities in any material. (True-False)_____.

55. The IIW (International Institute of Welding) reference blocks can be used to test welds in any material. (True - False) _____.

56. Direct reading ultrasonic calculators can be used to locate discontinuities in plate when:

a. Plate thickness and transducer refraction angle are known
b. Plate thickness and transducer wedge velocity are known
c. Transducer wedge and plate velocities are known
d. Transducer incident beam angle and plate sound velocity are known

57. A wetting agent is used in immersion test tanks to prevent the formation of small air bubbles that could produce confusing reflections. (True - False) _____.

58. The carriage used in immersion testing supports the:

a. Immersion tank
b. Equipment operator
c. Scanner tube and manipulator
d. Test instrument

59. The tubular device held by the manipulator is called a:

a. Vertical probe
b. Wand
c. Scanner tube
d. Transducer

60. Which of the following is an advantage of a focused transducer over a conventional transducer used in immersion testing?

a. Less sensitivity to small discontinuities
b. Increased resolving power
c. Increased effects from surface roughness
d. Greater penetrating power

61. If a test specimen is too large to be placed in an immersion tank, the advantages of immersion testing can still be attained by using a "bubbler" (water column). (True - False) _____.

62. In immersion testing, the water multiples that may be seen on the CRT screen between the front and back surface reflections can be eliminated by:

a. Using a different frequency transducer
b. Increasing distance from transducer to test specimen
c. Using a contour-correction lens
d. Decreasing instrument sensitivity

63. A general rule of thumb in determining the correct water distance to use in immersion testing is that the water distance should be:

a. Equal to the thickness of the test specimen
b. One-half the thickness of the test specimen
c. One-quarter the thickness of the test specimen plus 1/4 inch
d. Equal to the thickness of the test specimen plus 1/4 inch

64. In immersion testing, the transducer will be transmitting its sound beam perpendicular to the test surface when the following indication is received on the CRT:

a. Maximum front surface reflection
b. Elimination of water multiples
c. Minimum back surface amplitude
d. Maximum initial pulse amplitude

65. In immersion testing, the water distance between the transducer and test specimen should be:

a. As small as possible
b. As great as possible
c. Same as that used for standardization
d. Twice the specimen thickness

66. In immersion testing, the area in which a sound beam enters a specimen can be determined using a straight-edged "metal spoon." (True - False)_____.

67. During immersion testing, it is often necessary to angulate the transducer when a discontinuity is located to:

a. Avoid a large number of back reflections that could interfere with a normal test pattern
b. Obtain a maximum response if discontinuity is not originally oriented perpendicular to the sound beam
c. Obtain the maximum number of front surface reflections
d. Obtain a discontinuity indication that is the same height as the indication from the flat-bottom hole in a reference block

68. In immersion testing and with reference to straight beam testing where no facilities exist for automatic scanning and recording, the angle beam technique is generally the more rapid scanning technique to use. (True - False) _____.

69. Either longitudinal or shear waves can be used in immersion testing of cylindrical-shaped specimens. (True - False)

70. Thin-walled tubing is most effectively tested using:

a. Longitudinal waves
b. Shear waves
c. Articulated waves
d. Compressional waves

71. In immersion testing using the angle beam technique, the specimen front surface reflection will be:

a. Small and poorly-defined
b. Small but well-defined
c. Strong and well-defined
d. High in amplitude

72. When testing a spot weld with a sound beam the same size as the weld nugget, the CRT pattern from a good spot weld will show:

a. Both single- and double-sheet thickness indications
b. Double-sheet thickness indications with little decrease in amplitude
c. Double-sheet thickness indications, decreasing in amplitude

73. An unbonded condition can best be detected when the materials involved give a good coupling when bonded. (True - False) _____.

74. An irrelevant indication that appears as a discontinuity indication but is not synchronized with the sweep line on the CRT and moves from left to right will be due to:

a. Electrical interference
b. Loose transducer crystal
c. Material structure interference
d. Interference from refraction

75. A loose or defective transducer crystal will produce a ringing effect on a CRT screen. (True - False)_____.

76. In contact testing, spurious indications resulting from transducer wedge interference can be isolated simply by lifting the transducer off the test specimen and seeing if the indication remains on the CRT screen. (True - False)_____.

77. In straight beam testing, a discontinuity indication that moves with the transducer can be the result of:

a. Longitudinal waves striking a discontinuity
b. Specimen grain structure
c. Surface waves traveling on the test specimen surface
d. Electrical interference

78. An ultrasonic equipment operator should primarily look for indications appearing to the left of the back surface reflection because:

a. They are the strongest and most easily seen
b. They determine material thickness
c. They determine what test specification may be used
d. They are most likely to be caused by discontinuities

79. In testing long specimens, spurious signals may result if the sound beam spreads into the sides of the material before reaching the back surface. (True - False) _____.

80. Interference from coarse grain in a test specimen can sometimes be distinguished by numerous reflections following the front surface indication. (True - False)_____.

81. In contact angle beam testing, an indication that moves slowly across the CRT sweep or changes amplitude can be the result of:

a. Too much couplant
b. Not enough couplant

82. Continuous longitudinal waves are transmitted into a specimen in resonance testing. (True - False)_____.

83. Depending on the resonance instrument, a resonant indication may represent:

a. Actual material thickness
b. Frequency
c. Material soundness
d. a, b, or c

94. Like when testing with pulse-echo/through transmission equipment, some sort of reference standard must be used to set up resonance instruments and check their accuracy. (True - False)_____.

95. Accurate thickness measurements are obtained by comparing a materials resonance indications with those obtained from a known material thickness. (True - False)_____.

96. Constants (K) are predetermined factors used to convert frequency to thickness and vice versa. (True - False)_____.

97. Material thicknesses can be determined using constants (K) and the formula:

a. $T = KF$
b. $T = \frac{K}{\lambda}$
c. $T = \frac{K}{F}$
d. $T = \frac{F}{K}$

98. Resonance instruments usually indicate corrosion as a:

a. Decrease in material thickness and resonance amplitude
b. Increase in material thickness and resonance amplitude
c. Decrease in material thickness and increase in resonance amplitude
d. Increase in material thickness and decrease in resonance amplitude

99. Gross discontinuities can be detected with resonance instruments by observing resonance indications for any sudden changes in strength or frequency. (True - False)_____.

100. Resonance bond testers are used to:

a. Measure bonding thicknesses
b. Measure bonding strength
c. Determine the quality or soundness of bonded materials
d. Measure the thickness of bonded materials

84. Resonance testing requires access to only one surface of the test specimen. (True - False)_____.

85. Resonance instruments are most accurate when testing:

a. Thick materials and locating small discontinuities
b. Thin materials and locating small discontinuities
c. Very thick materials and locating gross discontinuities
d. Relatively thin materials and determining lack of bond

86. Both the contact and immersion methods are used in resonance testing, with the immersion method being the most common. (True - False)_____.

87. In immersed resonance testing, instrument indications are based on water path resonance amplitude changes. (True - False)_____.

88. The most critical factor to consider in immersed resonance testing is:

a. Transducer orientation
b. Water distance variations
c. The selection of water distance
d. Transducer frequency and size

89. The two basic types of resonance instruments are: (Choose two)

a. Contact testers
b. Thickness testers
c. Bond testers
d. Corrosion detectors

90. In resonance testing, the transducer resonant frequency should be:

a. Higher than the test frequencies used
b. Lower than the test frequencies used
c. Same as the test frequencies used
d. Same as the test specimen

91. In resonance testing, high frequencies are generally best for testing specimens having rough surfaces, large grain size, or excessive porosity. (True - False) _____.

92. In resonance testing, the most accurate indications are obtained using:

a. Harmonics
b. Resonant frequencies
c. Minimum resonant frequencies
d. Fundamental resonant frequencies

93. The couplant between the transducer and the specimen in resonance testing can be:

a. Water
b. Oil
c. Grease
d. a, b, or c

ANSWERS FOR SELF-TEST

		Page No. Ref.			Page No. Ref.
1.	b	1-1	27.	b	2-15
2.	d	1-5	28.	false	2-22
3.	d	1-6	29.	true	2-25
4.	b	1-10	30.	true	2-25
5.	b	1-12	31.	b	2-28
6.	false	1-16	32.	b and c	2-31
7.	true	1-19	33.	d	2-35
8.	false	1-19	34.	b	2-37
9.	d	1-19	35.	b	2-43
10.	c	1-22	36.	c	2-45
11.	a and d	1-22	37.	a	2-48
12.	a and d	1-23	38.	a	2-53
13.	c	1-24	39.	c	3-1
14.	d	1-28	40.	b	3-1
15.	a	1-29	41.	true	3-5
16.	true	1-31	42.	a	3-9
17.	b and c	1-33	43.	b	3-9
18.	c	1-36	44.	d	3-13
19.	true	1-40	45.	true	3-14
20.	false	1-42	46.	a	3-23
21.	true	2-2	47.	b	3-29
22.	d	2-4	48.	a	3-33
23.	a	2-5	49.	true	3-42
24.	d	2-9	50.	true	3-45
25.	false	2-11	51.	d	3-48
26.	a	2-11	52.	c	3-50

Review page reference on questions that you miss.

53.	true	3-56	83.	d	7-1
54.	false	3-62	84.	true	7-3
55.	false	3-64	85.	d	7-6
56.	a	3-67	86.	false	7-6
57.	true	4-2	87.	true	7-7
58.	c	4-3	88.	a	7-11
59.	c	4-6	89.	b and c	7-16
60.	b	4-13	90.	a	7-20
61.	true	4-18	91.	false	7-22
62.	b	4-20	92.	a	7-22
63.	c	4-21	93.	d	7-23
64.	a	4-30	94.	true	7-26
65.	c	4-30	95.	true	7-30
66.	true	4-33	96.	true	7-31
67.	b	4-35	97.	c	7-31
68.	true	5-3	98.	a	7-35
69.	true	5-6	99.	true	7-36
70.	b	5-13	100.	c	7-39
71.	a	5-19			
72.	c	5-21			
73.	true	5-23			
74.	a	6-3			
75.	true	6-8			
76.	true	6-9			
77.	c	6-10			
78.	d	6-19			
79.	true	6-19			
80.	true	6-28			
81.	a	6-29			
82.	true	7-1			

Review page reference on questions that you miss.

SHIPMENT COPY

UST July 26, 1968

TO : Scientific and Technic[illegible]tion Facility
Attn: Herbert S. Whit[illegible] Executive Director

THRU : US/NASA Facility Repre[illegible]

FROM : UST/Chief, Technical [illegible] Branch

SUBJECT: Documents prepared by [illegible]eral Dynamics/Convair under Contract NAS 8-20[illegible]

The original typed copy and glossy prints for the 13 reports transmitted with my April 26, 1968, memorandum (and subsequently returned to NASA) plus five additional reports are being sent to the Facility under separate cover.

These documents are to be publicly available, announ[illegible] in STA[illegible] and microfiched. The NH3 numerical designation located in the lower left-hand corner of the typed copy should not appear on the film image since these numbers have been cancelled from the NHS series. Please note that one copy of the reproducible material is provided.

Request for Proposal DHC-3-10-4103 will indicate that microfiche of these documents are availab[illegible] upon request to potential bidders. There are approximately 25 organizations who will receive the RFP initially and possibly 25 more are expected to apply. It is suggested that a minimum of 40 additional microfiche be prepared to meet the requirements of this RFP. The Facility is to provide microfiche to organizations citing the RFP.

Please send two copies of each microfiche and all original material to UST/NASA when the Facility has completed the processing.

Thank you for your cooperation.

[illegible]

Paul S. Fein[illegible]

cc:
KR/W.Ember
UT/E.Case
DHC-3/E.Balko