UT of Thin-walled Steel Pipe Flaws

Manual ultrasonic detection, characterizing and sizing of thin-walled steel pipe anomalies and flaws. From beginner's foundations to advanced sizing techniques with links to 57 YouTubes.

The "hands-on", "how-to", practical laboratory exercise book and UT field guide.

By Jimmy Ellis

- **For guidance on how to UT a Level 2 angle beam qual test coupon, go to pages 100-110.**
- **For a quick setup of shear wave cals using autocal, go to pages 44 & 46 and without autocal go to pages 43 & 45.**
- **To see how to do a quick setup of FAST-UT (high angle L-wave), go to page 65.**
- **To see the cause of hook flaws, see figures 53 & 54, pages 88-89.**
- **To make your own cal blocks; go to page 111.**
- **Captions shown in inches (for the USA) are highlighted blue:** BLUE
- **Captions shown in millimeters (for the rest of the world) are highlighted green:** GREEN
- **Many fill-in-the-blank sizing lab exercises to develop and verify skills.**
- **Open the QR code for the welcome message.**

Table of Contents

YouTube list

Subject (YouTube hyperlink)	Original YouTube file name	Length	QR code to YouTube	QR code page
Introduction to "UT of Thin-Walled Steel Pipe Flaws"		1:00		Front cover
Ultrasonic terms and math using fractions and decimals in inches	UT-PLdigs-2.0	8:33		15
Ultrasonic flaw detector menus options and settings	UT-PLdigs-1.0	24:29		19
Ultrasonic straight beam thickness calibration using zero and velocity	UT-PLdigs-3.0	8:28		22
Ultrasonic straight beam calibration using autocal		4:54		22
Ultrasonic thickness using crosstalk barrier orientation	UT-PLdigs-4.0	6:17		24
Ultrasonic A-scan rectification	UT-PLdigs-5.0	3:30		25
Ultrasonic walk of laminations vs internal corrosion	UT-PLdigs-6.0	3:49		26

Subject (YouTube hyperlink)	Original YouTube file name	Length	QR code to YouTube	QR code page
Ultrasonic echo to echo thickness thru coatings		7:43		27
Ultrasonic pencil probe thickness setup	UT-PLdigs-7.0	9:28		27
Ultrasonic thickness doubling		2:15		28
Saving your calibration setup files		6:19		28
Ultrasonic shear wave ID roll and OD roll signals	UT-PLdigs-8.0	1:57		29
Ultrasonic range 3 magic numbers for one-inch-deep screens	UT-PLdigs-9.0	9:56		32
Ultrasonic angle beam trigonometry	UT-PLdigs-10.0	5:06		32
Ultrasonic refracted angle, index point verification and range setting		26:46		41

Subject (YouTube hyperlink)	Original YouTube file name	Length	QR code to YouTube	QR code page
Ultrasonic 45-degree one-inch-deep shear wave cal setup	UT-PLdigs-11.0	11:08		42
Ultrasonic 45-degree side drilled hole measurements	UT-PLdigs-12.0	3:31		44
Ultrasonic 45-degree surface distance measurements	UT-PLdigs-13.0	3:09		47
UNL YouTube of corner reflection		5:06		47
Ultrasonic 45-degree shear RATT-relative arrival time technique	UT-PLdigs-14.0	7:57		48
Ultrasonic 45-degree shear tip diffraction depth sizing	UT-PLdigs-15.0	12:21		48
Ultrasonic 45-degree shear wave OD connected flaw tip sizing	UT-PLdigs-16.0	14:31		50
Ultrasonic 60-degree one-inch-deep shear wave setup	UT-PLdigs-17.0	10:56		52

Subject (YouTube hyperlink)	Original YouTube file name	Length	QR code to YouTube	QR code page
Ultrasonic 60-degree, why the corner trap signals do not peak up at the correct depths	UT-PLdigs-18.0	3:04		53
Ultrasonic 60-degree shear wave tip diffraction depth sizing	UT-PLdigs-19.0	19:51		54
Ultrasonic 70-degree shear PPATT probe positioning arrival time technique	UT-PLdigs-20.0	13:33		56
Ultrasonic 70-degree shear walking over the top of extremely deep ID connected planar flaws		8:20		57
Ultrasonic comparison of echo dynamics of 45°, 60°, and 70° shear	UT-PLdigs-22.0	15:24		59
Ultrasonic using 45° and 60° to determine ID connection	UT-PLdigs-30.0	8:37		60
Ultrasonic shear wave detection of slanted planar ID and OD flaws		8:09		60
Theoretical ultrasonic measurement of gaps under midwall flaws	UT-PLdigs-31.0	2:59		60

Subject (YouTube hyperlink)	Original YouTube file name	Length	QR code to YouTube	QR code page
Ultrasonic flaw height sizing of very small flaws using amplitude comparison		5:35		61
Ultrasonic shear wave flaw height tip sizing of real cracks		10:14		61
6dB drop flaw height sizing does not work	UT-PLdigs-36.0	15:14		61
Ultrasonic slinky demo of longitudinal & shear and why the "L" refracts to shear.		3:58		62 (fig 31)
FAST-UT cal setup	UT-PLdigs-23.0	5:07		67
FAST-UT of side-drilled holes	UT-PLdigs-24.0	5:10		69
FAST-UT surface distance measurement	UT-PLdigs-25.0	3:59		69
FAST-UT OD sizing technique	UT-PLdigs-26.0	15:55		70

Subject (YouTube hyperlink)	Original YouTube file name	Length	QR code to YouTube	QR code page
FAST-UT OD sizing technique with weld crown obstruction	UT-PLdigs-27.0	6:47		72
FAST-UT ID connected flaw height sizing technique	UT-PLdigs-28.0	13:47		73
FAST-UT embedded, midwall, rounded flaw sizing technique	UT-PLdigs-29.0	7:37		75
FAST-UT and identifying the L-wave	UT-PLdigs-32.0	5:01		76
FAST-UT recognition of ID gouges	UT-PLdigs-33.0	3:44		76
FAST-UT and establishing scan lines	UT-PLdigs-34.0	5:34		78
FAST-UT of weld seams		10:12		79
Ultrasonic 60-degree angle beam of SWLOF-side wall lack of fusion		6:37		103

Subject (YouTube hyperlink)	Original YouTube file name	Length	QR code to YouTube	QR code page
Ultrasonic angle beam detection of OD weld toe crack		7:38		105
Ultrasonic angle beam of HAZ (ID) cracks		11:20		105
Ultrasonic angle beam of a root crack		14:44		105
Ultrasonic angle beam of cluster porosity		9:10		106
Ultrasonic angle beam of slag		10:08		106
Ultrasonic angle beam of LOP (lack of penetration)		26:59		106
Home-made ultrasonic cal blocks		16:15		111
Home-made ultrasonic universal indication plotting tool		10:13		111

Section 1 Welcome

This book is similar to the material taught in manual UT (ultrasonic testing) training classes given by Jimmy Ellis at PfiNDE, SGS and then CBIS from 2010 to 2023. This version has been expanded to cover new subjects and be useful for more applications than just pipeline integrity.

The material presented here is intended to be a complete learning experience from a trainee's introduction to advanced techniques. This is intended to be a stand-alone guide for learning hands-on UT…actually doing UT. Most of the ideas here are made clearer with the hands-on demonstrations shown in the linked YouTubes. Easily accessed with the QR codes, these videos will help the UT apprentice to "see" what's in the book. The book also contains many "fill-in-the-blanks" exercises that help the apprentice to gauge their own hands-on UT progress. The references to the figures located in the back half of the book, the links to videos, and the "fill-in-the-blanks" exercises keep the trainee moving, alert and engaged.

This training is the practical part of UT training. This material is not intended to be the formal classroom training for ultrasonics theory. Most qualification programs in accordance with ASNT's SNT-TC-1A will require a separate 80 hours minimum in formal ultrasonic theory classroom training.

FAST-UT (Flaw Analysis and Sizing Technique) remains an important part of this training. FAST-UT is effectively used for the initial detection of flaws. FAST-UT is high angle L-wave UT technique usually containing a 70° L-wave. Most conventional shear wave angle beam UT is done with shear wave mode only. FAST-UT can hit flaws with several modes of sound at the same time and greatly increases the probability of detection. FAST-UT also has useful flaw sizing properties. For a review of shear and longitudinal wave mode generation, review the first and second critical angles as shown in figures 31 & 32.

When high angle L-wave UT is done in this book we will refer to it as FAST-UT. This does not require using the Krautkramer FAST Model 1, 2, or 3 probes. There are other high angle L-wave probes that can also be used and we will call this FAST-UT with any of them.

When Steve Sikorski and Rick Pfannenstiel began training people to perform FAST-UT in the 1990s, it was not as common to perform manual UT by scanning. Scanning is the side-to-side movement of the search unit, parallel to a weld centerline. Prior to that time, most of us old UT hands were trained to perform manual UT by rastering and skewing, mostly a back-and-forth motion of the search unit. Nowadays, it is common practice to perform all initial manual angle beam detection by scanning. This training book will emphasize scanning for detection with all angle beam search units, not just for FAST-UT. After doing scanning for detection, rastering-skewing is used for characterizing and sizing.

When FAST-UT was first introduced to the nuclear in-service sector in the 1990s it was emphasized how quickly an effective manual UT detection could be done; the quickest way to the needed information; cracked or not cracked. Now most users consider accuracy and precision, to be as important as quickness. For example, pipeline integrity programs want accuracy and precision of manual UT measures for detailed correlation to ILI predictions. (ILI: In Line Inspection tools)

This training stresses precision and accuracy using the basic tools normally available to a UT hand:

- Straight beam
- Pencil probe/Sonopen
- 45°
- 60°
- 70°
- FAST-UT

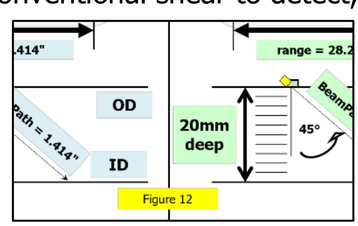
Quickness is now considered good when the results are also accurate and precise. Working from setups you are confident in, after enough repetitions a UT hand will get quick. By using all your search units together, you get the most accurate and precise results. This training will set you up, so you can be accurate, precise, and eventually quick in your UT. Accuracy and precision are related but not quite the same. Accuracy is being correct or not. Precision is having measures closest to the truth.

This training program originally evolved as preparation for work on in-service pipeline integrity digs. Usually, the objective was to find anomalies predicted by ILI smart tools. If a predicted anomaly location actually has a real flaw found, then the pipeline operators want to know if it is ID (inside surface) or OD (outside surface) connected, the nature of the flaw, exactly where the actual flaw is, and the measures of the flaw height and flaw length. This is what we call detection, characterizing and sizing. This is not 'code work' in the sense that an in-service longitudinal seam weld, for example, is not being examined in terms of a code standard such as evaluation with a DAC (Distance Amplitude Curve) as described in ASME V, Art 4 (American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, Article 4, Ultrasonic Examination Methods for Welds).

We were not generally accepting and rejecting. We were detecting, characterizing and sizing. Maybe in your industry sector you will be accepting and rejecting based on a code standard. You will still want all the skills described here for detecting, characterizing and sizing. The skills described here can be used in many applications for thin-walled steel pipe. Many examples described here are from pipeline integrity work. The wall thickness of most pipelines is 0.188" to 0.375" thick [4.78mm to 9.53mm]. There are some pipelines as thin as 0.125" [3.18mm] and some newer pipelines are much thicker; up to about 0.750" [19.05mm] thick. Many river crossings were made with 0.500" [12.7mm] pipe. Our work here will focus on steel pipe half inch thick or less.

Today, the 'state of the art' preferred inspection strategy for seam welds is:

- Use manual UT including FAST-UT, straight beam, 45°, 60°, and 70° conventional shear to detect, characterize, and size all the flaws.
- Perform encoded PAUT, ToFD, FMC-TFM or PCI* scans if the owner wants documentation of detections. See examples in figure 78. (Note: Figure numbers are labeled with yellow highlights as shown at right, snipped from page 33. Page number references are shown in red.) Also note that figure captions in Imperial-inches are in blue and items in Metric-millimeters are in green. Figure text boxes that are not Imperial or Metric are rust color.



rust color

*PAUT (phased array UT), ToFD (time of flight tip diffraction testing), FMC-TFM (full matrix capture, total focus method) and PCI (phase coherence imaging) are not within the scope of this training. If you enjoy the present task of developing your manual UT skills, you can certainly look forward to enjoying the challenge of learning these advanced techniques.

If you have questions or suggestions on how to make this book more useful, you are welcome to contact me anytime.

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Getting started; shortcuts: (maybe you are not a beginner and you want to jump ahead)

- For a thumbnail summary of how to set up all three conventional shear wave cals without autocal, see Figures 24 or 26. For a thumbnail summary of how to set up all three conventional shear wave cals with autocal, see figures 25 or 27.
- For a thumbnail summary of how to create a FAST-UT cal go to section "FAST-UT cal set-up" on page 65.
- For a thumbnail summary of FAST-UT basics go to figures 40-41.
- For a thumbnail summary of how to use FAST-UT to inspect a seam weld go to the section "Seam Weld Inspection Process" on page 79.
- For an instruction on how to do an angle beam UT on a qualification test coupon for a UT level 2 practical test, go to the section starting at page 100.

Math

A preliminary subject we should talk about is math. We have some things we talk about in terms of fractions, such as 1/16th of an inch. We have other things that we talk about in terms of decimal inches or mils or millimeters (mm). If you are a little rusty in measurement conversions and some basic angle beam UT terminology you could get a refresher at YouTube – Ultrasonic terms and math using fractions and decimals in inches .

NOTE: Be sure that when you are playing YouTubes, your settings are set for "HD", 1080P. Sometimes my browser will change to a lower resolution with no warning, so watch out for this. Or you might wish to lower the resolution to prevent "freeze-ups".

Also, note that this YouTube was one of the YouTubes in the original book and the YouTube title that appears at the opening is "UT-PLdigs-2.0". This indicates that it was the 2nd YouTube for the UT of Pipeline digs.

Throughout this book there are links that can be accessed to web pages and YouTubes. Depending on the format of this book that you have, (printed or PDF or eBook) you will find options for using the links. From a PDF or eBook you can just use CNTRL+Click on the blue underlined highlighted hyperlinks that start with https://...etc, or you can use a mobile phone or tablet camera to "see" the destination associated with the QR code like the one above.

Equipment:

Cal blocks

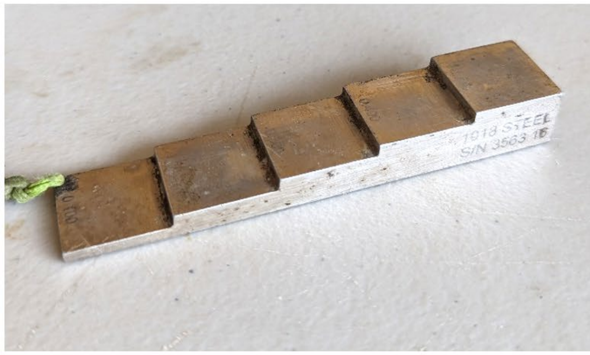
1 Step wedge

Half inch thick (Imperial inches) and 12.5mm thick (Metric) versions of the step wedge are available. This is usually used for straight beam thickness measurement. See figure 1.

Imperial-inches version

0.5" thick

Steps are 0.100", 0.200", 0.300", 0.400" and 0.500" thick.



Metric-mm version

12.5mm thick

Steps are 2.5mm, 5.0mm, 7.5mm, 10.0mm and 12.5mm thick

Figure 1

step wedge

2 Mini angle beam block.

This is also known as the Rompas block. Either the thick version or the thin version can be used, but the thicker (1" thick) version is also useful for doing instrument linearities. See figure 2. This block is nice to have, but everything that you can do with it can also be done with the FAST block and the notch block below. Metric versions of this block are available at 25mm thick.

Imperial-inches version

1.0" thick

The radii are 1.0" and 2.0"

Metric-mm Version

25mm thick

The radii are 25mm and 50mm

Miniature Angle Beam (MAB) block, also known as Rompas block

Figure 2

3 FAST block.

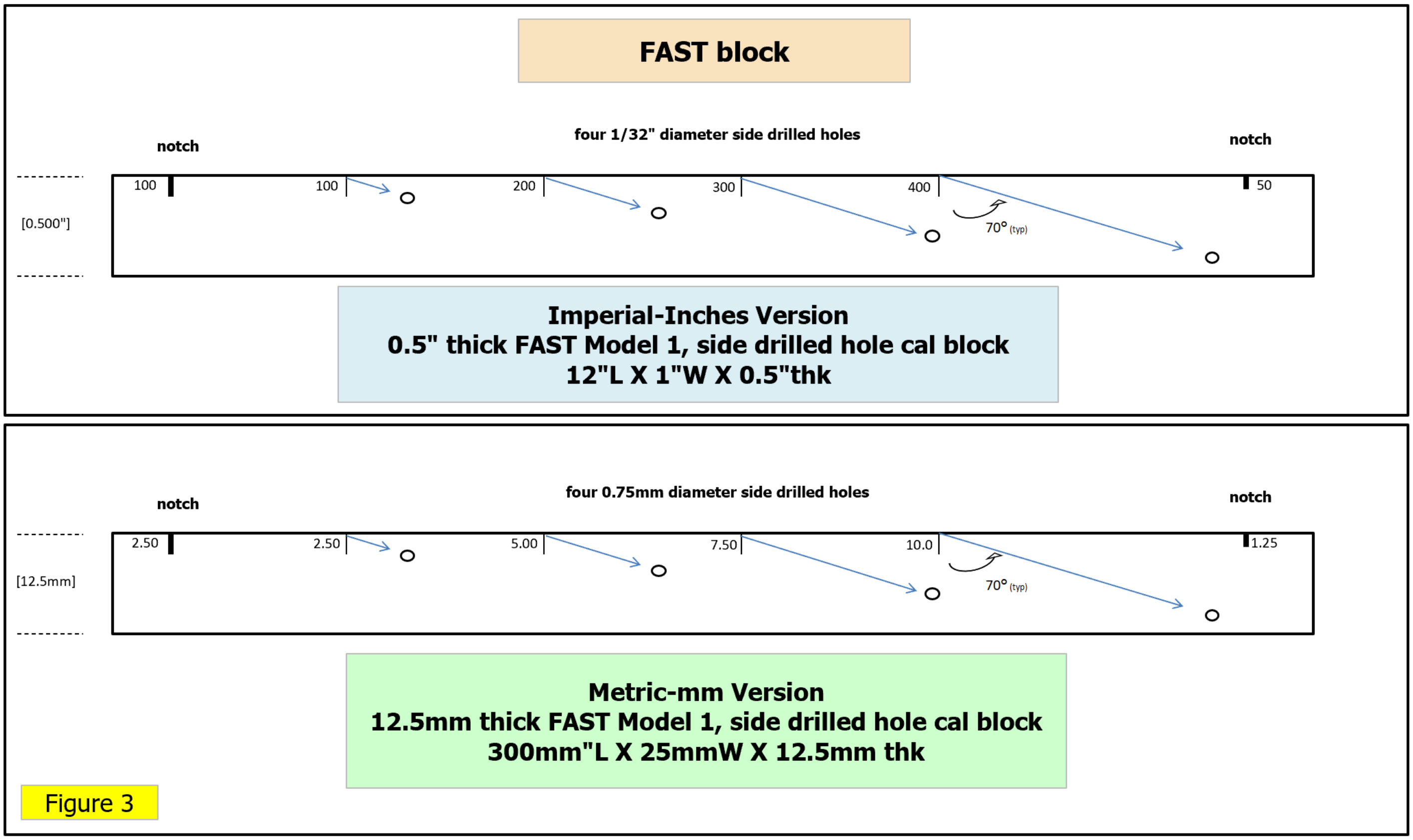


Figure 3

4 The 0.300” (8mm) thick notched block.

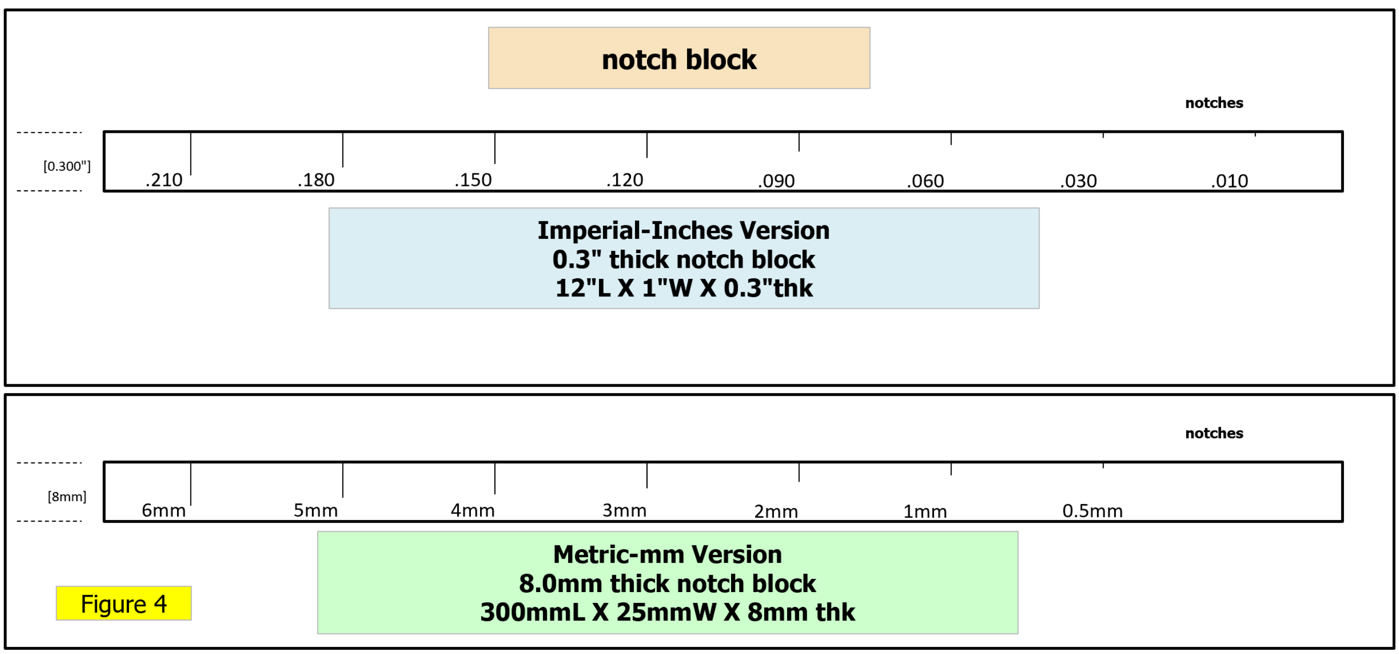


Figure 4

* Cal blocks, like everything else in NDT, are very expensive. These blocks should be provided by your employer. If you are doing this training on your own, you can make your own cal blocks with a minimum of tools; basically, a hack saw and a small drill press. Home-made cal blocks will not have the precision of EDM (Electric Discharge Machining) blocks. But they can work for you to develop your skills. See the section “Home-made cal blocks” page 111.

Search Units; Transducers and Wedges

The following table lists search unit accessories that have been found to work well.

Type	Manufacturer	Model	Comments
Straight Beam, dual element, 7.5MHz, tapered end	Evident	D798	Tapered shape allows a closer approach to a weld
	Sensor Networks	Fh2e+	"
Straight Beam, dual element, 7.5MHz, cylindrical end		Fh2e+wr	Cylindrical shape with its flat footprint scans more smoothly
Straight Beam, dual element, 10MHz	Evident	DHC713-RM	The higher frequency can be helpful for very thin material < 0.225" [5.72mm] thk.
Pencil probe	Evident	Sonopen V260-sm	
	Sensor Networks	00-011039	
Shear wave transducer, 5MHz, 0.25" [6.4mm] diam.	Evident	C543SM	
	Sensor Networks	00-010128MD	
Short approach wedges, 0.25" [6.4mm] diam. 45°	Evident	ABSA-4T-45°	Short approach has an index point closer to the weld
	Sensor Networks	01-012116	
60°	Evident	ABSA-4T-60°	
	Sensor Networks	01-012117	
70°	Evident	ABSA-4T-70°	
	Sensor Networks	01-012118	

Type	Manufacturer	Model	Comments
High angle L-wave	Waygate Technologies	FAST Model 1 389-016-880	For thk < 0.5″ [12.5mm]
		FAST Model 2 389-016-900	For thk 0.5″ to 1.5″ [12.7mm to 38.1mm]
		FAST Model 3 389-016-780	For thk ≥ 1.0″ [25.4mm] Waygate contact info: Waygate.usa@bakerhughes.com (+1)832-325-4368
	Sonatest	Q-Scan-1	Best choice for thin steel ≤ 0.5″ [12.7mm] Sonatest contact info: https://sonatest.com/ (+1)210-602-5398
Cables	CDInt		https://www.cdint.com/catalog/category/Cables

Flaw Detectors - Instruments

Manual angle beam UT is done with a UT flaw detector, not a thickness gauge. Thickness gauges are not suitable because the gates operate differently, and often the gates can't keep up with you while you are scanning a length or an area. Examples of thickness gauges are Waygate Technologies' Krautkramer CL5 and Evident-Olympus 38DL-Plus.

For angle beam UT you need a flaw detector. There are many good flaw detectors, some examples being Evident-Olympus Epoch 600, 650, 6LT or Waygate Technologies' Krautkramer USM100.

You will learn here that we often make use of how indications walk on the A-scan display as you move your search unit. It is very useful for the A-scan display to have an option that allows you to see 10 major divisions of the screen range or baseline. This is usually seen as 11 vertical lines on the screen (the zero line plus 10 equals 11). See figure 7 upper right page 25. This used to be standard on all flaw detectors, but now some manufacturers don't have any option for it. Their displays have arbitrarily defined sweep-range major and minor divisions.

You should try everything described here with <u>your</u> flaw detector. If you are new to manual UT, it can be a little overwhelming when you are trying to figure out how to navigate amongst all the screens, menus, options and settings on your flaw detector. Start by watching the YouTube- Ultrasonic flaw detector menus options and settings . This YouTube is done with an Olympus Epoch 650, and attempts to show you how to set up your instrument to prepare for straight beam UT; your "SB" (Straight Beam) setup. There are important differences among flaw detector manufacturers. If you are using a different brand or model of instrument, try to get help in figuring out the differences. Most things shown in this YouTube have similar options in other manufacturers flaw detectors.

The six manual UT setups we need are generically named the following:

- SB (straight beam)
- Sonopen
- 45
- 60
- 70
- FAST

We usually have generic versions of these cals that can be downloaded and installed on a flaw detector. Some generic versions of the setups are available for download from https://UTofPipelineDigs.com . (Don't download anything now.) You would only need to open them and tune them up a little. Every probe and wedge combination is slightly different. Sometimes the only difference is how much the contact surface has been worn down on the wedge footprint. To distinguish between the generic setups that can be downloaded, and your own setups, we usually recommend that after you have tuned them in for yourself you rename the setup files with your initials appended to the end of the file name. So, after I tune in precise setups with my search units, using my instrument, I name mine:

- SB-JE
- Sonopen-JE
- 45-JE
- 60-JE
- 70-JE
- FAST-JE

If you are new to manual UT, don't begin your training by downloading the generic setups and then just tuning them up. You won't learn as much if you do that. Build up each of your setups from scratch in the manner described in this training. This way you will understand how your setups work, how you can improve them and have reasoning for making adjustments if you run into problems.

After you have created final versions of all 6 of your setups, copy those files to your laptop and you can install them on a different instrument if you need to in the future.

The downloadable generic setups are good to have access to if you need to get set up on a new instrument in a hurry.

On my machine I use for field work, I only keep these 6 setups. This helps me do things quickly. I have 6 setups that I'm confident in. I can recall a cal, check the cal, set the gain, and go. This is a good mantra when you change probes. Repeat after me:

- Recall the cal
- Check the cal
- Set the gain
- Go

I usually look at every flaw with several search units. Having too many setups besides these will just get in the way and slow you down.

Now we can get down to work and start to build up our UT skills, step-by-step, starting with straight beam UT, then going on to 45°, 60°, 70° shear and then FAST-UT. Then we will apply our skills to using several sizing techniques, including advanced crack sizing techniques.

Section 2 Straight Beam UT

Dual element straight beam setups; Alternating zero and velocity adjustments…without autocal

Back in the day we were taught to calibrate for straight beam testing by taking our dual element 7.5MHz straight beam probe and then doing the following:

1. Couple to the 0.200" [0.50mm] thick step of the half inch thick [12.5mm] step wedge. Using gain, bring the signal to 80% FSH (full screen height). Dial in the correct thickness using "zero" (known as "probe delay" in some instruments).
2. Couple to the 0.500" [1.25mm] thick step. Using gain, bring the signal to 80%FSH. Dial in the correct thickness using velocity adjustment.
3. Repeat the above steps until the cal is accurate. Be sure to bring the signal to 80% FSH (full screen height) at each step.

The cal is accurate when you get the exact thickness reading when the signal is brought to 80%FSH without any zero or velocity adjustment. Try to remember this general rule; use 'zero' for the short distance and velocity for the long distance. If you are using an Evident-Olympus flaw detector and you have changed the velocity along the way, you may need to look at the Range and bring it back to 1.000" [25mm]. See YouTube – Ultrasonic straight beam thickness calibration using zero and velocity .

If you are a beginning student of UT now is the time when you should have turned on your instrument and attempted to create your straight beam setup. You need a step wedge, a straight beam probe, a flaw detector and some UT couplant (We recommend Ultragel II). I like to supplement my couplant with Windex.

If you have succeeded in creating a straight beam setup, go ahead and save it as your "SB-XX" setup. Here, XX represents your initials.

…with autocal

Another method is to follow the instrument manufacturer's instructions, which may use an "auto-cal" function. The steps are usually similar to the above only the autocal will instruct you step-by-step.

See YouTube – Ultrasonic straight beam calibration using autocal .

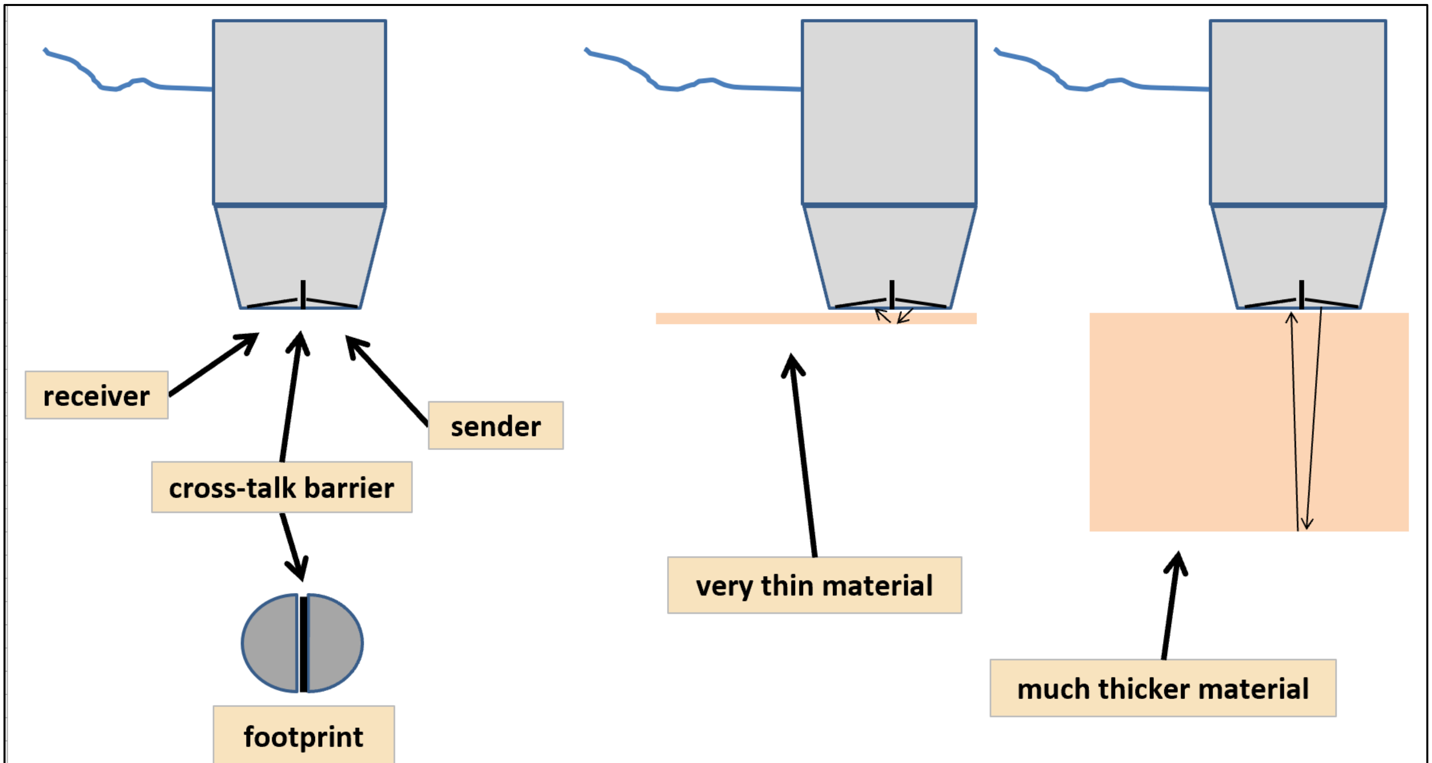
If you do this, become aware if it is measuring peak or edge. We generally don't use peak. We use edge. If you use peak, especially with FAST-UT, it is too much work to keep moving the gate around to gate on the correct signal.

Use of consistent gate and signal height

Take thickness measurements with gate mode of flank or edge, and not at peak. Use a consistent signal height on gates at a consistent %FSH. We typically set the gate at 30%FSH and would measure an indication thickness when it is at 80%FSH. Many instruments have a function called "Auto80" that quickly brings the highest indication in the gate to exactly 80%FSH.

Roof angle

Dual element thickness probes have two elements, a sender and a receiver. They are not parallel to the inspection surface. They are at a slight angle, called the roof angle. This angle may be the cause of some of the lack of linearity in thickness cals. See figure 5 and 6.



Above left: A dual element straight beam probe has a sending side and a receiving side. Where the probe comes into contact with the material is called the footprint.

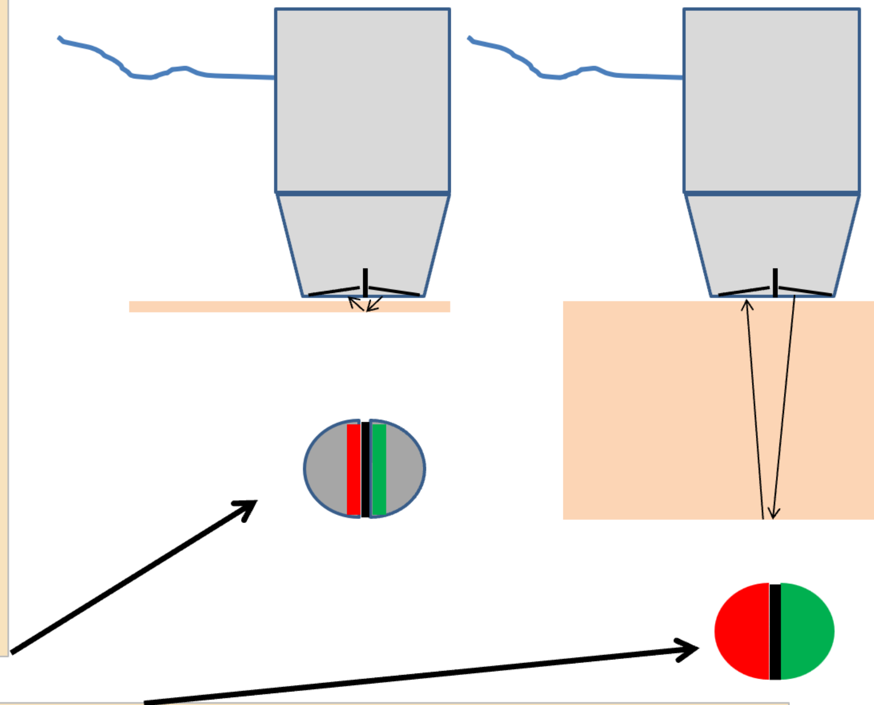
Center: Taking a thickness reading on very thin material.

Right: Taking a thickness reading on much thicker material.

Figure 5

For the thin material, for the first back reflction, only a narrow strip of sender (green) can talk to a narrow strip of receiver (red). The lateral edges of the sender and receiver only contribute to the second and other multiples of the back reflection. Only a narrow part of the center of the probe right next to the cross-talk barrier works for the first back reflection.

For very thin material, you could visualize that for the first back reflection your "footprint" works more like a very skinny rectangle than a circle.



For the thicker material, the entire sender (green) can talk to the entire receiver (red) for the first back reflection.

Note also that the angle the sound reflects at in the thin material is different than the angle the sound reflects at in the thick material. This changing angle accounts for some of the problems in getting a good thickness cal over an extremely large range of thicknesses.

Figure 6

The thickness calibration described above is good from 0.200" to 0.500". We would not be calibrated for thickness readings below 0.200". If you need to be accurate, precise, and calibrated for readings from 0.100" to 0.200" you can consider setting up another cal that is calibrated on the "100" step and the "300" step.

Below 0.100" thick we would need to say that any readings taken are out of the calibrated range, unless we can obtain a calibrated thickness standard that is less than 0.100" thick and recalibrate using it.

Orientation of crosstalk barrier

We've been taught to use a dual element thickness probe on a curved surface like the OD of a small to medium diameter pipe with the cross-talk barrier perpendicular to the axis of the pipe. There was good reason for this. If you put the cross-talk barrier parallel with the axis of the pipe, one side or the other of the probe may lose contact with the pipe. Also, a little bit of rocking motion can introduce a lot of soundpath differences and throw your thickness readings way off.

There are some occasions when it can be useful to turn the cross-talk barrier the "wrong" way. See YouTube – Ultrasonic thickness using crosstalk barrier orientation . Try practicing this on the ID notches of the 0.300" thick notch block.

Rectification

With your straight beam probe coupled to one of the steps of the step wedge, compare the differences in the 4 types of rectification:

- Full
- RF
- Negative half wave
- Positive half wave

See YouTube – [Ultrasonic A-scan rectification]() and figure 7. RF waveform is used for ToFD. We usually use full wave rectification for all our manual UT with the possible exception of this straight beam cal. Since I originally made this YouTube, I have come to the opinion that for most people it is a good idea to use negative half wave rectification for straight beam testing. You will get more consistent results. You are going to get less thickness reading variations due to slight changes in amplitudes.

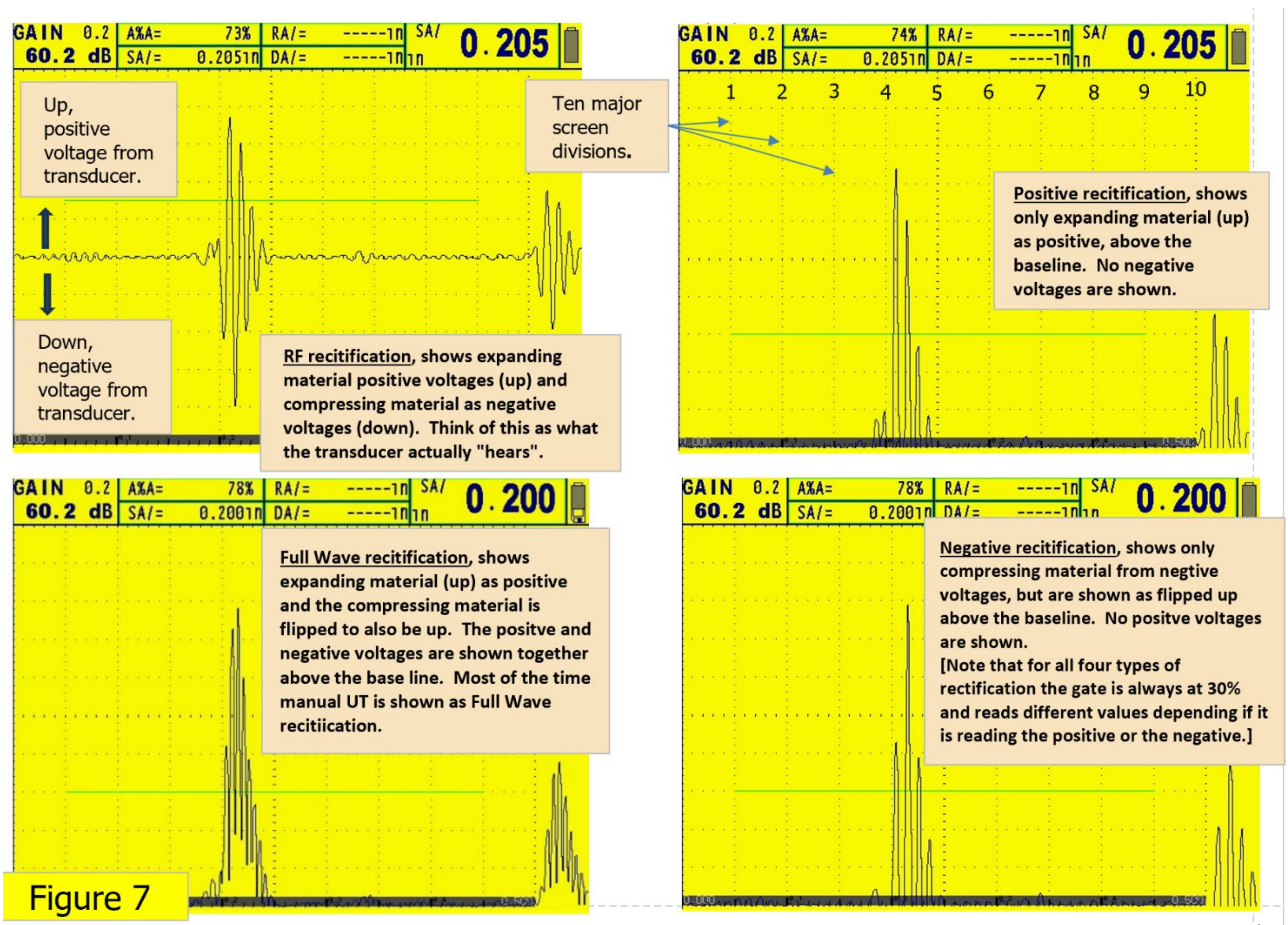


Figure 7

Gain settings for straight beam UT

A good amount of gain during most straight beam UT scanning to search for internal metal loss, laminations, or other mill defects can be obtained by going to an unflawed part of the pipe and then bringing the first back reflection to about 80%FSH, and then adding 6dB.

Recognizing the walk of laminations vs. internal corrosion.

Most of what we observe and learn from our UT has to do with the way indications walk on the screen as the probe is moved. Only in the case of taking a static thickness reading is the probe held still. The way laminations and internal corrosion walk on the screen is totally different. See YouTube - Ultrasonic walk of laminations vs internal corrosion .

Temperature changes

During the course of a work day the temperature can change, especially if you are working outdoors. Temperature changes will affect your UT cals. If the temperature has changed much since you first calibrated you should re-do your calibration.

Colder temperatures make UT louder. Warmer temperatures make UT signals less loud. If the temperature is going up you might need to add gain to compensate.

First back reflection vs multi-echo

Multi-echo is normally used for measuring material thickness through coatings.

For pipeline integrity industry sector we almost never needed multi-echo measurement functions because in-service pipeline digs almost always have the coatings removed by abrasive blasting. Most other industry sectors will sometimes need wall thickness measurement using multi-echo functions so that you can measure the steel thickness when the part has a paint coating on the outside surface.

Multi-echo functions work great on cal blocks but not so well when either the top-side coating is irregular or the top or bottom-side surface is rough, or irregular or corroded.

Keep in mind that if you find yourself needing to measure the steel wall thickness of an item that has a paint coating, you may want to learn how to do multi-echo readings. For multi-echo readings calibrate in the following manner:

- You set up two gates; gate A and gate B.
- Move Gate A to put the first steel back reflection of a step wedge step in gate A. Choose a step similar to the expected thickness in the item you will be measuring.
- Activate Gate B, then move Gate B to put the second back reflection of the same step in gate B.
- Change both gate modes to read First Reflector/Peak
- Using the "GateB minus GateA" measure function, adjust only the velocity until the reading is correct.
- Proceed with measurements on coated parts.

A handy way to test the above cal is to put a credit card on the step wedge to act as your coating of paint. Apply couplant on both sides of the plastic card.

See YouTube – Ultrasonic echo to echo thickness thru coatings .

Pencil Probe - Sonopen

Sonopen, is the Evident-Olympus version of a pencil probe. A Sonopen or pencil probe has a long delay tip in the shape of a cone that ends in a very small diameter tip. The pencil probe is only used for taking thickness measurements in the bottom of a corrosion pit. Pencil probes are notoriously difficult to use in the field. Due to the irregular surfaces found in the bottoms of corrosion pits, it often does not get good ultrasonic coupling. Sound does not make a good entry into the part and therefore does not get enough sound to reflect back and get a good reading. Don't "force" the readings. If the particular corrosion pit you are in does not give a good reading don't force it by adding too much gain.

Use as low a voltage or energy setting as possible, usually about 100 volts. High frequency probes are said to become degraded if hit with high voltage too much.

Establish a Sonopen cal. See YouTube – Ultrasonic pencil probe thickness setup . Consider using a half inch thick cal that starts at the fifth major division. This is a reminder that you are using sound that has gone thru a delay tip before entering the steel. As you couple the transducer to the delay tip, you can watch the delay tip screw into place. Re-couple the delay tip with a fresh dab of couplant before each day of Sonopen use. The first back reflection from the end of the delay tip is visible at the fifth major division. The first back reflection from the 0.100" thick step is at the sixth major division.

Note the effect of search unit angulations on amplitude.

Have a cal 'standard' for very thin material. Use a dial caliper to establish a thin step on something you normally have with you when you are at field sites.

Be able to recognize a second back reflection of very, very thin material and determine the actual thickness by dividing the second back reflection reading by two.

Extremely thin pipe.

When working with extremely thin pipe (T-nom; 0.201", 0.188", 0.156", 0.125" [5.11mm, 4.78mm, 3.96mm, 3.18mm]) try to obtain a 10 MHz dual element straight beam probe. See the recommended equipment list on pages 18 & 19.

Doubling

Doubling is what can happen when you are attempting to take a normal thickness reading with your usual 7.5MHz dual element straight beam probe, hopefully with your SB-XX setup, and you get an incorrect measurement because the material is too thin. As a current or future level 2, you should be used to navigating yourself with your A-scan display and not just accepting the numbers that might pop up in your reading boxes.

If the material is too thin there might not be enough amplitude to get a reading for the first back reflection. If the first reflector you can measure is the second back reflector you can just divide this thickness by two to get the actual thickness reading. See YouTube – Ultrasonic thickness doubling .

Very high frequency probes and welds

Be aware that if you are using very high frequency probes such as the 15MHz Sonopen that welds will give many tiny grain noise reflectors scattered through the weld volume. Overcome this effect by reducing gain so that the backwall reflector is not too loud. Only use the Sonopen for getting thicknesses in the bottom of pits.

Saving your calibration setup files

At this point you should have saved at least two calibration setup files; SB-XX and Sonopen-XX, which are your dual element straight beam and your pencil probe. (Only 4 more setups to go!) You could consider saving these setup files on your laptop. See YouTube – Saving your calibration setup files .

Section 3 Angle Beam UT

Getting ready for angle beam testing

Conventional Shear Wave Angle Beam UT Range Selection

Before we begin creating cal files for angle beam, we will digress for a moment to develop the one-inch-deep display (for metric the 20mm deep display). There are many ways to set up your A-scan display just by choice of screen range. Four common approaches are:

- Soundpath screen
- I.D. at 4, O.D. at 8
- Leg display
- One-inch-deep screen (or in Metric 20mm deep screen

Soundpath screen:

When I first began doing angle beam UT many years ago, I liked using the 10-inch soundpath screen. My screen range was 10 inches and each of the ten major divisions along the baseline of the screen was one inch of soundpath each. This helped with visualization for figuring out which reflectors on the screen belonged to which parts of the cal blocks like the IIW, the DSC or the Rompas (more on those later). For conventional shear wave angle beam UT we use angles of 45°, 60°, and 70°. For each angle, and for each T-nom (nominal thickness) I had different places on the screen that represented the end of leg 1, 2, and 3 for each angle. For a review of legs see the terms and definitions section at page 114. It was a lot of work to keep it all straight in my head. And when the material thickness changed, I had to keep track of a whole new set of legs locations. For the thin materials we are addressing here, an approach to the soundpath screen is a screen range of 2.5″. This makes each major division ¼″ of sound path travel. This could work for you, but you might need to have some china markers or dry erase markers to mark all your leg locations on the instrument screen face, for each angle and each thickness. This is lot of work to keep up with for all three angles and in my opinion can get confusing keeping it all straight in your mind, which is where UT is really done, inside your brain.

ID at 4, OD at 8, screen

Another approach, used frequently in ASME work, is to put the ID at the fourth major division and the OD at the eighth major division. [Note; ID literally, short for Inside Diameter, meaning the inside surface and OD literally, Outside Diameter, meaning outside surface] This was good for figuring out where different reflectors were. But it requires new cals for each thickness tested. This works really well when you have ASME cal blocks, and you can peak up on ID and OD corners to set up. If you don't have ASME calibration blocks made from a piece of the subject pipe then you don't have a block to use with the corners at the correct depths. For example, pipeline integrity digs never have any ASME cal blocks, or access to any ID or OD corners. This can still be done using the "ID roll" signal or the "OD roll" signal, but isn't as precise. Again, this was a lot of work to keep it all organized, because you would have to change each angle beam cal with every different thickness of pipe, for each angle. For a demonstration of what "ID roll" and "OD roll" signals look like see YouTube – Ultrasonic shear wave ID roll and OD roll signals .

Leg display screen

The leg display shows you where leg 1 ends, where leg 2 ends, where leg 3 ends, etc.…

Some UT platforms indicate where the end of each leg is along the baseline by displaying the labels L1, L2, L3, under the baseline of the screen at the position where they end. See figure 8. Some UT platforms show the legs by colorizing the whole screen a different background color for each leg. See figure 9.

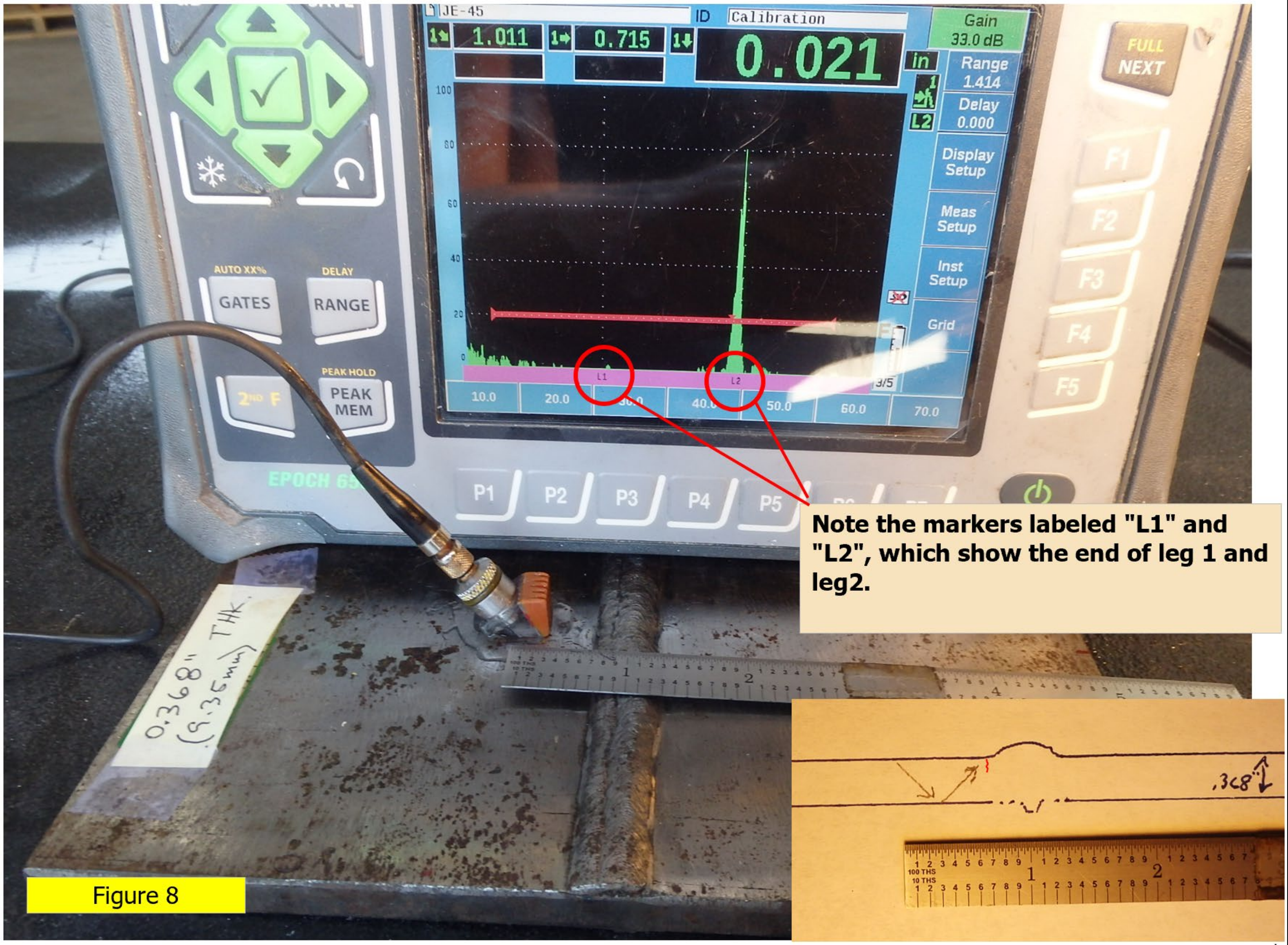


Figure 8

Most technicians find the leg display to be the easiest and most useful. The leg display helps make it easier to see what leg you are in when you find an indication. Normally when you find an indication your first question should be "where is it?". Is it ID, OD, or midwall? Being able to see it in relation to ID or OD is a great starting point and the leg display really is great for this.

In this training we concentrate on using the next type of display, the one-inch-deep (or in metric 20mm deep) screen display because it is best for FAST-UT. In your future career you may decide to use the leg display for shear wave. But for your training try to adapt to the one-inch-deep (20mm deep) display.

One-inch-deep screen or 20mm deep screen

The approach we take here is to use one cal for each angle, no matter the thickness. Makes everything simpler. For thin-walled material less than ½" [12.7mm] thick we can usually see all of leg 1 and 2 for almost all the pipe T-noms we are likely to see.

The one-inch-deep [20mm] cal also has the benefit of keeping the ID and OD at the same places on your angle beam screen no matter if you are using 45°, 60°, 70° or FAST-UT (which is also 70°) for each T-nom you work on. These cals are always ready to go. No need to make new cals when you show up on a job with a different T-nom. Later in this training we will progress from shear wave angle beam to angled L-wave. It is helpful to have the one-inch-deep screens established and be familiar with them before making the transition to angled L-wave; FAST-UT.

It should be obvious that one inch does not equal 20mm. One inch is 25.4mm. We use the 20mm deep screen when we are working in Metric-millimeters because we can easily tell how deep a reflector is by its location along the base line. Each major division is 2mm. On the one-inch-deep screen each major division is 1/10 inch deep, or 0.100". At first this might sound confusing but as you go along it becomes familiar and second nature to you that you can recognize how deep things are by their location relative to the 10 major divisions on the screen.

There are three magic numbers to use to get one-inch-deep screens for 45°, 60°, and 70°. There are also three magic numbers to use to get 20mm deep screens if you are working with the metric cal blocks:

Angle	Range to use for one-inch-deep screen	Range to use for 20mm deep screen
45°	1.414"	28.29mm
60°	2.000"	40.00mm
70°	2.924"	58.48mm

Figures 10-20 shows how these screen range numbers are derived. This is reviewed in YouTube – Ultrasonic range 3 magic numbers for one-inch-deep screens which has a bit of trigonometry in it.

Don't worry, you never need trigonometry to do angle beam UT. Nowadays, flaw detectors do all the trig for you. (If you are curious as to how the trig works you can watch YouTube – Ultrasonic angle beam trigonometry . Feel free to skip this.)

Three trig formulas can do everything you would ever need in angle beam UT:

#1:

soundpath or beampath or angular distance or leg 1 length = T/cos

#2

Surface distance = soundpath * sin

#3

Depth = soundpath *cos

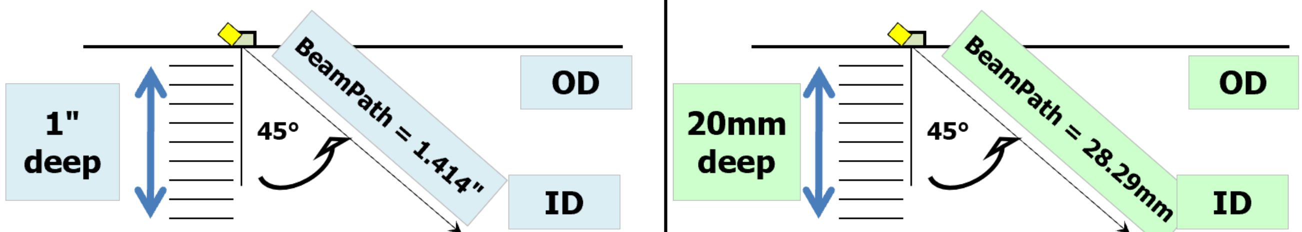
You won't need to memorize any trig formulas to do angle beam UT

Figure 10

45°

NOTE THAT ONE INCH DOES NOT EQUAL 20MM. We use these for our depth screens becasue they make it easier to see how deep things are. For the one-inch-deep screen each major screen division is 1/10 of one inch, or 0.100" of depth. For the 20mm deep screen each major screen division is 2mm of depth.

one-inch-deep screen	20mm deep screen
BP = T/cos45	BP = T/cos45
BP = 1" / cos45	BP = 20mm / cos45
BP = 1" / 0.707	BP = 20mm / 0.707
BP = 1.414"	BP = 28.29mm



This is the length of the first leg of sound with a 45° if your material was 1" thick.

This is the length of the first leg of sound with a 45° if your material was 20mm thick.

Figure 11

45°

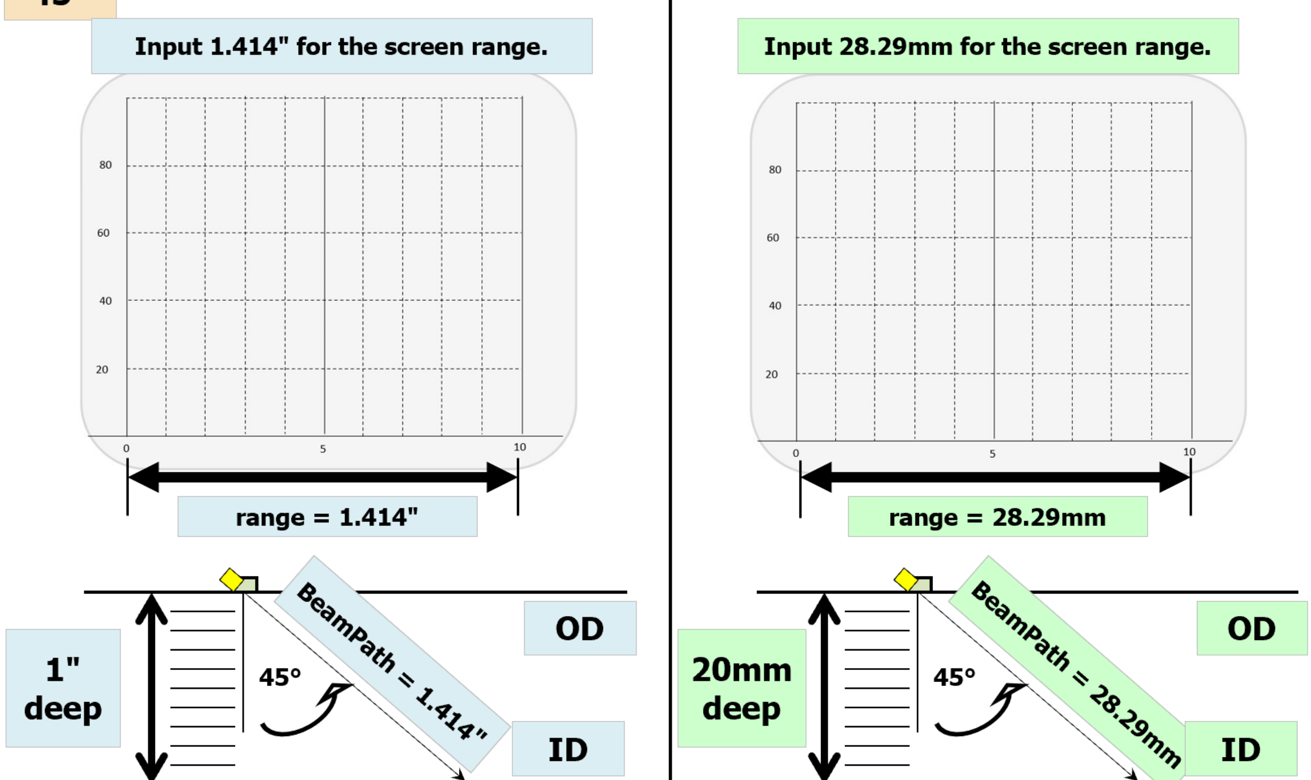


Figure 12

45°

Now you have a one inch deep screen. Shown here is one way to visualize it. Zero on your screen is the sound entering the material. The tenth major division on your screen is at one inch of depth.

Using a screen range of 1.414" gives you a one-inch-deep screen with a 45°.

Now you have a 20mm deep screen. Shown here is one way to visualize it. Zero on your screen is the sound entering the material. The tenth major division on your screen is at 20mm of depth.

Using a screen range of 28.29mm gives you a 20mm deep screen with a 45°.

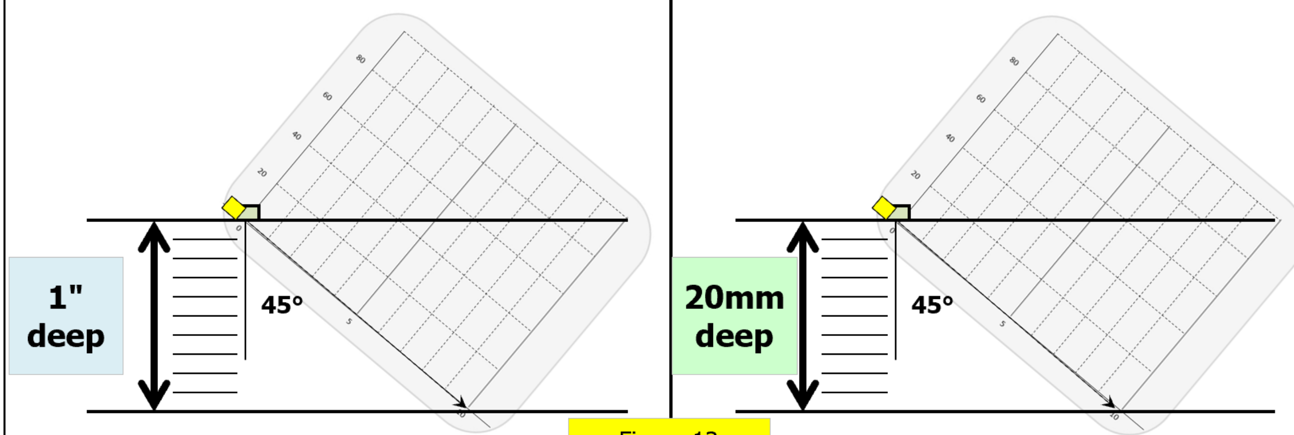


Figure 13

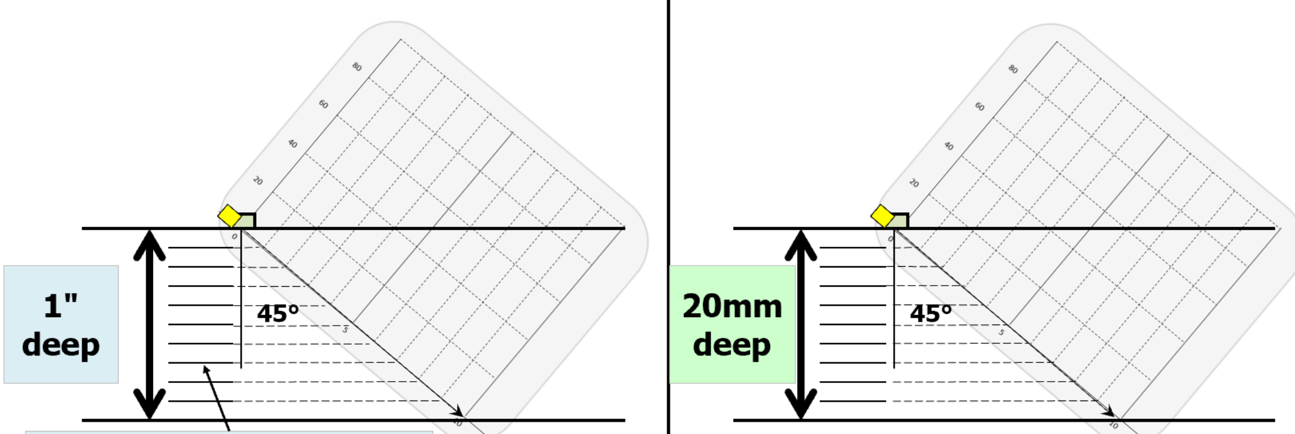
45°

Note that each of the horizontal lines on the left is 1/10 of the part thickness.

If you extend these to the right, they coincide with 1/10 of the screen range.

Note that each of the horizontal lines on the left is 1/10 of the part thickness.

If you extend these to the right they coincide with 1/10 of the screen range.



each horizontal line is 1/10 of the part thickness

Figure 14

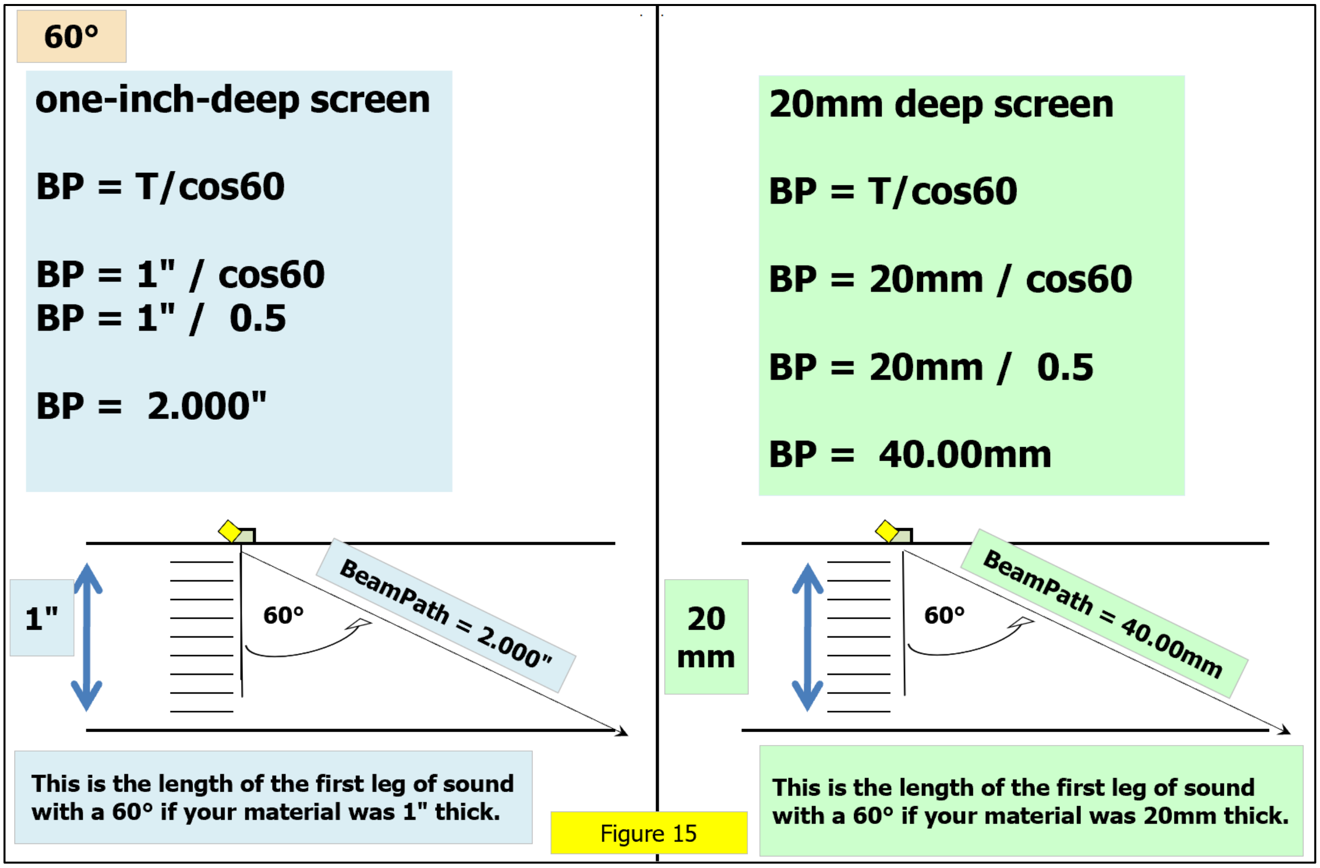


Figure 15

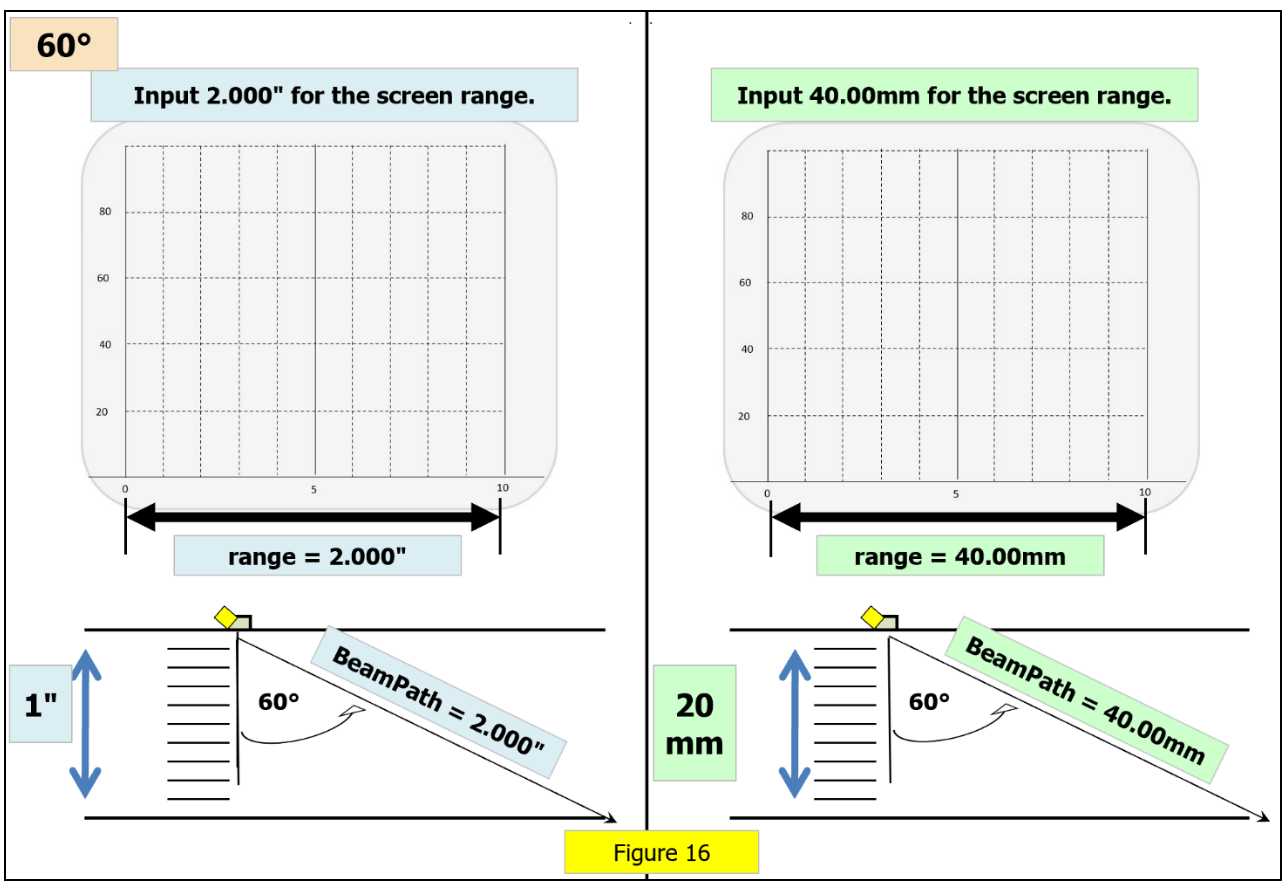


Figure 16

60°

Now you have a one inch deep screen. Shown here is one way to visualize it. Zero on your screen is the sound entering the material. The tenth major division on your screen is at one inch of depth.

Using a screen range of 2.000" gives you a one-inch-deep screen with a 60°.

Now you have a 20mm deep screen. Shown here is one way to visualize it. Zero on your screen is the sound entering the material. The tenth major division on your screen is at 20mm of depth.

Using a screen range of 40.00mm gives you a 20mm deep screen with a 60°.

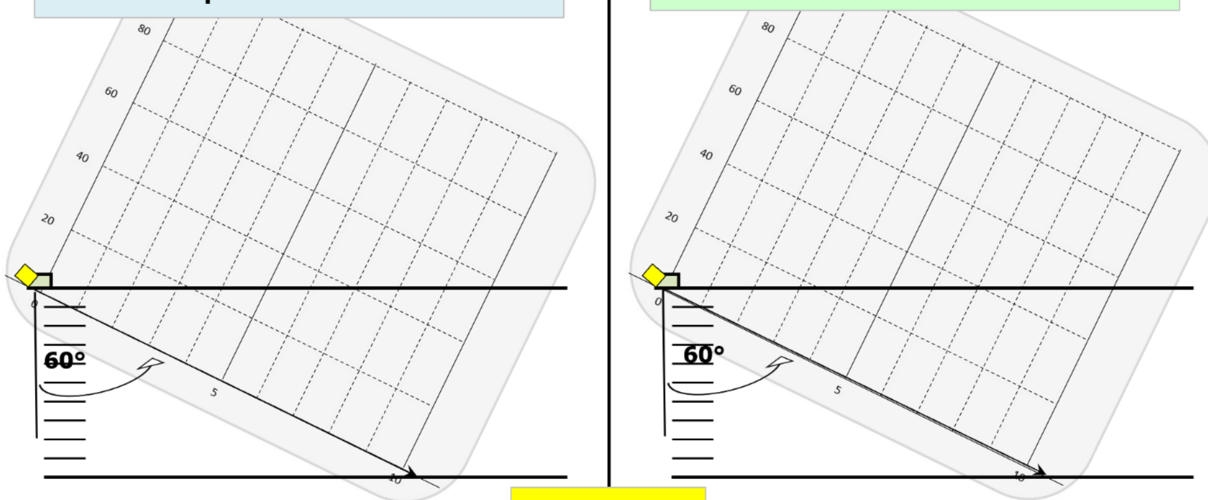


Figure 17

70°

one-inch-deep screen

BP = T/cos70

BP = 1" / cos70
BP = 1" / 0.342

BP = 2.924"

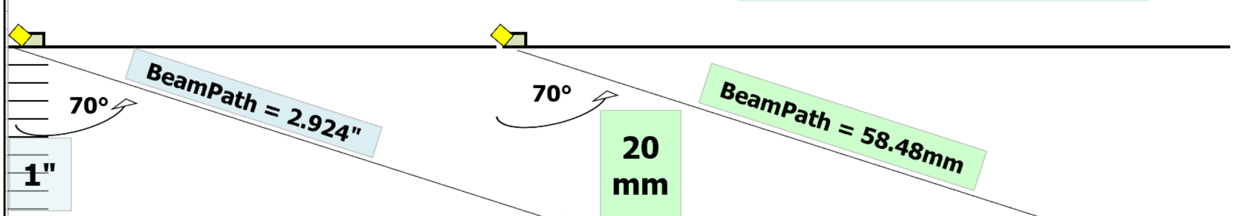
20mm deep screen

BP = T/cos70

BP = 20mm / cos70

BP = 20mm / 0.342

BP = 58.48mm



This is the length of the first leg of sound with a 70° if your material was 1" thick.

Figure 18

This is the length of the first leg of sound with a 70° if your material was 20mm thick.

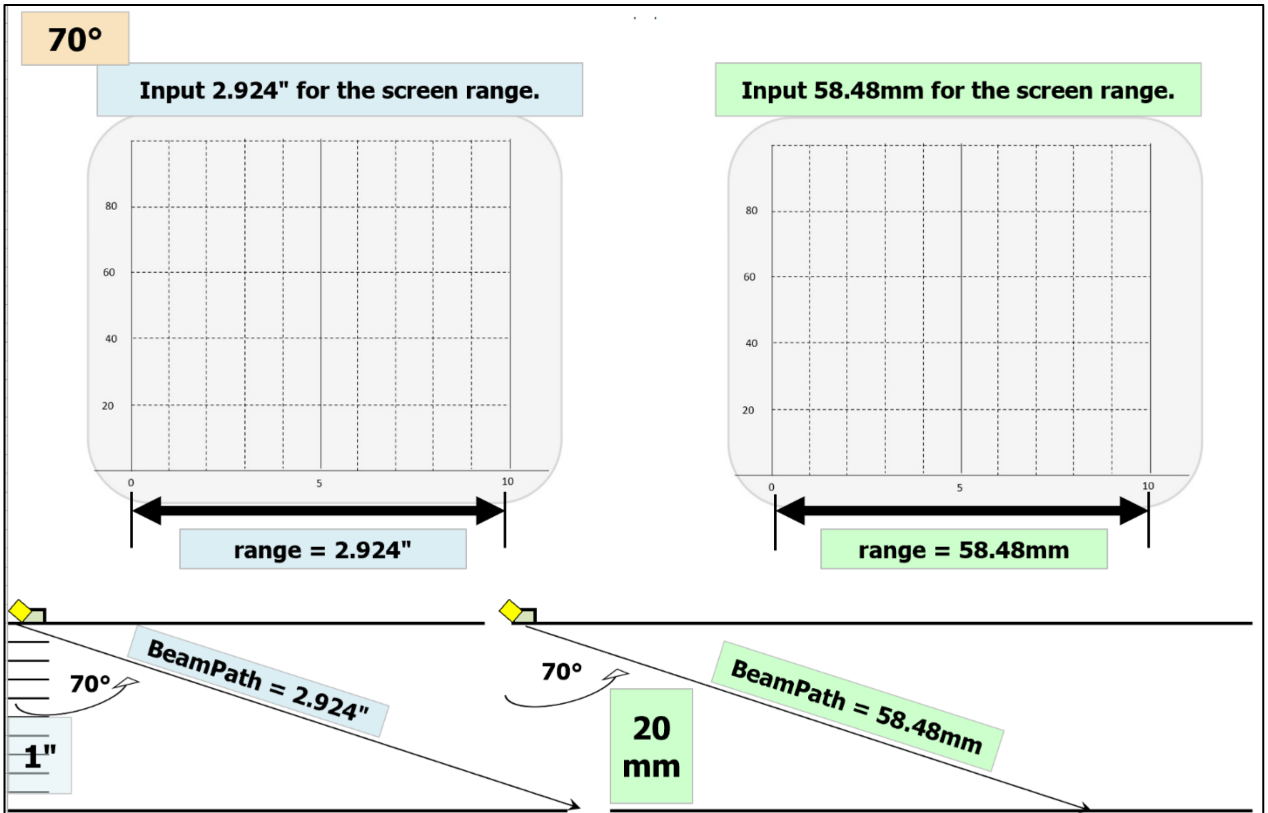


Figure 19

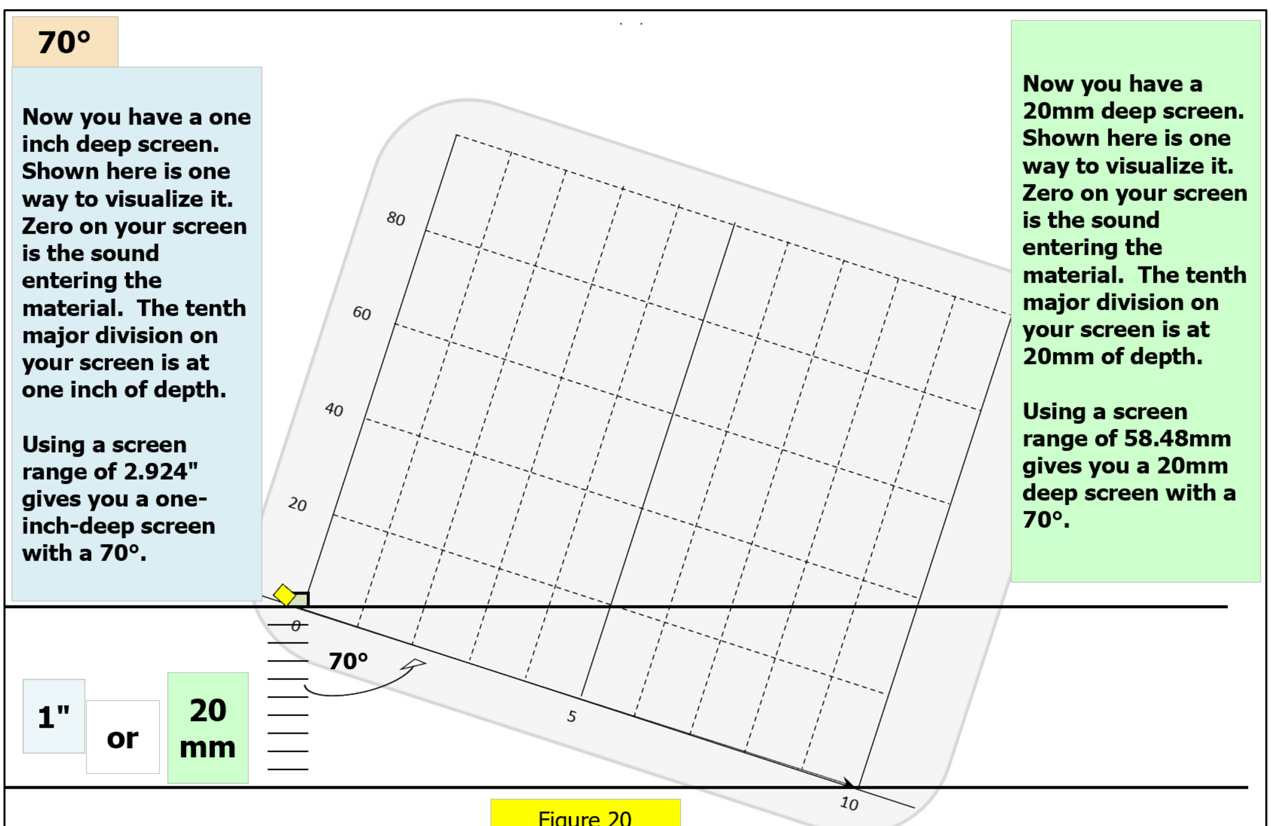


Figure 20

Figure 21 shows a summary comparing the advantages and disadvantages of the four methods of establishing screen range:

- Soundpath screen
- I.D. at 4, O.D. at 8
- Leg display
- One-inch-deep screen (or for Metric 20mm deep screen

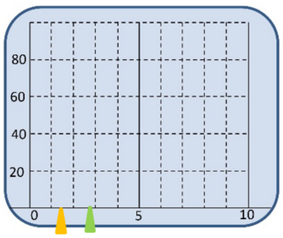
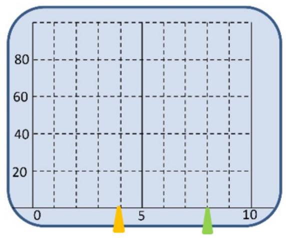
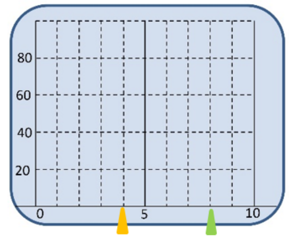
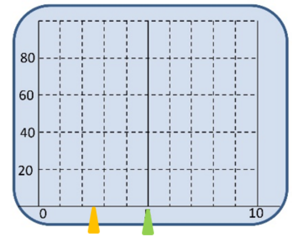
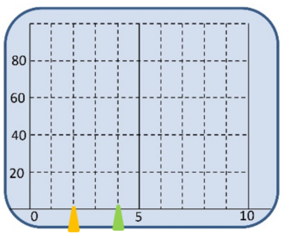
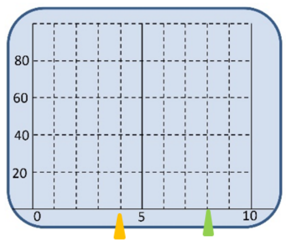
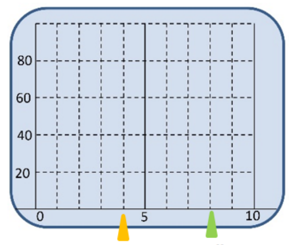
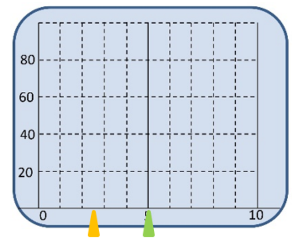
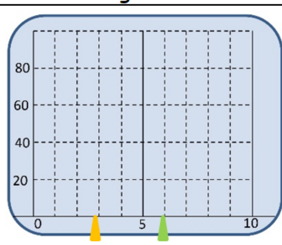
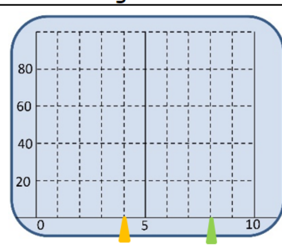
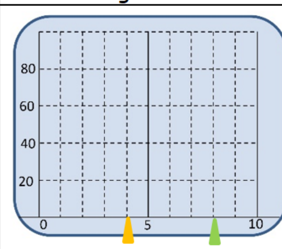
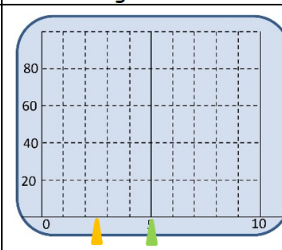
example shown Tnom = 0.25 inch	2.5 inch soundpath screen	ID at 4, OD at 8	leg display screen (showing 2.5 legs)	one-inch-deep screen (we train with this)
ID OD 45°	 Range = 2.5"	 Range = 0.875"	 Range = 0.875"	 Range = 1.414"
60°	 Range = 2.5"	 Range = 1.25"	 Range = 1.25"	 Range = 2.000"
70°	 Range = 2.5"	 Range = 1.825"	 Range = 1.825"	 Range = 2.924"
advantages	ea major div. is 1/4" of soundpath	always know where ID & OD are	always know where ID & OD are	never need new setups never need to change anything
disadvantages	diff screen range ea angle&thk	diff screen range for ea angle we usually don't have a cal block of every single thk	diff screen range for ea angle	new ID and OD for each thk

Figure 21

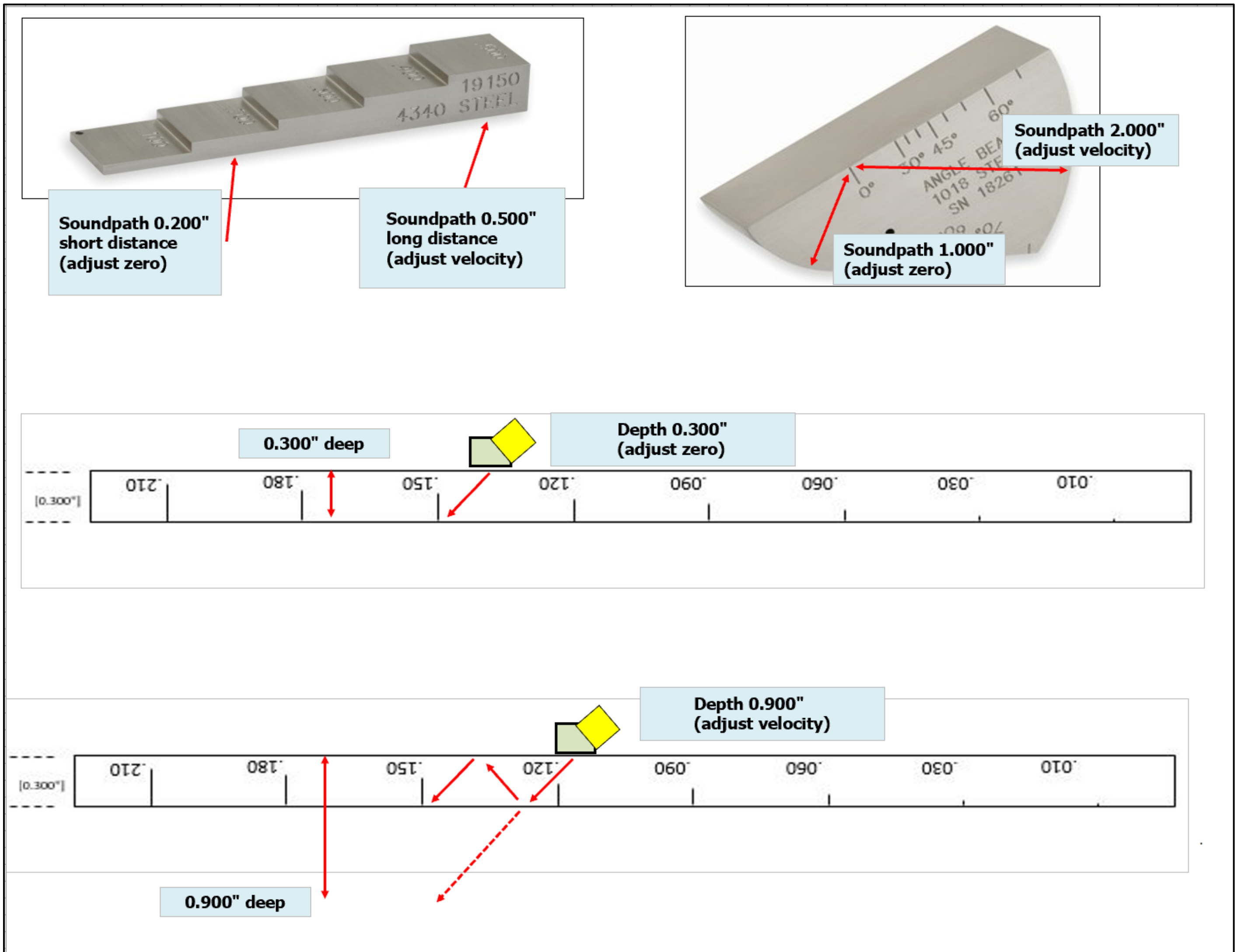
Now that we have developed the "one-inch-deep screen" [20mm deep screen] for all our angle beam work we can create our 3 conventional shear wave cals.

UT calibration for straight beam and for angle beam is essentially the same two-step process;

- Find the "zero" point; the point in time where the sound enters the material
- Find the correct velocity.

Once you have the correct "zero" and the correct velocity all your measurements will be accurate. Auto-cal is the same process; establish the "zero" and then find the velocity.

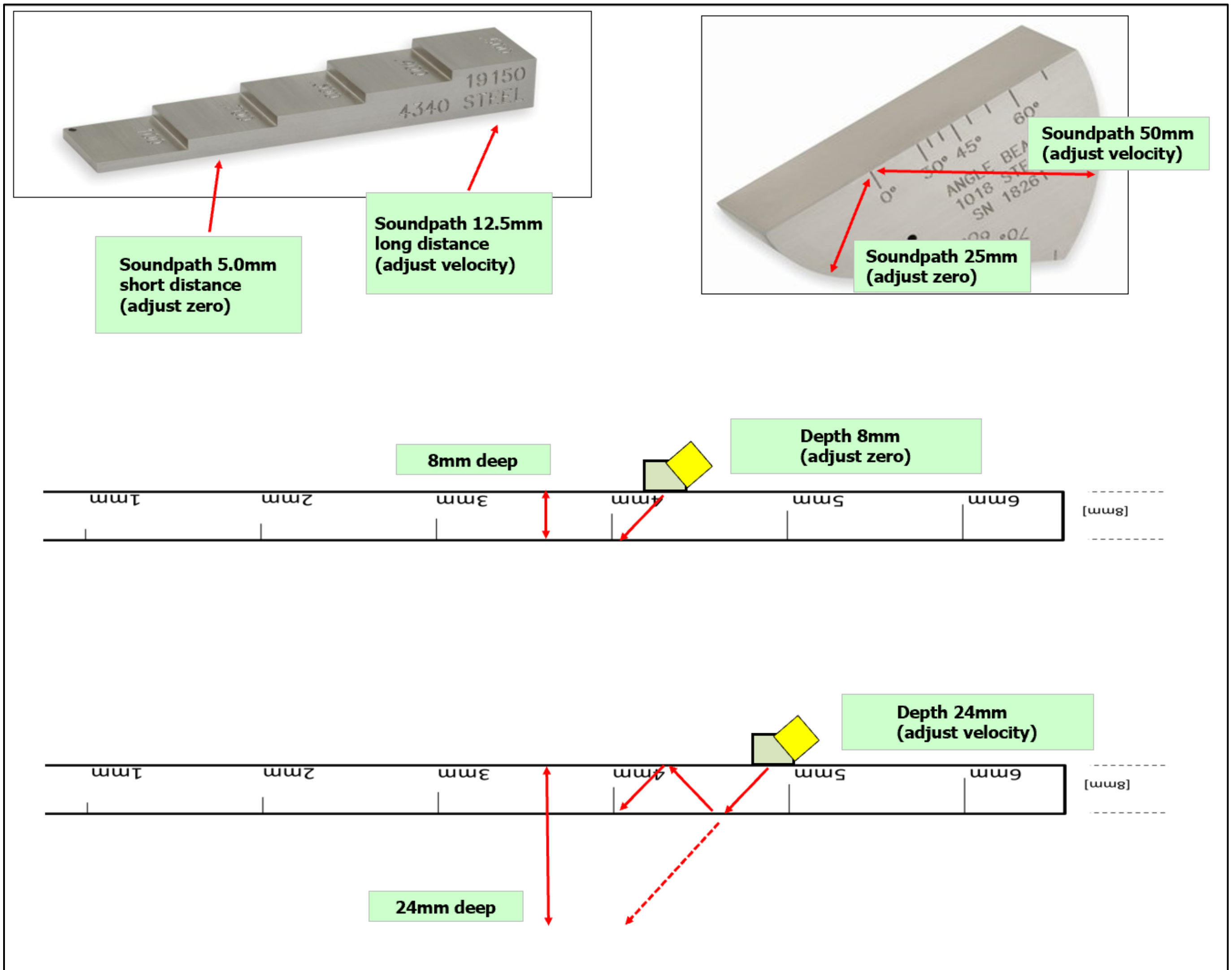
For both straight beam thickness and angle beam you do the same thing; establish the "zero" with a known short distance and establish velocity with a known long distance. This is shown in figure 22 for inches cal blocks and figure 23 for metric cal blocks.



For calibrating we usually use a process that involves adjusting "zero" at a short distance and velocity at a longer distance. "Zero" is called "probe delay" in some insturments. Examples of this for straight beam is shown above left, and for angle beam above, right.
To calibrate the 45° with the notch block:

*First peak up on the corner trap reflector of the 0.150" deep ID notch at the end of leg 1, then adjust "zero" to make the depth reading box read 0.300" depth. See middle figure above. This is your short distance using "zero".
*Second, peak up on the same reflector at the end of leg 3, then adjust Velocity to make the depth reading box read 0.900", becuase to get to it the sound will have traveled 0.900" in the up-and-down depth axis. See bottom figure. This is your long distance for velocity.
*Repeat until no more adjusting needed.

figure 22



For calibrating we usually use a process that involves adjusting "zero" at a short distance and velocity at a longer distance. "Zero" is called "probe delay" in some insturments. Examples of this for straight beam is shown above left, and for angle beam above, right.
To calibrate the 45° using the ntoch block:
*First peak up on the corner trap reflector of the 4mm deep ID notch at the end of leg 1, then adjust "zero" to make the depth reading box read 8mm depth. See middle figure above. This is your short distance using "zero".
*Second, peak up on the same reflector at the end of leg 3, then adjust Velocity to make the depth reading box read 24mm, becuase to get to it the sound will have traveled 24mm in the up-and-down depth axis. See bottom figure. This is your long distance for velocity.
*Repeat until no more adjusting needed.

figure 23

Should I start with angle and index point verification?

Most beginning hands-on instruction for angle beam UT will have you check your angle to make sure it is close (within 2°) to the nominal angle specified on the wedge; 45°, 60°, or 70°.

The given angle for a <u>new</u> wedge is always close to good. Likewise, the index point as marked on a new wedge is always good.

It is possible to have old, used wedges that are very badly worn and end up with angles way off from nominal markings. In pipeline integrity work, the pipe is always cleaned by abrasive blasting (sand blasting) which can leave a <u>very</u> abrasive surface finish. We have always instructed our examiners to prep the surface a bit in the areas where angle beam UT is going to be done. Ideally the prep is done with a knotted wire wheel attachment on a grinder. Some people use sanding discs but this should only be used with extreme care not to remove too much material. Prep with the knotted wire wheel or sanding discs will prevent the wedges from becoming worn down. If an examiner does no prep, then the wedges can become very worn down and this can change the angle and the index point

Do your angle beam UT using new or like-new wedges. Only use wedges with angles measured to be within 2 degrees of the nominal angle.

If your wedges are new or like-new you can skip this. If you are going to learn to check angle and index point verification you should probably also know how to set up a 5 or 10-inch screen range using commonly available cal blocks:

IIW type 1

IIW type 2

Mini IIW

Rompas

DSC

See YouTube - Ultrasonic refracted angle, index point verification and range setting .

A perfect cal with an IIW block and a ten-inch screen range might not work so hot for thin-walled applications. To get the best sizing accuracy for thin-walled applications you should make your cals with reflectors that are located in thin-walled cal blocks. The side drilled hole block (figure 3) and the notch block (figure 4) are ideal for thin-walled applications. If you have your "perfect" cal made with an IIW block, and then apply it to do sizing on these blocks your sizing might not be as precise as you would like.

Our bottom line is this: whatever blocks you use to calibrate with, you want your flaw height sizing to be good on the notch block with your final setup. No matter what you use initially to set yourself up with, your final cal should result in good sizing on the notch block.

We have found the quickest way to the most accurate and precise cal for thin-walled applications is to use the instructions for autocal in figure 25 or 27.

Shear wave cals

45° shear, 1″ deep screen

A summary of how to set up the 3 shear wave cals; 45°, 60°, and 70° without auto-cal is shown in figure 24.

A summary of how to set up the 3 shear wave cals; 45°, 60°, and 70° with auto-cal is shown in figure 25.

For your reading boxes use:

- Soundpath in gate 1
- Surface distance minus x-value in gate 1
- Depth in gate 1

Make a one-inch-deep screen by changing the range to 1.414″. Why 1.414″? (see figures 11-14). Select the built-in default shear wave velocity for plain carbon steel (examples: Evident-Olympus; 0.1280″/µSec or GE/Krautkramer; 0.1320″/µSec).

For the 45° search unit, the probe 'zero' and velocity can be made precisely accurate by looking at figures 22 and 24 and doing the following:

1. Go to the 0.3″ thick notch block and peak up on the ID corner trap of the 0.150″ deep ID notch at the end of leg #1. It should peak up at 0.300″ deep, in your "depth" reading box. If it does not read 0.300″, adjust 'zero' until it does.
2. Peak up on the same corner trap reflector, but this time at the end of the third leg of sound. It should peak up near 0.900″ deep in your depth reading box. Adjust 'velocity' until it does.
3. Repeat steps #1 and #2 until the cal is consistently accurate at both 0.300″ deep and 0.900″ deep. If you needed to adjust your velocity and you are using an Evident-Olympus flaw detector you may need to re-adjust your screen range to 1.414″.

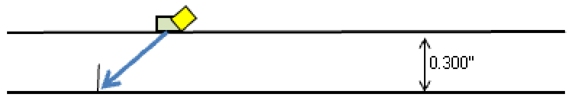
See YouTube - Ultrasonic 45-degree one-inch-deep shear wave cal setup for the set-up of the 45° in inches.

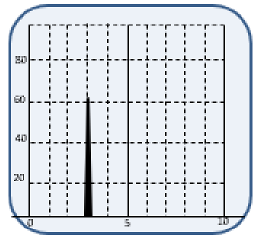
Summary of the steps to set up 45°, 60°, and 70° one-inch-deep shear wave cals without autocal

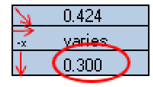
45 degree

Use a screen range of 1.414"

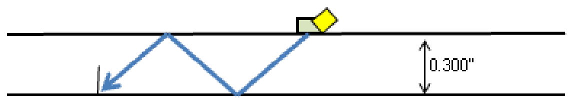
Peak up on the 0.150" deep ID notch at end of first leg
and use zero (probe delay) to bring depth reading to 0.300" deep

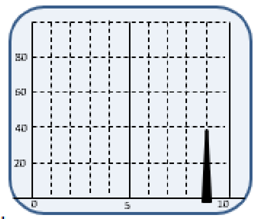


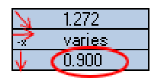




Peak up on the same 0.150" deep ID notch at the end of leg three and use velocity to bring depth reading to 0.900" deep







Repeat until end of leg one reads 0.300" deep and end of leg three reads 0.900" deep.

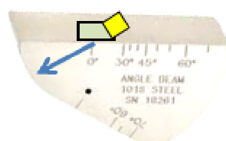
Re-position to check X-value.

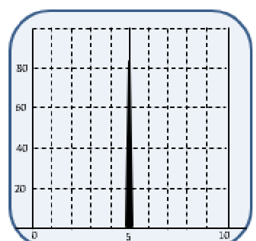
Adjust X-value until the surface distance minus X-value reading box agrees with what you measure with your scale.

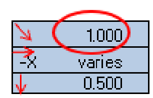
---

60 deg

Use a screen range of 2.000" and use the velocity found for the 45 deg.
Peak up on 1" radius of mini angle beam block and use zero (probe delay) to make it read 1.000" of soundpath in the soundpath reading box.

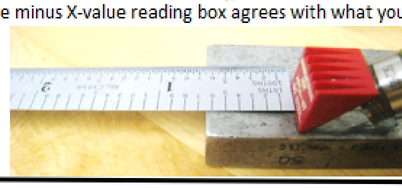


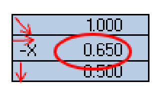




Re-position to check X-value.
Adjust X-value until the surface distance minus X-value reading box agrees with what you measure with your scale.

In this case 0.650"





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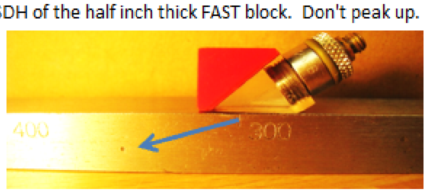
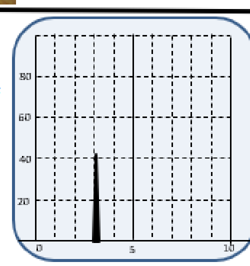
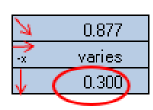
70 deg

Use a screen range of 2.924" and use the same velocity used for the 45 and 60.
Put the factory marked scribe line of the search unit on the mark for the 0.300" SDH of 0.300" deep SDH of the half inch thick FAST block. Don't peak up.







Use zero (probe delay) to make it read 0.300" deep in the depth reading box.
Adjust X-value until the surface distance minus X-value reading box agrees with what you measure with your scale.

In this case 0.510"

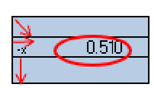


figure 24

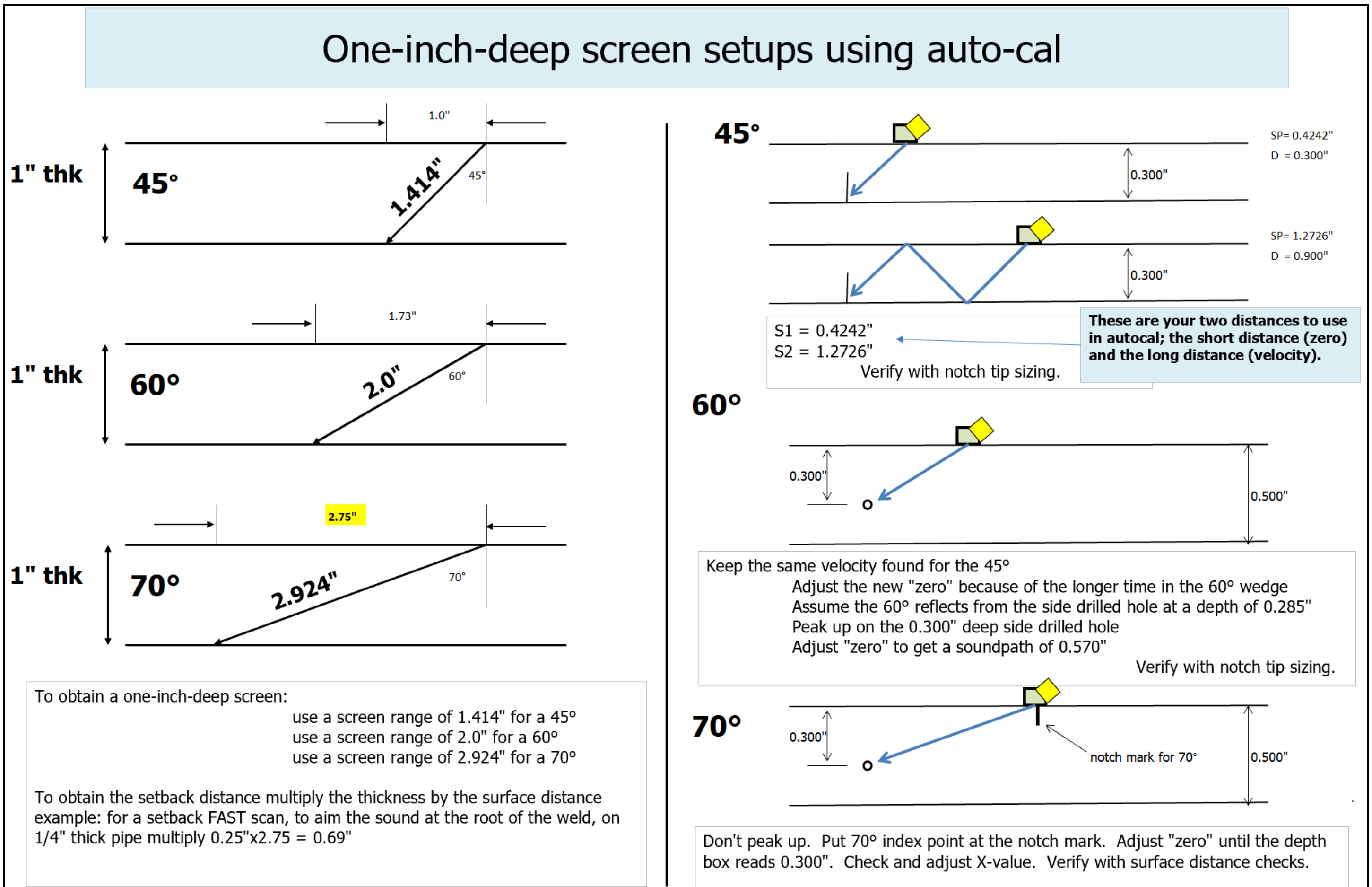


figure 25

Check the cal by peaking up on the SDHs of the half inch FAST block. Note your results in the table below. We sometimes refer to this table for midwall, rounded flaw height sizing.

Lab Exercise 1 - 45° SDHs (in.):

SDHs	0.100"	0.200"	0.300"	0.400"
Peaks at:				

(use pencil, not ink)

Note how reflectors have a short 'walk' with a 45° (also known as a short echo-dynamic, or envelope). See YouTube-[Ultrasonic 45-degree side drilled hole measurements] for the use and appearance of the 45°.

45° shear, 20mm deep screen

Follow the directions above but substitute the metric cal blocks; the 12.5mm thick, side drilled hole FAST block, and the 8mm thick notch block.

A summary of how to set up the 3 shear wave cals; 45°, 60°, and 70° without auto-cal is shown in figure 26.

A summary of how to set up the 3 shear wave cals; 45°, 60°, and 70° with auto-cal is shown in figure 27.

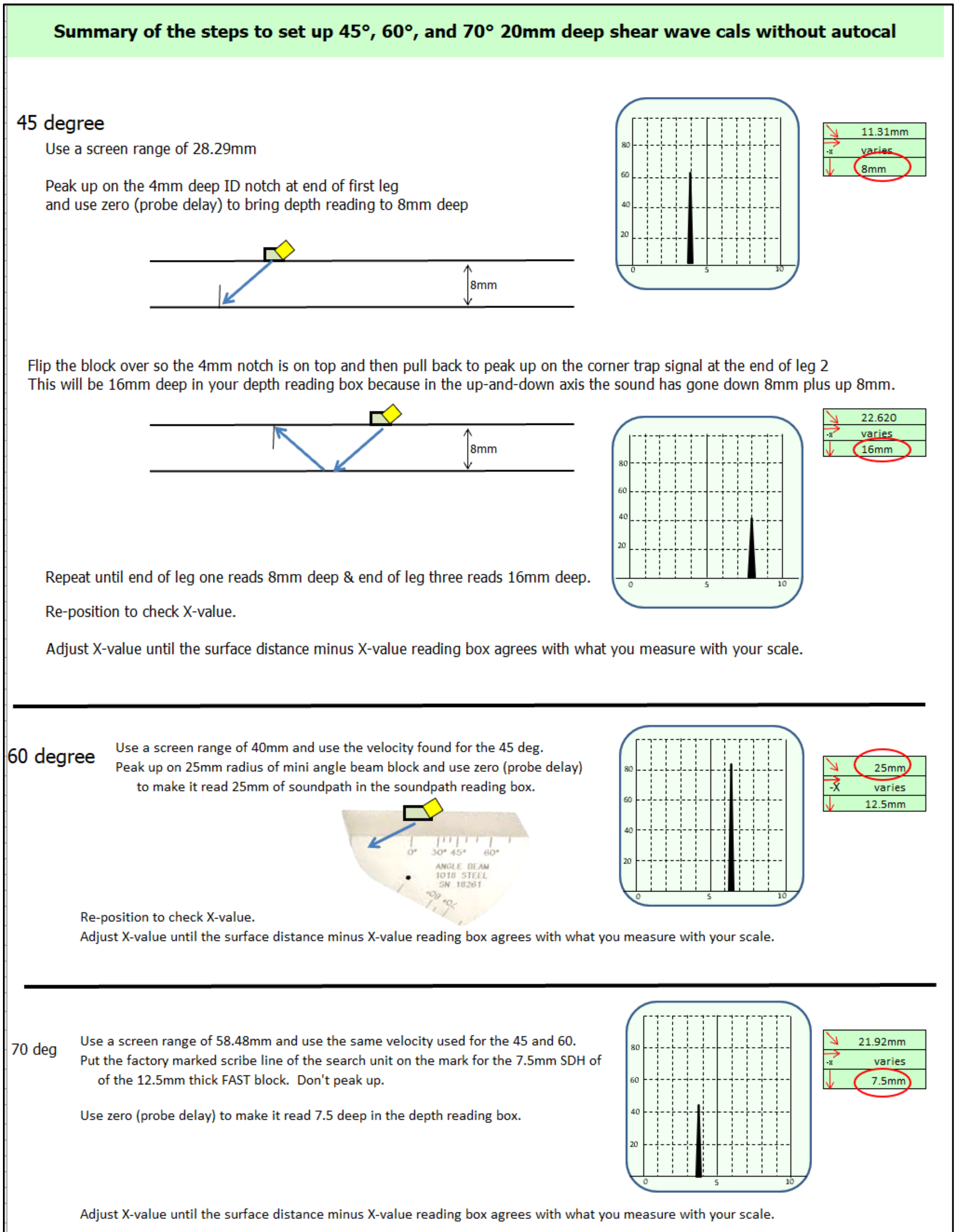


figure 26

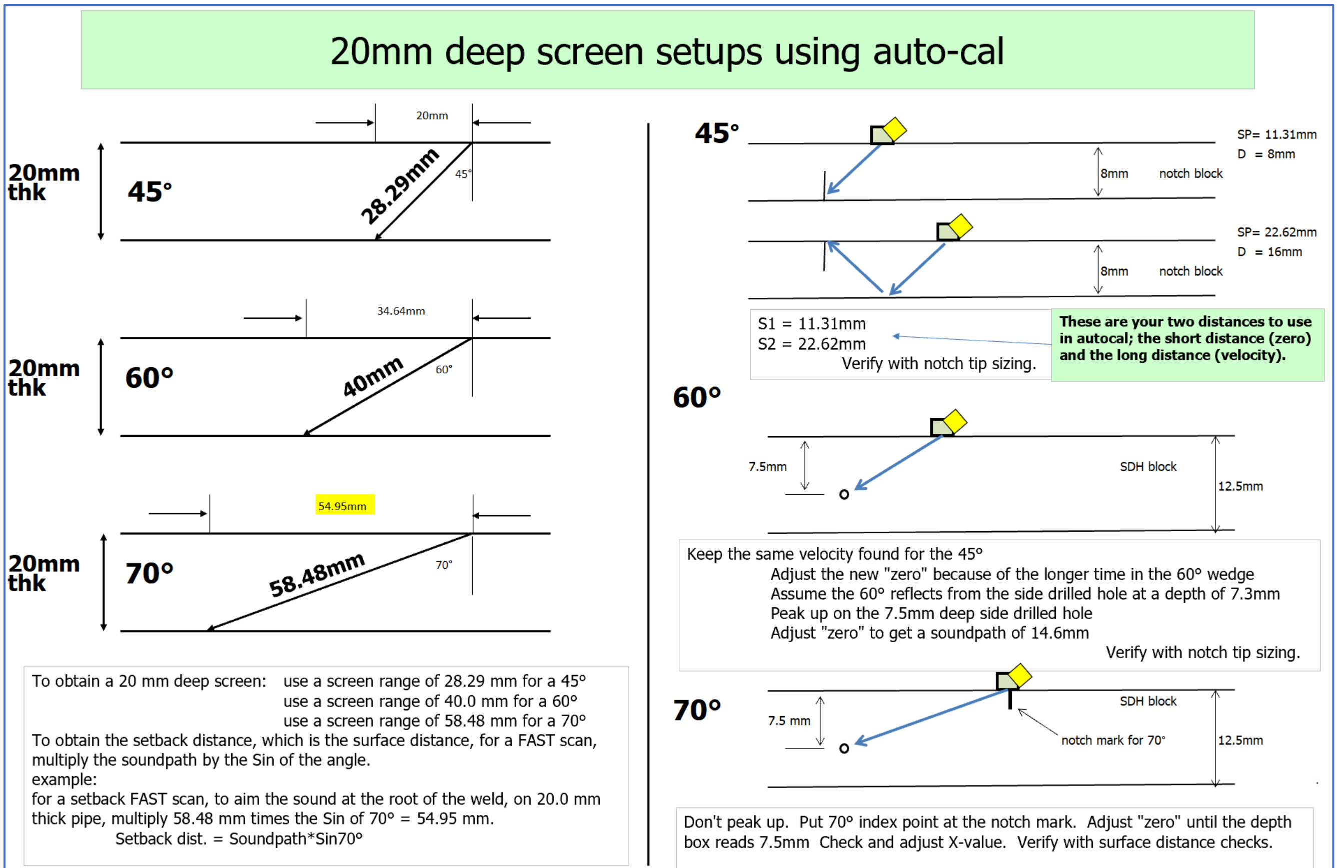


figure 27

If you are working in millimeters use the 12.5mm thick side drilled hole block and note your results in the table below. We might refer to this sizing table for midwall flaws.

Lab Exercise 1 - 45° SDHs (mm):

SDHs	2.5mm	5.0mm	7.5mm	10.0mm
Peaks at:				

(use pencil, not ink)

45° surface distance measurements:

Put the index point 0.5" back from the end of the 0.5" FAST block (or for metric, 12.5mm from the end of the 12.5mm thick FAST block) and move the probe into the position that shows the corner trap reflector is at 0.500" (or 12.5mm) deep in the depth reading box. This is the point at which 45 degrees is aimed at the corner. Measure the distance from the front of the wedge to the end of the block with your scale. This is the actual "surface distance minus X-value." This is what you should see in your "surface distance minus X-value" reading box. If not, adjust your X-value until the "surface distance minus X-value" reading box agrees with what you see on your scale. With an Epoch 600, or similar, you can watch it as you "dial it in" with X-value. With the USMGO, or similar, you have to go back and forth between the menus. For the USMGO, or similar, if the surface distance (-)x value is too great, increase the x value.

See YouTube Ultrasonic 45-degree surface distance measurements for the use and appearance of the 45° surface distance measure function.

I often see folks struggling with the use of the Surface Distance Minus X-value function. Even experienced technicians have problems using this correctly consistently. This function can be a help, but if you find that you are having problems using it always remember that you can always change it to the Surface Distance in gate one function and then use your scale to measure surface distances from the index point of the search unit instead of the front of the search unit.

RATT

Relative Arrival Time Technique

You will observe relative distances between corners and tips. The deeper the crack gets, the more separation along the baseline between the corner and the tip.

This is the beginning of learning advanced crack sizing techniques. This is where we begin talking about "sizing", and flaw height measurement. First, we'll start with a technique that requires observation of how signals walk on the screen. Actually, most sizing and characterizing is obtained from how signals walk on the screen. When we raster (back and forth motion) at the ID notches on the notch block with the 45° we can see a very loud corner trap signal from the notch root and low amplitude tip signal radiating out from the notch tip. This low amplitude tip signal is mostly from diffraction.

What is diffraction? When sound encounters a tip or facet, diffracted sound echoes radiate out from the tips or facets in all directions. This is often compared to dropping a pebble in a pond and seeing the wave pattern that travels outward in all directions. The amplitude of the tip diffracted signal is much, much lower than the corner trap reflector; as much as 20dB. There are some really fascinating YouTubes out there contrasting the differences between corner reflectors and tip diffractions. Corners reflect sound from the corner itself and from angles that approach near the corner as shown in the YouTube from the University of Nebraska at Lincoln (UNL) at about 2:00 minutes; UNL YouTube of corner reflection .

The loud corner trap, and the low amplitude tip signal walk with each other on the screen. The deeper the notch, the further apart these signals are along the base line. See YouTube- Ultrasonic 45-degree shear RATT-relative arrival time technique .

We can use this difference in arrival times for the corner and the tip for qualitative sizing:

- When the space between the corner trap and the tip along the baseline is small, the notch height (or crack) is small.
- When the distance along the baseline between the corner trap and the tip is large, the notch height (or crack) is large.

So don't size a crack as being very big if the corner and tip are very close together.

This is called the "RATT" (pronounced "rat") or Relative Arrival Time Technique because we are observing the arrival times of the corner and tip, relative to each other.

If we possessed a notched cal block that was exactly equal in thickness to each pipe that we test in the field, we could use this technique to make flaw height measurements. We usually only have the one notch block that is 0.300" thick (or 8mm for the metric cal block) and we almost never have pipe with an actual thickness of exactly 0.300" so this technique will almost always be qualitative for us.

AATT

Absolute Arrival Time Technique (pronounced "at")

This might also be called "tip sizing" or "tip diffraction sizing". With the same set-up we are able to do tip diffraction depth sizing measurements by peaking up the tip signal and then reading its depth from the depth reading box.

We can check how our cal looks by filling in the table below. It's a good idea to use pencil so it can be erased and re-used later. See YouTube-Ultrasonic 45-degree shear tip diffraction depth sizing . These ID notch tips are in leg number one.

Lab Exercise 2 - 45° ID notch tip sizing (in.):

(USE PENCIL, NOT PEN, for all the "fill in the blanks")

Notch	0.010"	0.030"	0.060"	0.090"	0.120"	0.150"	0.180"	0.210"
RL* (depth to tip)	0.290"	0.270"	0.240"	0.210"	0.180"	0.150"	0.120"	0.090"
Your measure	**	**						

*RL is shorthand for remaining ligament. This is the amount of good material above the tip, not affected by the notch or the crack or other flaw.

**We usually can't reliably detect a tip for the 0.010" and 0.030" notches if we are using a 5MHz search unit because there isn't enough resolution.

Lab Exercise 2 - 45° ID notch tip sizing (mm):

Notch	0.5mm	1mm	2mm	3mm	4mm	5mm	6mm
RL* (depth to tip)	7.5mm	7mm	6mm	5mm	4mm	3mm	2mm
Your measure	**						

*RL is shorthand for remaining ligament. This is the amount of good material above the tip, not affected by the notch or the crack or other flaw.

**We usually can't reliably detect a tip for the 0.5mm notch if we are using a 5MHz search unit because there isn't enough resolution.

Once we have the above tables filled in, we can decide if we like our cal for the 45°. If your sizing numbers are plus or minus 0.005" then you are about as close as we should ever expect to get with manual UT. If you are plus or minus 0.015" you are probably good enough for most sizing purposes.

If your "depth to tip" is close to the RLs listed above you are done. If you think you are too far off you can make adjustments to your cal.

If everything is off by the same amount, for example, all depths are +0.020", you can usually make a good adjustment with Zero alone.

If everything is off by more, for example, (-)0.005", (-) 0.010", (-) 0.015", (-) 0.020", etc., you can adjust velocity alone.

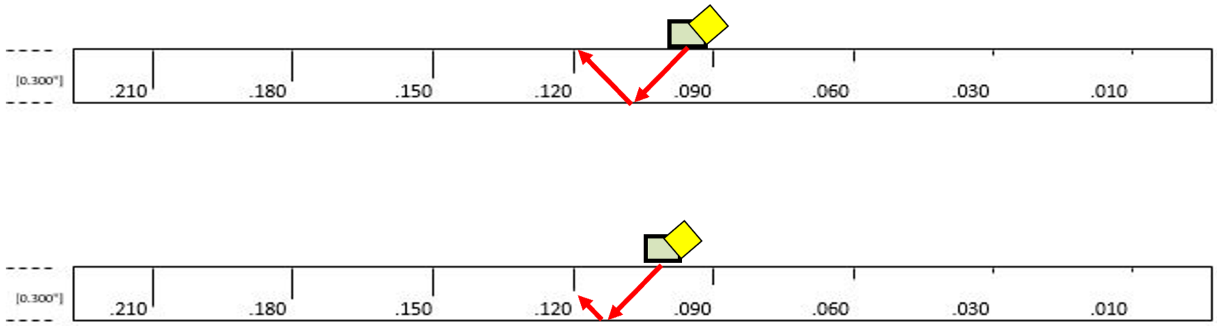
If everything is off by random amounts, plus and minus, assume that you need more practice with your "hand-to-screen" coordination. When you 'peak up' on a reflector you are rastering back and forth, and skewing clockwise and counterclockwise, and observing the resultant signal on the screen. The moves you make with your hand have to be coordinated with what you see on the screen. This "hand-to-screen" coordination is an essential part of doing manual UT. Most people need a lot of practice to peak up on signals consistently well. Don't be frustrated if you don't master this at the first attempt. This takes practice; repetitions.

If you make an adjustment to your cal recheck the "fill-in-the-blanks" above.

OD notches:

We can use the same technique to do tip diffraction depth sizing for OD connected cracks. The technique we are still talking about is AATT, taking a measure to the tip signal.

This time please flip the notched block over so that the notches are on the top side as in figure 28.



For OD crack depth sizing using tip diffraction (AATT) using 45° first peak up on the corner trap signal as shown top, above. If you don't have a thickness input for your part, or have a very thick number, the depth reading box will read 0.600" in depth because in terms of the depth axis (which is the up and down direction) the sound will have traveled down 0.300" and then up 0.300", for a total of "depth" travel of 0.600".

If you then push the probe forward you can peak up on the lower amplitude tip signal. The tip signal should read close to 0.480" in the depth reading box because the sound will have traveled down 0.300" and then up another 0.180".

0.300" + 0.180" = 0.480"

This would be 0.120" below the top surface at 0.600". This is your flaw height; 0.120".

figure 28

We can use the table below to use "AATT" for sizing of OD connected flaws. See YouTube-Ultrasonic 45-degree shear wave OD connected flaw tip sizing .

At this point in your training only try to do this for the following three OD notches: 0.060", 0.090", and 0.120".

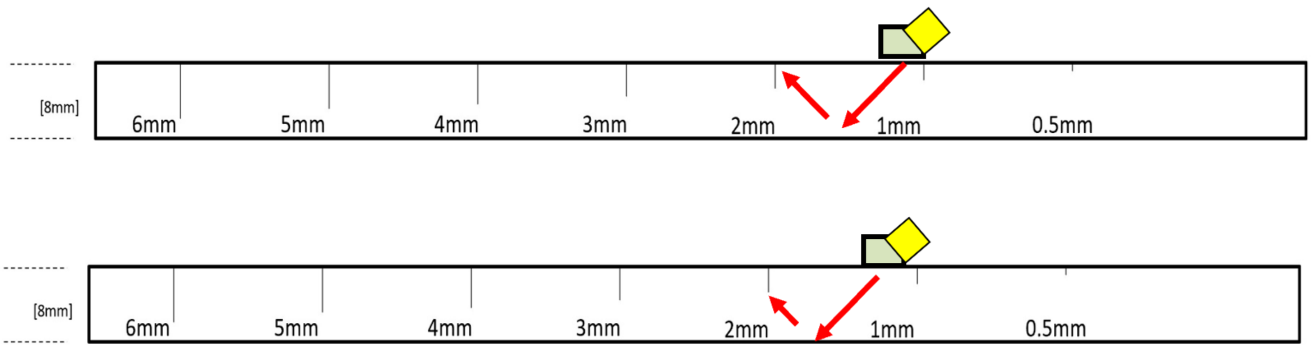
Lab Exercise 3 - 45° OD notch tip sizing (in.)

Notch	0.010"	0.030"	0.060"	0.090"	0.120"	0.150"	0.180"	0.210"
RL* (Depth to tip)	0.590"	0.570"	0.540"	0.510"	0.480"	0.450"	0.420"	0.390"
Your measure	**	**				-	-	-

*RL is shorthand for remaining ligament. This is the amount of good material, not affected by the notch or the crack or other flaw.

**We usually can't reliably detect a tip for the 0.010" and 0.030" notches if we are using a 5MHz search unit because there isn't enough resolution.

If you are working with the metric cal block, see figure 29.



For OD crack depth sizing using tip diffraction (AATT) first peak up on the corner trap signal as shown top, above. If you don't have a thickness input for your part, or have a very thick number, the depth reading box will read 16mm in depth because in terms of the depth axis (which is the up and down direction) the sound will have traveled down 8mm and then up 8mm, for a total of "depth" travel of 16mm.

If you then push the probe forward you can peak up on the lower amplitude tip signal, as shown in the lower sketch. The tip signal will read 14mm in the depth reading box because the sound will have traveled down 8mm and then up another 6mm.

8mm + 6mm = 14mm

This would be 2mm below the top surface. This is your flaw height; 2mm.

figure 29

Lab Exercise 3 - 45° OD notch tip sizing (mm)

Use the table below to work on your metric version of OD connected flaw height sizing. At this point in your training only try to do this with the following notches: 1mm, 2mm, and 3mm.

Notch	0.5mm	1mm	2mm	3mm	4mm	5mm	6mm
RL* (Depth to tip)	15.5mm	15mm	14mm	13mm	12mm	11mm	10mm
Your measure	**				-	-	-

*RL is shorthand for remaining ligament. This is the amount of good material, not affected by the notch or the crack or other flaw.

**We usually can't reliably detect a tip for the 0.5mm notch if we are using a 5MHz search unit because there isn't enough resolution.

60° shear, 1" deep screen

A summary of how to set up the 3 shear wave cals; 45°, 60°, and 70° without auto-cal is shown in figure 24 on page 43.

A summary of how to set up the 3 shear wave cals; 45°, 60°, and 70° with auto-cal is shown in figure 25 on page 44.

For your reading boxes use:

- Soundpath in gate A
- Surface distance minus x-value
- Depth in gate A

Make a 1" deep screen by using a 2.000" screen range. Why 2.000"? See figures 15-17. Use the velocity found for the 45°. The velocity in the material doesn't change with different angles. Use the one-inch radius of the mini-angle beam block as shown in figure 24 on page 43 to find the new probe zero.

Check surface distance measurements by walking the reflector from the bottom corner of the half inch thick SDH block to the point where the depth reading box indicates that the reflector is 0.500" deep. This is not where the signal peaks up. Then measure with your scale the distance from the front of the search unit wedge to the end of the block. This is the actual "surface distance minus X-value". Adjust your X-value until the "surface distance minus X-value" reading box has the same number as what you see on your scale. The example in figure 24 is shown for a 60° wedge and the "surface distance minus X-value" reading box should read 0.650" just as shown on the scale. Your number will likely be different.

See YouTube-Ultrasonic 60-degree one-inch-deep shear wave setup .

Raster back-and-forth to peak up at each of the SDHs of the 0.5" FAST block and record here the depth that the signal peaks. We may refer to this later for midwall sizing.

Lab Exercise 4 - 60° SDHs (in.)

SDHs	0.100"	0.200"	0.300"	0.400"
Peaks at:				

(use pencil, not ink)

60° shear, 40mm deep screen

A summary of how to set up the 3 shear wave cals; 45°, 60°, and 70° without auto-cal is shown in figure 26 on page 45.

A summary of how to set up the 3 shear wave cals; 45°, 60°, and 70° with auto-cal is shown in figure 27 on page 46.

For your reading boxes use:

- Soundpath in gate 1
- Surface distance minus x-value in gate 1
- Depth in gate 1

Make a 20mm deep screen by using a 40mm screen range. Why 40mm? See figures 15-17 on pages 35-36. Use the velocity found for the 45°. The velocity in the material doesn't change with different angles. Use the 25mm radius of the mini-angle beam block as shown in figure 26 page 45 to find the new probe zero.

Check surface distance measurements by walking the reflector from the bottom corner of the 12.5mm thick SDH block to the point where the depth reading box indicates that the reflector is 12.5mm deep. This is not where the signal peaks up. Then measure with your scale the distance from the front of the search unit wedge to the end of the block. This is the actual "surface distance minus X-value".

Raster back-and-forth to peak up at each of the SDHs of the 12.5mm FAST block and record here the depth that the signal peaks. We may use this later for midwall sizing.

Lab Exercise 4 - 60° SDHs (mm)

SDHs	2.5mm	5.0mm	7.5mm	10.0mm
Peaks at:				

(use pencil, not ink)

The reason why the 60° corners do not peak up at the correct depth.

For the 60°, SDHs and tip signals peak up at close to the correct depth. The corner trap signals do not. For an explanation of why the 60° does not peak up at the correct depth for a corner trap reflector see YouTube- Ultrasonic 60-degree, why the corner trap signals do not peak up at the correct depths .

AATT - Absolute Arrival Time Technique (60°)

Half Vee (ID notches)

Peak up on each corner trap reflector and then peak up on its associated tip diffracted signal. Observe the 60° 'walk'. It is a longer walk on the screen than the 45° was. Use the table below to record the depth reading where you peak up on each notch tip signal.

Lab Exercise 5 - 60° ID notch tip sizing (in.)

Notch	0.010″	0.030″	0.060″	0.090″	0.120″	0.150″	0.180″	0.210″
RL (Depth to tip)	0.290″	0.270″	0.240″	0.210″	0.180″	0.150″	0.120″	0.090″
Your measure	**	**						

**We usually can’t reliably detect a tip for the 0.010″ and 0.030″ notches if we are using a 5MHz search unit because there isn’t enough resolution.

If you are working in millimeters fill in this table using your 8mm thick notch block:

Lab Exercise 5 - 60° ID notch tip sizing (mm)

Notch	0.5mm	1mm	2mm	3mm	4mm	5mm	6mm
RL (Depth to tip)	7.5mm	7mm	6mm	5mm	4mm	3mm	2mm
Your measure	**						

**We usually can’t reliably detect a tip for the 0.5mm notch if we are using a 5MHz search unit because there isn’t enough resolution.

Once we have the above tables filled in, we can decide if we like our 60° cal. If your measure of the depth to tip is close to the RLs listed above you are done. If you think you are too far off you can make adjustments to your cal. If everything is off by the same amount you can usually make a good adjustment with Zero alone. If everything is off by more and more positive or negative, you can make adjustments to velocity. If you make an adjustment, recheck the “fill-in-the-blanks” above.

See YouTube-Ultrasonic 60-degree shear wave tip diffraction depth sizing .

Save this setup file when you are satisfied with it.

70° shear, PPATT; Probe Positioning Arrival Time Technique

A summary of how to set up the 3 shear wave cals; 45°, 60°, and 70° without auto-cal is shown in figures 24 on page 43.

A summary of how to set up the 3 shear wave cals; 45°, 60°, and 70° with auto-cal is shown in figure 25 on page 44.

For your reading boxes use:

- Soundpath in gate 1
- Surface distance minus x-value in gate 1
- Depth in gate 1

70° shear, 1" deep screen

Make a 1" deep screen by using a 2.924" screen range. Why 2.924"? See figures 18-20 on pages 36-37. Use the same velocity as the 45° and 60°. The velocity in the material doesn't change when you change angles.

Find the new probe zero by putting the index point of the search unit lined up with the mark on the half inch thick FAST block for the 0.300" deep SDH and adjust zero (probe delay) until you get 0.300" in your depth box. Do not peak up. This is not a peaking cal. Now each SDH should be close to 0.100", 0.200", 0.300" and 0.400" when the index point is on each marked spot.

This setup is actually very different than the setup for the 45° or the 60°. Those two setups were based on where the 45° peaked up on the ID corner trap signals. They were both "peaking" cals. The setups were based on where things peaked up. This 70° setup is not based on where things peak up. This 70° setup is based on the probe position. The 70° is positioned with the index point on the exact spot that directs 70° to the SDH. Steve Sikorski refers to this type of setup as a "PPATT"; Probe Positioning Arrival Time Technique.

We use the probe positioning set up for the 70° because the half inch thick side-drilled-hole block (of figure 3 is built for a 70° probe. It is very quick to set up and most of the time, for very thin-walled material, we are most concerned with getting precise surface distance measurements with the 70°, and this type of cal is ideal for that. When we are working on thin walled pipe we usually do a lot of indication verification by taking surface distance measurements from both sides of a flaw. We often do this instead of traditional indication plotting. (Note: We will do traditional indication plotting in the section "How to UT a level 2 qualification test coupon".)

Now check how it works when we do peak up on each SDH:

Lab Exercise 6 - 70° SDHs PPATT cal (in.)

SDHs	0.100"	0.200"	0.300"	0.400"
Peaks at:				

(use pencil, not ink)

Observe the 70° 'walk'. It is a long walk. Repeat for ID and OD notches on the 0.3" thick notch block.

Check surface distance measurements by walking the bottom corner reflector from the end of the 0.300″ thick notch block to a point where the depth reading box reads 0.300″ deep. Now you are hitting the corner with 70°. Hold the search unit still at that position. Use a scale to measure the distance from the front of the search unit wedge to the end of the block. This is the actual "surface distance minus X-value". See the bottom of figure 24. Adjust the X-value in the instrument until the "surface distance minus X-value" reading reads the same as what you see on your scale. For the 70° search unit shown in figure 24 the "surface distance minus X-value" reading box should say 0.510″ for that probe.

We don't need to take surface distance measurements as often with a 45° or a 60° but we need to be able to take accurate precise surface distance measurements with a 70° shear and with FAST-UT.

On the very thin material, we often do surface distance measurement checks instead of traditional indication plotting. See YouTube-Ultrasonic 70-degree shear PPATT probe positioning arrival time technique .

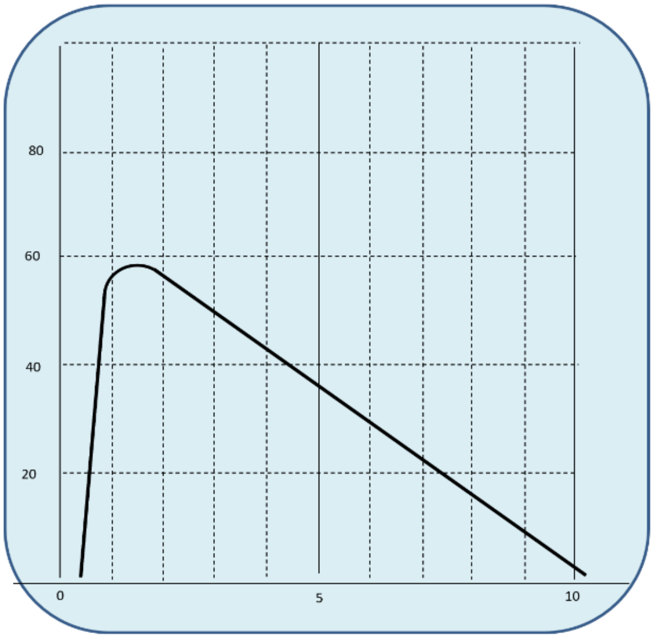
The previous two sections for 45° and 60° ended with exercises for taking ID crack depth measurements by going to each ID notch corner trap signal and then pushing forward to search for its tip signal. Those tip signals were from separate tip diffraction echoes. With the 70° shear, the corner and the tip are so close together in time that it is sometimes difficult to distinguish them from each other. When you find the corner trap reflector near 0.300″ deep and then push forward you are seeing the reflection from the face of the notch or the crack as the shear wave walks up the face of the notch and walks into the tip at the top of the notch face. Sometimes, if you have enough resolution, the tip is a separate signal. It is easier to see this tip on a cal block notch than on a flaw in the field. As you continue to walk up the face of the notch, eventually the center of the sound beam walks over the top of the notch or the crack. You can see the top of the flaw or notch by following the walk of the 70° and watching for where it goes over the top. To get accurate depths to the tips you have to re-zero your cal for this type of sizing. This should only be used for extremely deep ID connected flaws. A good way to set this up is by doing the following whenever you need it:

- Walk over the top of the 0.210″ deep ID notch. The depth to the top of the notch (or RL) is 0.090″. When the echo dynamic is at its peak, like the walk shown in figure 30, stop the search unit at the peak and hold it there.
- Use zero (probe delay for USMGO and similar) and make the depth reading box read 0.090″.
- Verify the ID notch sizing by walking up the face of the following notches, and record it in the table below.
- Decide if you want to save this as a separate cal file or not. I never do.

Lab Exercise 7 - 70°, deep ID connected notch flaw height sizing with peaking cal (in.)

Notch	0.010″	0.030″	0.060″	0.090″	0.120″	0.150″	0.180″	0.210″
RL (Depth to tip)	0.290″	0.270″	0.240″	0.210″	0.180″	0.150″	0.120″	0.090″
Your measure	**	**	**	**				

**Only use this sizing technique for extremely deep, perpendicular, ID connected flaws.



Walk of 0.090" deep tip for the 0.210" deep ID notch using 70° or FAST-UT, which is also a 70°.

The walk of going over the top of the 2mm deep tip of the 6mm deep ID notch would be similar.

figure 30

See YouTube- [Ultrasonic 70-degree shear walking over the top of extremely deep ID connected planar flaws](#) .

70° shear, 20mm deep screen

The above description (70° one-inch-deep screen) can be referred to, but use the metric cal blocks; the 12.5mm thick side drilled hole block and the 8mm thick notch block. For the exercise above, to perform deep ID connected flaw height sizing use the following table:

Lab Exercise 6 - 70° SDHs PPATT cal (mm)

SDHs	2.5mm	5.0mm	7.5mm	10.0mm
Peaks at:				

(use pencil, not ink)

Lab Exercise 7 -70°, deep ID connected notch flaw height sizing with peaking cal (mm)

Notch	0.5mm	1mm	2mm	3mm	4mm	5mm	6mm
RL (depth to tip)	7.5mm	7mm	6mm	5mm	4mm	3mm	2mm
Your measure	**	**	**	**			

**Only use this sizing technique for extremely deep, perpendicular, ID connected flaws.

Angle Beam Gain settings

Be careful not to use too much gain. It's often tempting to use a little more gain to see things 'better'. Using too much gain can be just as bad as not enough gain. Too little gain and you won't find anything. Too much gain and everything will look cracked.

As a general rule, set your gain with whatever angle beam search unit you are using (including FAST-UT) so that the SDH at the thickness you are working with is at 50%FSH. Example: for T-nom = 0.312", bring the 0.300" deep SDH to 50% FSH. Set reference dB here.

Here is a general angle beam set-up routine. Try to form this habit every time you open an angle beam or FAST-UT cal:

- Recall the cal
- Check the cal; go briefly to each SDH in the SDH block. They should appear on your 1-inch depth screen close to 0.100", 0.200", 0.300", and 0.400" deep. (For the metric 12.5mm thick block, each side drilled hole should appear near 2.5mm, 5mm, 7.5mm and 10mm deep.)
- Set your gain: go to the SDH closest in depth to the thickness of the material you will be examining and bring it to 50%FSH in whole numbers of gain. Note this home base gain setting. Set reference dB here. Try to stay at this gain setting. Always return to this gain setting. Change your gain increments to increments of 6dB. If for some reason you momentarily need to increase or decrease your gain, do it in increments of 6dB, then immediately return to your home base gain setting (reference dB) and try to always stay there. At this gain setting everything you see will be from something real. Could be geometry.
- Go!

Get into the habit of looking at your flaws with several different search units. These steps above should become a mantra for you each time you open a different cal;

- Recall the cal
- Check the cal
- Set the gain
- And GO!

Comparison of 45°, 60° and 70°

Echo Dynamics of 45°, 60°, and 70°

Switch back and forth between the 45°, 60° and 70°. Scan the SDHs and the notches and observe the characteristic 'walks' of the 3 different angles. See YouTube- Ultrasonic comparison of echo dynamics of 45°, 60°, and 70° shear .

45° has a short walk along the length of the baseline.

60° has a medium walk.

70° (and FAST-UT, which is also a 70°) has a long walk.

45°

The 45° has very loud corner trap reflectors because of the prism-type reflection from the corner described earlier in a YouTube from UNL. The sound path measurements to corners should be accurate.

The tips of a notch or crack can create radiating tip diffraction signals that go out in all directions. Tip diffraction amplitudes are much less than corner reflectors; 20dB or even more. Take caution not to be fooled by "virtual" corner trap signals described in two following sections; "Determining ID connection with shear" and "Planar, midwall flaw sizing with shear".

60°

The 60° has loud corner trap reflectors but the sound path measurements to corners are not accurate because it is actually other angles included in the beam spread of a 60° that do louder reflecting from a corner. The measurements will not be accurate because your 60° has the trig functions set for 60°. The 60° does not find "virtual" corners like the 45° can.

The tips of a notch or crack, and the reflectors from side drilled holes should be accurate soundpath measurements.

70°

The 70° is good at finding corners and walking up the faces of planar reflectors, like walking up the face of an ID notch from the corner at the ID up to the tip. The 70° is also really useful for initial detection scans.

Determining ID connection with shear

It can be difficult to determine if a flaw is ID connected or only near the ID. To verify if a flaw is ID connected the best method we have now is to look for a corner trap signal near the ID on your depth screen with both 45° and 60°. If there is an ID connected flaw present you should find a good corner trap signal near the ID with both. If only the 45° has a corner trap signal near the ID, then it is likely not ID connected. Use both 45° and 60° together to determine if something is ID connected. See YouTube-Ultrasonic using 45° and 60° to determine ID connection .

Angled/Slanted, Planar, ID and OD connected flaws

Many cal blocks have reflectors to simulate planar flaws. A good example is the 0.300" thick notch block (or for metric the 8.0mm thick notch block) we have been frequently using in this training. See figure 4. These notches are not angled or slanted. They are perpendicular to the surface.

Sometimes flaws can be angled or slanted and not perpendicular to the surface. Hook flaws, for example, are at unpredictable shapes, curves and angles. See figures 52-58, pages 88-91.

When an angled flaw is ID or OD connected there will usually be one direction that is much louder and that is difficult or impossible to do tip sizing from. The other side that is usually not as loud sometimes has two separate signals; a loud corner and a tip that is less loud. See YouTube- Ultrasonic shear wave detection of slanted planar ID and OD flaws .

Planar, midwall flaw sizing with shear

For planar midwall reflectors like lack of fusion in an ERW weld that is not ID or OD connected it is difficult to measure the flaw height with manual UT. We can measure the depth to the top of the flaw with several of the techniques previously described; one way is by walking FAST-UT or 45° or 60° over the top of the flaw and noting the depth where you go over top.

The bottom of the flaw is difficult to measure with manual UT. One method is measuring how loud the "gaps", or virtual corners, are between the bottom of the OD notches and the ID of the block for the 0.210", 0.180" and 0.150" notches using 45°. See YouTube-Theoretical ultrasonic measurement of gaps under midwall flaws .

Flaw height sizing of very small flaws using amplitude comparison

When flaws are very, very small it is usually not possible to take flaw height sizing measurements by using tip diffraction because there is usually not enough resolution to separate the corner from the tip. For very, very small flaws that are thought to be similar in size to the 0.010" notch or the 0.030" notch we will sometimes use the amplitudes of those notches to estimate the flaw height sizing. (For metric work we could compare the amplitudes of the 1mm and the 0.5mm notches.) See YouTube- Ultrasonic flaw height sizing of very small flaws using amplitude comparison .

Shear wave flaw height tip sizing of real cracks

Up until now we have been mostly doing our flaw height sizing using notches. The video below shows several of the cracks from real cracks naturally grown in a lab. These cracks, like many cracks we see in real life, do not look like machined notches. They have a lot of variability associated with them. These cracks appear to have jagged faces with many tiny facets and spurs hanging off of them. See YouTube- Ultrasonic shear wave flaw height tip sizing of real cracks.

6 dB flaw height sizing does not work.

We often find folks using a 6dB drop technique to do flaw height sizing. This does not work. See YouTube- 6dB drop flaw height sizing does not work .

Section 4 Angled L-wave UT

FAST-UT and similar search units are high angle L-wave search units. FAST-UT probes will ideally produce a 70° L-wave.

Let's take a moment to review some UT basics. If you have taken formal Level 2 ultrasonic theory classroom training you might recall that zero-degree straight beam probes produce compression waves which are also known as L-waves or longitudinal waves. If these L-wave producing transducers are put on plastic angled wedges the sound can be refracted into steel at a chosen mode (shear or L) or angle. The origin of conventional shear wave probes and FAST-UT high angle L-wave probes is shown in figures 31 and 32.

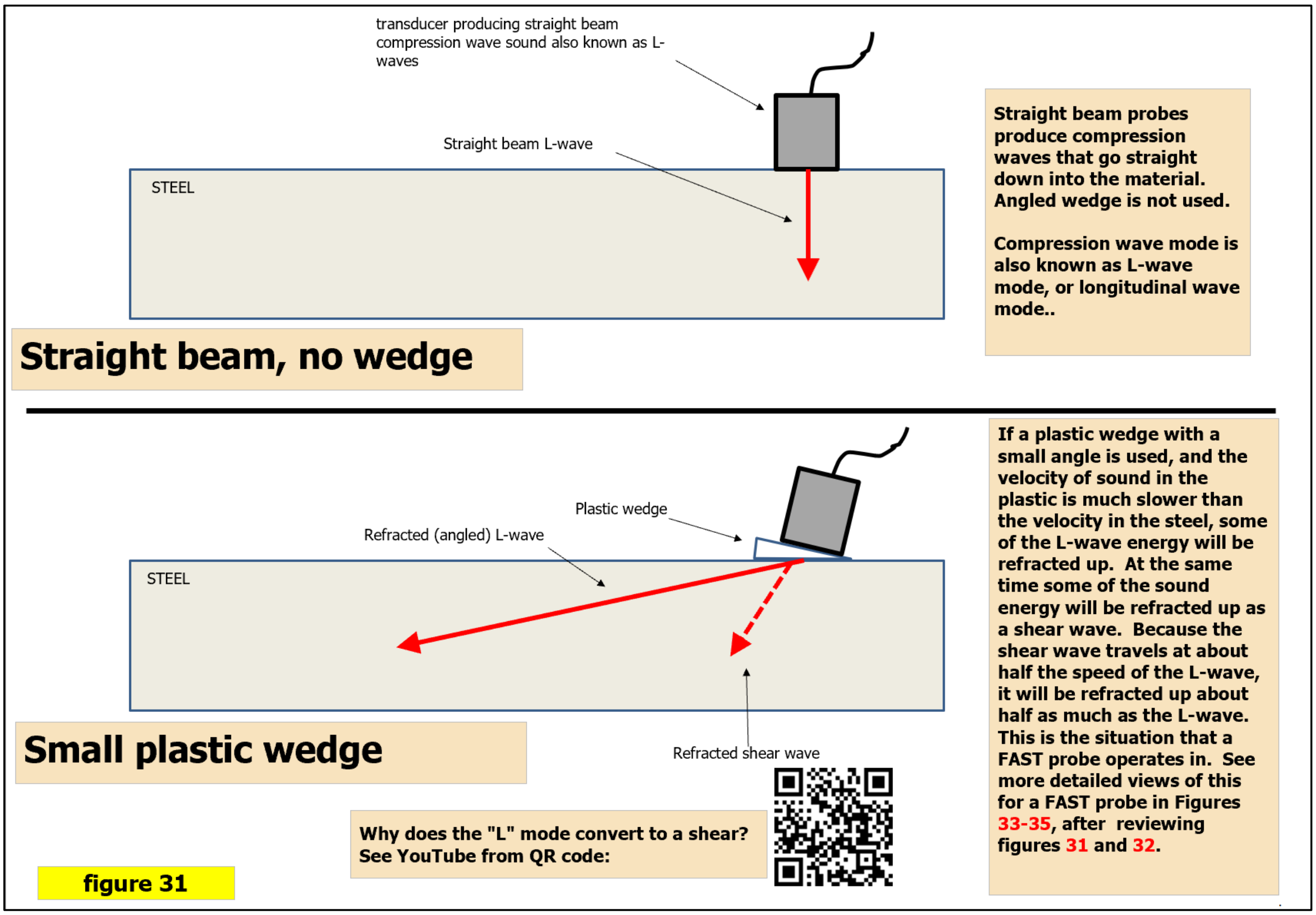


figure 31

See YouTube Ultrasonic slinky demo of longitudinal & shear and why the "L" refracts to shear.

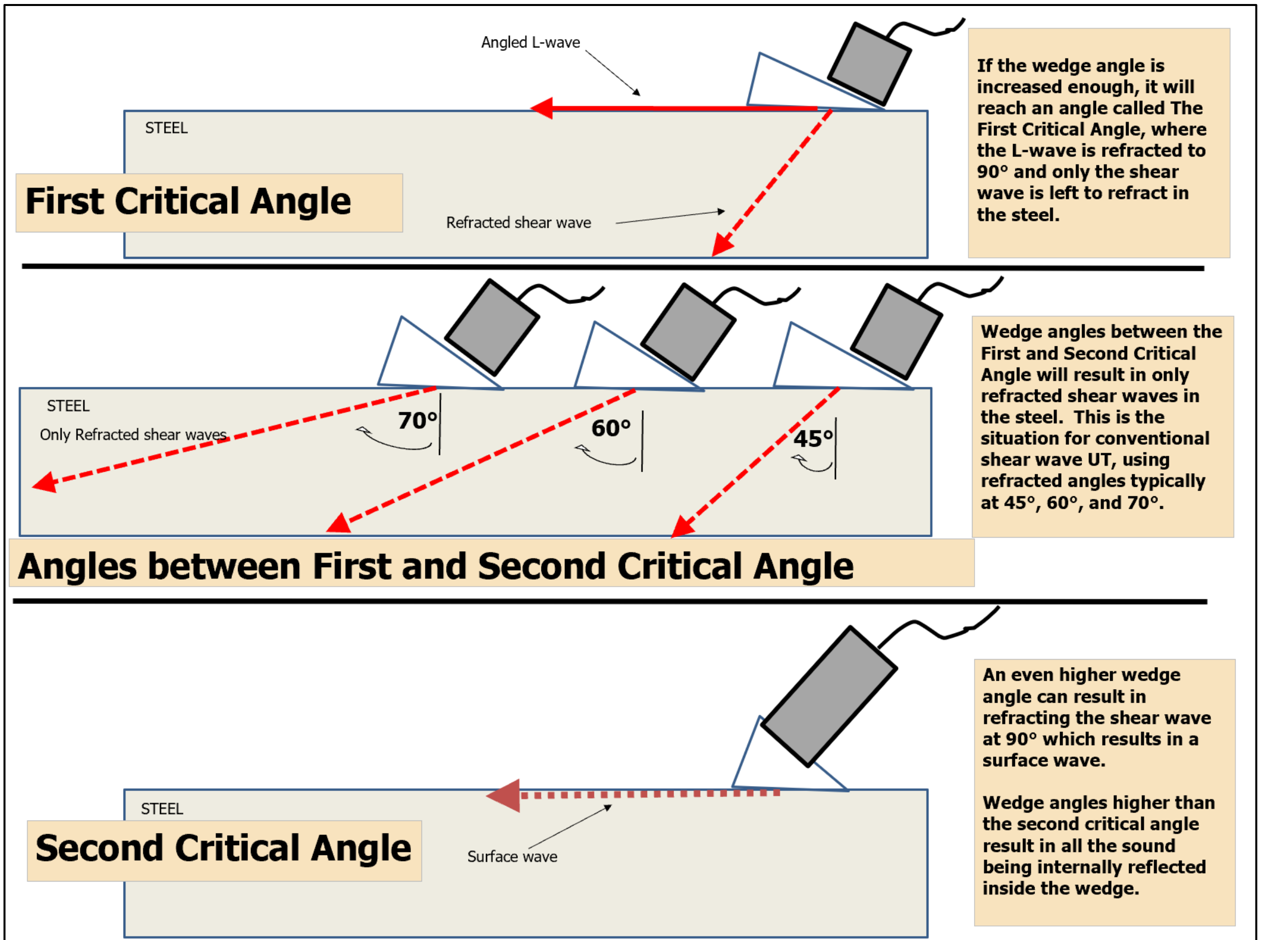


figure 32

Angled L-waves are not the only mode of sound produced by an angled L-wave probe. They will also always have an associated low angle shear. There are actually many modes or combinations of modes that can be generated although we primarily want to work with the angled L-wave. See figures 33-35.

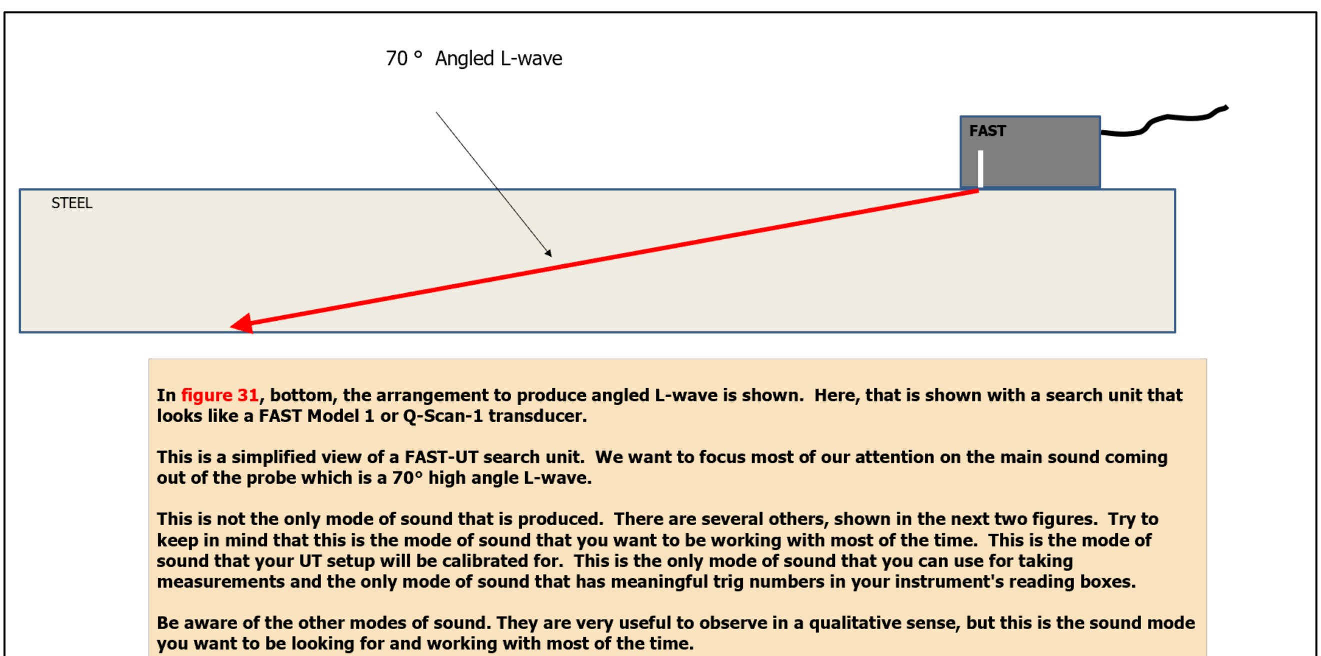
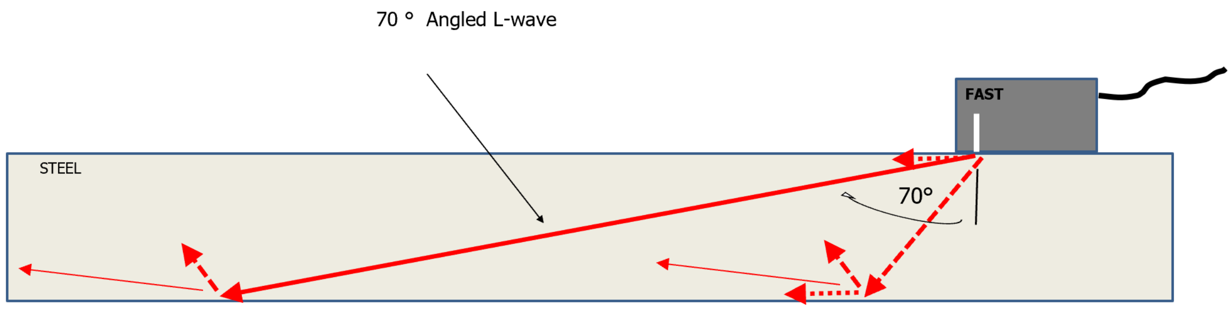


figure 33

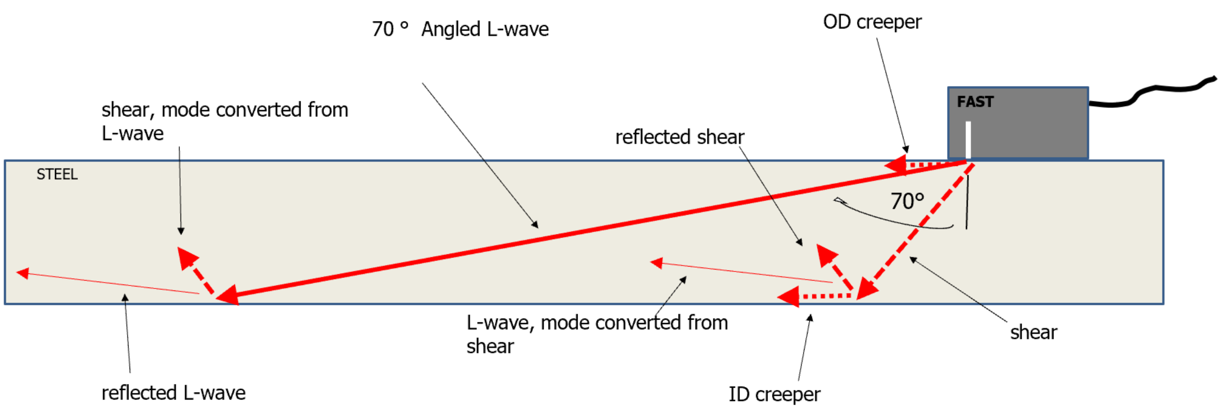


Any high angle L-wave probe has refracted L-wave and refracted shear wave coming out of it, as we showed in figure 31, bottom. There are actually many modes and combinations of modes of sound coming out of a high angle L-wave probe.

L-waves travel faster than any other mode of sound.

See the next figure for identification of all these theoretical modes of sound.

figure 34



Sound modes and mode combinations theoretically produced by the high angle L-wave probe are identified above.

Creeper wave modes are theoretically generated by the intereaction of the shear mode with a surface, travel at about the speed of an L-wave, but only travel a very short distance before attenuating to nothing.

Although we are aware of, and can see the affects of these other modes, and combinations of modes of sound, we are normally only attempting to identify the main 70° L-wave sound in leg 1. The relected L-wave in leg 2 is very weak, with most of that sound mode converted to shear.

figure 35

Note that the ID and OD creeper waves shown above are also shown by others to be interactions of shear and L-wave. See "The Truth behind Creeping Waves" by Blanshan and Ginzel, in Materials Evaluation magazine of May 2008.

FAST-UT

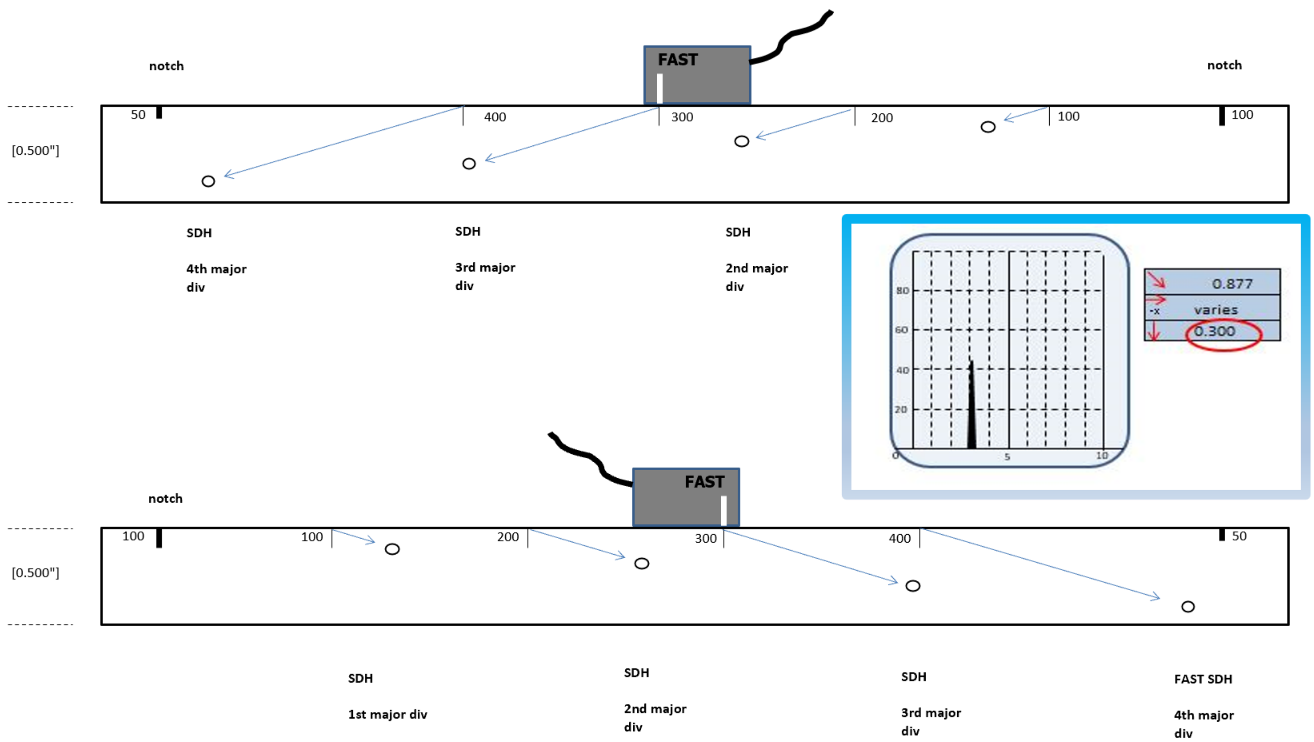
A FAST-UT search unit has a nominal angle of 70 degrees. The original version of the FAST probes made by GEIT-Krautkramer (now Waygate Technologies of Baker Hughes) were made to produce 70° angled L-wave in stainless steel. Those probes used on carbon steel will result in 74° angled L-wave. Now we usually use Sonatest Q-Scan-1 probes for thin-walled steel. See recommended search units pages 18-19.

When high angle L-wave UT is done in this book we refer to it as FAST-UT. This does not require using the Krautkramer FAST Model 1, 2, or 3 probes. There are other high angle L-wave probes that can also be used and we call this FAST-UT with any of them.

See below for a step-by-step FAST-UT setup.

FAST-UT, set-up

Inches	**Millimeters**
1. FAST Model 1 probes often have mis-marked index points from the factory. Remark them to show the index point as being 0.250" from the front of the search unit on both sides of the search unit. For the Q-Scan-1 probe mark the index point as being 0.360" from the front of the search unit. 2. Set velocity to 0.2330"/microSec. Frequency 5.0MHz Dual element. Tell the trig function this is 70°. Enter 0.250" (or 0.360") for an initial "X-value". 3. Start with an initial gain setting of about 59 dB. For your reading boxes to work you need to have a signal in the gate. 4. Set range to 2.924". This converts you to a 1" deep screen as shown in figures 18-20 for a 70° probe. 5. Put the index point on the mark for the 0.300" deep side drilled hole on the 0.5" thick FAST block and point the search unit towards the 0.300" side drilled hole. See figure 36. 6. Adjust 'zero' to make the depth reading box read 0.300" deep. 7. Bring to 50% FSH. Done.	1. FAST model one probes often have mis-marked index points from the factory. Remark them to show the index point as being 6.4mm from the front of the search unit on both sides of the search unit. For the Q-Scan-1 probe mark the index point as being 9.1mm from the front of the search unit. 2. Set velocity to 5918 meter/Sec. Frequency 5.0MHz Dual element. Tell the trig function this is 70°. Enter 6.4mm (or 9.1mm) for an initial "X-value". 3. Start with an initial gain setting of about 59 dB. For your reading boxes to work you need to have a signal in the gate. 4. Set range to 58.48mm. This converts you to a 20mm deep screen as shown in figures 18-20 for a 70° probe. 5. Put the index point on the mark for the 7.5mm deep side drilled hole on the 12.5mm thick FAST block and point the search unit towards the 7.5mm side drilled hole. See this as shown on the inches block in figure 36. 6. Adjust 'zero' to make the depth reading box read 7.5mm deep. 7. Bring to 50% FSH. Done



The setup for the FAST cal is done by putting the index point on the marker for the 0.300" deep SDH, then adjusting "zero" until you see 0.300" deep in the depth reading box.

You can do this on either side of the block, as shown above. Be sure you are pointing the sound towards the 0.300" deep SDH.

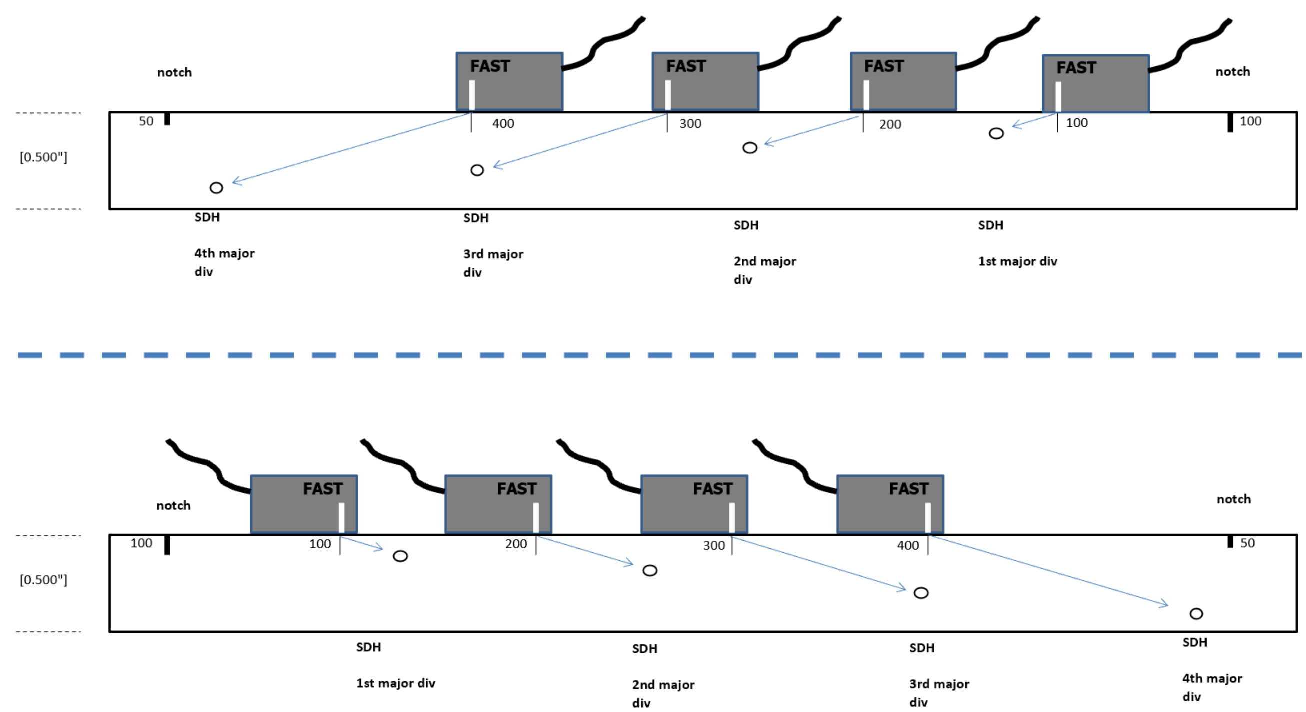
figure 36

For metric work, use the 12.5mm thick side drilled hole block and aim at the 7.5mm deep side drilled hole. Adjust the "zero" function to make the depth reading box say 7.5mm.

You can do this on either side of the block as shown above.

Check your cal, inches:

Check your cal by putting your index point on each marked spot on the 0.5” thick FAST block. Each side drilled hole should come up near the major division line on the screen; 0.100”, 0.200”, 0.300”, and 0.400”. See figure 37. See YouTube- FAST-UT cal setup .



The first check of your FAST cal is to put the index point on each of the four marks for the four SDHs. These marks are positioned on the block to send 70° sound directly to it's SDH.

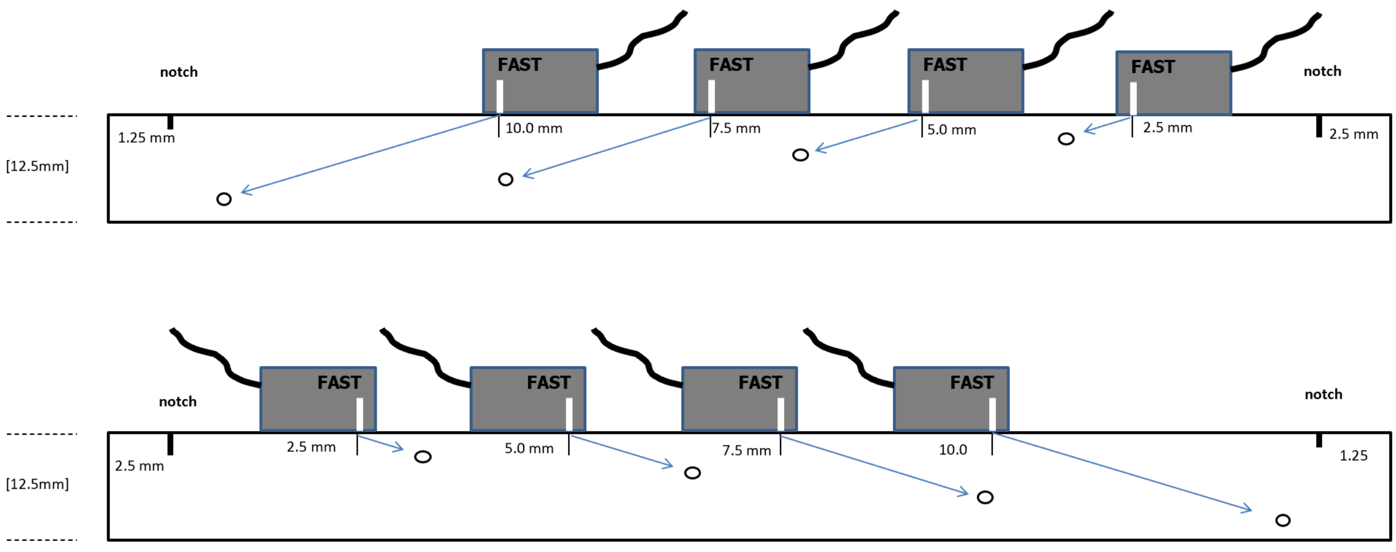
You can do this on either side of the block as shown above and below.

Each side drilled hole should result in an indication very near the 1st, 2nd, 3rd and 4th major divisions on your A-scan display and the depth reading box should read near 0.100", 0.200", 0.300" and 0.400".

figure 37

Check your cal, millimeters:

Check your cal by putting your index point on each marked spot on the 12.5mm thick FAST block. Each side drilled hole should come up related to the major division lines on the screen; 2.5mm, 5mm, 7.5mm and 10mm deep. See figure 38.



The first check of your FAST cal is to put the index point on each of the four marks for the four SDHs. These marks are positioned on the block to send 70° sound directly to it's SDH.

You can do this on either side of the block as shown above and below.

Each side drilled hole should result in an indication very near 2.5 mm, 5.0 mm, 7.5 mm and 10.0 mm in your depth reading box.

figure 38

For inches, further check your cal:

Peak up on each side drilled hole. Raster (back and forth motion) to peak up the SDHs of the 0.5″ FAST block. This might be a useful reference for sizing midwall rounded (not planar shaped) reflectors.

Lab Exercise 8 – FAST-UT, SDHs, peaking up (in.)

SDHs	0.100"	0.200"	0.300"	0.400"
Peaks at:				

(use pencil, not ink)

See YouTube FAST-UT of side-drilled holes .

For millimeters, further check your cal:

Peak up on each side drilled hole. Raster (back and forth motion) to peak up the SDHs of the 8mm thick FAST block. This might be a useful reference for sizing midwall rounded (not planar shaped) reflectors.

Lab Exercise 8 – FAST-UT, SDHs, peaking up (mm)

SDHs	2.5mm	5.0mm	7.5mm	10.0mm
Peaks at:				

(Use pencil, not ink)

Adjust the X-value

For inches:

Adjust the X-value for surface distance measurements bringing any ID corner trap reflector on the 0.300″ thick notch block to 0.300″ deep in the depth reading box. Don't peak up. You could walk this signal back and forth to almost any depth you want because a 70° has a very long walk. When you walk it to 0.300″ deep in the depth reading box, you are hitting the notch root with 70 degrees. Adjust the x-value until you get the same reading in your surface distance minus x-value reading box as you see on your scale. Surface distance measurements with 70° shear and FAST-UT are very important so be sure this works consistently precisely well. See YouTube- FAST-UT surface distance measurement .

Adjust the X-value

For millimeters:

Adjust the X-value for surface distance measurements bringing any ID corner trap reflector on the 8mm thick notch block to 8mm deep in the depth reading box. Don't peak up. You could walk this signal back and forth to almost any depth you want because a 70° has a very long walk. When you walk it to 8mm deep in the depth reading box, you are hitting the notch root with 70 degrees. Adjust the x-value until you get the same reading in your surface distance minus x-value reading box as you read on your scale. Surface distance measurements with 70° shear and FAST-UT are very important so be sure this works consistently precisely well.

OD sizing with FAST-UT

Inches:

The following technique is intended for flaws propagating more or less perpendicular to the OD surface.

Use the 0.300" thick notch block and raster over the top of each of the OD notches and find the point where the %FSH is maximum for the L-wave and record the depth reading and %FSH at that point.

Lab Exercise 9 – FAST-UT, OD notch sizing (in.)

FAST OD sizing -- inches

dB ________

OD notch	% FSH	depth reading	
0.010"			
0.030"			
0.050"			
0.060"			< 0.075"
0.090"			> 0.075"
0.100"			
0.120"			

do OD sizing from the louder side

For now, don't go deeper than a 0.120" deep OD notch.

Use your table to estimate OD crack depths by comparison. Always try to look at each flaw from both sides.

Make a new table like this one for each day of OD sizing, or whenever the temperature changes much. As the blue arrow indicates, start at the top of the table and work your way down.

If it is confusing to read the items below with blanks in them, see the next YouTube first. The general pattern usually seen is:

- For OD cracks/notches less than or equal to about 0.075" deep, they will peak up near _____ deep on the screen. However, the deeper these are, the louder they will be. So generally, if an OD crack peaks up near ______ deep, its depth should be judged from its amplitude.
- For OD cracks/notches deeper than 0.075" the reflector will peak up deeper than ______ so the depth should be judged more by where the signal peaks up along the baseline. It's not how loud it is, it's where it peaks up along the baseline.

So, to state this another way:

- For the shallow ones, you can tell how deep they are by how loud they are.
- For the deep ones, you can tell how deep they are by where they peak up along the baseline.

The best OD depth sizing is done from whichever side of the weld is louder. See YouTube-FAST-UT OD sizing technique .

OD sizing with FAST

Millimeters:

The following technique is intended for flaws propagating more or less perpendicular to the OD surface.

Use the 8mm notch block and raster over the top of each of the OD notches and find the point where the %FSH is maximum for the L-wave and record the depth reading and %FSH at that point.

Lab Exercase 9 – FAST-UT, OD notch sizing (mm)

FAST OD sizing -- millimeters			
dB	________		
OD notch	% FSH	depth reading	
0.5mm			
1mm			
1.25mm			< 1.91mm
2mm			> 1.91mm
2.5mm			
3mm			
do OD sizing from the louder side			

For now, don't go deeper than a 3mm deep OD notch.

Use your table to estimate OD crack depths by comparison. Always try to look at each flaw from both sides.

Make a new table like this one for each day of OD sizing, or whenever the temperature changes much. As the blue arrow indicates, start at the top of the table and work your way down.

If the items below are confusing because of the blanks in them, see the YouTube for inches above first. The general pattern usually seen is:

- For OD cracks/notches less than or equal to about 1.91mm deep, they will peak up near ______ deep on the screen. However, the deeper these are, the louder they will be. So generally, if an OD crack peaks up near _______ deep, its depth should be judged from its amplitude.
- For OD cracks/notches deeper than 1.91mm the reflector will peak up deeper than _______ so the depth should be judged more by where the signal peaks up along the baseline. It's not how loud it is, it's where it peaks up along the baseline.

So, to state this another way:

- For the shallow ones, you can tell how deep they are by how loud they are.
- For the deep ones, you can tell how deep they are by where they peak up along the baseline.

The best OD depth sizing is done from whichever side of the weld is louder.

OD Weld crown obstruction

When you can't raster over the top of the flaw (because of the weld crown) use a piece of mag tape to simulate the obstruction on the block. Find the combination of echo-dynamic and %FSH that is the closest match to make depth sizing determination.

Always try to do this from both sides of the flaw. If the obstruction distance is different from each side take this into consideration.

Determine the obstruction distance ultrasonically. See YouTube- FAST-UT OD sizing technique with weld crown obstruction .

SCC, Stress Corrosion Cracking, depth sizing prep grinding

Thin-walled pipelines can be subject to SCC, stress corrosion cracking. SCC usually appears as a dense field of cracks, crowded together with similar orientations. The FAST OD depth sizing described above is usually done on SCC in conjunction with surface prep done with sanding discs. The more the surface is prepped to remove the adjacent shallow SCC cracks, the better the sizing gets.

Two other things to think about while doing SCC prep or removing SCC a little at a time is "dishing" and "flattening".

When you grind out SCC a little at a time, pausing for re-MT-ing and re-FAST-UT-ing, you will get a much better result on your FAST-UT depth sizing if you don't create a 'dished out' concave excavation. UT coupling becomes poorer when you do this. Make the grind spot into a 'flat'. The 'flat' is similar to the surface of your OD notches on your notched block you are using to compare for sizing. Measuring on a 'flat' improves the sizing accuracy. When you are done sizing, blend the flat smoothly into the adjacent base material without making the excavation any deeper.

Axially oriented SCC is said to have an improved stress situation when the SCC is removed with sanding discs.

Circumferentially oriented SCC should never be ground out because this is said to weaken the pipe.

FAST-UT ID connected, perpendicular, planar flaw sizing technique

FAST-UT ID flaw height sizing works well when cracks or other flaws are propagating more or less perpendicular to the ID. When pipe is pressurized, the stress from the pressure can cause cracks to grow perpendicular from the ID. When flaws are expected to grow perpendicular to the ID this sizing technique can work well.

When cracks or other flaws are known to be oriented at angles other than perpendicular this sizing technique won't work too well. For example, ERW (Electro Resistance Welding) longitudinal seam welds known to have hook flaws (see figures 47-58) would be difficult to size with this technique. The following is for flaws oriented perpendicular to the ID.

Raster scan from way back to well beyond for each ID notch. Watch the echo dynamic or envelope of the L-wave signal. As you raster towards the notch it's signal gradually rises to a maximum and then drops off when the sound beam centerline goes over the top of the notch. The envelope of the walk for the deepest ID notch is shown in figure 30. A typical pattern for the walk (envelope) of all the ID notches is shown in figure 39.

Choose your depth sizing key point of the envelope. It could be:

- Signal peak
- Where the signal begins a straight slope change (shown with bold red "**X**" in figure 39)
  See YouTube- [FAST-UT ID connected flaw height sizing technique](#) .

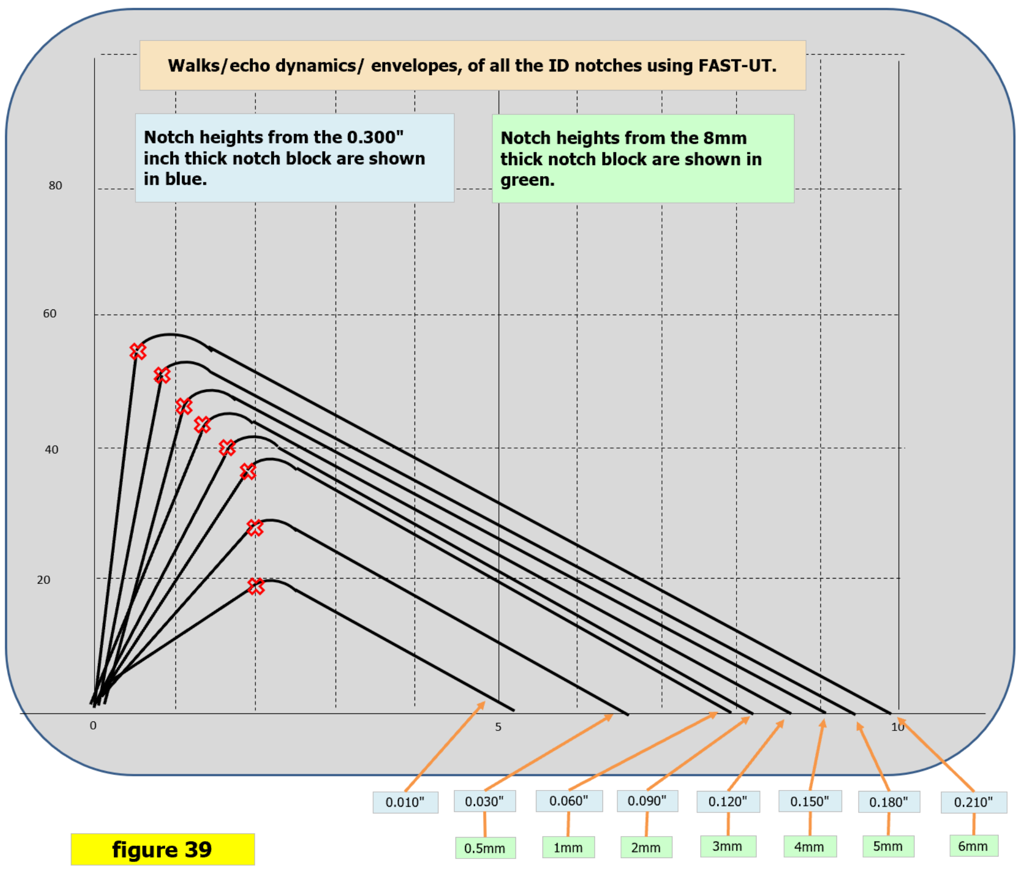


figure 39

Inches…FAST ID connected flaw height sizing…

Fill in the table below for ID connected flaw sizing. Start at the bottom and work your way up the table.

Lab Exercise 10 – FAST-UT, ID notch sizing (in.)

FAST ID sizing -- 0.3" thk notched block

dB ______

notch depth	remaining ligament	FAST-UT depth	%FSH
0.010"	0.290"		
0.030"	0.270"		
0.060"	0.240"		
0.090"	0.210"		
0.120"	0.180"		
0.150"	0.150"		
0.180"	0.120"		
0.210"	0.090"		

Do the ID depth sizing from the side where you walk over the top of the flaw at furthest point towards the left on the screen.
It might not be the loudest spot.

Millimeters…FAST ID connected flaw height sizing…

Fill in the table below for ID connected flaw sizing. Start at the bottom and work your way up the table. Refer to the above YouTube for guidance.

Lab Exercise 10 – FAST-UT, ID notch sizing (in.)

FAST ID sizing -- 8mm thk notched block

dB ______

notch depth	remaining ligament	FAST-UT depth	%FSH
0.5mm	7.5mm		
1mm	7mm		
2mm	6mm		
3mm	5mm		
4mm	4mm		
5mm	3mm		
6mm	2mm		

Do the ID depth sizing from the side where you walk over the top of the flaw at furthest point towards the left on the screen.
It might not be the loudest spot.

Embedded, midwall, rounded flaw sizing with FAST-UT

Raster over each SDH in the 0.5" FAST block. Note that the side drilled holes have a lot less mode converted signals than the equivalent depth ID or OD notches do. If the flaw you are looking at in the field does not have much mode converted signals, it might be an embedded, rounded, midwall flaw (not ID or OD connected). If you see flaws and you think they are embedded, rounded, midwall flaws, use the table below to help with your depth sizing to the top of the flaw.

Peak up on each of the SDHs and record below:

Lab Exercise 11 – FAST-UT, SDHs (in.) [note; same as Lab Exercise 8]

FAST embedded (midwall) flaw sizing with SDHs - 0.5" thk block				
dB	______			
SDH	0.100	0.200	0.300	0.400
depth reading				

It is difficult to detect and depth size the bottom of a midwall flaw. Finding the bottom of a midwall flaw is best done with special advanced techniques such as ToFD, FMC-TFM, or PCI.

See YouTube- FAST-UT embedded, midwall, rounded flaw sizing technique . This YouTube helps contrast different "walks" for ID & OD connected flaws from midwall flaws.

If you are working in metric units and cal blocks use the table below:

Lab Exercise 11 – FAST-UT, SDHs (mm) [note; same as Lab Exercise 8]

FAST embedded (midwall) flaw sizing with SDHs - 8mm thk block				
dB	______			
SDH	2.5mm	5.0mm	7.5mm	10mm
depth reading				

NOTE:

When we were developing each shear wave setup; 45°, 60°, and 70°, we took a moment to look at where the side drilled holes peak up and we recorded it in a small table. We did this so that we can refer to these tables when we think we are sizing an embedded, rounded, midwall flaw.

Identifying the L-wave

Because FAST-UT probes have high angle L-waves near 70°, low angle shear waves near 33° and so-called "ID creeper" and "OD creeper" effects, and many other possible mode conversion combinations, it's important to correctly identify which signal is the high angle L-wave signal. The high angle L-wave signal has a 'walk' or echo dynamic that is similar to a 70° shear, since they are both 70°. It is a long walk.

If you are having difficulty identifying the L-wave, try pulling back from the flaw. If the flaw is in fact an ID connected planar reflector, the last signal up, as you pull back, is the L-wave. Be sure to pull way back.

If you are still not sure, take a 'surface distance minus X-value' measure at the point where the flaw has been walked to the ID. Mark this distance on the surface. Repeat from the other side of the weld. For an ID connected crack, if you have correctly identified the L-wave from both sides, the two plots will plot to the same point on the surface from both sides. See YouTube FAST-UT and identifying the L-wave .

FAST-UT in the first leg

Always be aware of where leg one ends with FAST-UT. The high angle L-wave is the mode of sound we are most often looking for with FAST-UT. We can use it to take surface distance measurements in leg one and we can use it for ID, OD, and midwall flaw height sizing measures in leg one. We cannot do these things in leg two. There is not much sound from the high angle (70°) L-wave reflected into leg two. This high angle L-wave mode of sound is mostly mode converted to shear at a different angle in leg two. See figure 35. So, **CAUTION**, DON'T TRY TO TAKE MEASUREMENTS WITH THE L-WAVE MODE IN OTHER LEGS. You can only take measurements with the L-wave in leg one.

The fact that these other modes are present is very useful, though, in a qualitative sense. When we see a lot of mode converted signals deeper on our screen it is usually telling us that there are significant planar reflectors present, or ID/OD connected flaws present. This would be a very important observation.

If you are going to take sizing measures with your FAST-UT, make sure you have identified the high angle L-wave AND that you are in leg one.

Recognizing low angle shear in FAST-UT due to ID gouges

If you have access to a real or simulated ID gouge, look at an ID gouge. This can show you what a shear wave walk from an ID gouge looks like. It is low amplitude, has a short walk, and often appears as a series of 3 indications as you raster back-and-forth. See YouTube- FAST-UT recognition of ID gouges . This YouTube is actually of an inside undercut of a DSAW (double sub arc weld) longitudinal pipe seam. The series of 3 indications here is louder than you would see from an ID gouge in a Flash weld, but is a similar walk on the screen.

Flaw Length Sizing

A reliable and consistent flaw length measurement method uses your dual element FAST-UT probe.

Use the nature of the side-by-side arrangement of the sending and receiving elements of the FAST-UT search unit to define the starts and stops of flaws. A flaw can be seen with a side-by-side, dual element, angle beam search unit when there is some flaw centered between the two elements. This is the center of the FAST-UT search unit. As you scan side-to-side on the part, the flaw begins where the signal emerges from the baseline and ends where it disappears back into the baseline. Use these points as starts and stops for length sizing. The closer you can get to the flaw, the more accurate the end points are.

Don't use the traditional, conventional UT shear wave angle beam method for measuring flaw lengths which was one of the variations of the 6dB drop method:

- Start at a loud part of the flaw, somewhere in the middle of the flaw length, if the flaw was longer than the width of the search unit, then note the %FSH.
- Move side-to-side and note the points at which the amplitude drops by 6dB. These points are used as the start and stop of the length.

This 6dB drop method of flaw length measurement is not accurate. Natural flaws have varying textures, orientations, and amounts of reflectivity. Using the amplitude of the flaw to define its length is inconsistent and unreliable.

Establishing scan lines

Before beginning a FAST-UT scan of a seam or girth weld you should measure the material thickness and adjust the scan line location in relation to the base metal thickness.

We normally want to have enough scans to get sound into the whole volume of weld by the time we are done. We do this from both sides of the weld and from several different scan setback distances. We usually want to at least have the index point of the probe located at:

- As "up-close" to the weld toe or edge as possible.
- "Setback" at a half skip distance (half Vee) from the weld so the center of the sound beam is directed at the root or ID of the weld.
- At additional setback distances between the "up-close" and the "set back".

The setback distance for FAST-UT using a one-inch-deep screen in inches and a 20mm deep screen for metric is:

For FAST-UT, inches: Setback dist. = T*2.75

For FAST-UT, mm: Setback dist. = Soundpath*Sin70°

If we only have 70° shear and not angled L-wave (FAST-UT) to work with, we should have our "setback" scan at a full skip from the weld centerline. The setback distance for 70° shear using a one-inch-deep screen in inches and a 20mm deep screen for metric is:

For 70° shear, inches: Setback dist. = (T*2.75) *2

For 70° shear, mm: Setback dist. = (Soundpath* Sin70°) *2

See left side of figure 25 for inches and the left side of figure 27 for millimeters.

This distance is the distance from the weld centerline to where you put your FAST-UT probe index point (Not the search unit front edge). See YouTube- FAST-UT and establishing scan lines .

Seam weld inspection process:

To inspect a longitudinal seam weld the following is a good way to get started:

1. Do the mag of the weld first to find all the OD connected flaws. It is helpful to know where those are because it will be less distracting when you see mode converted signals at those spots.

2. File down or power wire wheel or very lightly buff to remove the WCAMT paint if you used white contrast aid MT, from the areas where you will be UT scanning. Anywhere you do FAST scanning should be nice and smooth so you can get a nice smooth scan. Paint interferes with sound transmission.

3. Know the material thickness to figure out the set-back distance for your FAST scans.

   [for inches, setback dist. = T * 2.75]

   [for mm, setback dist. = soundpath * Sin70]

4. Figure out where to put the mag tape guide to get a good set-back distance.

5.

<u>Detect</u>:

Do the scans from both sides. Scan the entire length without stopping to get the big picture.

Do both "butt up" and "set back" scans.

Re-scan and mark indication hot spots.

<u>Characterize</u>:

Determine, one at time, if each of the reflectors are:

- OD connected
- ID connected
- Embedded
- ID gouge

<u>Size</u>:

Find the starts and stops for flaw lengths. Determine flaw height sizing using OD sizing or ID sizing techniques.

6. Verify indications from both sides by comparing surface distances.

7. Use additional search units and angles to refine your sizing and characterizing. See YouTube [FAST-UT of weld seams](#) .

Summary of FAST-UT basics

Now that the individual parts of FAST-UT have been described, review figure 40 for inches and figure 41 for millimeters for a summary of FAST-UT basics, including the three flaw sizing tables you have developed for OD, ID, and midwall flaws.

Inches:

FAST OD sizing -- inches

dB ______

OD notch	% FSH	depth reading	
0.010"			
0.030"			
0.050"			
0.060"			< 0.075"
0.090"			> 0.075"
0.100"			
0.120"			

do OD sizing from the louder side

FAST embedded (midwall) flaw sizing with SDHs - 0.5" thk block

dB ______

SDH	0.100	0.200	0.300	0.400
depth reading				

FAST ID sizing -- 0.3" thk notched block

dB ______

notch depth	remaining ligament	FAST-UT depth	%FSH
0.010"	0.290"		
0.030"	0.270"		
0.060"	0.240"		
0.090"	0.210"		
0.120"	0.180"		
0.150"	0.150"		
0.180"	0.120"		
0.210"	0.090"		

Do the ID depth sizing from the side where you walk over the top of the flaw at furthest point towards the left on the screen.
It might not be the loudest spot.

Summary of steps for performing FAST-UT of a seam weld:

1.
Know your pipe thickness, T. The setback scan lines are at T*2.75

2.
Perform FAST scans from both sides, from both butt-up and setback. Mark the hot spots. Real flaws are usually seen to some degree from both sides.

3.
Characterize the flaw as ID, OD, midwall or ID gouge.

4.
For ID connected flaws; from each side, verify the signal walks like a high angle L-wave and then walk the L-wave signal to the ID and check surface distance plot. It should plot to the same point on the surface from both sides.

5.
Do FAST ID , OD, or midwall depth sizing.

FAST-UT basics:

-70° L-wave has a long walk and for ID flaws is the last one up when you pull way back

-Flaws are usually seen from both sides

-Surface distances should plot good

-Planar flaws have a lot of mode converted signals

figure 40

Millimeters:

FAST OD sizing -- metric blocks

dB ______

OD notch	% FSH	depth reading	
0.5mm			
1.0mm			
1.25mm			<1.91mm
2.0mm			>1.91mm
2.5mm			
3.0mm			

do OD sizing from the louder side

FAST embedded (midwall) flaw sizing with SDHs - 8mm thk block

dB ______

SDH	2.5mm	5.0mm	7.5mm	10mm
depth reading				

FAST ID sizing -- 8mm thk notched block

dB ______

notch depth	remaining ligament	FAST-UT depth	%FSH
0.5mm	7.5mm		
1mm	7mm		
2mm	6mm		
3mm	5mm		
4mm	4mm		
5mm	3mm		
6mm	2mm		

Do the ID depth sizing from the side where you walk over the top of the flaw at furthest point towards the left on the screen.
It might not be the loudest spot.

Summary of steps for performing FAST-UT of a seam weld:

1.
Know your pipe thickness, T. The setback scan lines are at soundpath * Sin70

2.
Perform FAST scans from both sides, from both butt-up and setback. Mark the hot spots. Real flaws are usually seen to some degree from both sides.

3.
Characterize the flaw as ID, OD, midwall or ID gouge.

4.
For ID connected flaws; from each side, verify the signal walks like a high angle L-wave and then walk the L-wave signal to the ID and check surface distance plot. It should plot to the same point on the surface from both sides.

5.
Do FAST ID , OD, or midwall depth sizing.

FAST-UT basics:

-70° L-wave has a long walk and for ID flaws is the last one up when you pull way back

-Flaws are usually seen from both sides

-Surface distances should plot good

-Planar flaws have a lot of mode converted signals

figure 41

Saving your setups (cals)

Once you have your setups that you like finalized, it is a good idea to copy them from your flaw detector and save them on your laptop in case you need to set up again on a different flaw detector of the same model and software. Not all flaw detectors can do this easily but it is a good capability to have.

This might be a good time to go back and look at the section "Saving your calibration setup files" on page 28.

Section 5 Types of Longitudinal Seam Welds

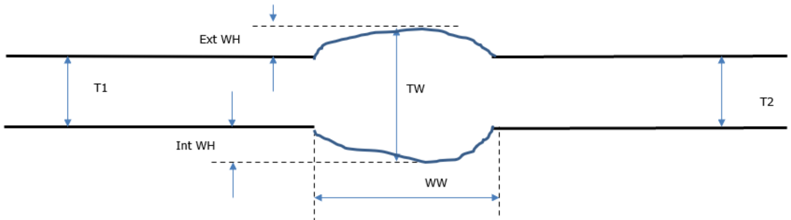
Once you have detected, characterized and sized a seam flaw indication you must create a flaw sketch for it. The flaw sketch must show the sizing measures of the flaw with no doubt as to what you have decided is the correct sizing. The weld types that you are likely to encounter for the seam welds of longitudinally welded pipe are:

- Double sub-arc weld
- Flash weld
- ERW (high frequency or low frequency)

See figures 42-45 for generalized cross sectional sketches of these seam weld types. There is a very large variety of appearances for ERW welds. Figures 46 and 47 shows three more types of appearance of ERW seam welds. Figure 47 (bottom) shows a plan view of one type of ERW weld sometimes seen to look like the figure 47 (top) cross sectional view. These ERW welds often have three different types of MT indications as shown in Figures 48-52:

1. Arc burns from the welding contacts. These linear indications are irregular, curved and jagged. They run along one or both parallel weld edges and usually can be ground out within 0.025" of the surface. See figure 47 & 48.
2. Extremely dark, straight, centerline indications and can be depth sized well with many different techniques and are usually found to be due to lack of fusion at the bond line. See figure 47 & 49.
3. Hook flaws are distinct, very straight, but not very dark, linear MT indications, that could be any distance from centerline, and usually don't depth size easily. They are sometimes offset from each other but stay parallel to the seam axis. See figures 47 and 50-58. Hook flaws are caused by inclusions or laminations that were present in the plate the pipe was made from. See figures 53 & 54. (See 'hook flaws' in Terms and Definitions). Metallurgical laboratory sections (metlabs) are polished cross sections showing the grain structure and plastic flow. See 55-58.

Double SubArc Weld



Above; cross-section of a typical Double SubArc weld. These welds are quite wide and quite thick.
Below; a view from the outside of a pipe with a double subarc weld that is quite wide. The scale showing inches in tenths shows that this weld is 0.75" wide. Also shown is a FAST1 probe being held-frozen as a surface distance measurement is being taken. See the next page for a view of the inside of this weld.

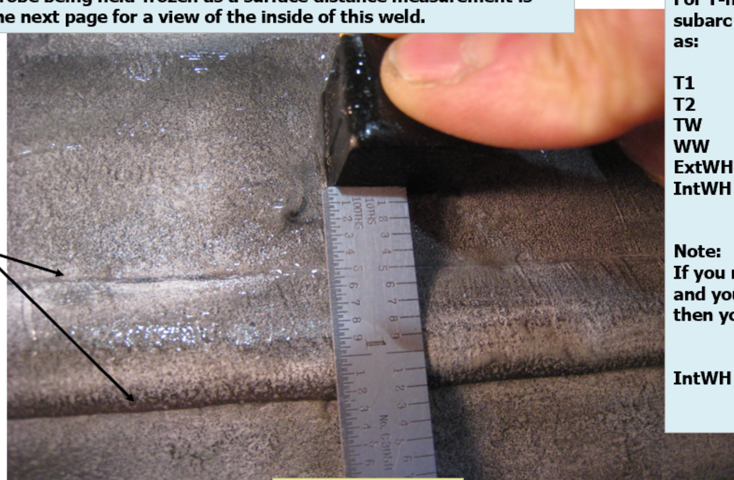


figure 42

The abbreviations at left are for typical measures of welds:

T1	**Pipe thickness on the counter clockwise side of the seam.**
T2	**Pipe thickness on the clockwise side of the seam.**
TW	**Weld thickness**
WW	**Weld width**
ExtWH	**External reinforcement height**
IntWH	**Internal reinforcement height**

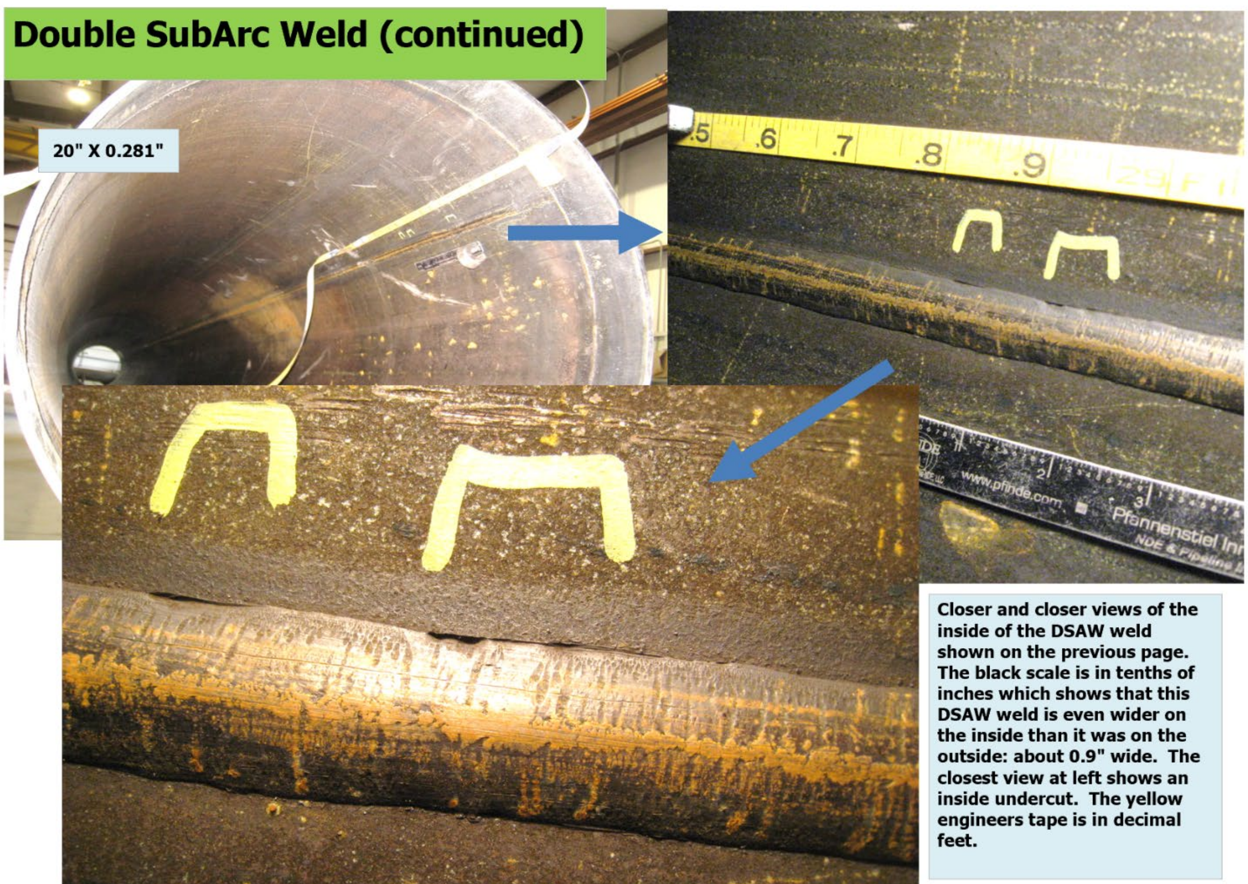
For T-nom of 0.250" a typical double subarc seam weld might measure (mils) as:

T1	**250**
T2	**245**
TW	**500**
WW	**625**
ExtWH	**125**
IntWH	**125**

Note:
If you measure T1, T2 and TW with UT, and you measure ExtWH with a scale, then you can calculate the IntWH:

IntWH = TW - (ExtWH + T1)

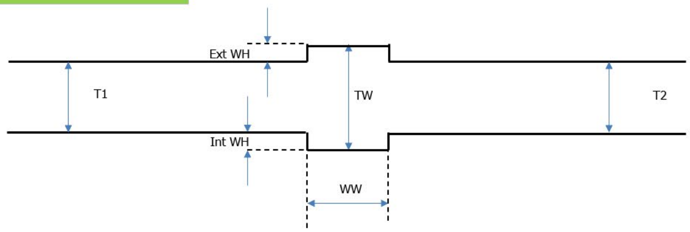
Double SubArc Weld (continued)



Closer and closer views of the inside of the DSAW weld shown on the previous page. The black scale is in tenths of inches which shows that this DSAW weld is even wider on the inside than it was on the outside: about 0.9" wide. The closest view at left shows an inside undercut. The yellow engineers tape is in decimal feet.

figure 43

Flash Weld



Above; cross-section of a typical flash weld. These welds have lots of geometry reflectors. There are four corner trap refelctors; one at the ID and one at the OD from each side.
Below, left; a flash weld.
Below, right; cross-sectional end view of the near end shown at left. There is HiLo present in this joint.

For T-nom of 0.250" a typical flash weld seam weld might measure (mils) as:

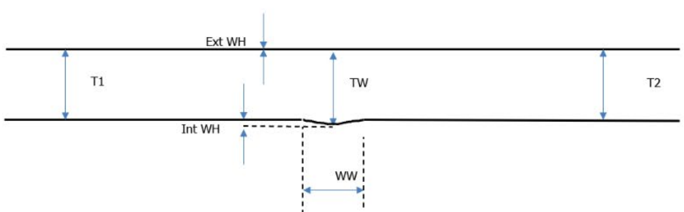
T1	**250**
T2	**245**
TW	**390**
WW	**250**
ExtWH	**75**
IntWH	**65**

Note:
If you measure T1, T2 and TW with UT, and you measure ExtWH with a scale, then you can calculate the IntWH:

IntWH = TW - (ExtWH + T1)

figure 44

ERW Weld



Above; cross-section of one type of ERW weld. Actually, ERW welds have many types of cross sections. Sometimes there is external reinforcement. The root can be convex, as shown above, or can be concave, or a combination. There are tools that "scrape" the weld close to flush with the base metal and these tools can leave many types of profiles; flush, concave, convex or combinations on both the ID and the OD.

Below; an ERW seam weld and zoomed in at right.

For T-nom of 0.250" one possible ERW weld seam might measure (mils) as:

T1	**250**
T2	**245**
TW	**260**
WW	**300**
ExtWH	**0**
IntWH	**10**

Note:
The actual weld itself, in both a Flash weld and an ERW weld, is a narrow bond line of fusion, about 1/32" wide. In a good weld, any melt gets completely squeezed out of the joint. The area that visually appears to be weld is the area that undergoes plastic flow during the time the joint is squeezed together like a forging.

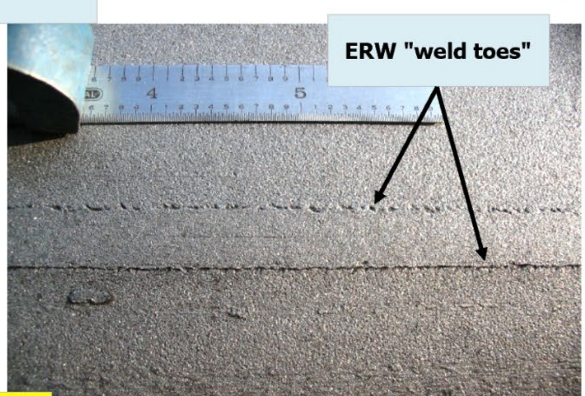


figure 45

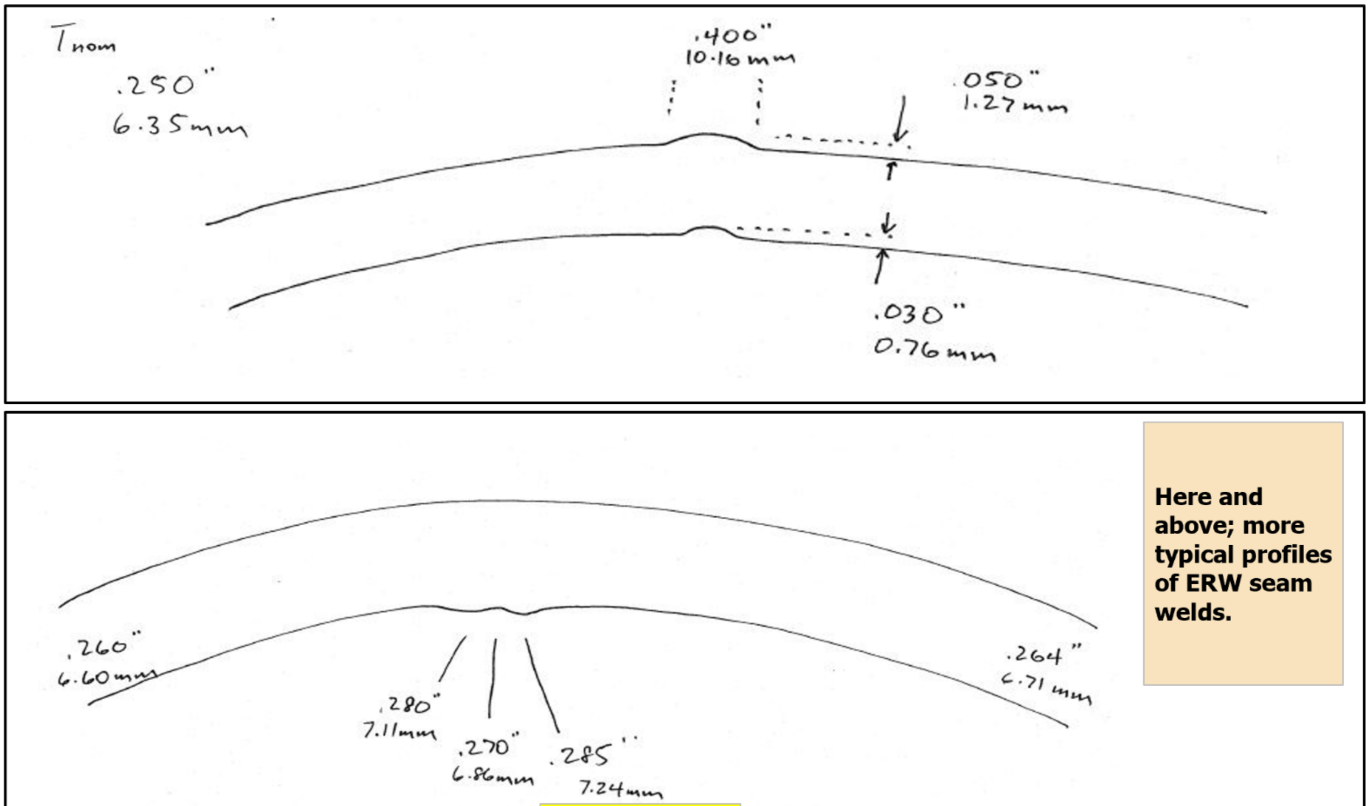


figure 46

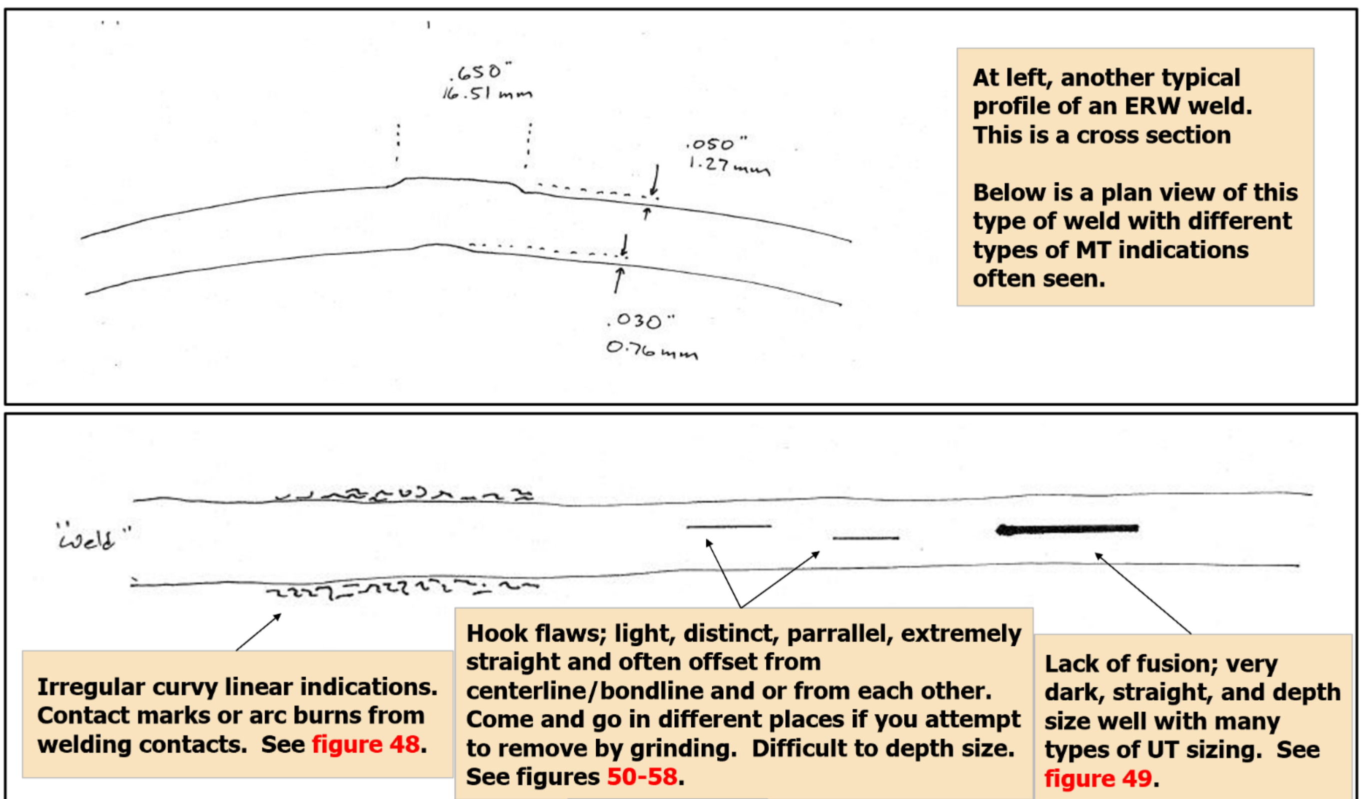
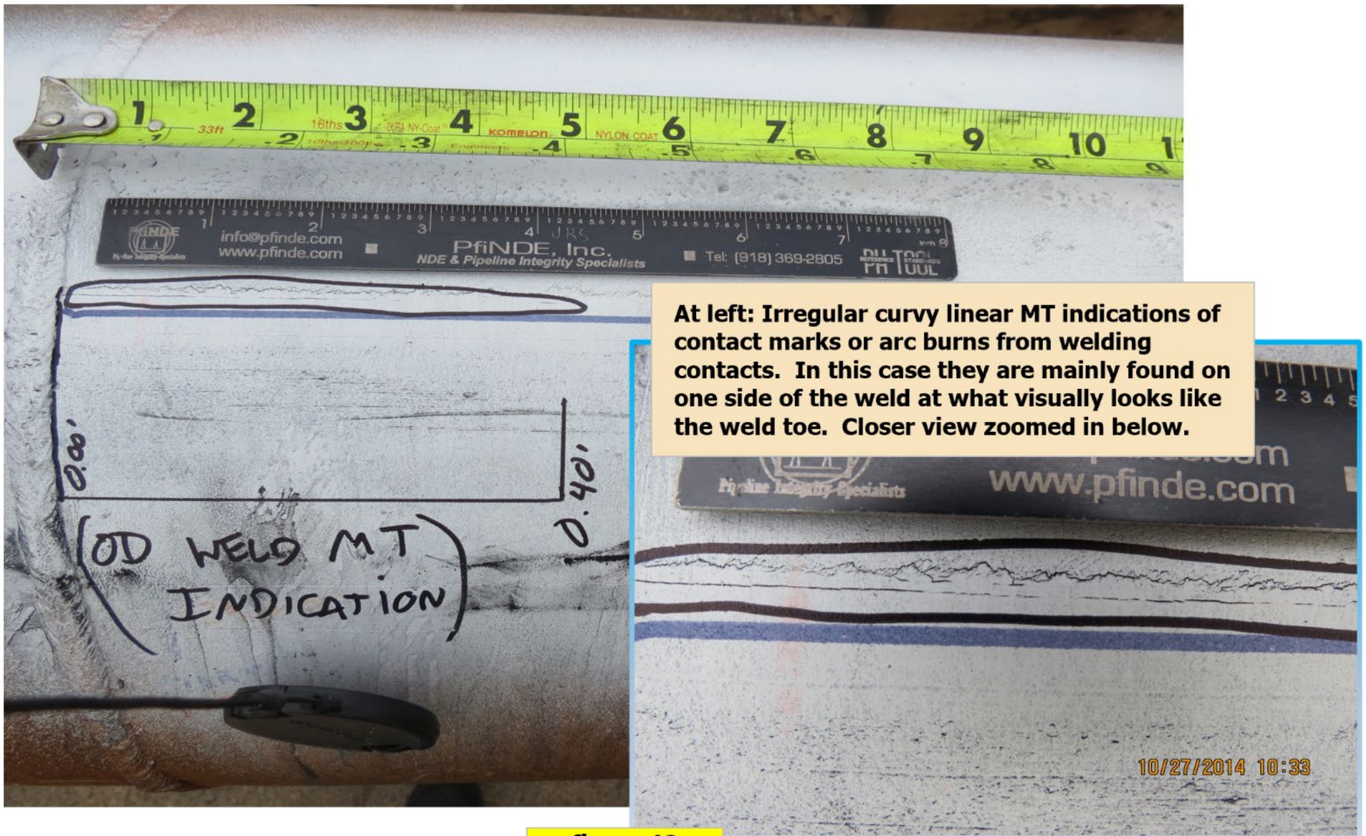
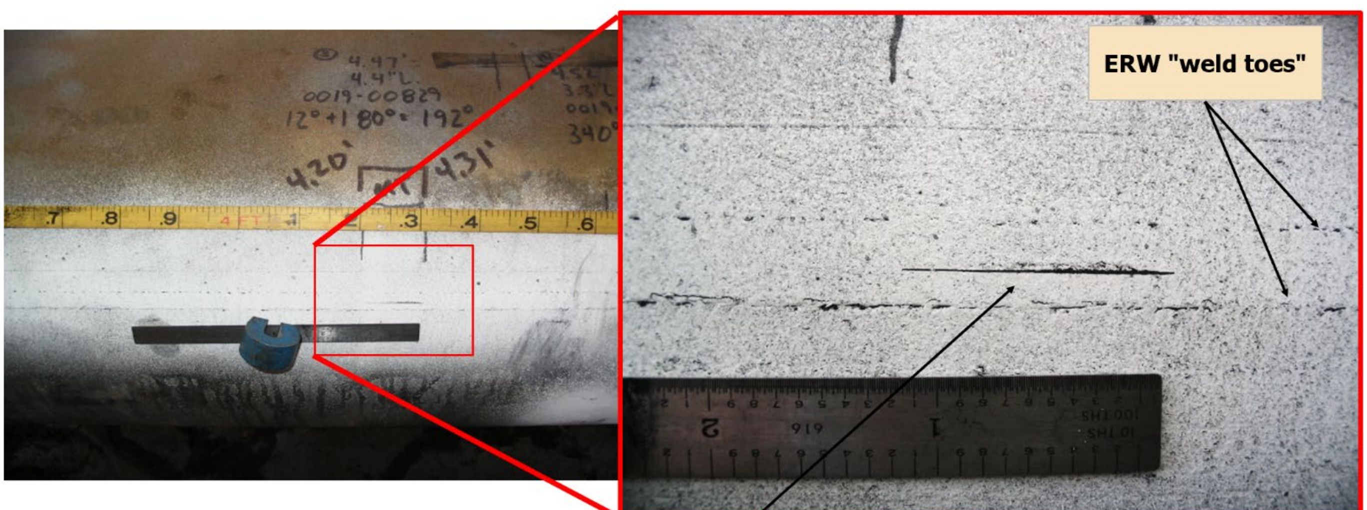


figure 47



At left: Irregular curvy linear MT indications of contact marks or arc burns from welding contacts. In this case they are mainly found on one side of the weld at what visually looks like the weld toe. Closer view zoomed in below.

figure 48



<u>Lack of Fusion</u> linear MT indicatons near the center of what visually looks like the ERW seam, result in very dark MT indications. They can often be depth sized very well with many different UT techniques;

- ***FAST OD depth sizing technique**
- ***Shear wave tip sizing at the end of leg 2**
- ***phased array sector scans**
- ***phased array linear scans**

Above left, an ERW seam weld. Above right, zoomed in view.

figure 49

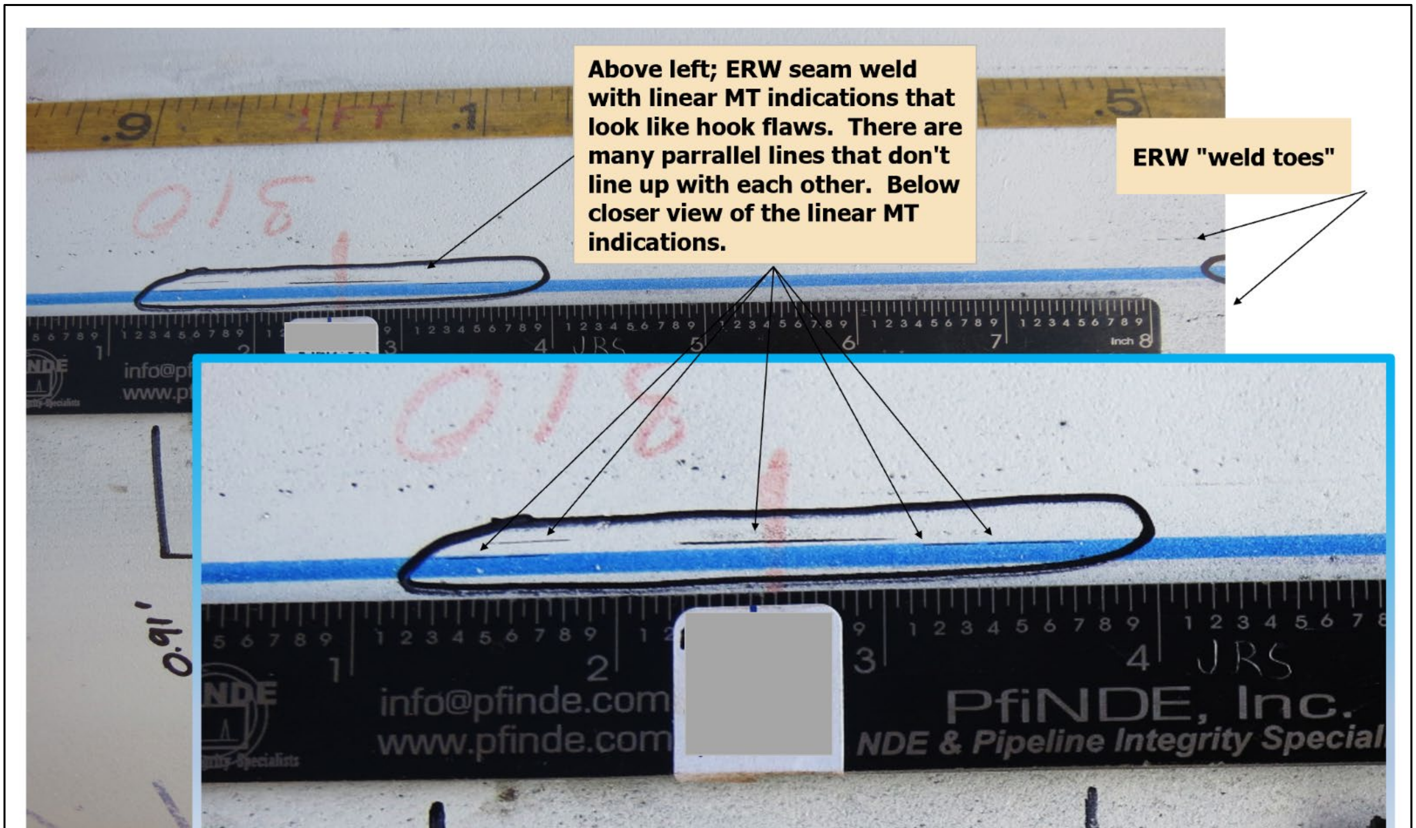


figure 50

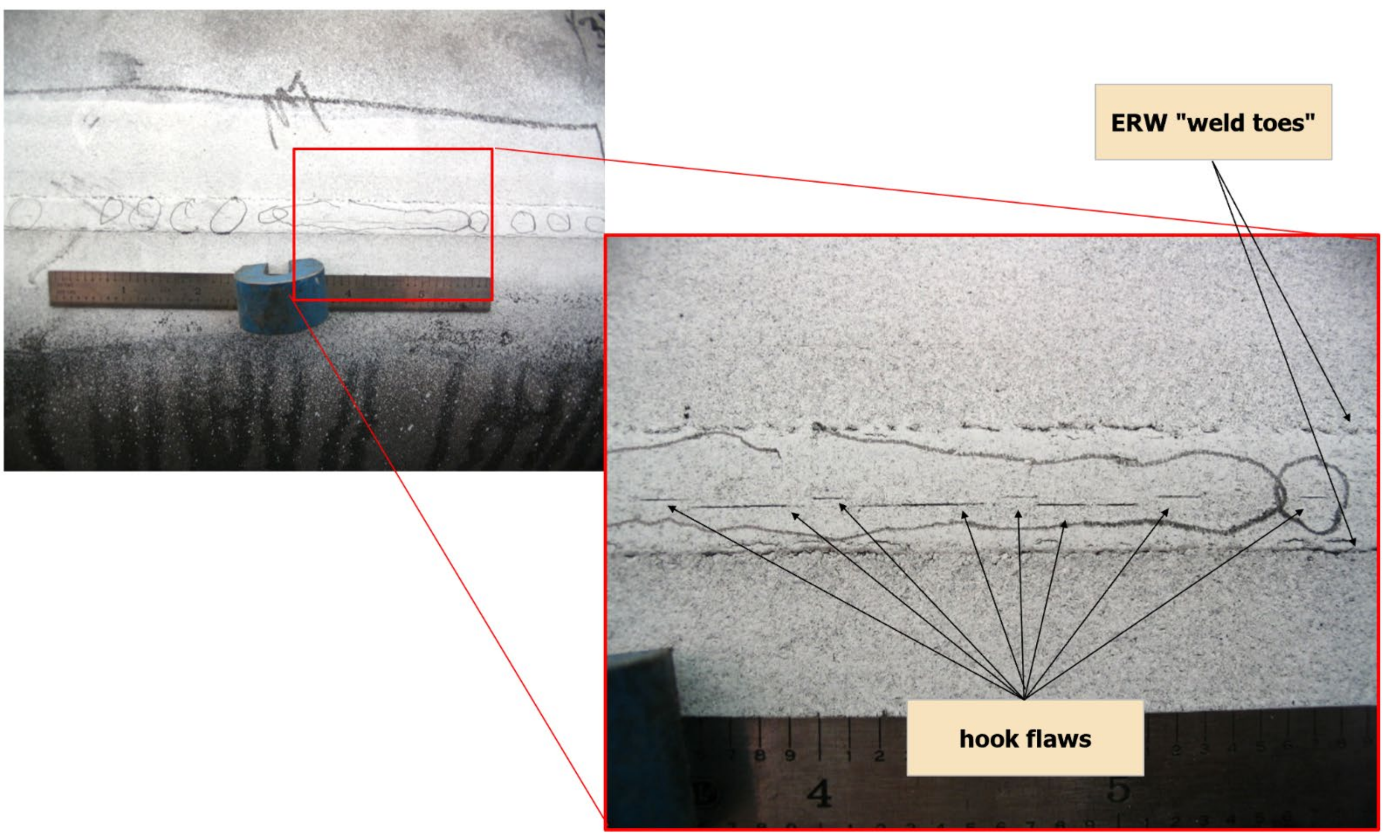


figure 51

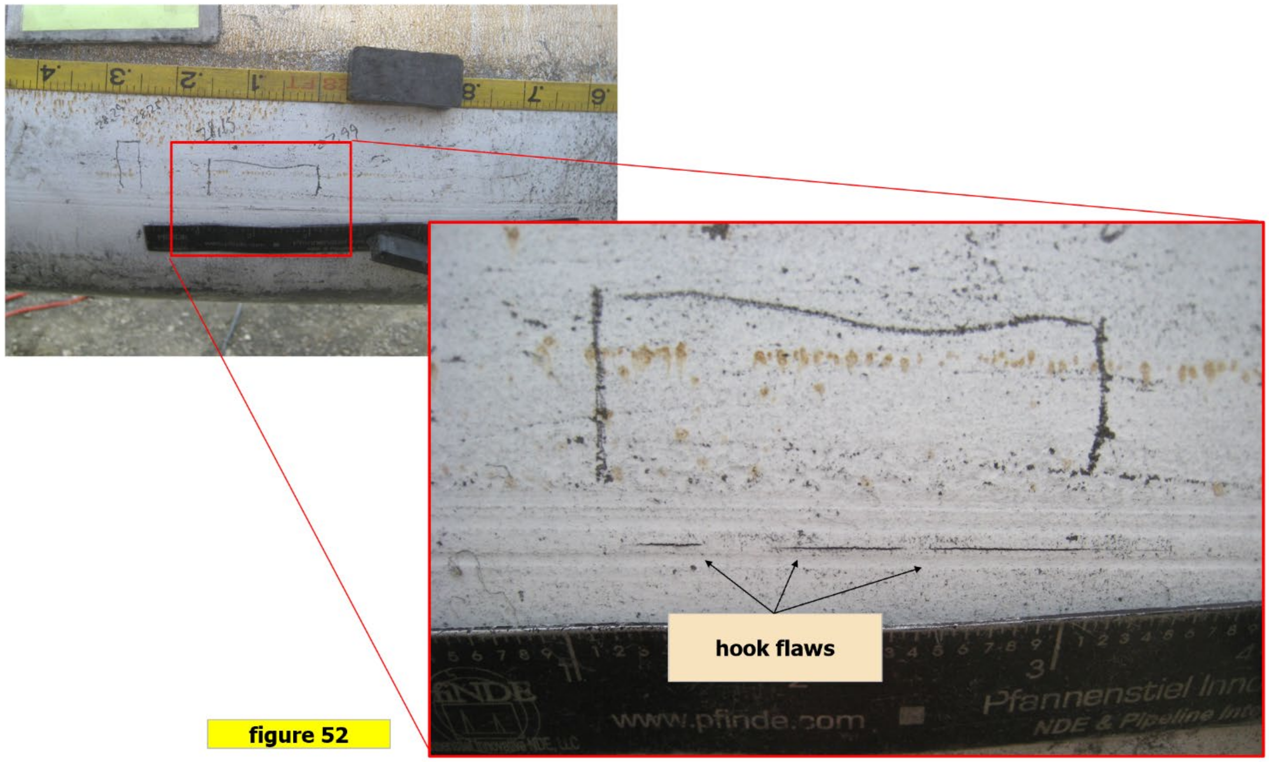
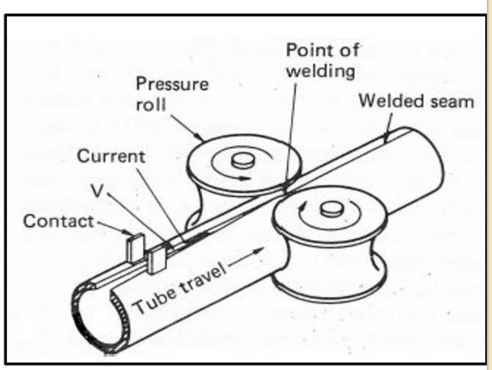


figure 52



At left a typical setup for ERW (electric resitance weld) longitudinal seam welding. The pipe starts out as a piece of plate which is curved into a pipe shape and then welded along the joint. Alternating electric current travels between the contacts along the shortest path of the surface skin to heat the joint and then the joint is squeezed together at the pressure rollers. The squeezing action jams to the two sides together with forging type action causing plastic flow and joining of the two members.
Below:
plastic flow during squeezing/forging/welding

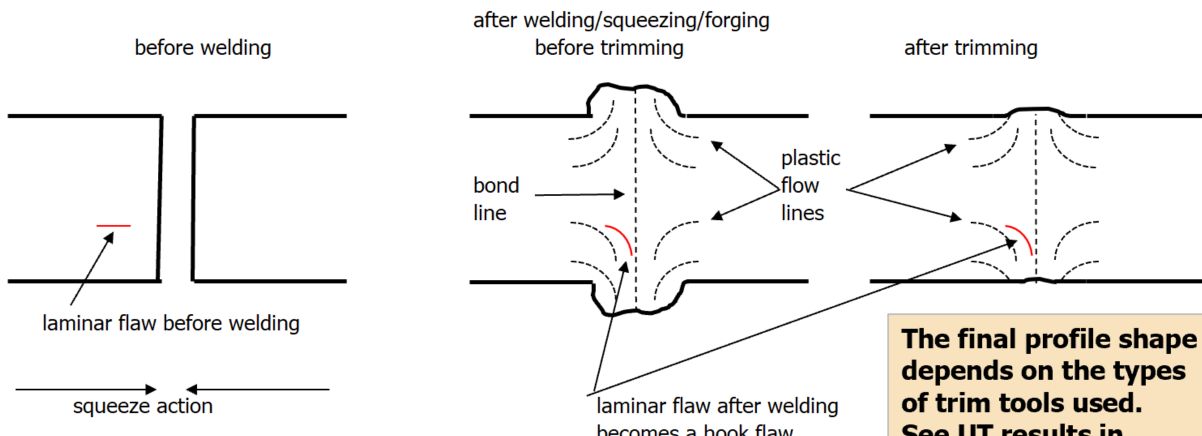


figure 53

The final profile shape depends on the types of trim tools used. See UT results in figure 54.

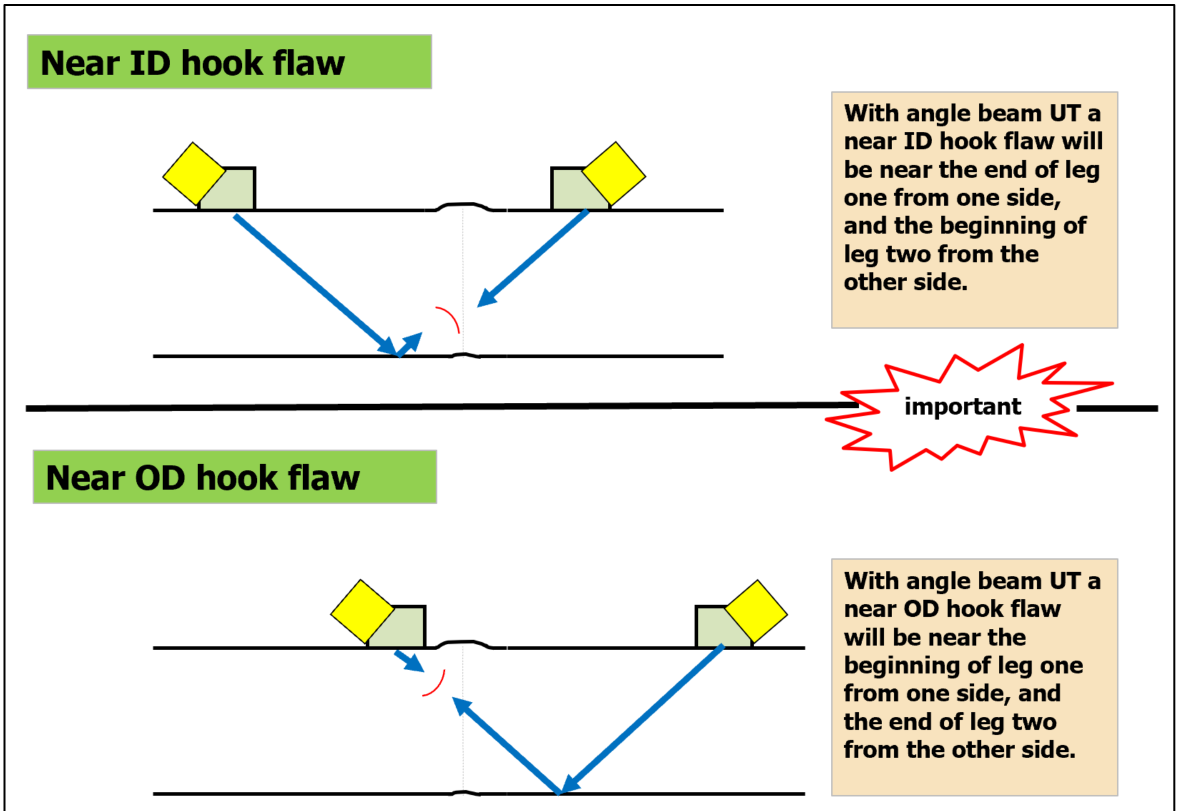


figure 54

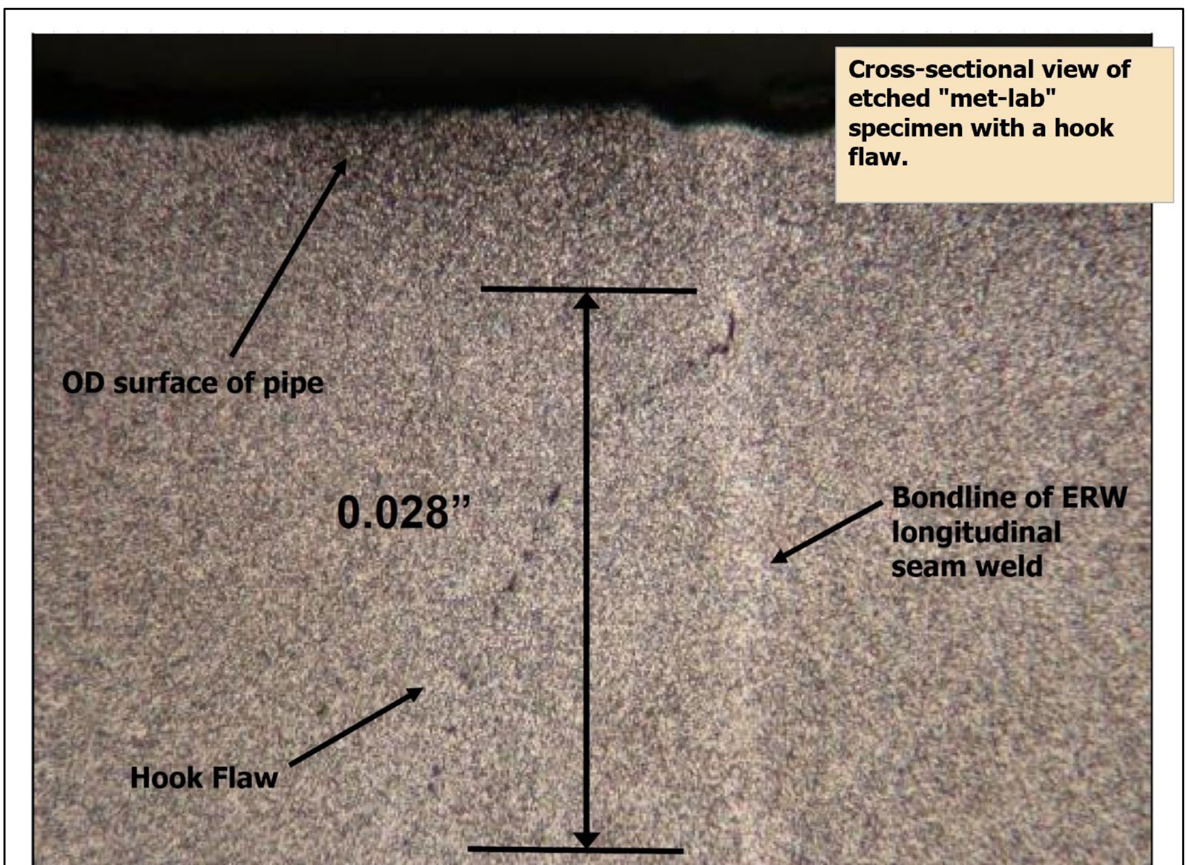


figure 55

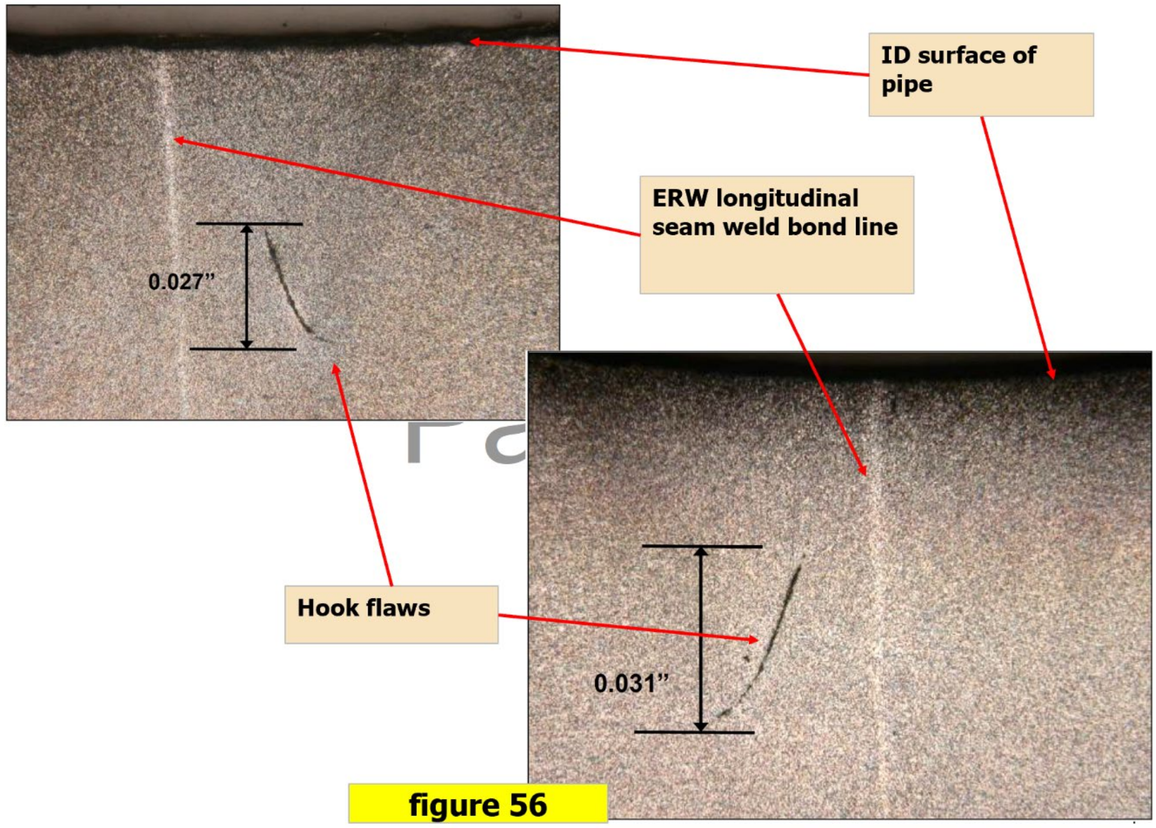


figure 56

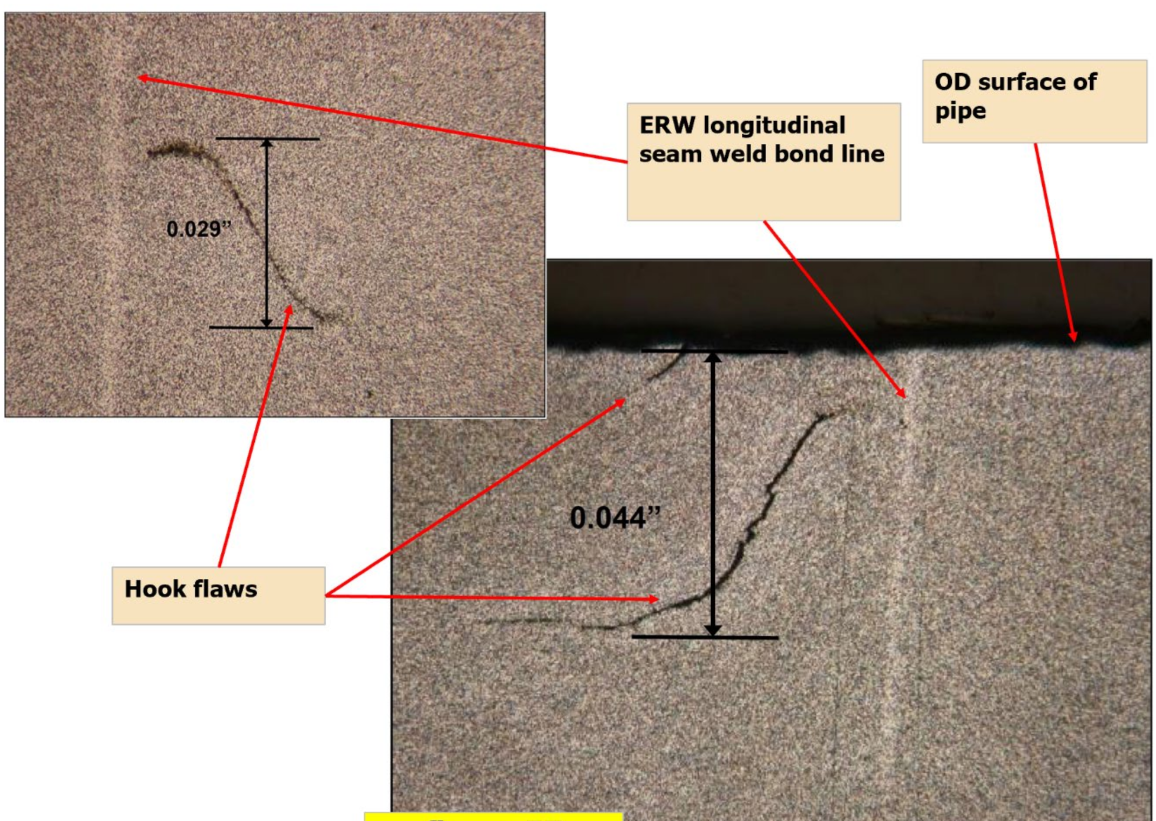


figure 57

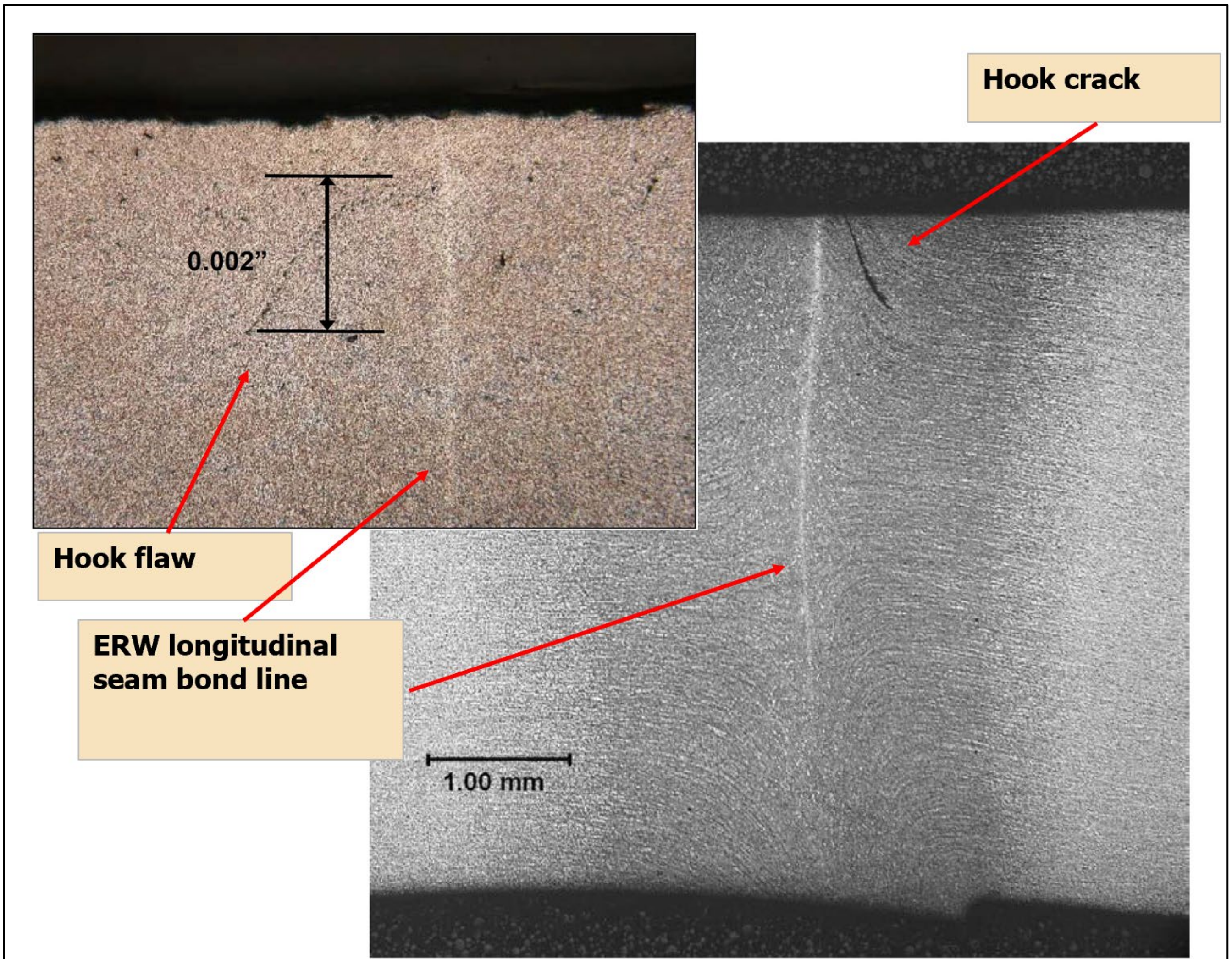


figure 58

The photo above, right is by permission of Kiefner Associates, Columbus OH.

Geometric Indications

Geometric indications are due to the shape of the part. For example, the internal weld reinforcement of a flash weld (figure 44) causes loud geometric indications at the ID and the OD. They are real indications, but they are not flaws.

Sometimes ILI tools will find ID or OD geometry. It is not enough to record in your report the word "geometry" and then move on, like a 'get-out-of-jail-free' card in a game of Monopoly. You should have a sketch that shows the cause of the geometric indication. Some geometry is thought to be bad and some not to be harmful at all.

The table below describes some characteristics of "good" and "bad" geometry. See figures 59 & 60.

ID Geometry	
Good	Bad
Seen with angle beam UT from only one side	Seen from both sides and plots to same surface distance location
Does not encroach on the pipe ligament	Does encroach on the pipe ligament; reduces effective pipe thickness
	Has a notch-like or crack-like stress riser whether it encroaches on the pipe ligament or not

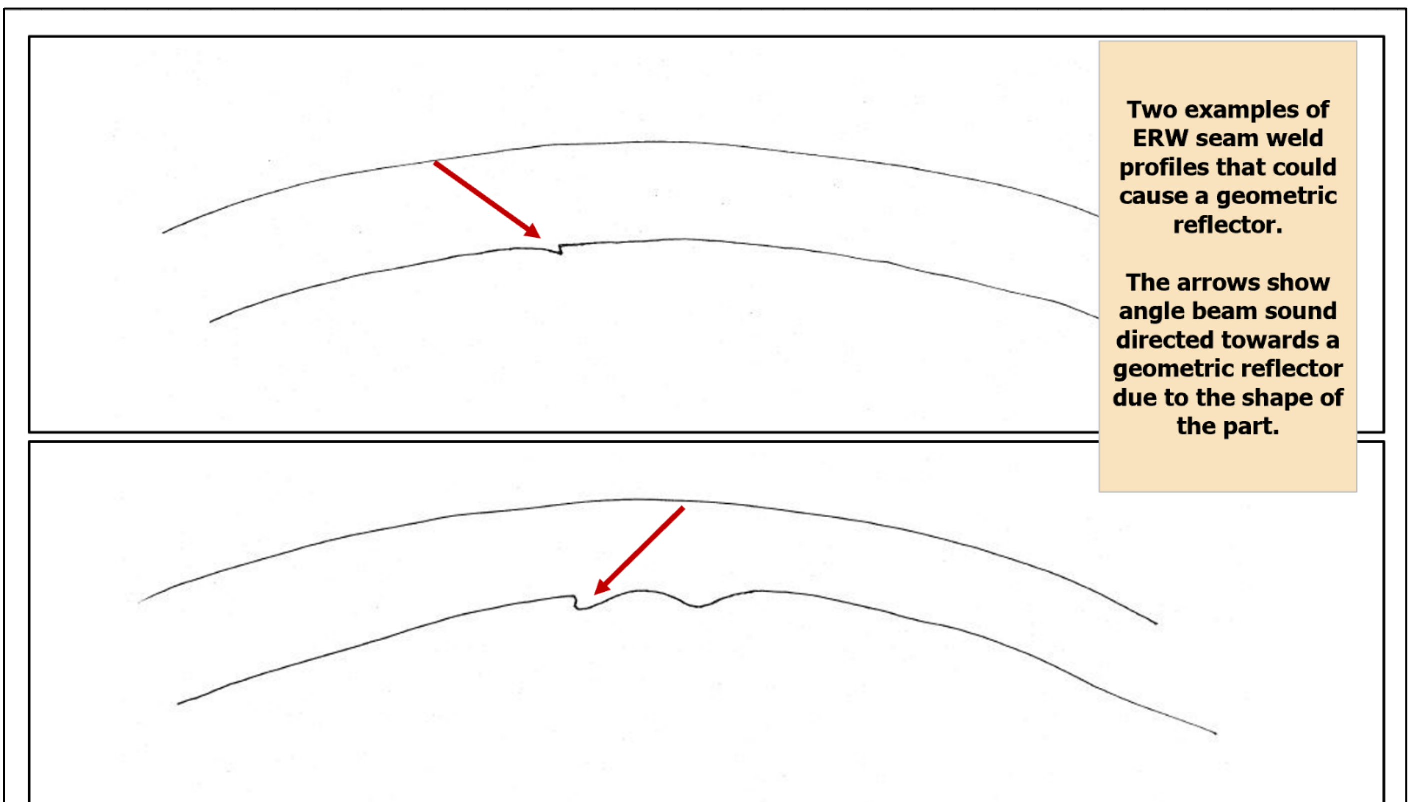


figure 59

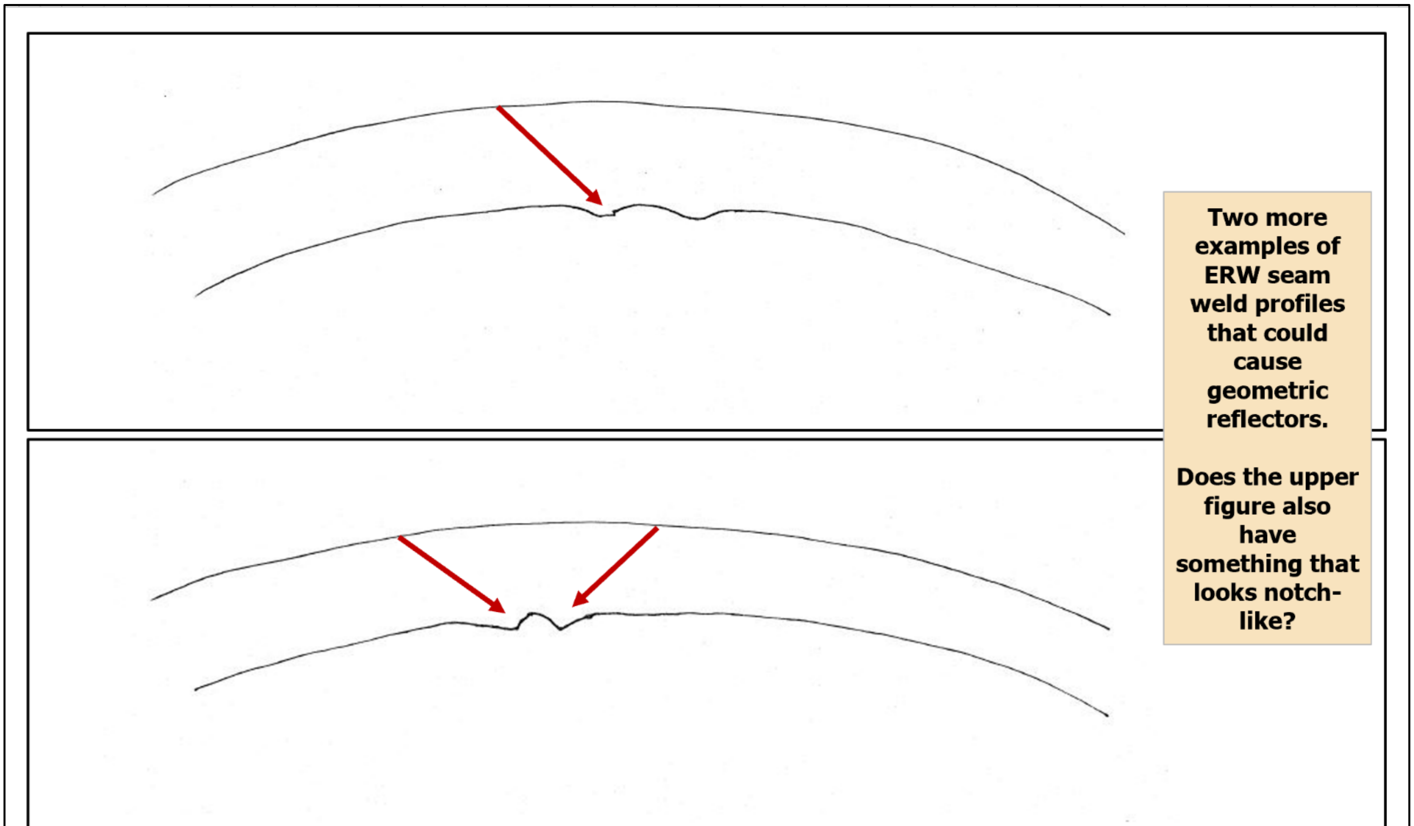


figure 60

How to tell ERW seam weld trim tool geometry from flaws

Recalling how an ERW longitudinal seam weld is made from figure 53 we can see how the plate material is bent into a tube shape and then forced between the rollers during the application of heat. The members are squeezed together and joined to form the seam weld. This is a continuous process, not a stop and go process. During this continuous process various forces are at play and the combination of all the forces and the alignment of the trim tools scraping at the ID and the OD can result in gradual changes of alignment. These gradual changes are often something we can see in our UT. These gradual changes look very different than the abrupt changes we usually see as flaws start and stop. Most flaws are abrupt changes. Often geometry can be recognized just by the fact that the changes on the screen are very gradual. These gradual changes are usually easiest to recognize with FAST-UT. These geometry changes can be verified and measured with straight beam and angle beam shear.

Flaw Sketches

Each flaw that is reported for a seam weld or girth weld or pipe body must be described with a flaw sketch that leaves no doubt as to what you are reporting as the correct sizing. It is difficult to make a flaw sketch that cannot be misinterpreted. This might require some practice.

Figure 61 shows examples of items that can be included in flaw sketches of ID or OD connected hook flaws in flash welds. There are so many measurable items, and dotted lines and arrows and labels that could go to them, that a flaw sketch can become difficult to understand because of too much detail. Figure 62 shows the same type of flaw sketch as in figure 61, but it is simplified to make it easier to interpret. All the quantities described in figure 61 can be found in figure 62.

Note that the items in figures 61 and 62 have some things in common:

- ExtWH + T + IntWH = TW
- T = CD + RL
- TRL + TCD = TW
- If the IntWH cannot be physically measured because it is inside the pipe, it can be found from knowing the Ext WH, T and TW with the following:

Int WH = TW – (Ext WH +T)

If you submit a report with a flaw sketch where the math does not "add up", it will put doubt into the whole sketch.

Flaw sketches may be drawn on the pipe next to the actual flaw location, drawn on paper and scanned or drawn with Excel drawing tools. See figures 63-67 for examples of flaw sketches. An approach sometimes used is to draw to scale, using a scale of ten to one. (If your pipe is 0.300" thick, then draw the pipe thickness as 3.0" on the sketch.) If you have never drawn a flaw sketch this can be a good way to get started.

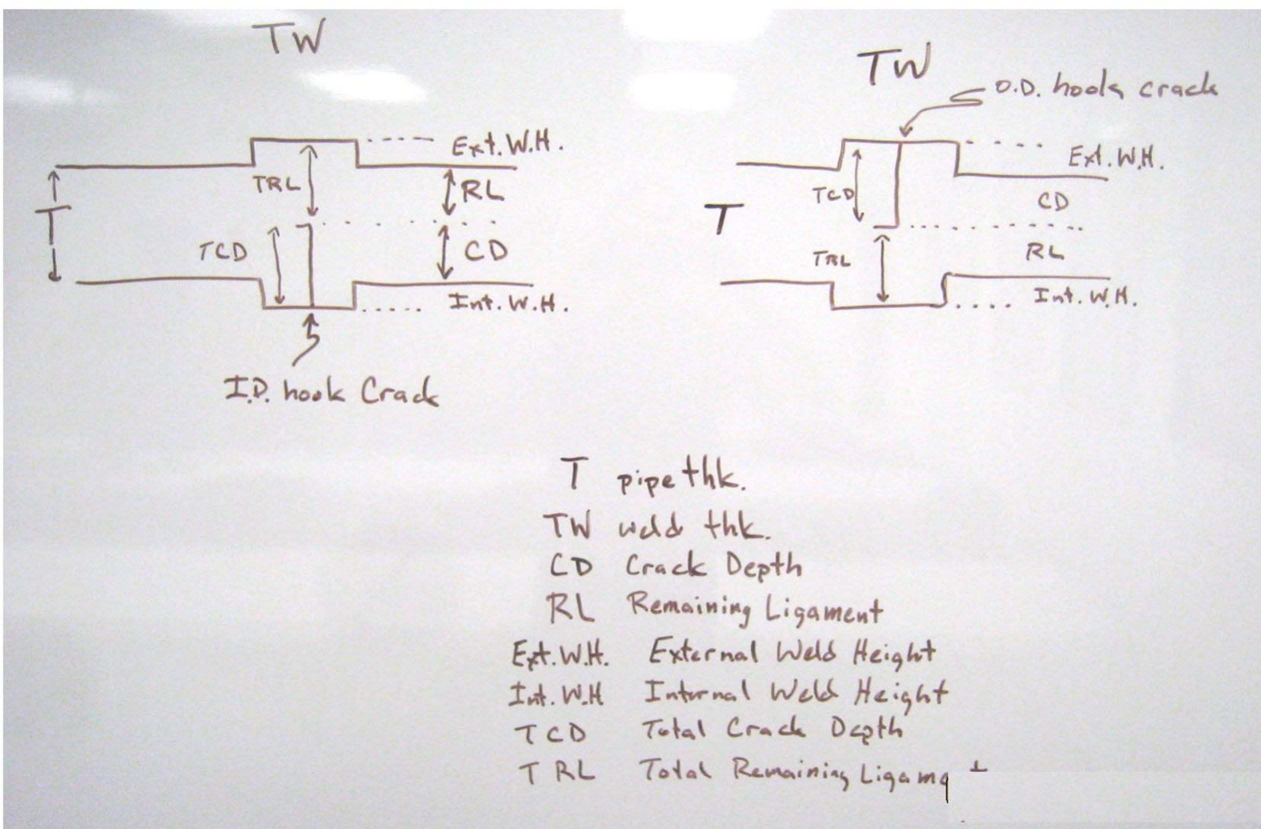


figure 61

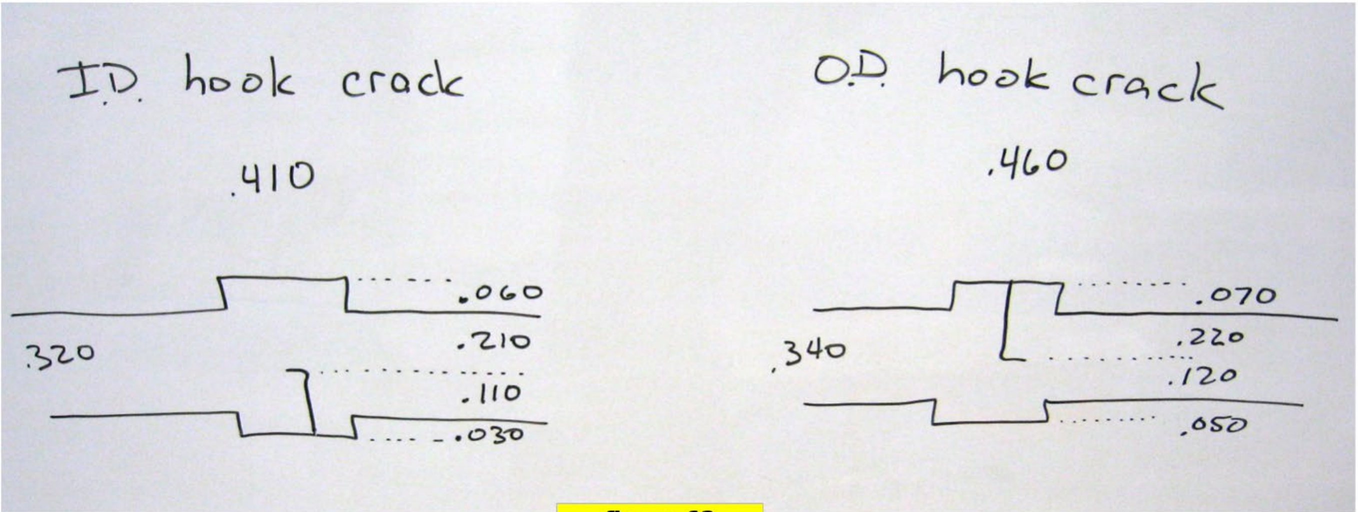
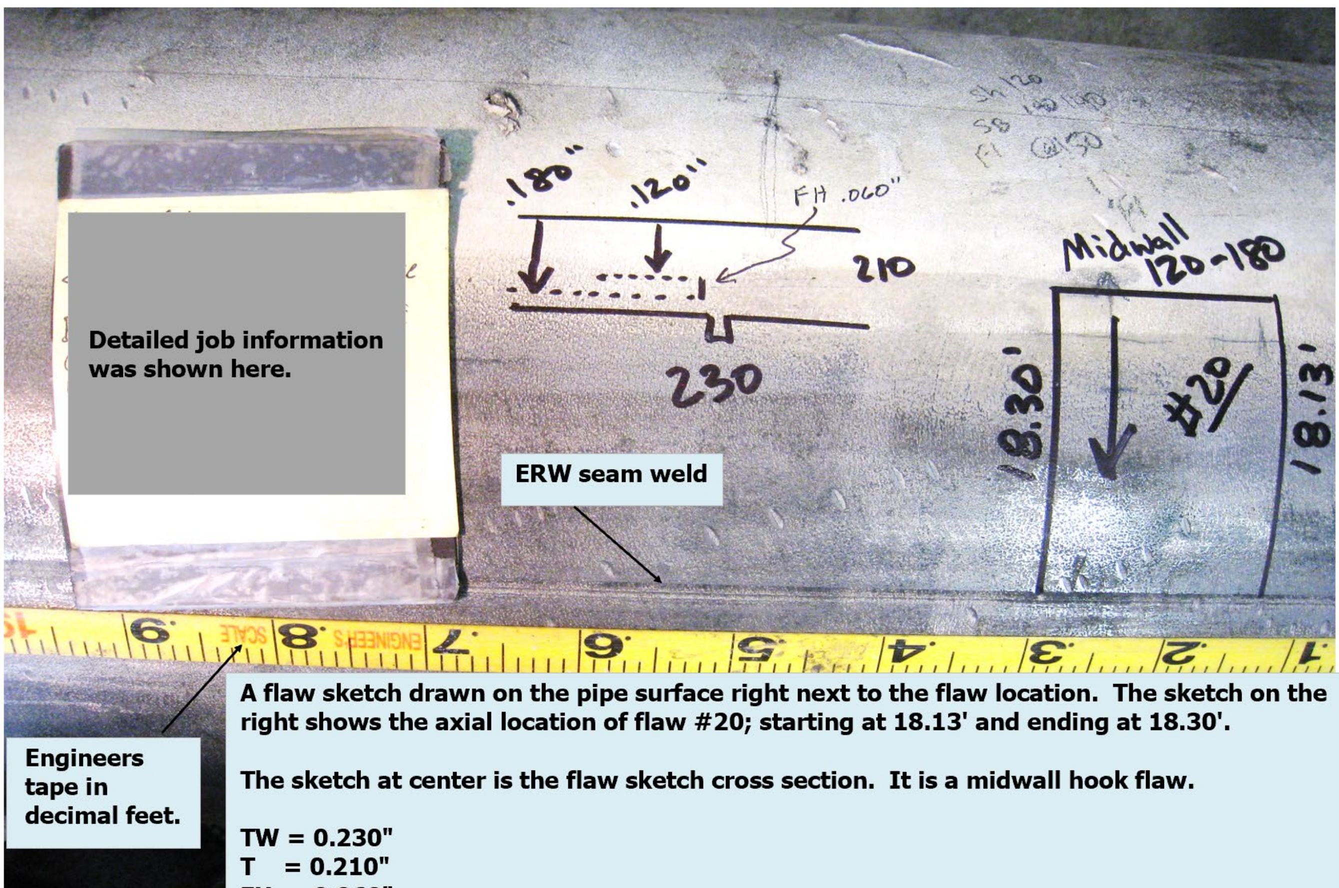


figure 62

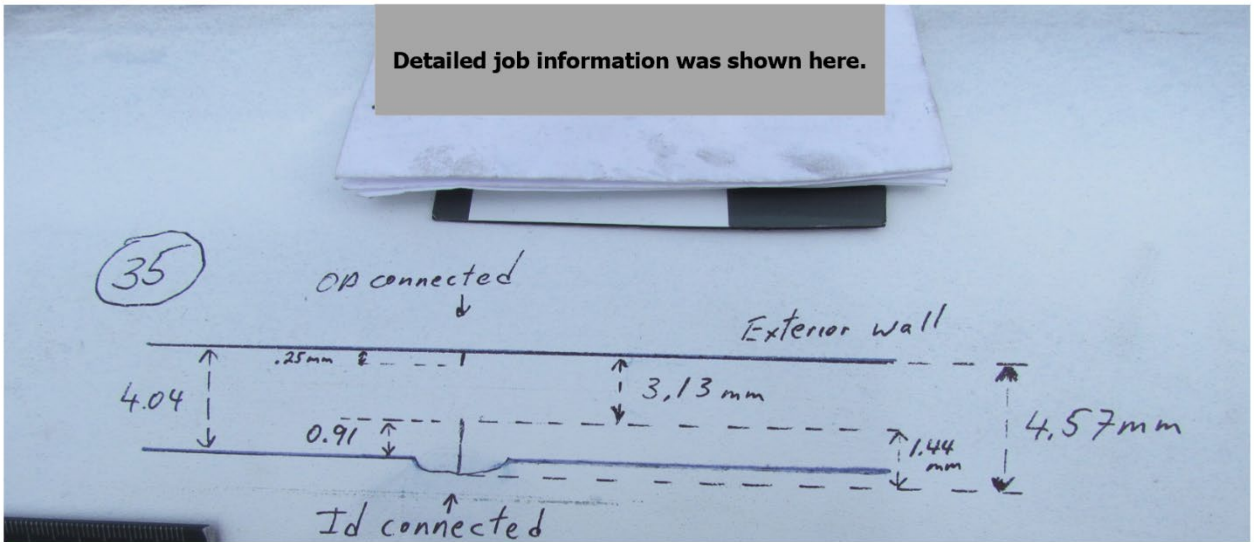


A flaw sketch drawn on the pipe surface right next to the flaw location. The sketch on the right shows the axial location of flaw #20; starting at 18.13' and ending at 18.30'.

The sketch at center is the flaw sketch cross section. It is a midwall hook flaw.

TW = 0.230"
T = 0.210"
FH = 0.060"
RL = 0.120"

figure 63

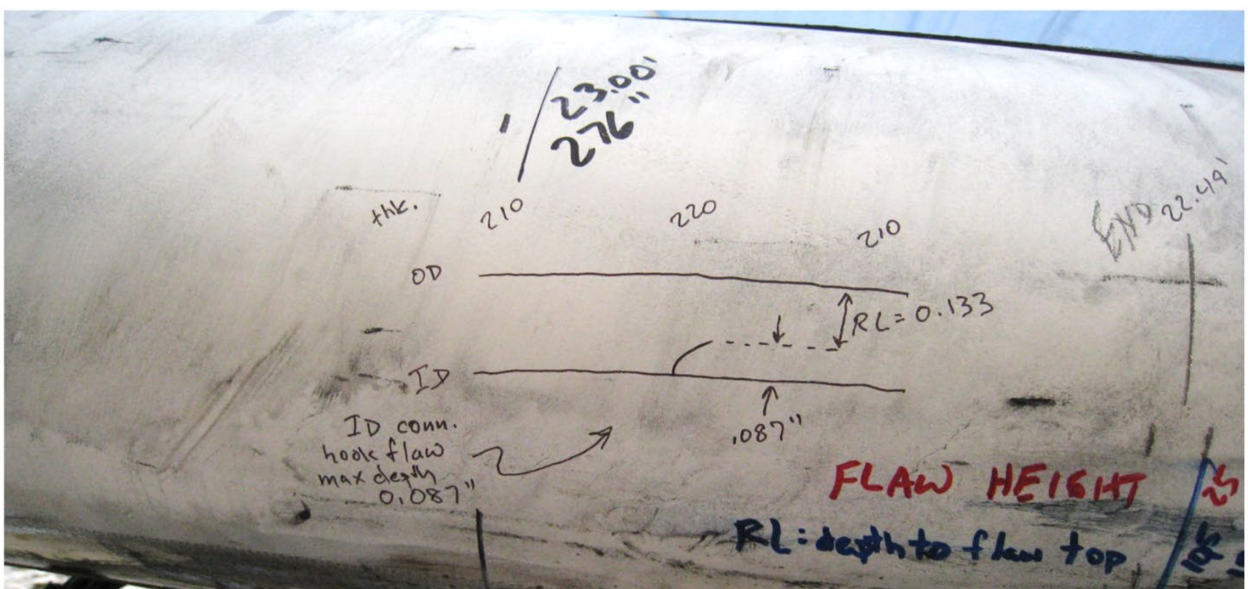


Above is a flaw sketch for an ERW seam weld drawn on the pipe next to the flaw location that had two flaws in the same spot; an OD connected hook flaw and an ID connected hook flaw. This work was done in Canada so everything is measured in millimeters (mm).

OD connected:	ID connected:
TW = 4.57mm	TW = 4.57mm
T = 4.04mm	T = 4.04mm
FH = 0.25mm	FH = 0.91mm
	TFH = 1.44mm
	RL = 3.13mm

The lengths of these flaws were both also UT sized and reported.

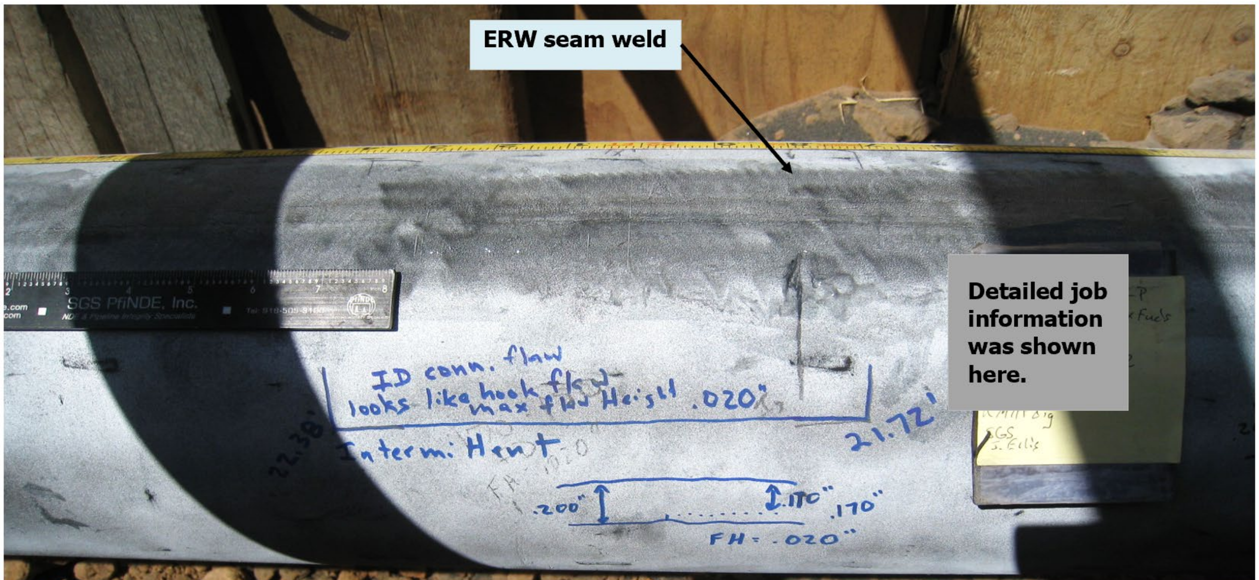
figure 64



Above is a flaw sketch for an ERW seam weld that had an ID connected hook flaw. The flaw sketch was drawn on the pipe next to the flaw location.

TW = 0.220"
T = 0.210"
FH = 0.087"
RL = 0.133"

figure 65

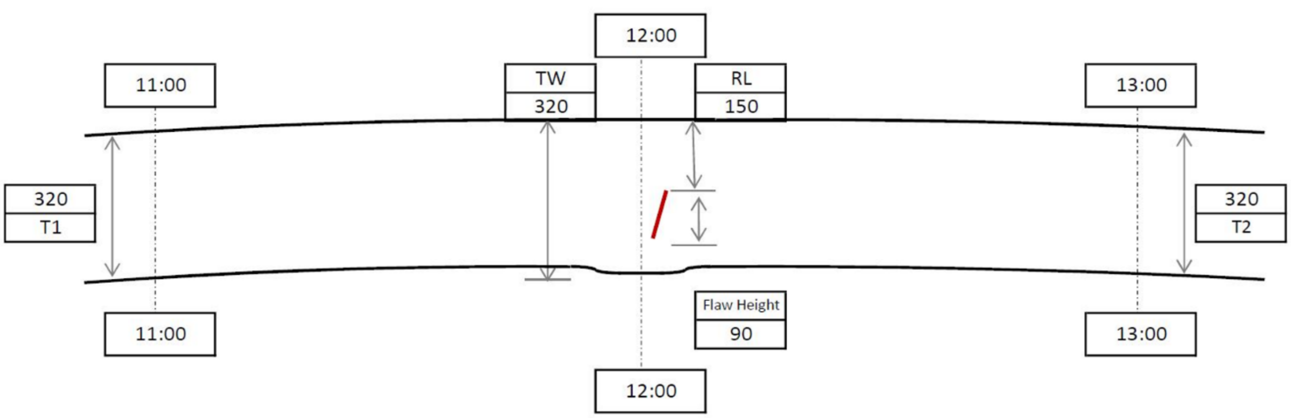


Above is a flaw sketch for an ERW seam weld that had an ID connected hook flaw. The flaw sketch was drawn on the pipe next to the flaw location.

TW = 0.190"
T = 0.200"
FH = 0.020"
RL = 0.170"

flaw start = 21.72'
flaw end = 22.38'

figure 66



Flaw sketch for an ERW seam flaw drawn with excel drawing tools. Measures shown in mils in this example.

figure 67

Seamless pipe

Some steel pipe is seamless. It is fabricated without longitudinal seam welds. These pipe often:

- Have numerous shallow irregular linear MT indications from laps.
- Have MT indications with a spiral orientation, with all the indications spiraling in similar directions. See figures 68-70.
- Have inconsistent wall thicknesses that often have a very thin clock position and a very thick clock position, sometimes found 180° away from the thin clock position.
- Have wall thickness that can vary as much as plus or minus 0.060" from nominal.

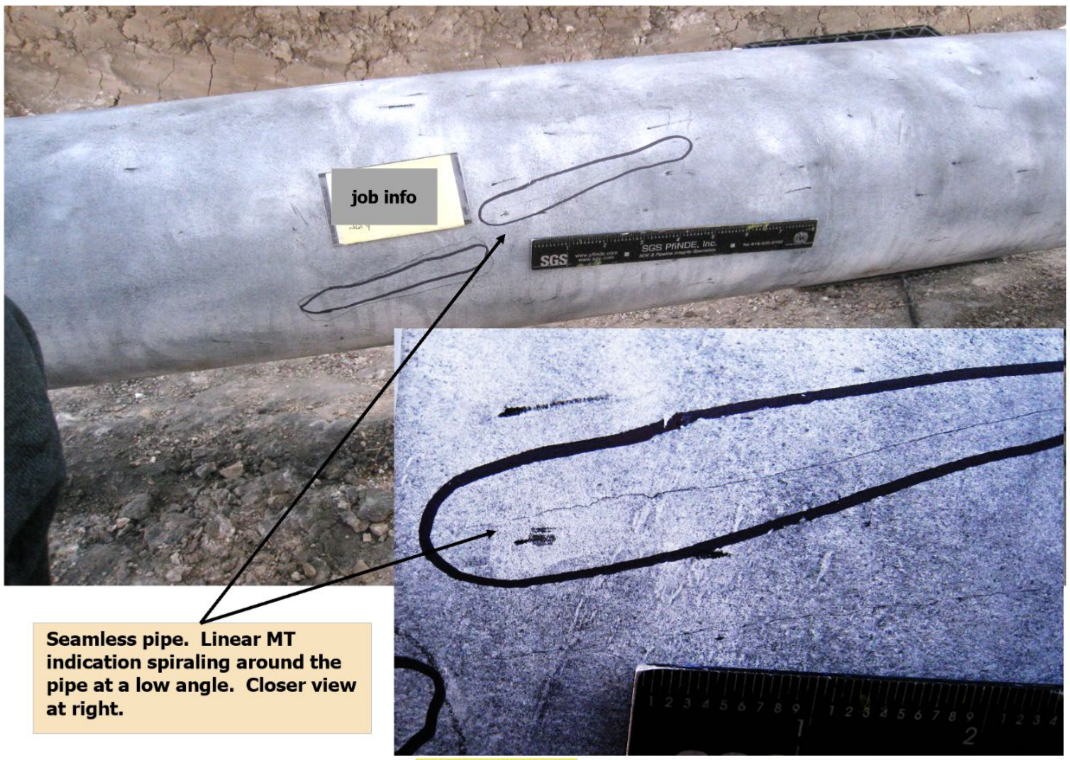


figure 68

Seamless pipe. Linear MT indications spiraling around the pipe at a high angle and in an axial orientation. See closer view figure 70.

figure 69

Seamless pipe. Linear MT indications spiraling around the pipe at a high angle and others parrallel with the pipe axis.

figure 70

Section 6

How to UT a level 2 qualification test coupon

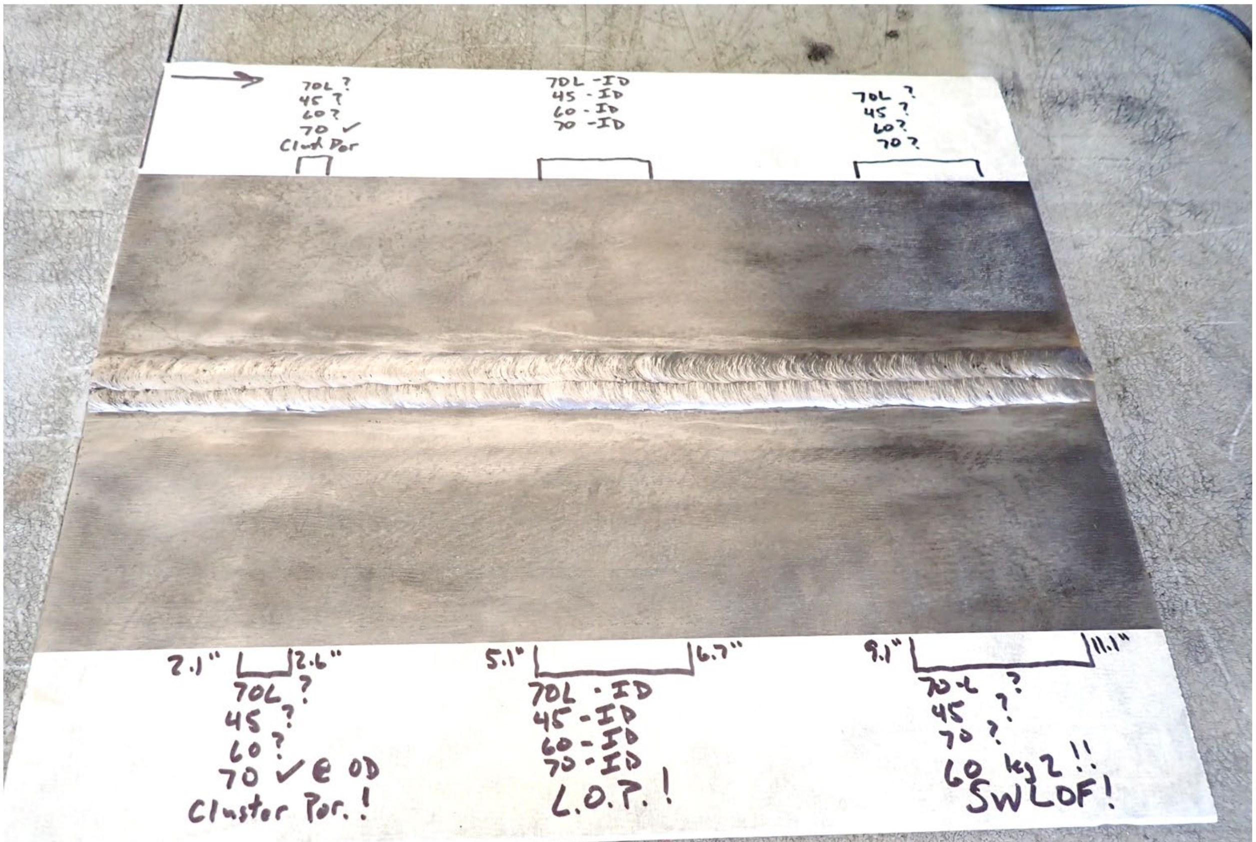
Thumbnail summary:

1. Masking tape notes
2. Thickness & Contour (T&C)
3. Initial detection scans, with 70° shear or FAST-UT.
4. Look at each detection with 45°, 60°, 70° and FAST-UT
5. Plot
6. Interpret
7. Report
8. Cautions

Here is a summary of steps for a half inch thick single Vee groove plate weld. Assume the groove bevels are 30° each.

Masking tape notes

- Lay out masking tapes along the upper and lower edges of the coupon for taking notes as you UT the coupon with different probes. See figure 71.



Before starting to do your UT of your level 2 qualification test coupon, put some nice wide strips of masking tapes along the top and bottom edges of the coupon for taking notes on. It is hard to remember everything without some notes.

figure 71

Thickness & Contour (T&C)

- Take UT thickness of both sides of the base metal (and along weld centerline if possible) to establish the thickness you are working with.
- Take a surface profile across the weld with a contour gauge and create a T&C (thickness & contour) for indication plotting. See the front cover of this book and the YouTubes of the coupon flaws.
- Most procedures require "lam scans" to look for laminations in the adjacent base metal that could interfere with angle beam exams. Plate made today for pressure vessel applications seldom has laminations.

Perform initial detection scans.

FAST-UT

- If you have a high angle L-wave probe like FAST-Model 1 or a Q-Scan-1, use it for the initial detection scans. As with all your angle beam probes, set your gain by bringing the side drilled hole closest in depth to the material thickness to 50%FSH. The material being half inch thick, the closest hole would be the 0.400” deep SDH.

70° shear

- If you don’t have a high angle L-wave probe, use the 70° to perform your initial detection scans.

Establish scan lines.

- For FAST-UT do a scan as close to the weld toe as possible and at a half skip back. For inches, the index point at half skip should be at T*2.75 from the weld root center. For metric, at soundpath *sin70.
- For 70° shear do the same as above for FAST-UT plus at twice T*2.75; a full skip, for inches. For metric, at soundpath * 2 * sin70
- For FAST-UT and 70° do additional insurance scans at setback distances between those described above.

Scan

- Perform side-to-side scans at the setback distances described above. Use a mag tape to help keep the scans straight.
- Make notes on the masking tapes showing positions where the screen shows something different happening.
- For 70°, differences are likely due to individual reflectors appearing.
- For FAST-UT it could be individual reflectors or very dramatic changes in the numbers of reflectors because of interactions with the many modes and combinations of modes.
- These are your detections. They may be seen from only one side, but often something can be seen from both sides, especially with FAST-UT. For toe cracks at the OD the “up-close” scan might only show a low amplitude signal close to zero on your screen (all the way to the left of the screen).

Look at each detection with 45°, 60°, 70° and FAST-UT.

Once you re-acquire the indication the predominant motion should be a back-and-forth (rastering) motion with each probe. Skewing is also important. Be sure you have acquired the indication and not something present in the whole joint by scanning (side-to-side). This should result in losing the indication when you go off of it side-to-side. If you can continue the indication for the whole length of the joint, it is probably from the convex root surface or the OD weld cap. Go back and try to re-acquire the indication. Once you are sure you are on the indication, raster (back-and-forth) and skew, and answer the following questions:

- Is it ID, OD, or midwall? (Very important!)
- How loud is it?
- Does it have a fast or slow rise and fall time. (If slow, could be slag.)
- Does it have a long walk? Longer than usual for the given angle? (For example, an extremely long walk with the 60° in leg 2 is probably SWLOF)

- Is it a single reflector or a group of several reflectors closely spaced in time? (Could be cluster porosity.)
- Take notes on your masking tapes.

Plot, interpret, report.

Plot the indication on your T&C. This is demonstrated for each of the flaw types listed below. The indication plot is the flaw sketch.

Interpretation

In some situations, determining if a flaw is ID, OD, or midwall is called characterizing.

In some other situations, determining the nature of the flaw is called characterizing. Here, we are calling it "interpretation".

Coupons fabricated for UT qualification tests that are 12" long commonly have three flaws in them, but there could be more or less than three. Very rarely a candidate is presented a coupon with no flaws in it, but beware of that. The following are the types of flaws that are usually found:

- Side wall lack of fusion-SWLOF, midwall
- Toe crack, OD
- HAZ crack, ID
- Root crack, ID
- Cluster Porosity, midwall
- Slag, midwall
- Lack of penetration-LOP, ID

Side Wall Lack of Fusion (SWLOF). See figure 72 and 73.

- Side wall lack of fusion has a perfectly flat, planar, unfused area on the bevel.
- It is midwall, not ID or OD connected.
- SWLOF is usually the easiest flaw to identify because with a 60° from the flawed side there is an extremely loud signal near midwall in the second leg that walks a long, long way. In fact, the walk is so long that it walks like a 70°.
- From the unflawed side there may be a low amplitude signal that plots midwall with one or more angles and looks like slag with a slow rise and fall time.
- See YouTube- Ultrasonic 60-degree angle beam of SWLOF-side wall lack of fusion

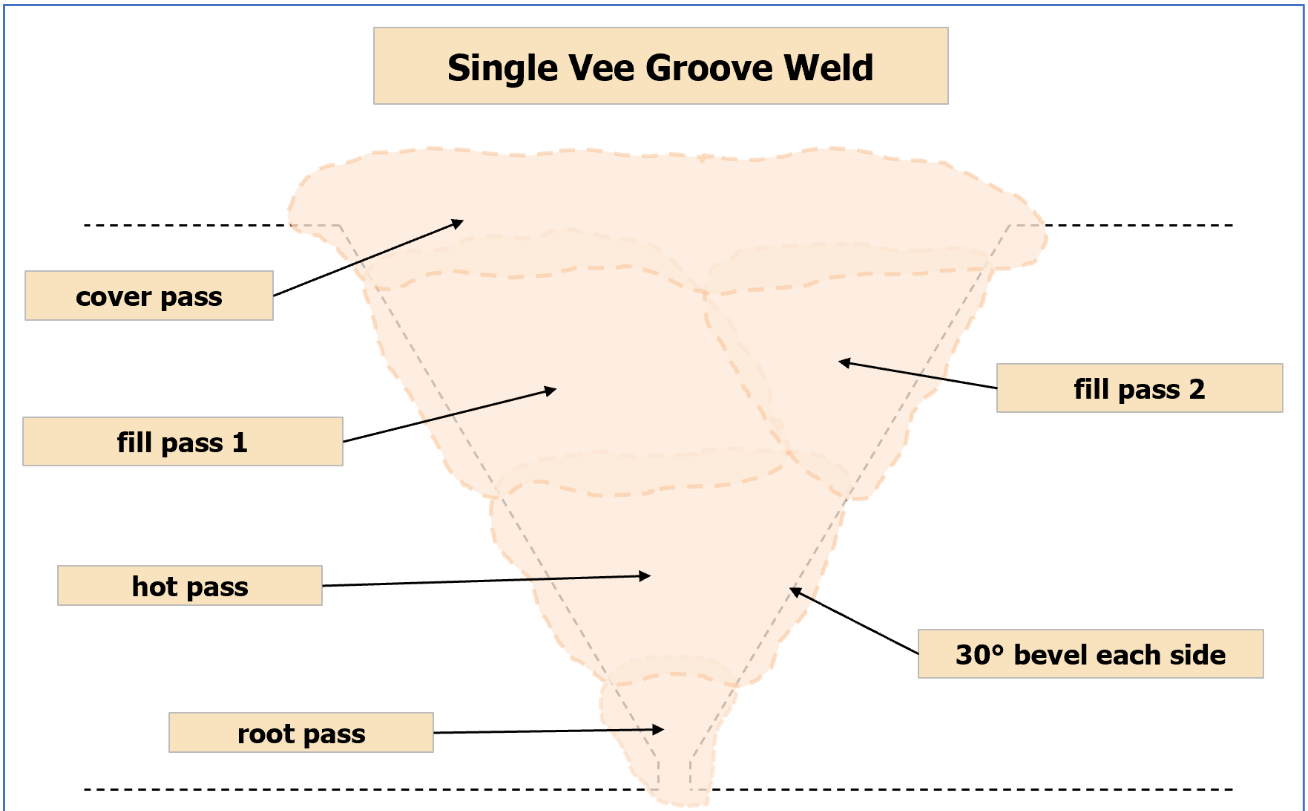


figure 72

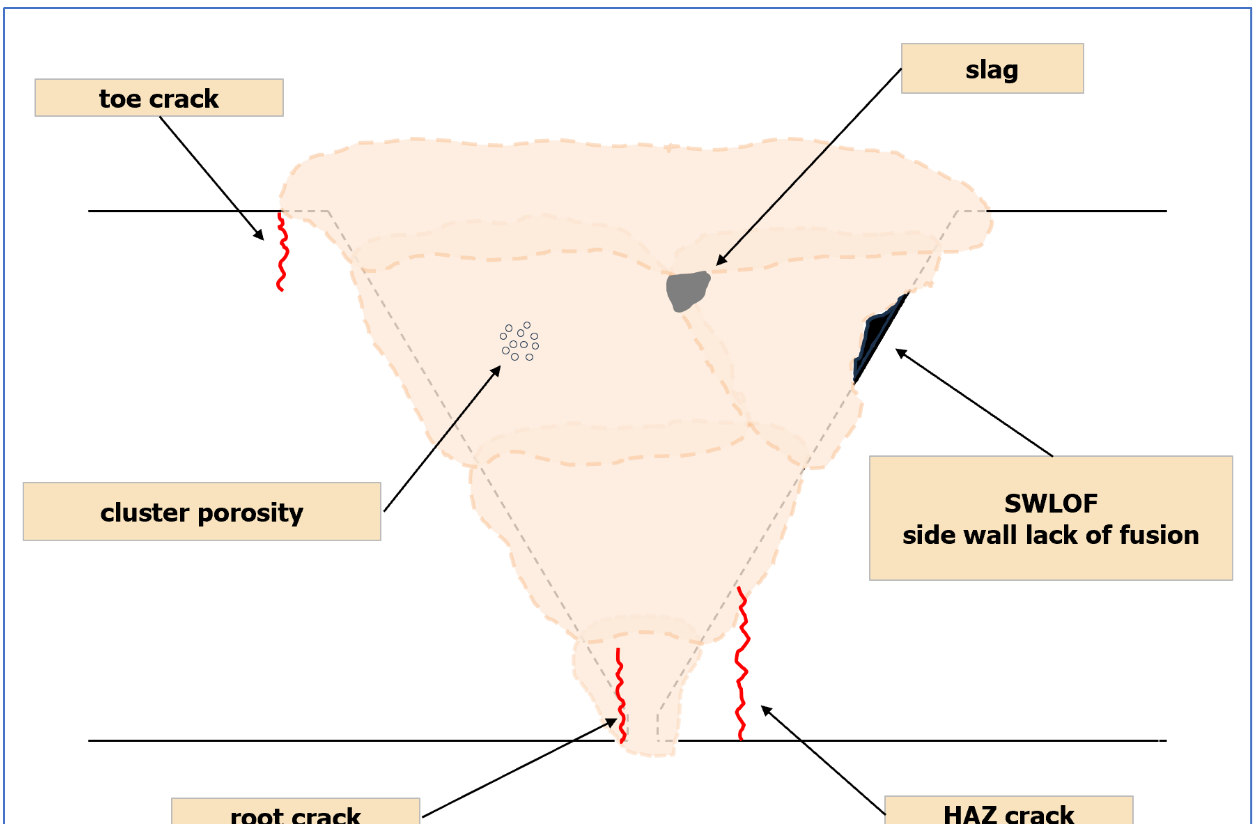


figure 73

Toe crack at OD

- There is a loud corner trap signal at the OD found from the flawed side. It is usually difficult to see from the unflawed side.
- Plots to the weld toe.
- Fast rise and fall time.
- The corner trap signal is always found with 45°, and often with 60° from the flawed side.
- 70° in leg one depends on how close the index point is to the flaw. It might not be close enough and the sound in leg one may go under the flaw and not detect it if the flaw is relatively shallow. 70° at the end of leg two is possible.
- A FAST-UT scan "butt-up" to the weld toe will almost always have a low amplitude L-wave detection near the start of the A-scan. This is a key tip-off to a toe crack.
- See the figure on the front cover of the book and figure 73.
- See YouTube- Ultrasonic angle beam detection of OD weld toe crack .

HAZ crack (ID)

- There is a loud corner trap signal at the ID found from the flawed side. It is usually difficult to see from the unflawed side.
- Plots to the HAZ (heat affected zone) within about ¼" of the root edge.
- Fast rise and fall time.
- Corner trap signal always found with 60° near the end of leg one.
- Corner trap can be found be found with the 45° but you can't usually peak up on it because the wedge bumps into the weld cap before it can be peaked up at the end of leg one. This can usually be overcome by attempting to peak up on the corner trap at the end of leg three. (You might need to increase your screen range if it is not long enough to show three legs. A good way to do this is by turning your one-inch-deep screen into a two-inch-deep screen. Just double the range.)
- 70° usually also good for detection from the flawed side, and also possibly from the unflawed side in leg one.
- See figure 73 and see YouTube- Ultrasonic angle beam of HAZ (ID) cracks .

Root crack (ID)

- Same as HAZ crack (ID) but from the flawed side will plot to weld root edge.
- See figure 73 and see YouTube- Ultrasonic angle beam of a root crack

Cluster porosity

- Midwall.
- Low amplitude, slow rise and fall time.
- Has a number of indications close together in time.
- The search unit can be orbited around the flaw and the number and spacing of indications can change but the distance to the group can be held near the same position in time while orbiting.
- See figure 73 and see YouTube- Ultrasonic angle beam of cluster porosity .

Slag

- Rounded, odd shaped glass-like material trapped between weld passes.
- Midwall.
- Low amplitude, slow rise and fall time.
- Can usually be detected with more than one angle, but detection with different angles depends on where it is.
- See figure 73 and see YouTube- Ultrasonic angle beam of slag .

Lack of penetration (LOP)

- Failure to melt and then fuse to the base metal root preparation edge, at the ID, at both sides of the root of single Vee grooves.
- Looks the same from both sides with each angle that can detect it.
- For single Vee groove welds there is a loud ID corner trap with a fast rise and fall time.
- If the scan line is straight and parallel to the weld centerline, the signal does not move at all left or right along the base line.
- There could be a loud "tip" signal for flaw height sizing, where the sound climbs over the top of the L.O.P.
- Plots to just short of centerline from each side data is taken from.
- See figure 74 and see YouTube- Ultrasonic angle beam of LOP (lack of penetration)

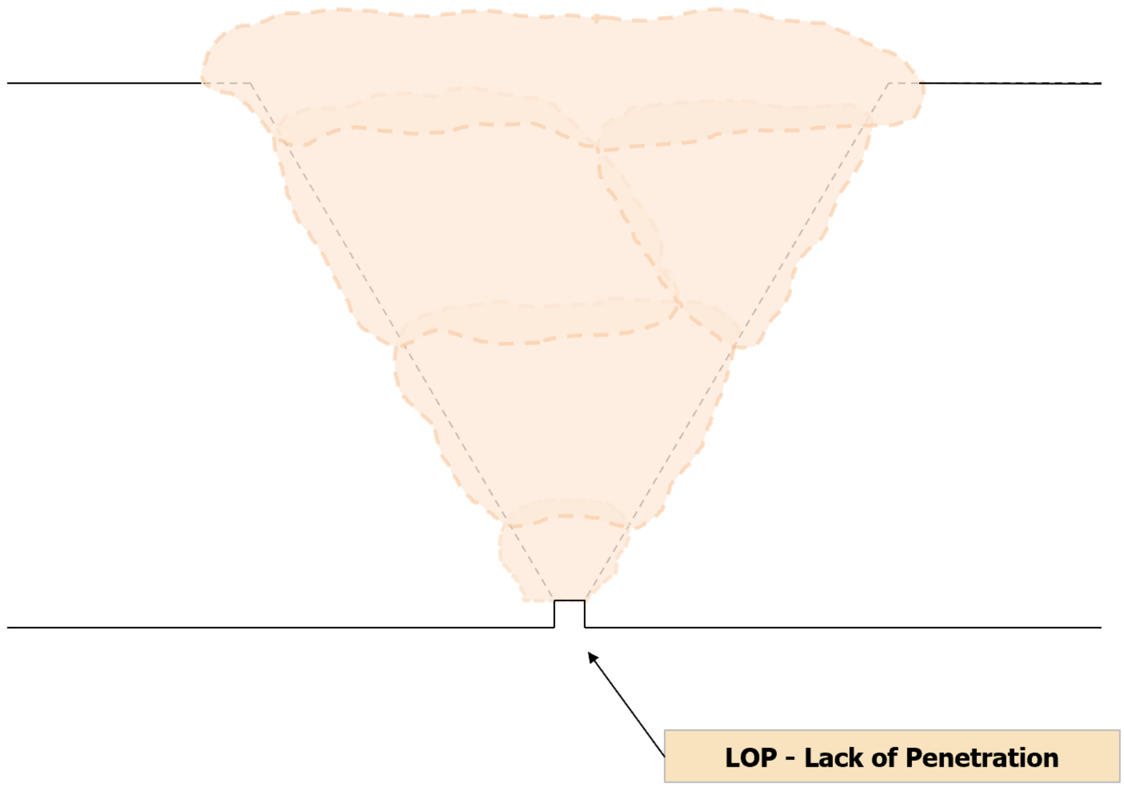


figure 74

Report

Use your notes for each flaw to make your report. State the following:

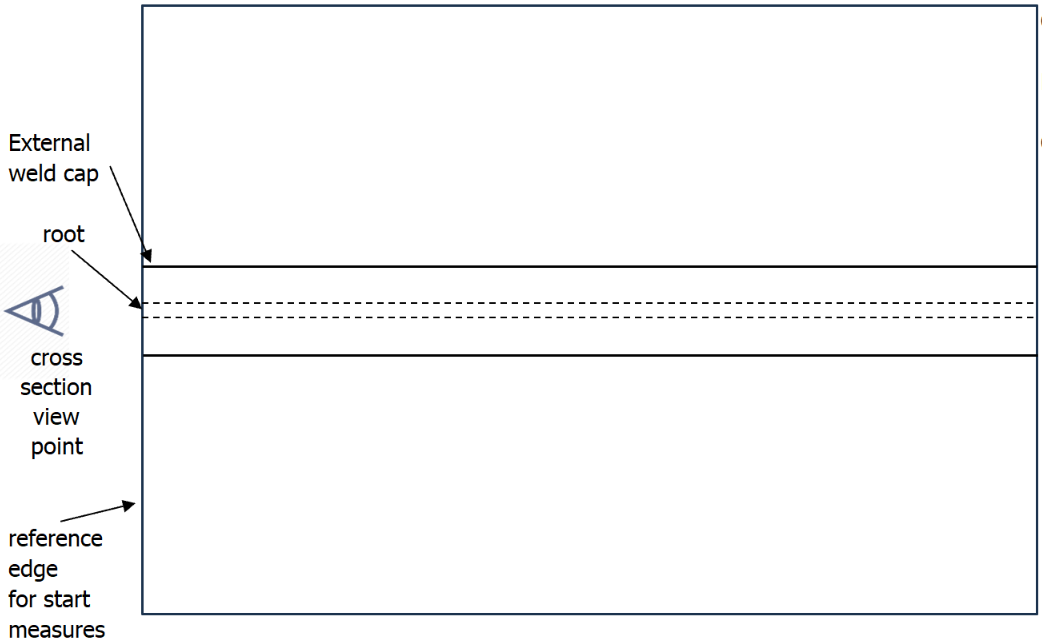
- Type of flaw; crack, LOP, SWLOF, etc…
- Start and stop, or start and length. See section "Flaw Length Sizing".
- State if it is ID or OD connected or midwall
- Flaw height size, if possible.
- Include a plan view for location and a flaw sketch for cross section view. See figures 63-67 for examples from field work. For an example of a report form you might use for a UT level 2 qualification test, the form might look something like figure 75. For an example of how this form might look from the exam notes of figure 71, see figure 76.

Plan View

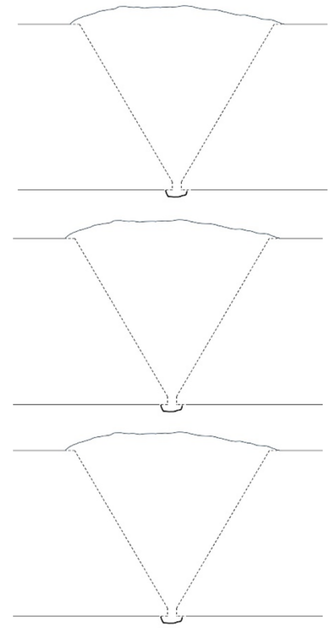
Examiner: ______________________

Coupon Ident: ______________________

Date: ______________________



Cross-Sectional Flaw Sketches



indication #	start	length	ID/OD/midwall	flaw height	flaw type

figure 75

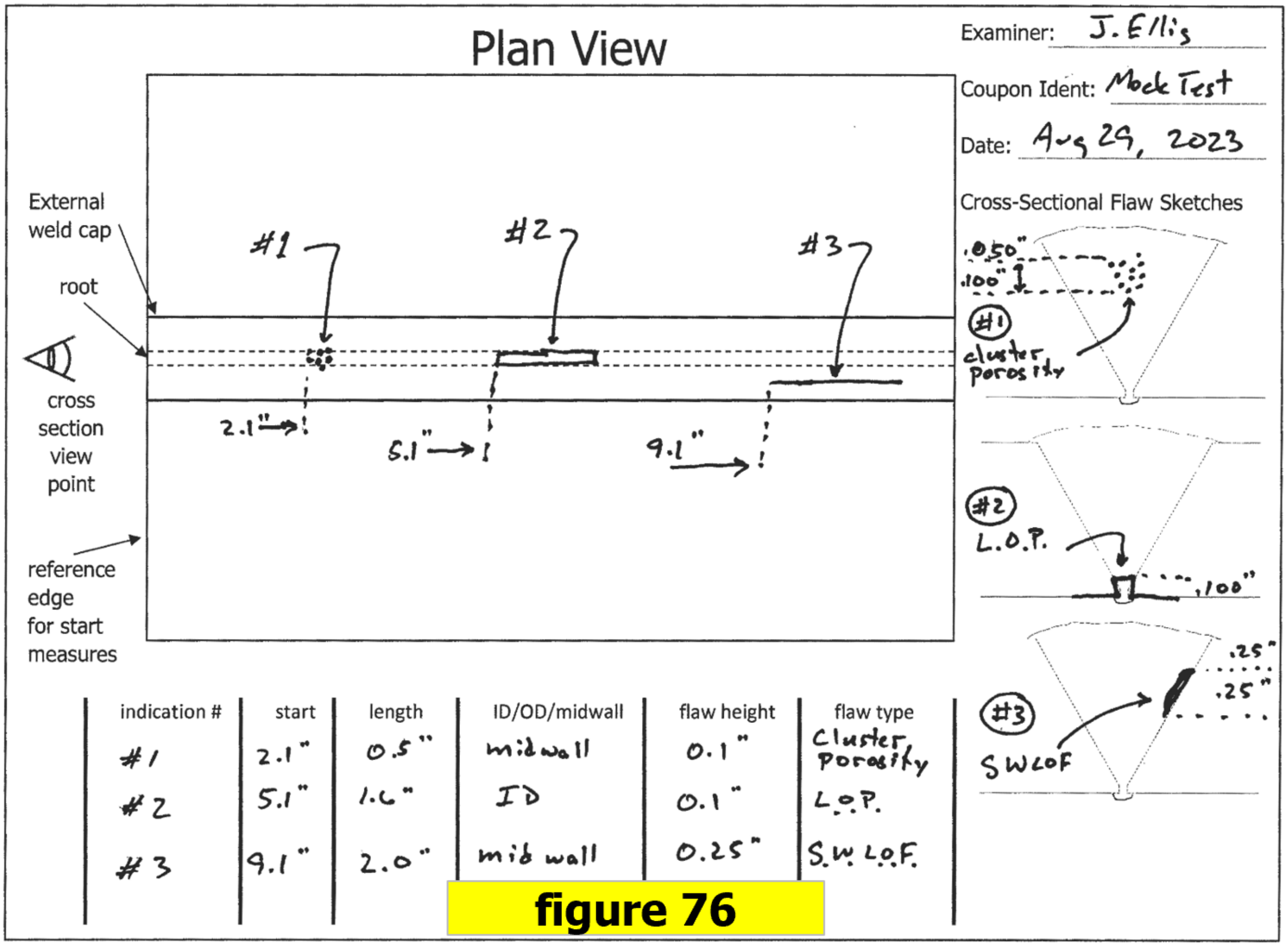


figure 76

Cautions

- Once you have your detections from your initial scans look at each flaw one at a time. This requires switching from angle to angle (and FAST-UT) for each flaw. Resist the temptation to look at all flaws with 45°, then all with 60°, etc. The notes are good, essential in fact. But if you look at all flaws with one angle it is hard to remember all the subtle things you can see and remember which flaw it goes with. Better to stay with one flaw until you have completed it. If you look at a flaw with all your search units and you are still not sure, do them again and eventually you'll find that there will be good notes to get you to the final answer you need.
- When you change probes re-set yourself with the "mantra":
  - Recall the cal
  - Check the cal
  - Set the gain (and ref dB) and…
  - Go
- When you go to re-acquire each detection with each angle, remember to guarantee yourself that you are on the flaw by scanning a bit left and right to prove that you have gone off the flaw. If you maintain the signal beyond the detection length you have probably acquired root convexity or the OD weld cap and not the flaw.

Good luck with your first attempt at passing a level 2, angle beam, UT qualification test! 😊 This is a difficult milestone to achieve. Don't be discouraged if you don't pass the first time you try. Everyone struggles to wrap their mind around what they are seeing with angle beam on the flaw detector screen. Understanding what is on the screen has a high level of difficulty and the hand-to-screen coordination takes practice (repetition) to develop.

Achieving angle beam level 2 is a very valuable skill.

Section 7 Home-made blocks and universal indication plotting tool

Home-made cal blocks.

You should start off with at least a "store bought" quality step wedge. Hopefully you are working with a company that can supply you with all your cal blocks including the FAST block (see figure 3) and the notch block (see figure 4). If you are on your own it may be too expensive for an individual to buy these blocks. But you could make some at home. They won't be as good as cal blocks made in machine shops using EDM (electric discharge machining) but with a little practice you could make them good enough to practice developing your UT skills. To make the FAST block and notch block you would need the following with their approximate cost as shown.

WEN drill press	$110.00
12 quality drill bits, 1/16" diameter, see example figure 77	$30.00
General No. 78 Automatic Center Punch, see figure 77	$30.00
Hack saw with 12" long, 24 teeth per inch, metal cutting blade	$20.00
Ten pieces ½" hot rolled square steel bar, 12" long each,	
from www.MetalSupermarkets.com	$40.00
Have a local machine shop mill down five pieces of the bar to 0.5" x 0.3"	$150.00
Total	$380.00

Once you have your materials you can make your own FAST and notch blocks. To get a good result you will need to practice. This is why I recommend having five pieces of steel to work with for each type of block. It is not easy to make a clean hack saw cut and hold it to a depth dimension. You can check your notch depth dimensions with your straight beam UT! Likewise, a 1/16" diameter drill is very easy to break and it takes practice to get 4 good holes drilled on center. See YouTube- Home-made ultrasonic cal blocks .

Home-made universal indication plotting tool

To make your own indication plotting tool that is universally adaptable to any weld size or type see the YouTube- Home-made ultrasonic universal indication plotting tool . For a look at the universal indication plotting tool in action review the YouTubes for the flaws found in Section 5, "How to UT a level 2 qualification test coupon". These can also be printed from "universal plotting tool.zip" that can be downloaded from the website, but be careful that you do not use a transparency that will foul your printer!!


Qty 12
List # 600C 1/16
Cobalt
Screw Machine
Drill
135 Split Point
28012 18092 2 M
TWIST DRILLS
HIGH SPEED STEEL
MADE IN THE U.S.A
These are drills that worked for me, drilling thru steel up to 0.625" (1.59mm) thick. They are 1.62" (41.28mm) long.
MICHIGAN DRILL
TROY, MICHIGAN
MIAMI, FLORIDA
Center punch tool that helps get each drilled hole started in the right perpendicular direction.

figure 77

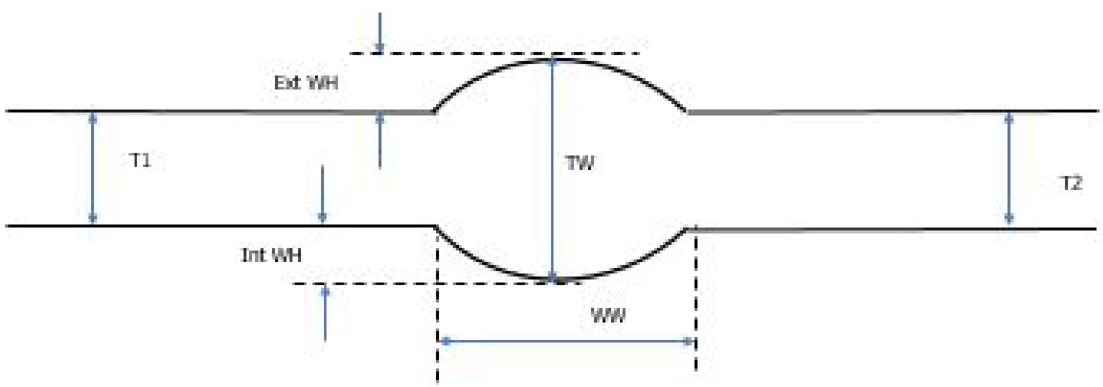
i

Section 8 Terms, Definitions Acronyms

Terms, Definitions, Acronyms

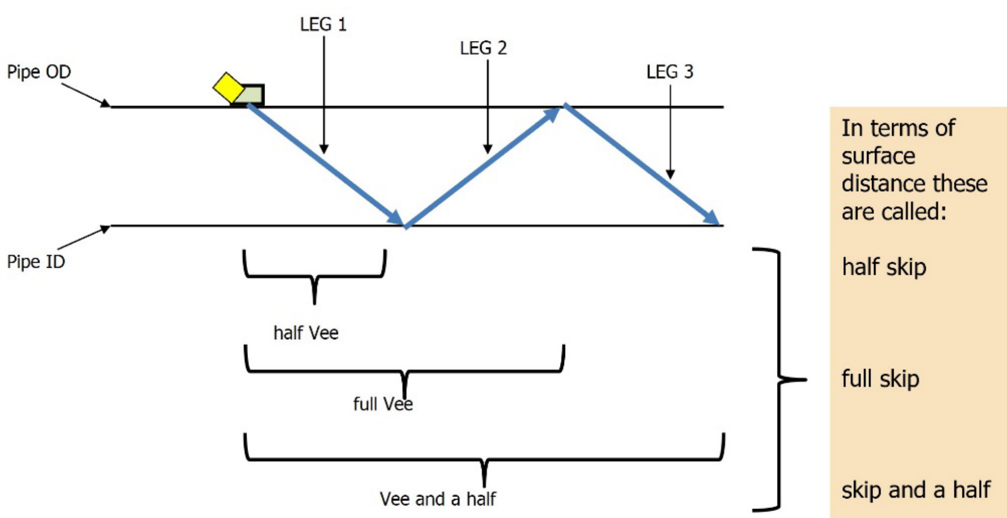
Not in alphabetical order. Related terms are grouped together.

Anomaly	An ILI indication of a flaw
ILI	In Line Inspection tool
Indication	A response from the NDE test
Flaw	A discontinuity or interruption in the homogeneity of a material
Defect	A flaw that is unacceptable; reject.
Geometry	An indication that is caused by the shape of the part, such as an inside corner of a flash weld, a convex root surface, or the external weld reinforcement at a weld cap
Detection	The action or process of discovering the presence of a flaw
Characterization	Describing a flaw by position or by nature: • Position: ID, OD, or Midwall • Nature: SWLOF, hook flaw, crack, etc.
Sizing	Determining the measures of a flaw; length, height, location, orientation



T1	The thickness of the pipe body base metal on the counterclockwise side of the seam weld, when the pipe is viewed in the direction of flow.
T2	The thickness of the pipe body base metal on the clockwise side of the seam weld, when the pipe is viewed in the direction of flow.
TW	Weld thickness
WW	Weld Width (normally the weld width as it appears visually), knowing that ERW seam welds, for example, have a bond line that is actually only about 1/32 inch (0.8mm) wide.

WH	Weld crown (or cap) height. Also known as ExtWH (external weld height). When the ID is visible or measurable there can also be Internal Weld Height or IntWH. If T1, T2, ExtWH and TW are known, the IntWH can be calculated.
RL	Remaining Ligament. This is the through-wall thickness of pipe wall that is not involved with ID, OD, or midwall flaws.
ID	Literally; Inside Diameter, is the inside surface.
OD	Literally; Outside Diameter, is the outside surface.
ID connected	A flaw that extends in the through-thickness direction and is connected to the inside surface
OD connected	A flaw that extends in the through-thickness direction and is connected to the outside surface.
ID roll signal	If enough gain is added during a 45° angle beam exam, the grain boundaries at the inside surface of the part will generate a series of signals close in time whose peaks fit noisily into a bell curve centered near the end of leg 1
OD roll signal	If enough gain is added during a 45° angle beam exam, the grain boundaries at the outside surface of the part will generate a series of signals close in time whose peaks fit noisily into a bell curve centered near the end of leg 2
FH	Flaw height. Through-wall extent of a flaw.
T-nom	Nominal wall thickness. This is usually the specified thickness, not the measured thickness.



Leg 1	Angle beam sound travel from the search unit to the pipe ID
Leg 2	Angle beam sound travel bounced from the ID and traveling towards the OD
Leg 3	Angle beam sound travel bounced from the OD and traveling to the ID.
Half Vee	First leg of sound travel

Full Vee	First two legs of sound travel
Vee-and-a-half	First three legs of sound travel
Half Skip	Surface distance traveled by sound in leg 1
Full Skip	Surface distance traveled by sound in legs 1 and 2
Skip-and-a-half	Surface distance traveled by sound in legs 1, 2, and 3

ERW	Electric Resistance Weld. A type of pipe longitudinal seam weld. See figure 45.
Flash Weld	Another type of longitudinal seam weld. The entire seam is forced together at the same time with an extremely high amperage (as much as a million amps), arcing (flashing) the entire joint at once. Uniquely made by a single fabricator, the A.O. Smith company, from 1930 to 1969. See figure 44.
DSAW	Double Sub Arc Welding. A common type of longitudinal seam weld. This process is often used today for large diameter pipe with the seam weld in a spiraling orientation. See figures 42-43.
Hook flaw	An ERW or Flash weld seam flaw that originates from mill defects in the plate the pipe was made from. These mill defects, such as laminations or stringers get turned into curved shapes along flow lines where material has been squeezed by plastic flow. See figures 47, and 50-58.
Hook crack	A hook flaw that is cracking open. It is often difficult to ultrasonically distinguish a Hook Flaw from a Hook Crack.
Upturned Fibers	API Bulletin 5T1 2017 seems to define hook cracks and upturned fibers as equivalents; “Metal separations – resulting from imperfections at the edge of the plate or skelp – parallel to the surface which turn towards the ID or OD pipe surface when the edges are upset during welding”.
LOF	Lack of Fusion
SWLOF	Side Wall Lack of Fusion
Mill defect	A flaw in the plate or pipe material from the original manufacturing process. Longitudinally seam welded pipe can have plate rolling type mill defects from the plate the pipe was made from.

	The following 3 terms, inclusion, stringer and lamination are often confusingly used interchangeably. The definition of each should be agreed upon beforehand.
Inclusion	Foreign material within a wrought product.
Stringer	Foreign material within a wrought product form, that has been stretched to have appreciable length in the direction of work, but small or no measurable width. If open to an outside surface it would be called a ‘seam’, not to be confused with the longitudinal seam weld of a seamed pipe.

Lamination	Foreign material in a wrought, plate rolling process, having both measurable length and measurable width and is wholly parallel to the inside and outside surface.

Scanning	Side-to-side search unit movement. Nowadays, this is how detection is normally done.
Rastering	Back-and-forth search unit movement.
Oscillating	A Skewing-swiveling, rotational movement of the search unit from a specific probe position, although it can be combined with rastering and scanning.
Orbiting	A search unit motion that maintains the same distance to a reflector as the search unit is angled towards the flaw from different angles, as it continues to point straight at the reflector. This is often useful for identifying individual porosity or cluster porosity.
Rocking	When performing a UT of a (round) pipe, if the contact surface of the search unit is flat, it can "rock" back and forth without changing position on the pipe. This can have a big effect on the amount of sound received by the search unit. These are the five possible ranges of motion a probe is subject to: scanning, rastering, skewing-oscillating, orbiting, and rocking. This is why it is difficult to "peak up" on a flaw.

%FSH	Percent Full Screen Height; a measure of ultrasonic loudness or amplitude
SDH	Side Drilled Hole. A common type of calibration reflector.
Amplitude Based Method	Some industry sectors employ ultrasonic inspection acceptance standards that are based on the amplitude (loudness in dB) of sound received from reflectors. If the amplitude is too loud, it is a reject. The UT described in this training material is not amplitude based. The objective here is to find; where reflectors are located, what the dimensions of the reflectors are, and what is the orientation, shape, and nature of the reflectors.
DAC	Distance Amplitude Curve. Indications from the same size reflector at different angles or depths are made to be equal amplitude.
TCG	Time Corrected Gain. In a defined range of angles and depths all reflectors of the same physical size are made equal amplitude.

L-wave	A longitudinal wave mode of sound travel, also known as a compression wave. Sound travels through material by displacing tiny particles (molecules) of material in a direction parallel to the direction of sound travel in alternating series of compression and rarefaction. Straight beam UT is done with L-waves. FAST-UT uses high angle refracted L-waves. See figures 31-32.
Shear wave	A mode of sound travel, also known as a transverse wave, where the particle motion is transverse to the direction of wave motion and consists of particle motion in alternating directions. Most conventional angle beam UT is done with shear. Shear travels at about half the speed of L-waves in a given material. See figures 31-32.
FAST-UT	Is high angle L-wave, with the angled L-wave close to 70°. See figures 31-35.
PAUT	Phased Array UT. A beam forming method from a transducer array that times (or phases) sending and receiving sounds to form an image of the reflectors. See figure 78.
ToFD	Time of Flight tip Diffraction. A two-transducer, pitch-catch advanced ultrasonic technique. See figure 78.
PCS	Probe Center Separation. A term used in defining a ToFD setup.
FMC-TFM	Full Matrix Capture – Total Focus Method. A phased array UT method that ideally might show all depths in focus. See figure 78.
IWEX	Inverse Wave Extrapolation. A proprietary array method from Applus+ that generates 3D views of weld volumes.
PCI	Phase Coherence Imaging. A method of image forming from array transducers that is based on the frequency of sounds. Amplitude (loudness) is no factor at all. See figure 78.
90°	The sound travel direction for seam welds is called "90°" when the sound is traveling clockwise when one is looking in the direction of flow, and for a girth weld the sound is traveling upstream. Conventions can vary between companies and industry sectors.
270°	The sound travel direction for seam welds is called "270°" when the sound is traveling counterclockwise when one is looking in the direction of flow, and for a girth weld the sound is traveling downstream. Conventions can vary between companies and industry sectors.
A-scan	An ultrasonic presentation of amplitude vs. time. The A-scan can be fully rectified, RF waveform which is used in ToFD, negative half wave, or positive half wave. See figure 7.
B-scan	An ultrasonic presentation of depth vs. index axis. B-scan and D-scan are often reversed depending on author and context.
D-scan	An ultrasonic presentation of depth vs. scanning axis. B-scan and D-scan are often reversed depending on author and context.

C-scan	Usually thought of as a plan view of the part with the vertical and horizontal axes correlating with width and length of the part. In Evident-Olympus phased array sector scans, the “C-scan” is angle (vertical axis) vs. scanning (horizontal) axis.
Sector scan	A phased array ultrasonic presentation showing a range of angles, such as 45° to 70°, shown at the same time. The vertical axis is usually depth and horizontal axis is index axis in the direction the sound is traveling towards. It is usually like a pie-shaped cross section transverse through a weld. A sector can also show a range of angles plus and minus from 0° which can be thought of as being an enhanced form of straight beam UT.
Linear scan	A phased array ultrasonic presentation showing the same angle being used from a series of virtual probe positions, also known as an electronic scan or “E-scan”. This is sometimes used to find reflectors detected by an ILI 45° UT tool.

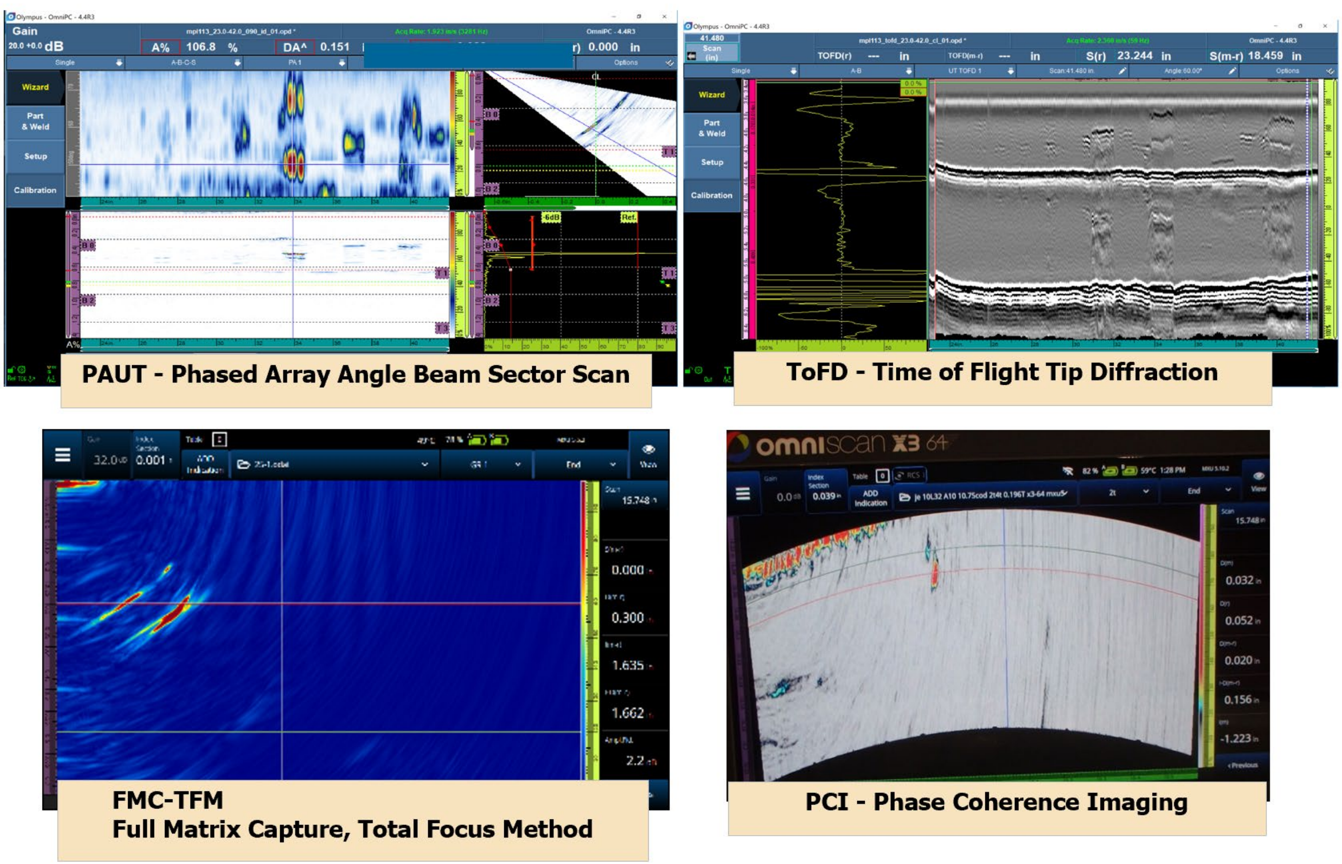


figure 78

Think of these four snips as being previews of coming attractions. They are advanced UT techniques that you may look forward to in your future career as a UT level 2 or 3.

After this training you should…

1. Recognize the difference between the 'walk' of ID corrosion and the 'walk' of laminar reflectors with your dual element straight beam. [See section "Recognizing the walk of laminations vs. internal corrosion"]
2. Be able to use the orientation of the crosstalk barrier of your dual element straight beam probe to help define ID geometry of thin-walled seam welds. [See section "Orientation of crosstalk barrier"]
3. Know that if you are working with extremely thin nominal pipe wall thicknesses you should find out about getting a 10MHz dual element straight beam probe. [See section "Extremely thin pipe"]
4. Know that if you are using very high frequency straight beam probes, such as the 15 MHz Sonopen, that weld metal can give many tiny grain noise reflectors. [See section "Very high frequency probes and welds"]
5. Know that if you are peaking up on a SDH (side drilled hole) centered at a specific depth you won't 'size' the depth of the hole there, because your angle beam reflects from the outside of the hole, not the center of the hole. [See YouTube "Ultrasonic 45-degree side drilled hole measurements"]
6. Be able to determine where a good scan line is located for a FAST-UT of any given thickness of pipe using the shortcut formula: For inches: Setback Dist. = T * 2.75
For mm: Setback dist. = Soundpath*Sin70°
[See section "Establishing scan lines"]
7. Be able to establish your own cals on a different model instrument than you have now for the 6 cals we normally use. [See section "Flaw detectors – instruments"]
8. Recognize what a good FAST-UT scan of both flawed and unflawed material looks like. [see Video FAST-UT scans of weld seams]
9. Be able to do tip diffraction flaw height measurement with a 45° and a 60° shear at a half Vee or a full Vee. [See AATT]
10. Know how to walk the 70° over the top of an extremely deep planar flaw for ID connected depth sizing. [See video "Ultrasonic 70-degree shear walking over the top of extremely deep ID connected planar flaws"]
11. Be able to do FAST-UT, ID and OD crack depth estimates on welds ground flush or as welded. [See section "OD weld crown obstruction"]
12. Know that OD cracks less than 0.075" deep all peak up at the same place on your 1" deep screen with the FAST OD depth sizing technique. For metric, 1.91mm deep on your 20mm deep screen. [See "OD sizing with FAST"]
13. Know how to back up your cals using the instrument's SD card and be able to download a fresh set of cals from your laptop and install them. See section "Saving your calibration setup files"
14. Know how to construct a weld flaw sketch for describing ID, OD, or midwall defects for any type of weld. [See "Flaw sketches"]
15. Know how to use both the 45° and 60° together to decide if a planar flaw is midwall or ID connected. [See "Determining ID connection with shear"]
16. Know that generally speaking we don't do flaw height sizing by amplitude because too many factors affect flaw reflectivity like orientation, shape and texture. However, for very small ID connected planar flaws we sometimes use the amplitude of the 0.010" and 0.030" deep ID notches to help with sizing of very small ID flaws. See "Flaw height sizing of very small flaws using amplitude comparison".
17. Be able to demonstrate that 6dB drop flaw height sizing does not work. [See section "6dB drop flaw height sizing does not work"]

Collected Lab Exercises in inches (use pencil, not ink)

Lab Exercise 1 - 45° SDHs (in.), see page 44

Uses: flaw height sizing of rounded midwall flaws

SDHs	0.100"	0.200"	0.300"	0.400"
Peaks at:				

Lab Exercise 2 - 45° ID notch tip sizing (in.), see page 48

Uses: flaw height sizing of ID connected planar flaws

Notch	0.010″	0.030″	0.060″	0.090″	0.120″	0.150″	0.180″	0.210″
RL* (depth to tip)	0.290″	0.270″	0.240″	0.210″	0.180″	0.150″	0.120″	0.090″
Your measure	**	**						

Lab Exercise 3 - 45° OD notch tip sizing (in.), see page 50

Uses: flaw height sizing of OD connected planar flaws

Notch	0.010″	0.030″	0.060″	0.090″	0.120″	0.150″	0.180″	0.210″
RL* (Depth to tip)	0.590″	0.570″	0.540″	0.510″	0.480″	0.450″	0.420″	0.390″
Your measure	**	**				-	-	-

Lab Exercise 4 - 60° SDHs (in.)

Uses: flaw height sizing of rounded, midwall flaws, see page 52

SDHs	0.100"	0.200"	0.300"	0.400"
Peaks at:				

Lab Exercise 5 - 60° ID notch tip sizing (in.), see **page 54**

Uses: Flaw height sizing of ID connected planar flaws

Notch	0.010″	0.030″	0.060″	0.090″	0.120″	0.150″	0.180″	0.210″
RL (Depth to tip)	0.290″	0.270″	0.240″	0.210″	0.180″	0.150″	0.120″	0.090″
Your measure	**	**						

Lab Exercise 6 - 70° SDHs PPATT cal (in.), see **page 55**

Uses: Flaw height sizing of rounded, midwall flaws

SDHs	0.100"	0.200"	0.300"	0.400"
Peaks at:				

Lab Exercise 7 - 70°, deep ID connected notch flaw height sizing with peaking cal (in.), see **page 56**

Uses: Flaw height sizing of VERY deep, planar, perpendicular, ID connected flaws

Notch	0.010″	0.030″	0.060″	0.090″	0.120″	0.150″	0.180″	0.210″
RL (Depth to tip)	0.290″	0.270″	0.240″	0.210″	0.180″	0.150″	0.120″	0.090″
Your measure	**	**	**	**				

Lab Exercise 8 – FAST-UT, PPATT, SDHs, peaking up (in.), see **page 69**

Uses: Flaw height sizing of rounded, midwall flaws

SDHs	0.100"	0.200"	0.300"	0.400"
Peaks at:				

Lab Exercise 9 – FAST-UT, PPATT, OD notch sizing (in.), see page 70

Uses: Flaw height sizing of perpendicular OD connected flaws

FAST OD sizing -- inches			
dB	______		
OD notch	% FSH	depth reading	
0.010" ↓			
0.030"			
0.050"			
0.060"			< 0.075"
0.090"			> 0.075"
0.100"			
0.120"			
do OD sizing from the louder side			

Lab Exercise 10 – FAST-UT, PPATT, ID notch sizing (in.), see page 74

Uses: Flaw height sizing of perpendicular ID connected flaws

FAST ID sizing -- 0.3" thk notched block			
dB	**______**		
notch depth	**remaining ligament**	**FAST-UT depth**	**%FSH**
0.010"	0.290"		
0.030"	0.270"		
0.060"	0.240"		
0.090"	0.210"		
0.120"	0.180"		
0.150"	0.150"		
0.180"	0.120"		
0.210" ↑	0.090"		

Do the ID depth sizing from the side where you walk over the top of the flaw at furthest point towards the left on the screen.
It might not be the loudest spot.

Lab Exercise 11 – FAST-UT, SDHs, PPATT (in.) [note; same as Lab Exercise 8], see page 75

Uses: Flaw height sizing of rounded, midwall, flaws

FAST embedded (midwall) flaw sizing with SDHs - 0.5" thk block				
dB	______			
SDH	0.100	0.200	0.300	0.400
depth reading				

Collected Lab Exercises in millimeters (use pencil, not ink)

Lab Exercise 1 - 45° SDHs (mm), see page 46

Uses: flaw height sizing of rounded midwall flaws

SDHs	2.5mm	5.0mm	7.5mm	10.0mm
Peaks at:				

Lab Exercise 2 - 45° ID notch tip sizing (mm), see page 49

Uses: flaw height sizing of ID connected planar flaws

Notch	0.5mm	1mm	2mm	3mm	4mm	5mm	6mm
RL* (depth to tip)	7.5mm	7mm	6mm	5mm	4mm	3mm	2mm
Your measure	**						

Lab Exercise 3 - 45° OD notch tip sizing (mm), see page 51

Uses: flaw height sizing of OD connected planar flaws

Notch	0.5mm	1mm	2mm	3mm	4mm	5mm	6mm
RL* (Depth to tip)	15.5mm	15mm	14mm	13mm	12mm	11mm	10mm
Your measure	**				-	-	-

Lab Exercise 4 - 60° SDHs (mm), see page 53

Uses: flaw height sizing of rounded, midwall flaws

SDHs	2.5mm	5.0mm	7.5mm	10.0mm
Peaks at:				

Lab Exercise 5 - 60° ID notch tip sizing (mm), see **page 54**

Uses: Flaw height sizing of ID connected planar flaws

Notch	0.5mm	1mm	2mm	3mm	4mm	5mm	6mm
RL (Depth to tip)	7.5mm	7mm	6mm	5mm	4mm	3mm	2mm
Your measure	**						

Lab Exercise 6 - 70° SDHs PPATT cal (mm), see **page 57**

Uses: Flaw height sizing of rounded, midwall flaws

SDHs	2.5mm	5.0mm	7.5mm	10.0mm
Peaks at:				

Lab Exercise 7 -deep ID connected notch flaw height sizing with peaking cal (mm) see **page 58**

Uses: Flaw height sizing of VERY deep, planar, perpendicular, ID connected flaws

Notch	0.5mm	1mm	2mm	3mm	4mm	5mm	6mm
RL (depth to tip)	7.5mm	7mm	6mm	5mm	4mm	3mm	2mm
Your measure	**	**	**	**			

Lab Exercise 8 – FAST-UT, SDHs, peaking up (mm), see **page 69**

Uses: Flaw height sizing of rounded, midwall flaws

SDHs	2.5mm	5.0mm	7.5mm	10.0mm
Peaks at:				

Lab Exercise 9 – FAST-UT, OD notch sizing (mm), see page 71

Uses: Flaw height sizing of perpendicular OD connected flaws

FAST OD sizing -- millimeters

dB ________

OD notch	% FSH	depth reading	
0.5mm ⇩			
1mm			
1.25mm			< 1.91mm
2mm			> 1.91mm
2.5mm			
3mm			

do OD sizing from the louder side

Lab Exercise 10 – FAST-UT, ID notch sizing (mm), see page 74

Uses: Flaw height sizing of perpendicular ID connected flaws

FAST ID sizing -- 8mm thk notched block

dB ______

notch depth	remaining ligament	FAST-UT depth	%FSH
0.5mm	7.5mm		
1mm	7mm		
2mm	6mm		
3mm	5mm		
4mm	4mm		
5mm	3mm		
6mm	2mm		
⇧			

Do the ID depth sizing from the side where you walk over the top of the flaw at furthest point towards the left on the screen.
It might not be the loudest spot.

Lab Exercise 11 – FAST-UT, SDHs (mm) [note; same as Lab Exercise 8], see page 75

Uses: Flaw height sizing of rounded, midwall, flaws

FAST embedded (midwall) flaw sizing with SDHs - 8mm thk block

dB ______

SDH	2.5mm	5.0mm	7.5mm	10mm
depth reading				