

March 2010

JOINT PWI / RTSA **SITE VISIT** on THURSDAY 8TH APRIL

Adelaide Tramline Upgrade Projects

LOCATION: Glengowrie Tram Depot

TIME: 1030hrs

SPECIAL REQUIREMENTS: Participants are requested to assemble outside the gates in Maxwell Terrace. Participants must wear low heeled enclosed shoes. Bring an orange vest if you have one and a sun hat is recommended.



The inspection will commence at the Glengowrie Tram Depot where the upgrade of the depot and other facilities to cater for the differing tram types and doubled tram fleet size may be observed.

At 1130hrs a special tram will then take the participants on a tour of the tramline to its new terminus at the AEC. A brief stop at the new South Road Overpass Stop 6 will be made on the way. Work associated with the renewal of the overhead and renewal of track at South Terrace may also be observed. After a brief stop at the AEC terminus to inspect facilities, the tram will return to Glengowrie Depot at approx. 1320hrs. Alternatively, PWI members and participants are invited to alight the tram at Stop 3 Goodwood Road at approx. 1310hrs and adjourn to the nearby Goodwood Hotel where refreshments will be provided.

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Chapter Meetings

Thursday 6th May 2010

Adelaide Tram Overpass, McConnell Dowell.

Thursday 3rd June 2010

Field Visit to new Dry Creek Maintenance Facility

Thursday 1st July 2010

Cairns Tilt Train Accident, Larry Matters, ATSB

Thursday 5th August 2010

Wheel Profiles, Carolyne Southern and John Furness, Pacific National/ARTC.

Publisher

This newsletter is a publication of the South Australian Chapter of the Railway Technical Society of Australasia, Engineering House, 11 Bagot Street, North Adelaide SA 5006. Opinions expressed within are not necessarily those of the Chapter, Society or Editor.

Contributions

Contributions, including news, opinions, or letters to the editor, are always welcome. Send material by e-mail to sa-editor@rtsa.com.au

Continuing Professional Development

Engineers Australia members are reminded that attendance at RTSA technical meetings contributes towards CPD requirements. Each RTSA technical meeting generally has a value of 1 CPD point.

RTSA Website

The RTSA website www.rtsa.com.au has details of RTSA activities, including future meetings and reports from past meetings, for all Chapters.

Membership

Information for potential new members and an application form may be found at www.rtsa.com.au.

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Newsletter Dispatch

Despatch of the newsletter is undertaken by Steve Torok. Contact Steve on storok@tge.com.au if you have any problems receiving newsletter electronically or in hard copy, or change your e-mail address.

News

SA Chapter Meeting March 4th, 2010

The last Chapter meeting, and our first at our new venue on King William St, provided attendees with a

very informative presentation on ultrasonic rail defects, including the history of this important subject area. Comprehensive notes on this presentation can be seen at the end of this newsletter.

Coming Events

CORE 2010 – Wellington, NZ

The RTSA's biennial Conference on Railway Engineering (CORE) is to be held this year in

Wellington, NZ with the theme 'Rail – Rejuvenation & Renaissance'. Register your interest at <http://www.core2010.org.nz/>

Chairman's Chatter

Meeting Venue

My thanks to the Committee for making the transition to the new venue go seamlessly. Tasks like setting up presentations and preparing drinks and nibbles tend to go unnoticed generally, let alone in a new environment, so I appreciate that it seemed to go off without a hitch. Though turnout was down a little, those that made it appeared to take the trip to town in their stride; I hope that in time this trend continues for existing members, and that the new central location becomes an attractor for new members.

RTSA Executive Committee meeting, Auckland, 15-16 March.

New faces appearing at this meeting included Simon Wood, Associate Director of AECOM in Auckland and the RTSA's new Deputy Executive Chair / future Executive Chair; Peter Bishop, recently appointed to the new, paid and part-time position of RTSA Project Planning Officer designed to better-pursue initiatives of the Executive; and Special Interest Representatives Darrien Welsby, of Monash IRT, and our very own Tom Hampton;

Topics arising included the decision to undertake a professionally-directed market research survey to properly define the problem that we have been trying to solve over the last few years with separate attempts at improving the RTSA branding, our website, and channels of communication.

The Chairman of the Wellington CORE2010 Organising Committee also presented a full-steam-ahead status report, describing how his Technical Review Committee faced an oversubscription of more than three-to-one of Abstracts for the Conference Technical Program – so don't feel too bad if your Paper missed out on this occasion.

Road speed + road safety = good news for rail?

Local headlines and commentary about speed and road safety provided an interesting counterpoise for rail, recently. For a given piece of transport infrastructure and type of vehicle using it, the interests of safety eventually tend to clash with that of mobility - and striking a balance between the two

using science and reason seems to increasingly be fraught with difficulties when dealing with road infrastructure used by the public, rather than urban rail infrastructure that carries it.

Going by much of this commentary about SA roads, there seems to be two extremes emerging. One appears to perceive an ever-increasing amount of regulation, to suspect opportunistic approaches to its enforcement, and to consider this combination itself an ironic contributor to outbursts of reckless driving and flagrant – rather than 'creeping' – exceedences of speed limits. This view also queries why headline road tolls are not adjusted by the increasing quantum of transit. The other view seems to unquestioningly equate legality to safety and to overlook the economic cost to society of delays, while tending to demonise any dissenting view - however pragmatic - as irresponsibly impatient. While understandably illustrating the tragedy of *any* road death, the emotion apparent in this view doesn't seem to tally with how Australia's rate of 0.7 deaths per 100 million vehicle kilometres travelled in 2007 was *no worse than the median* for OECD countries that year.

As society changes, could it be said that this second view is prevailing? If so, without expensive infrastructure improvements to solve the clash of safety and mobility, it is difficult to see how far this trend will go of making willing sacrifices in road mobility for the sake of road safety.

Happily, rail doesn't seem to have this trend at the moment; it has the advantage of being a mode that can offer speed *with* safety through both its inherent design and by an operation that is highly controlled compared to road. As such, rail is almost becoming the only mode that can still legitimately *go fast* – especially through urban areas – and thus ought to be in a position to benefit from the trend discussed above. That is, of course, unless this trend does spread to rail by manipulating its traditions of intrinsic safety - and what a disservice to the system it would be if this was allowed to occur.

On a lighter note, I look forward to seeing you at the joint PWI/RTSA Tramline Expedition!

Daniel Martucci – Chair, RTSA SA Chapter

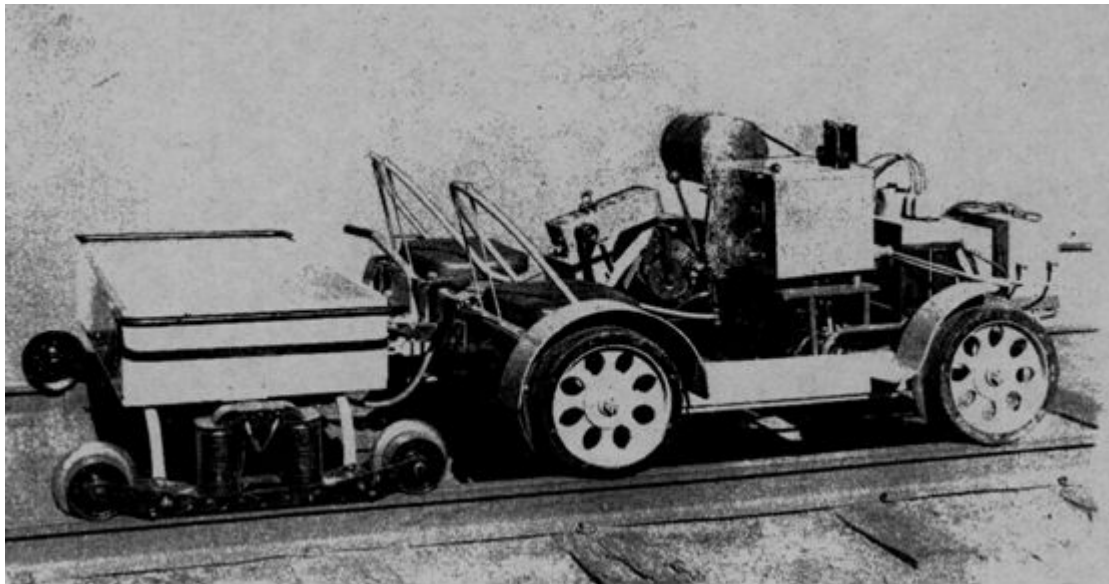
Introduction

The use of ultrasonic sound waves to test metals and other forms of solid materials dates back to the end of the nineteenth century when the existence of ultrasonic vibrations was discovered in Germany using a small pronged tuning fork. Ultrasonics is now one of the two common methods to detect internal defects that do not come to the surface, the other being X-ray inspection. The term, ultrasonic waves, is used for sound waves above the upper limit of human hearing which is approximately 20,000 cycles. The term “supersonic” was first used instead of “ultrasonic” but was later changed when aircraft started to break the sound barrier and the term “Super Sonic” was used in that context.



“Flawtone” Ultrasonic Hand Tester.

Using continuous waves, through wave transmission techniques were perhaps the earliest forms of ultrasonic testing. Methods of detecting the sound included using mercury and watching for patterns on the surface¹ or watching aluminium flakes align themselves to the sound wave. Two men, Firestone and Sproule working independently developed the pulse reflected wave method during the 1940s. This overcomes the requirement to have access to both sides of the test piece. From this time new techniques and methods are being developed to this day.



Early Railways Magnetic Test Vehicle

Rail Testing

The sizing of internal defects in rail became possible with the introduction of ultrasonic inspection methods. Initially ultrasonic inspection in the rail industry was introduced to test axles on rolling stock. This new technique was then adapted for rail inspection in NSW, Victoria, Queensland and South Australia in the nineteen fifties and early nineteen sixties along with magnetic induction techniques in the three Eastern states. However many the techniques we use today were first introduced when Automation Sperry bought the first rail testing vehicle, SRS801 to Australia in October 1969².



SRS 801 & SRS 141

The heavy haul systems in Western Australia were the first to use SRS801 which was later used in NSW after a successful test run near Goulbourn in NSW². It was replaced in WA by SRS141, a rail bound ultrasonic and induction testing vehicle. Later SRS141 was also transferred to the state systems it being

replaced by SRS140. The early test vehicles arrived with crews from the United States and stayed until local technicians were able to operate and maintain these rail testing vehicles.

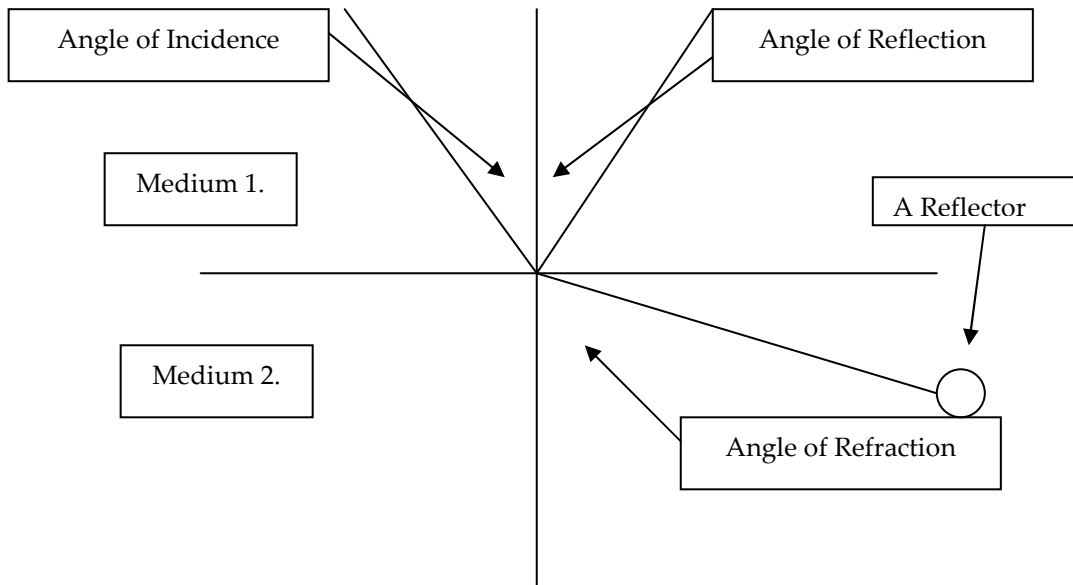
Along with the test vehicles came the testing procedures and much of the terminology we still use to this day. As already mentioned, NSW was about the first state rail system to test their rails and were the first state to start training people to test rails and new welds. With the introduction of continuously welded rail (CWR) it became even more important to test new welds and rails.



Broken Rail.
(The cause of this derailment)

Training Ultrasonic Testing Inspectors

A training course was established in Sydney and selected workers from the various welding gangs were trained to operate Kraut Kramer ultrasonic flaw detectors. These inspectors became known as KK operators, a term still sometimes used. The training was based on a system that could be loosely described as pattern recognition. Very limited ultrasonic theory was introduced and the calibration techniques were based on corner reflections from the head of the rail for the 70° search unit. Using this method the 70° search unit only looked at the head section of the rail.



Incident, Reflected and Refracted Angles.

The 38° search unit was selected to examine the web section of the rail and the rail foot directly below the web. The selection of this particular search unit is based on the fact that the predictable angle for most bolthole cracks will be “normal”, or 90°, to the sound beam from this search unit. If there are no boltholes a 45° search unit can be a better choice for weld inspection.

A dual zero degree search unit was selected for longitudinal orientated defects and a dual miniature 70° search unit for the inspection of the foot section of both Thermit and flash butt welds.

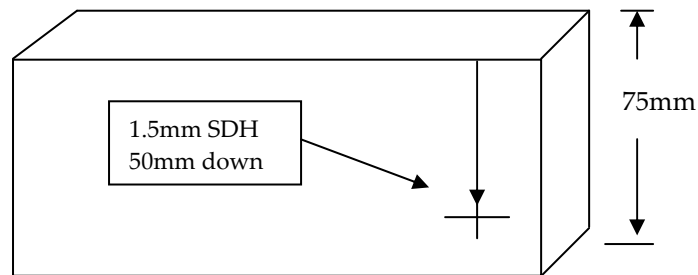
Sensitivity was established by the observation of the grain structure which is seen on the ultrasonic flaw detector and known as “grass”. This “grass” level was established and kept while testing at about 10% full screen height (FSH).

The recorded defect size, when using the 70° search uni, was horizontal probe movement, measured along the running face of the rail. The approx. vertical reflector height can be calculated by dividing the horizontal distance by three.

This system was used for many years in NSW and later used in Queensland and a variation of it was also used in New Zealand. As the operators had very limited understanding of the principals of ultrasonic theory, they relied on constant supervision and support if any abnormal “defects” were detected or the ultrasonic machines and equipment required maintenance.

I joined the South Australian Railways in 1975 having previously been involved in the sale of a Sperry Ultrasonic Flaw Detector to Special works when I previously worked for Automation Industries. I had inspected Thermit welds in Queensland and had also worked for a short time on SRS801 when it was testing rail in NSW. No training was then available for the inspection of rail or rail welds. At that time I believe in NSW they were then starting to test Thermit welds by using only a 0° search unit, looking mostly for porosity.

When the Australian Rail Track Corporation (ARTC) took over the non-metro system in NSW the KK operators became isolated from their support base which was still based in Sydney. This now required that these inspectors to be trained in basic ultrasonic theory as well as the use of general calibration blocks as described in Australian Standard AS 2083-2005. In addition new digital ultrasonic flaw detectors were introduced replacing the Kraut Kramer analogue machines.



Rail Specific Sensitivity Block

A company in Newcastle, CC Pope, later to become Bureau Veritas, was engaged to construct a course based on the American system of specific industry requirements. The course needed to acknowledge that the people to be trained, or retrained, would possibly have limited academic learning and therefore the course was required to be very “hands on” and very limited in the requirements for maths. In addition, a module was introduced explaining rail production, rail marking and common rail defects. To establish a common working sensitivity a “Rail Specific Sensitivity Block” was designed, manufactured in Newcastle, and issued to the various inspection groups. Much work went into the design of this course, working on a need to know basis, the main problem being able to decide not so much what to put in the course but what ultrasonic theory to leave out. The mathematical calculations were included in the course and demonstrated but were not part of the final assessment. A training and development consultant, Mr. Gabriel (Gabby) Serhan structured the course with the technical content coming from Mr. David Cowan, Mr. Ken Brown, Mr. David Murrell and I. The collection of defect samples, the sizing, recording and stamping was also a requirement for a successful course. Although difficult, the course time was limited to one week, classified as being the theory component. Later an “on the job” assessment, after working under supervision of a previously trained operator, or more experienced worker in the early days, is carried out.



Learning the Practical Applications of Ultrasonic Inspection.

In addition to the ultrasonic content the principles of dye penetrant and magnetic particle inspection was introduced and demonstrated. X-Ray, eddy current and visual inspection techniques were also introduced and discussed.

The first course started on the 27-1-2006 in Newcastle, Gabby being is attendance to fine tune the presentation and assist both David and I in the delivery of the course. Since that first course there have been another fourteen courses and perhaps more to come.

Now that the training has been done and the inspectors are testing new welds and assessing defects what level of confidence can be expected in the sizing of defects?

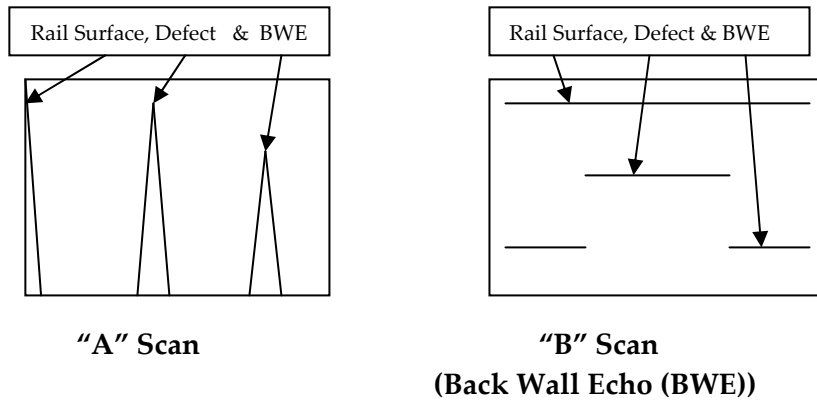
With the introduction of the “rail specific sensitivity block” and the use of recognised calibration blocks it is now possible to prepare a standard for the operators to work to. This standard is important as it enables the rail management to have a level of confidence that significant rail and weld defects will be found, assessed for size and the appropriate action taken to ensure significant defects are removed from track. Perhaps more important is the protection of the inspector if, after an assessment, there is a failure causing major damage or the loss of life.

Basic Ultrasonic Theory.

At this time it is necessary to introduce some of the basic principles of ultrasonic inspection and defect sizing.

Most ultrasonic rail inspection is carried out using what is known as a pulse/echo system. This applies to both the hand testing techniques and the rail test vehicles. The pulse is a high frequency sound wave, typically between two and five megahertz (for rail testing) of very short duration, about four or five cycles. These are generated using a piezoelectric crystal. At these frequencies, the sound wave can be directed at various angles, these being selected to reflect from expected reflectors at or near normal (90°) to the sound beam.

It is the reflections from these reflectors that “hopefully” return to the piezoelectric crystal. The returning sound wave generates a voltage across the crystal which is amplified and displayed for evaluation. Several methods can be used to display the returning sound wave but the most common method is what is known as an “A Scan” presentation. The rail test vehicles use a display known as a “B Scan” presentation”. However, on the test vehicles, the various probes, or crystals, are set up and adjusted using the “A scan” presentation.



Two types of sound wave propagation are used for rail testing. These are compression (or longitudinal) waves; and shear (or transverse) waves. Surface waves can also be generated under certain conditions. However, these are generally avoided by careful search unit maintenance. Compression waves travel at a speed of 5,920 metres per second and shear waves travel at approx half that speed, or to be more exact, 3,240 metres per second in mild steel. The wave length depends on the search unit frequency and the mode of propagation. The pulse length depends on the search unit frequency, mode of propagation, the search unit design and the method of crystal excitation (Square wave or spiked pulse).

As can be imagined, recognising the speed of the sound waves, the comparatively short distances travelled in normal rail testing (typically 200/250mm or less) that some parts of the testing cycle are very rapid. The overall efficiency of the system is such that, it has been stated, that only a little over two percent (2%) of the sound generated in the probe ever gets back to the display¹.

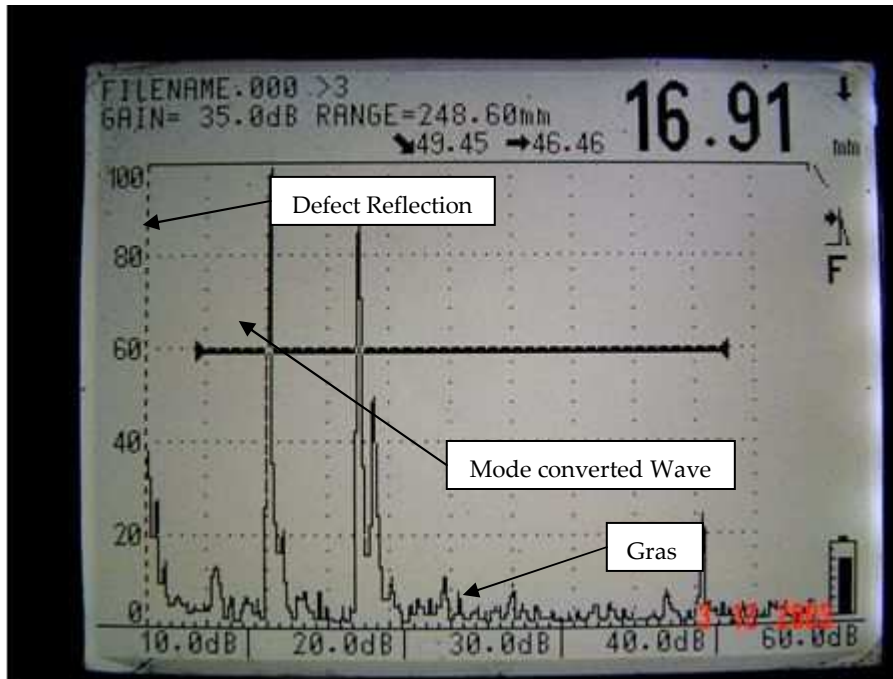
Defect Sizing & Standards.

Having briefly dealt with the ultrasonic theory, it is now time to examine reflectors, some of which may be defects.

The sound reflected from a reflecting surface, or interface as it is generally referred to, depends on some of the following variables:

- The size of the reflector.
- Its shape.
- The angle of the reflector to the ultrasonic wave.
- The reflecting surface profile.
- The surface condition of the rail.
- The shape of the rail surface compared to the shape of the sole on the search unit.
- The sound beam distance to (and from) the reflector.

- The grain structure of the parent material. (sound is scatted & absorbed; termed attenuation)
- The sound frequency being used.
- The dead zone, near zone & far zone of a particular search unit.
- Search unit damping & processing of the sound wave
- The rail temperature.
- Mode conversion.



Mode Conversion (A scan presentation).

From all the above it can be seen that there are many factors that will affect the sound we receive from a potential defect. There are at least two Australian standards applicable to the testing of rail welds and, by inference, rail defects.

These are:

- Australian Standard, AS 2207-2007, Non-Destructive testing—Ultrasonic testing of fusion welded joints in carbon and low alloy steel.
- Australian Standard, AS-1085.20-2006. Rail track material. Part 20: Welding of steel rail.

AS2207-2007 in Appendix G describes three procedures for sizing defects.

These are:

- The 20 dB drop technique.
- The 6 dB drop Technique.
- The last significant echo technique.

The first two techniques require the beam spread to be plotted for the material being tested and a reasonable expectation of the defect type and its orientation.

The last significant defect technique is the method that is claimed for the inspection of both rail and weld defects. Again this technique requires some expectation about the defect type and its orientation.

In practice by using the introduced "Rail Specific Sensitivity Block", a combination of the 6dB and the Last Significant Echo method has been introduced. This method uses the 1.5mm side drilled hole (SDH), at the appropriate depth (either 50mm or 25mm), as a "universal" back wall echo. The reflection from this SDH is set at 80% full screen height (FSH) and echoes above half this level, 40% FSH, or less than 6dB from the 80%, are evaluated for size. Normally another 6dBs is added for scanning, or looking for the defect, but removed to the evaluation sensitivity for assessment.

Having previously listed the variable that can, and do, affect the reflectivity of a potential defect is it possible to accurately size a defect?

Defects that are orientated parallel to a rail surface and examined with a 0° search unit are reasonable easy to measure for size. This measurement is usually expressed in terms of length. Defects such as horizontal and vertical split heads would be in this category.

Bolthole cracks are generally sensitive to the inspection by the 38° search unit because of the general orientation of the crack that allows the sound wave to strike the crack at 90° (normal). All detected bolthole defects are now recorded and removed from track.

Transverse vertical defects are far more difficult to size. By using the 70° search unit the best theoretical angle to strike the reflectors interface is 20° off the normal angle. AS-2207-2007 (page 10) states:

"1. Incident angles greater than 20° to the major expected reflector should not be used."

As we are bound by Snell's Law and critical angles, 70° is the best practical angle that can be used.

Fortunately many of the apparently negative aspects of the reflecting surfaces do assist in detecting and assisting in sizing defects. Surfaces that are not mirror smooth tend to defuse (scatter) the sound beam thereby assisting in their detection.

Fatigue defects in rails and rail welds are seldom vertical, their orientation being dependant to the "more loaded" direction of traffic. They can be up to about 20° off the vertical making them ideal for detection with the 70° search unit, at least from one direction.

The use of the lower frequency search units, 2 MHz, (larger beam spread) assists in the detection of defects. Higher frequency search units, 5 MHz, may be better for sizing defects in some circumstances but are seldom used in the rail industry for this purpose.

A high level of accuracy when testing some defects is difficult. During the continuous testing of rail very limited time is allowed to carry out the test. The angles selected by the rail industry, 70°, 38° (or 45°) & 0° search units, does limit the angular response that may be achievable from some defects that are present in the rail or weld. This also applies to the test vehicle that has only one pass with the search units in a fixed position to detect a reflector.

Additional Techniques

Advances in technology have improved some techniques and introduced some new methods that may be of some use for testing rail in the future.

Many new digital ultrasonic machines are now equipped with a digital generated form of Distance Amplitude Correction (DAC) and Time Variable Gain (TVG), also known as Time-corrected Gain. This technology allows for equal size reflectors at various depths to be displayed at a uniform height (TVG) or generates a curve to indicate the presence of equal size reflectors (DAC). Some older analogue machines were also equipped with this facility however it was difficult to use.

A system known as Phased Array Probe Technology is another interesting concept. This system allows the “steering” of the ultrasonic sound beam rather than having a number of fixed angle search unit. The display for this system is a form of “B” scan presentation.

Summary

Years ago I introduced the phrase “Ultrasonics doesn’t find defects, it finds reflectors and some of these reflectors may be defects”. Having previously listed a number of variables that will have an effect on the outcome of any ultrasonic test it can be seen that it is difficult to be precise when sizing some defects. It is however possible to state, in general terms, whether a defect reflection is small, medium or large, these categories being determined to some extent by the rail engineers or empirical knowledge. If some defects are to be left in track it is an advantage to record, in numerical terms the result of the ultrasonic test. This enables later inspections to determine if the defect is growing and may establish a time frame for its removal, not necessarily based on the apparent size of the defect.

Much progress has been made in the processing of the ultrasonic reflector in terms of processing speed, presentation and the recording of rail examinations. New techniques are being developed to enable the identification of various defects and comparisons made to defects of a similar type and size found on previous rail tests. An Australian company, Rail Test International (RTI) using modern communications, where available, allow for remote assessment of what the test vehicle has detected while the test is in progress and can, if necessary, alter the testing parameters of the test vehicle at that time.

In spite of all these advances, the basic physics of introducing the sound into the rail and the receiving of the reflection is still the same. Hand testing or test vehicles still need the sound to return (or reflect) to identify and size defects.

References:

1. J. C. Drury, “Ultrasonic Flaw Detection for Technicians 3rd Edition”.
- 2.. David Barnett, “History of Non-Destructive Testing in Australia