Identifying Internal Rail Defects with Non Destructive Methods

1. **Basic Testing Methods and Principles with obstacles during Rail Testing.**
2. **Defect Type and Orientation**
3. **Technologies advancements.**
4. **Frequencies / Planning of testing.**

Ultrasonic Testing

Testing Methods and Principles.

Current testing methods today that are used to conduct non destructive inspection of rail for internal flaws:

1. **Ultrasonic.**
2. **Induction.**
3. **Vision.**

Ultrasonic Testing

Terminology

1. Indication – any response.
2. Discontinuity – An unexpected response in the rail that may be intentional or unintentional.
3. Reflector – Response to a surface that is perpendicular to the angle of the ultrasonic signal
4. Flaw – An imperfection that may be acceptable or not acceptable.
5. Defect – A discontinuity that is not acceptable.

Testing Methods and Principles.

Ultrasonic testing

Ultrasonic sound is created when an electric current causes a piezoelectric crystal to transmit a high frequency vibration (sound wave).

Ultrasonic sound is a high frequency sound wave. Testing sound frequency is between 2.5 MHz to 5 MHz.

Sound reflects when it strikes and acoustic interface boundary. Different material velocities or simply a defect or grain boundary.

Testing Methods and Principles.

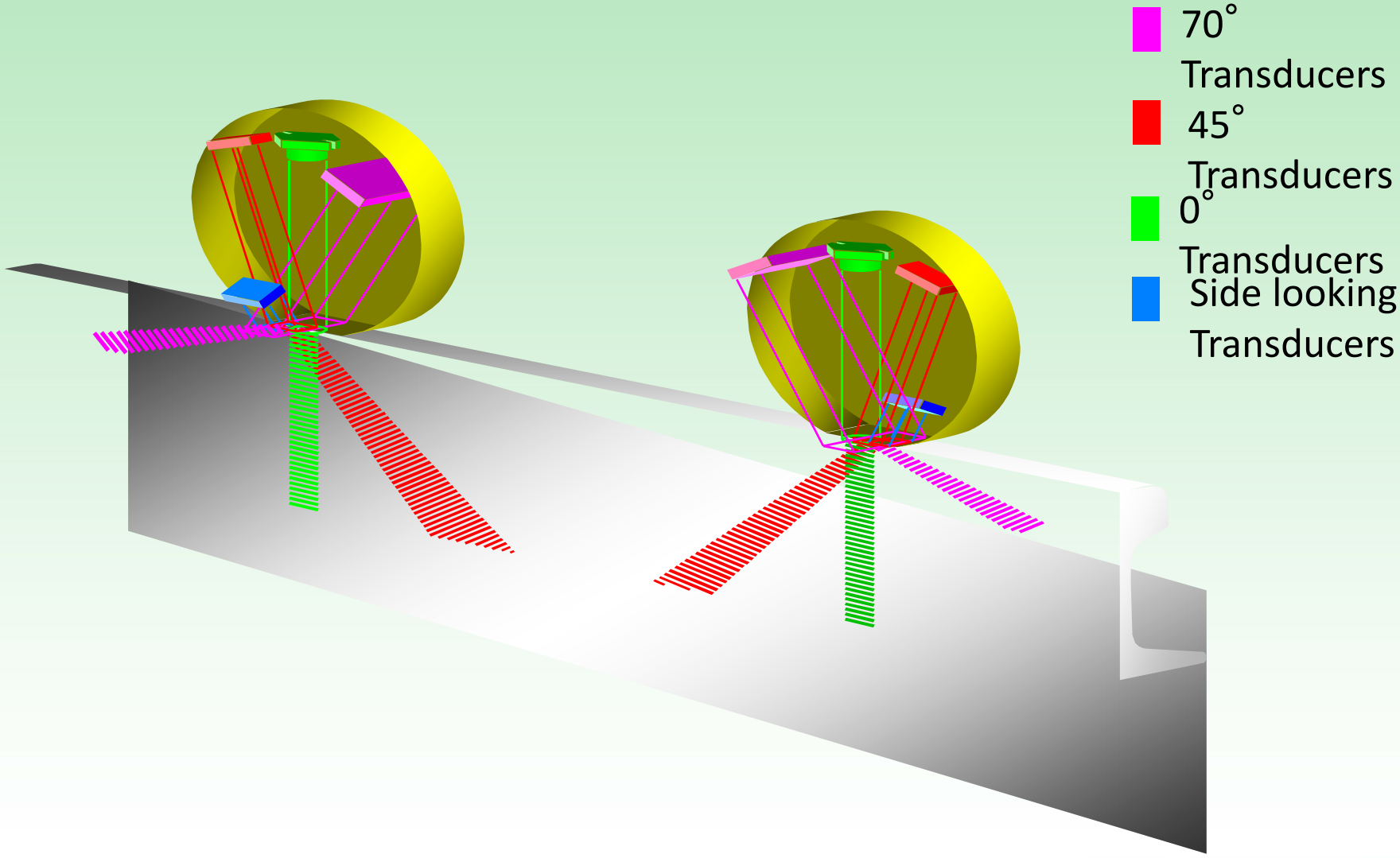
Ultrasonic testing

- Couplant (water) is required to carry sound waves.
- Know angles used for typical defect detection based on experience.

  70 degree, 37.5 degree, and 0 degree transducers are commonly used.
- Speeds are usually below 25 mph.
- Roller Search Units are used in North America

  Transducers are inside a wheel filled with fluid.

Ultrasonic Testing



Testing Methods and Principles

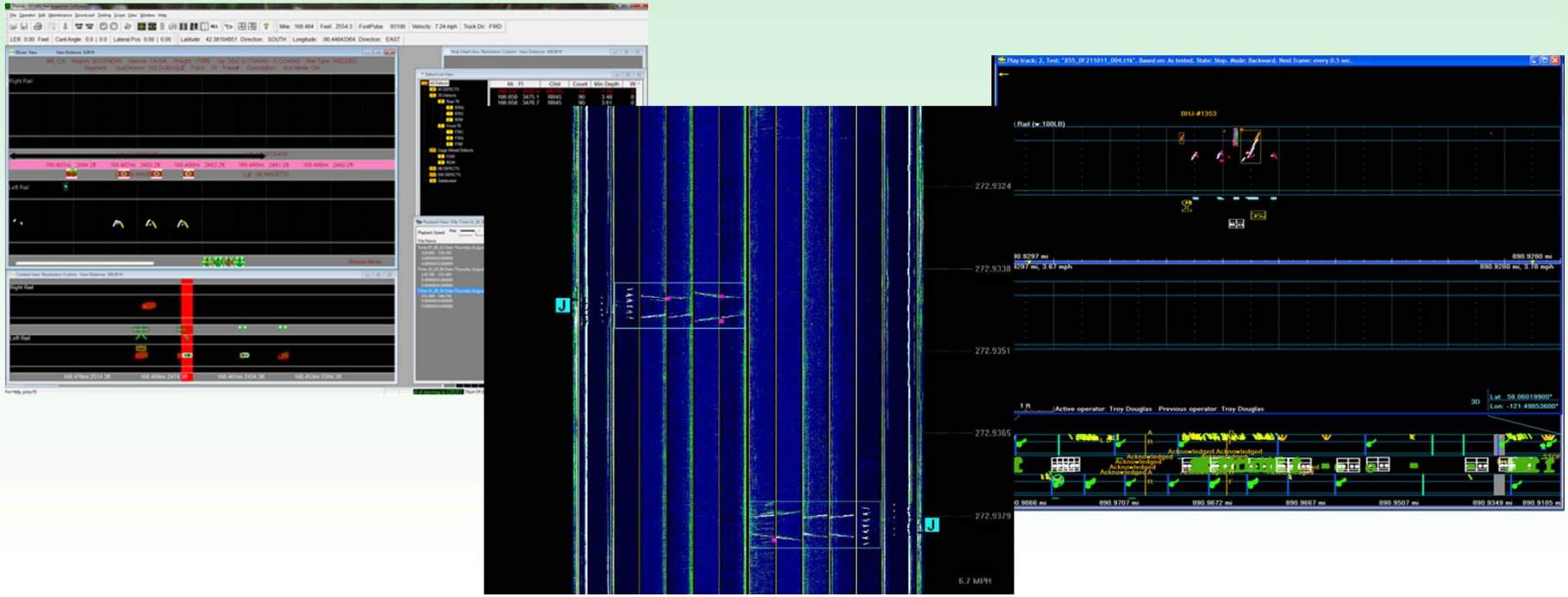
Ultrasonic testing

Disadvantages or shortcomings of Ultrasonic Testing

1. Rail Surface issues or irregularities
2. Speed or return of the Signal
3. Weather and contaminates
4. Area of coverage (base of rail and weld collars)

Testing Methods and Principles.

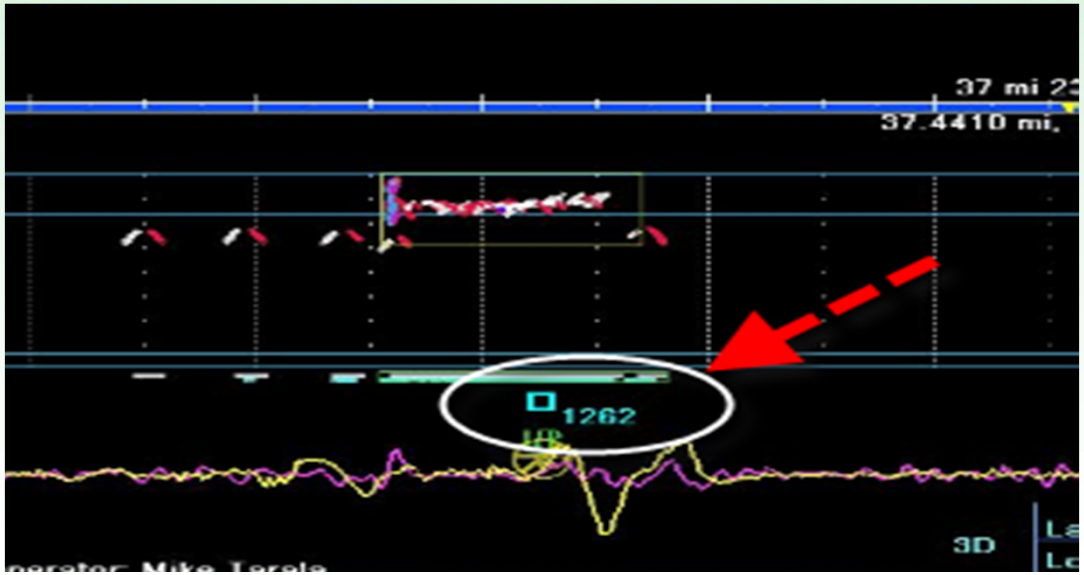
Currently all the North American suppliers use some form of a B-Scan image. This simplifies the information by organizing the data into an easily read presentation.



Testing Methods and Principles

Vision

1. When and ultrasonic indication is present meeting a specific criteria, a vision photo taken of that location.



Vision

Testing Methods and Principles

Disadvantages or shortcomings of Vision

1. Weather dependent
2. Only take photo when alarmed
3. Operator dependent
4. Large file sizes

Testing Methods and Principles

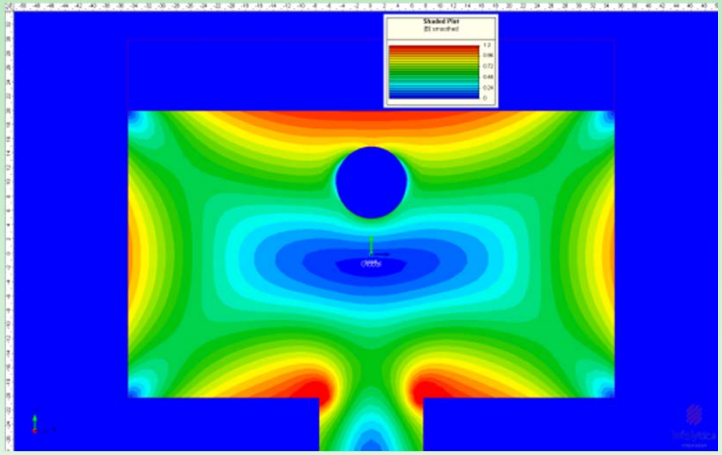
Induction

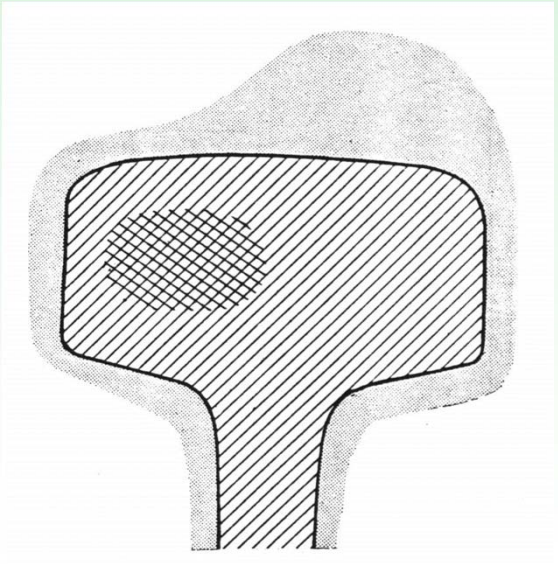
The introduction of electric current into a conductor to create a magnetic field.

The main area of inspection is the head of the rail.

When the magnetic filed is disrupted or a flaw is present, a change in the magnetic response is noticed

Induction Testing





Testing Methods and Principles

Disadvantages or shortcomings of Induction

1. Current limitation is that it only tests the head of the rail
2. Does not test thru turnout and diamond areas
3. Area of coverage (web and base)

Testing Methods and Principles

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Rail Defects

Ultrasonic Testing

Rail Flaws (Defects)

1. Three type of flaws or discontinuities
   - Inherent
   - In-service
   - Process (Manufacturing)

Ultrasonic Testing

Rail Flaws (Defects)

1. Inherent

- This is from the materials or alloy material

  - Discontinuities include some of the following items inclusions, porosity, shrinkage and segregation.
  - Note that inclusions can be non-metallic and metallic.

Ultrasonic Testing

Rail Flaws (Defects)

In-service

Discontinuities that occur while rail is in revenue service. There are many causes such as vibration, heat, impact and other items.

Ultrasonic Testing

Rail Flaws (Defects)

Process (Manufacturing)

Primary Processing – This is the initial part of the rail manufacturing and shaping of the rolling rail.

Secondary Processing – This is the final process to finish the rail such as heat treating and machining.

REMEDIAL ACTION TABLE

Defect	Length of defect (inch(es))		Percentage of existing rail head cross-sectional area weakened by defect		If the defective rail is not replaced or repaired, take the remedial action prescribed in note
	More than	But not more than	Less than	But not less than	
Compound Fissure	....	....	70..... 100.....	5..... 70..... 100.....	B. A2. A.
Transverse Fissure Detail Fracture Engine Burn Fracture Defective Weld	....	....	25 ..... 60 ..... 100	5..... 25..... 60..... 100.....	C. D. A2, or [E and H]. A, or [E and H].
Horizontal Split Head Vertical Split Head Split Web Piped Rail Head Web Separation Defective Weld (Longitudinal)	1..... 2..... 4..... (1).....	2..... 4..... ..... (1).....	....	....	H and F. I and G. B. A.
Bolt Hole Crack	½..... 1..... 1½ ..... (1).....	1 ..... 1½..... ..... (1)	....	....	H and F. H and G. B. A.
Broken Base	1..... 6 (2).....	6.....	....	....	D. A, or [E and I].
Ordinary Break	.....	.....	.....	.....	A or E.
Damaged Rail	.....	.....	.....	.....	C.
Flattened Rail Crushed Head	Depth ≥ ⅜ and Length ≥ 8.....	.....	.....	.....	H.

(1) Break out in rail head.

(2) Remedial action D applies to a moon-shaped breakout, resulting from a derailment, with length greater than 6 inches but not exceeding 12 inches and width not exceeding one-third of the rail base width.

RAIL DEFECT REVIEW

Transverse Defects in the Rail Head

Compound Fissure

RAIL DEFECT REVIEW

Transverse Defects in the Rail Head

Transverse Fissure

RAIL DEFECT REVIEW

Transverse Defects in the Rail Head

Detail Fracture (from Shelling)

RAIL DEFECT REVIEW

Transverse Defects in the Rail Head

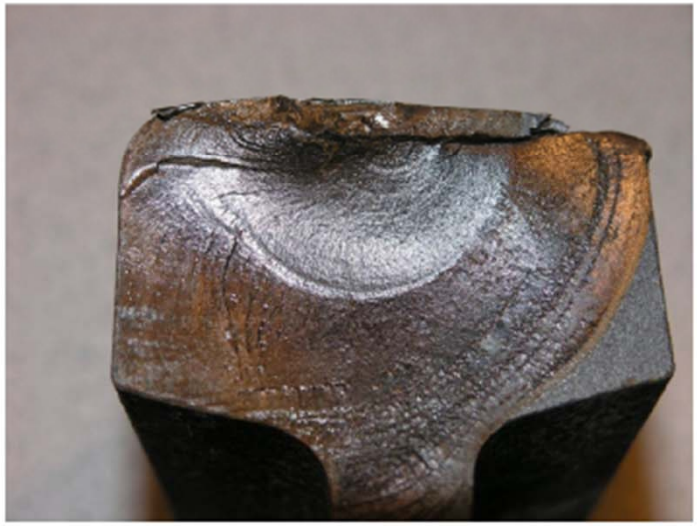
Reverse Detail Fracture

RAIL DEFECT REVIEW

Engine Burn Fracture

RAIL DEFECT REVIEW

Welded Burn Fracture



RAIL DEFECT REVIEW

Weld Defects



RAIL DEFECT REVIEW

More Weld Defects

RAIL DEFECT REVIEW

Longitudinal Defects in the Rail Head

Horizontal Split Head

RAIL DEFECT REVIEW

Longitudinal Defects in the Rail Head

Vertical Split Head

RAIL DEFECT REVIEW

Longitudinal Defects in the Rail Head

Shear Break

RAIL DEFECT REVIEW

Longitudinal Defects in the Rail Web and Base

Split Web

RAIL DEFECT REVIEW

Longitudinal Defects in the Rail Web and Base

Piped Rail

RAIL DEFECT REVIEW

Longitudinal Defects in the Rail Web and Base

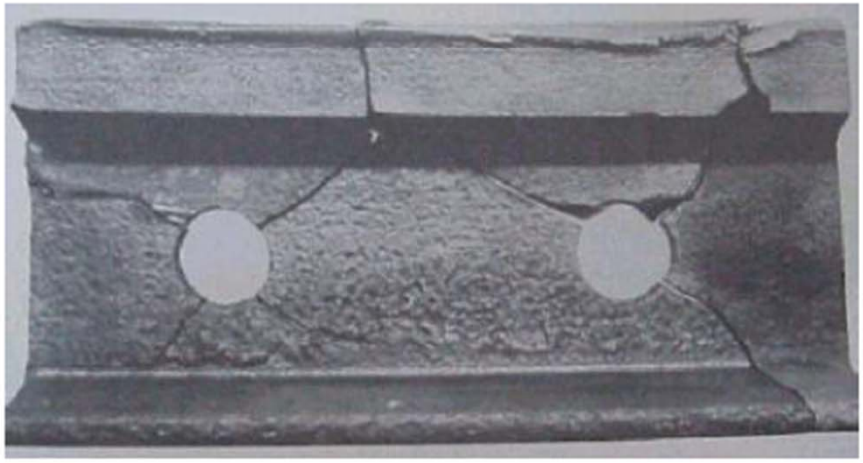
Head and Web Separation

RAIL DEFECT REVIEW

Joint Defects

Bolt Hole Crack

- A progressive fracture which originates at a bolt hole and progresses away from the hole, usually at an angle



RAIL DEFECT REVIEW

Longitudinal Defects in the Rail Web and Base

Broken Base

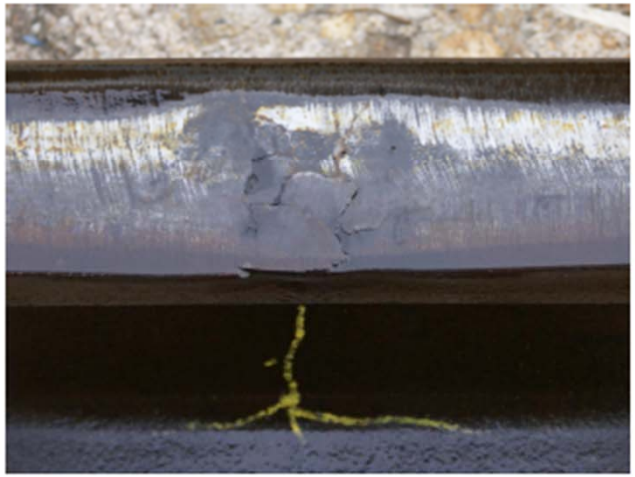
RAIL DEFECT REVIEW

Shelling

RAIL DEFECT REVIEW

Surface Defects

Engine Burn



Testing Methods and Principles.

Currently in North American on most Railroads use stop / start mode. However there are 2 other concepts that are starting to be explored.

1. **Stop and Start Mode. (Commonly used in North America)**
2. **Combo / Chase. (concept)**
3. **Non Stop. (widely used in Europe and being introduced to North America)**

Testing Methods and Principles.

Stop and Start Mode

1. Test is conducted by an Operator who interprets the indications from the test systems.
2. Conducts hand tests to validate suspect indications at time of test.

Testing Methods and Principles.

Combo / Chase unit.

1. Lead unit tests the track and the Operator identifies suspect indications that need to be validated.
2. Information is sent to a chase car that is behind the test car same day or sent to a Combo car to verify the next day.

Non Stop Testing

1. **Test unit tests without stopping.**
2. **The information is then sent to a remote location and post processed.**
3. **The suspect locations identified during processing are tested by either a portable hand test unit or a chase truck with a test system on board**

Transmits to be post processed

Suspect indications sent for verification

Report findings

Ultrasonic Testing

Frequency Planning

1. **At CN, we developed a risk based model to establish testing frequency that meet or exceed FRA and TC minimum requirements.**

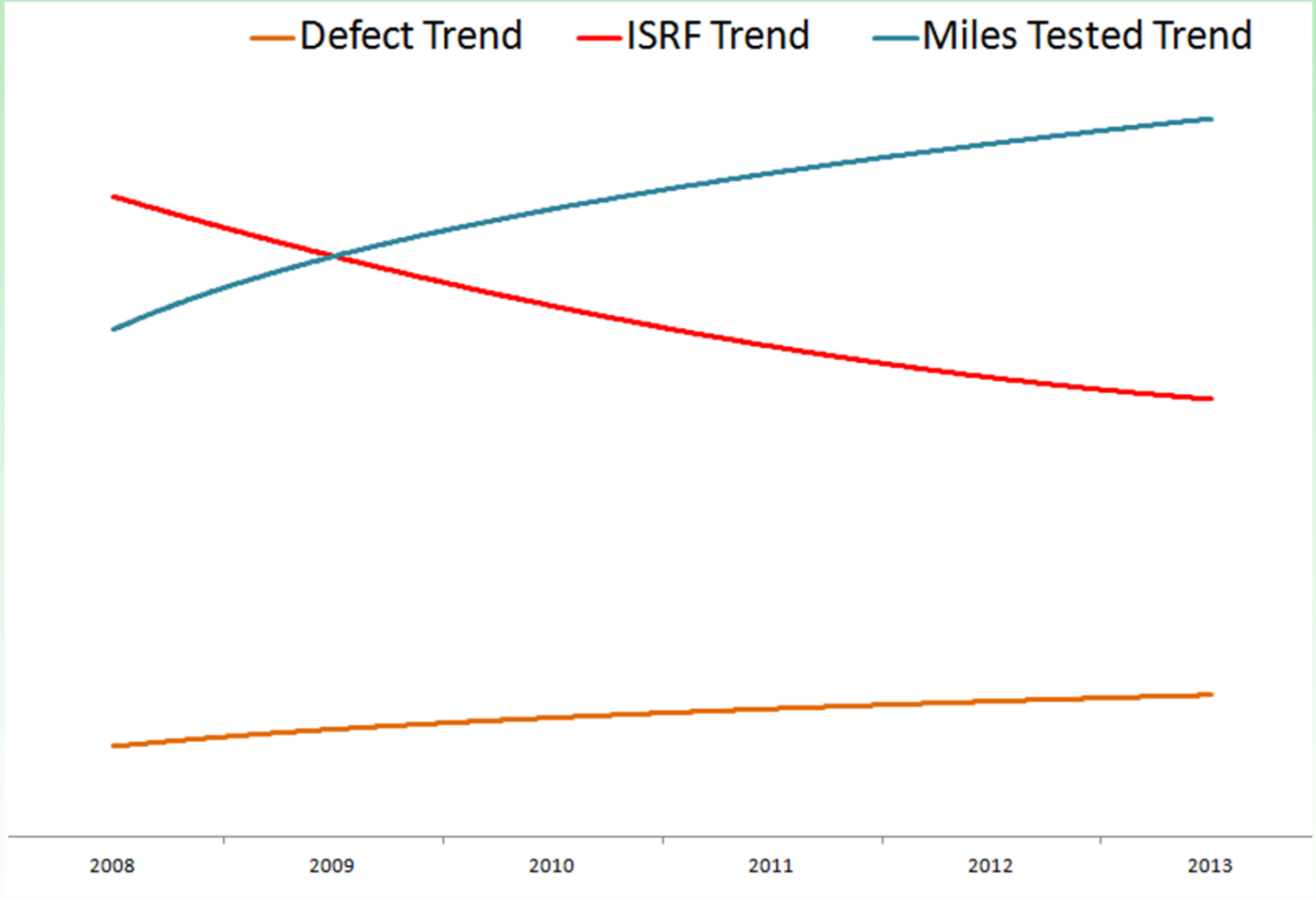
   ***Some examples of risks considered would be rail weight, ISRF, Defect history, and TQI.**

2. **Use rail testing historical average to develop car count plan.**

   ***Using the history of each subdivision and average miles tested to forecast car counts.**

Ultrasonic Testing

This chart has been scaled



Ultrasonic Testing

Where do we go from here ?

1. **Eddy current – start to measure and better understand RCF**
2. **Base defect detection.**
3. **Joint bar testing / defect detection.**
4. **Better modes of testing heavy haul main corridors.**
5. **Laser induced ultra-sonics.**