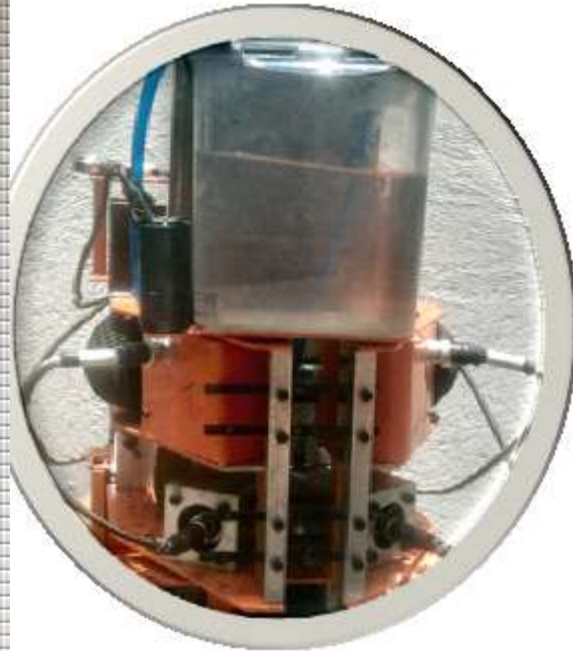
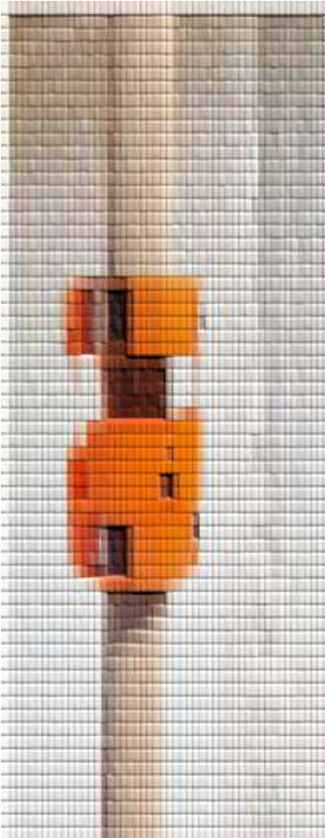


# Principles and Working of Automated Reformer Tube Inspection System ARTiS



TCR Advanced Engineering Pvt Ltd,  
Vadodara India

TCR Engineering Services Pvt. Ltd.,  
Mumbai India

# Background on Reformer Tubes

The primary reformers are used in various industries like fertilizers, petrochemical and refineries, for cracking of hydrocarbons in presence of nickel based catalyst in reformer tubes.



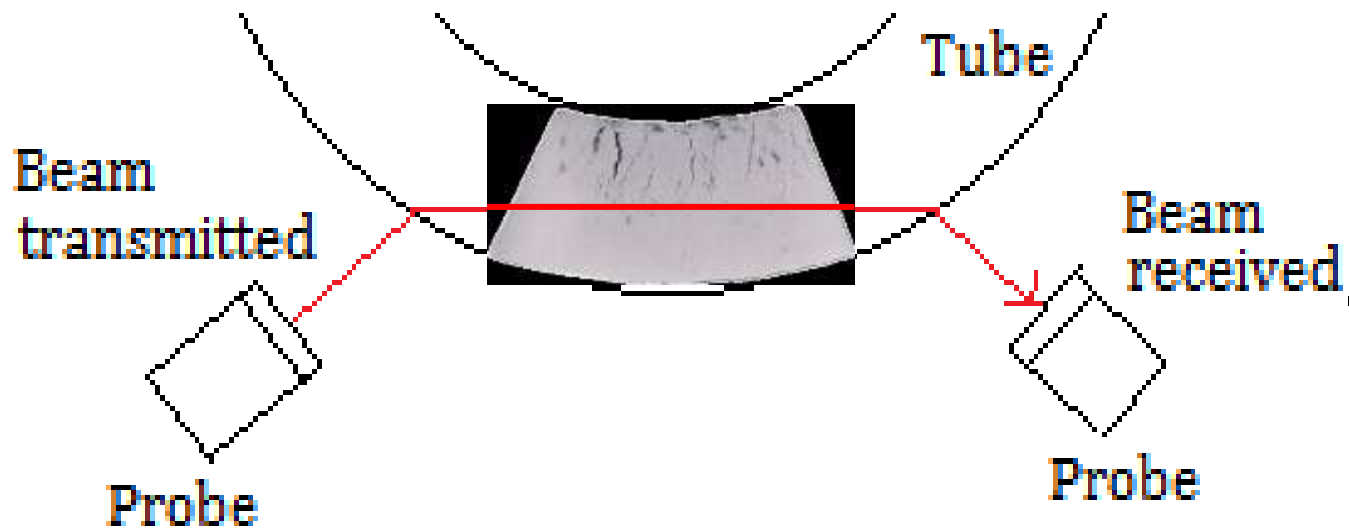
The reformer tubes are operational at 800+ °C temperature and are internally pressurized.

Over long operational life, the material undergoes high temperature creep damage, which is often reflected as increase in tube diameter and with or without formation of internal creep fissures.

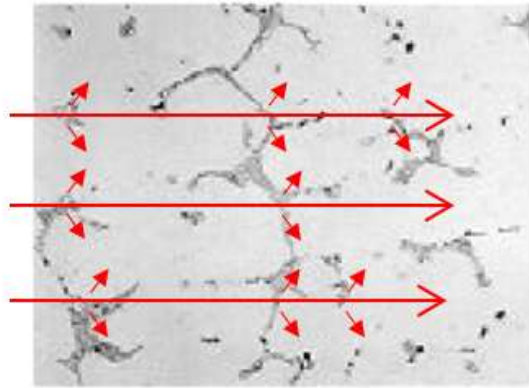
The extent of damage is quantified through various non-destructive such as diameter measurement, apparent bowing and increase in diameter along with Ultrasonic Inspection.

# Principles of reformer tube inspection

The ultrasonic inspection of reformer tubes is done in T-R (Transmit-Receive) mode where ultrasound energy is transmitted from one sensor, passed through middle of the wall section and received at other sensor (Figure 1). The energy transmitted is the sum of energy received and the energy lost in beam scatter.



# Principles of reformer tube inspection



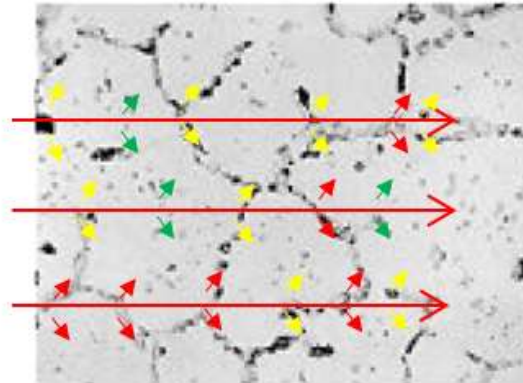
As cast condition

## Potential regions for ultrasound attenuation

In as-cast condition, ultrasound scattering occurs at dendrite boundaries from primary carbides.




After prolonged exposure to high temperature, precipitation of secondary carbides and creep void formation additionally scatters the ultrasound.

The additive effect of beam scatter becomes the measure of energy lost.



Having affected of creep damage

Beam scatter at:

-  Dendrite boundary
-  Secondary carbide precipitates
-  Creep voids

# Principle of Ultrasonic Test in reformer tubes

## **Increase in diameter:**

Internal or external tube diameter growth is also a material degradation indicator. Whenever catalytic tubes are operating under pressure in their creep temperature range, their diameters will increase in time. Generally, diameter increases in the range of 1-6% are potential indicators of certain stages of creep.

## **Tube bowing:**

Sometimes, tubes exhibit bending or bowing after being in service. Tube bowing could potentially be harmful when it touches to the other tube or excessively bowed. Generally, bowing beyond 1x tube diameter is considered as replacement planning.

# Tube inspection by ARTiS

ARTiS is a proprietarily developed method referred as the Automated Ultrasonic test System used to override the manual ultrasonic scanning.

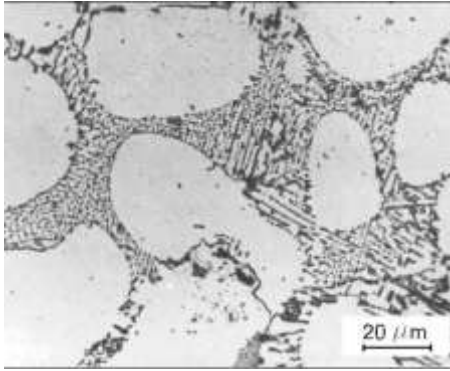
TCR has developed the technology and necessary instrumentation for ARTiS.

This is a robotic crawler that aids ultrasonic testing of reformer tubes in more systematic manner and provide tabular output.

The sensors fitted on the crawler measures the tube diameter. During crawling, the diameter is measured at fixed interval of distance.

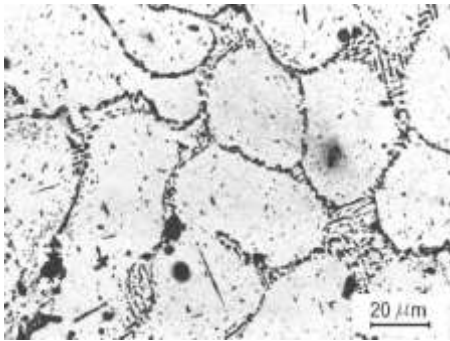
The gyro-sensors fitted on the crawler aids for angular measurements. Post analysis of angles would give quantitative figure of bowing.

# Microstructural degradation v/s Ultrasound attenuation



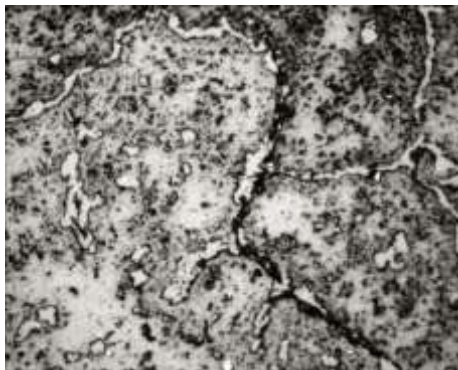
The microstructure of unused tubes is shown in Figure left, having dendritic columnar austenite grains oriented perpendicularly to tube walls.

Attenuation level: 35 – 55 dB



Upon aging, the structure degrades. The original morphology of eutectic carbides gets modified after exposure at elevated temperatures.

Attenuation level: 55 – 62 dB



At life fraction near to 80 - 95%, the microstructure is coarsened secondary carbides with presence of inter dendritic micro cracks.

Attenuation level: 62 – 72 dB

# Microstructural interpretation capability of TCR

TCR has expert metallographers with high skills.

TCR has database of microstructure of nearly 1000 spots. This includes the tube condition having virgin condition, tubes after normal aging and tubes that have failed in service.

TCR has microstructure interpretation expertise for evaluation of the tube condition based on surface replication method – to identify creep stage classification.

TCR has provided services on in-situ microstructural replication and condition assessment of tubes to more than 50 different customers in India and outside country.



# Comparison between Manual v/s ARTiS

Parameter	Manual method	ARTiS
Ultrasound test	Manual scanning	Automated tube crawler
Requirement of scaffolding	Needed	Not needed
Time of test inclusive of construction of scaffolding	4 to 5 days for 100 tubes	2 days for 100 tubes
Resolution of test result	Reported in 6 feet segments	As low as 100mm distance.
Outer diameter measurement	One or two locations manually	Every 100 mm distance
Tube bowing	Apparent assessment	Quantitative figure 5 to 200mm

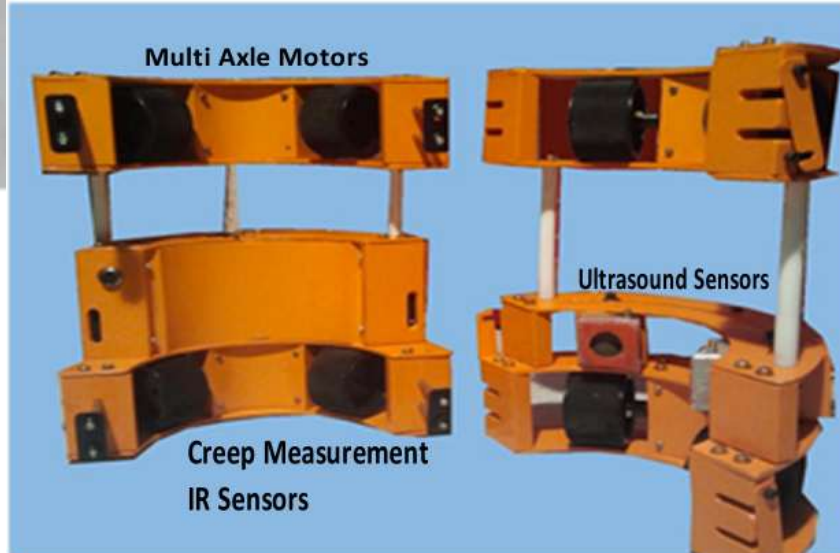
# Tube inspection by ARTiS



The crawler is powered by 4 metal gear motors, with total capacity of 200 watts.

Rubber padded shoe assembly carries the ultrasound sensors for T-R mode inspection.

IR Sensors provide diameter measurements.



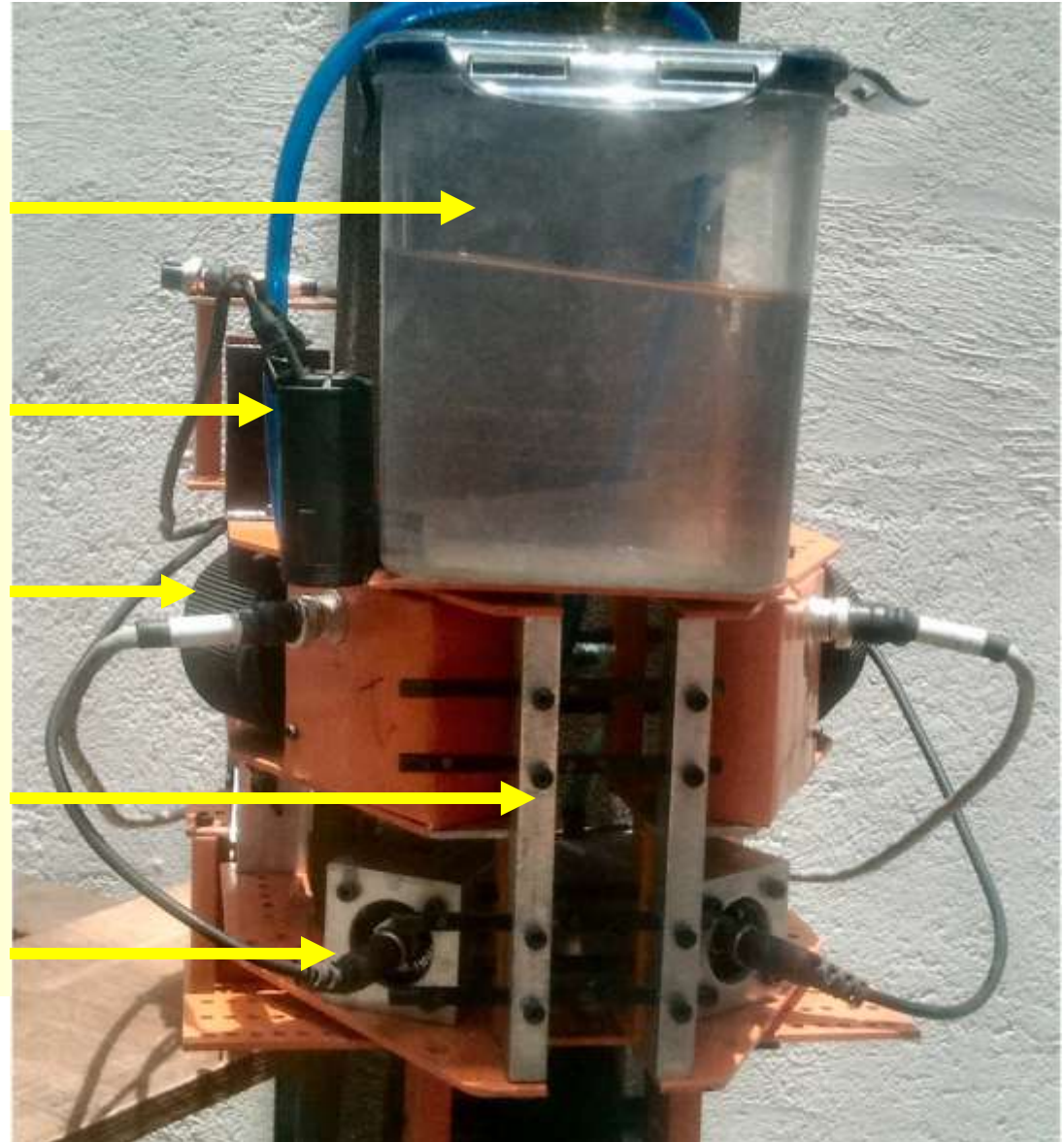
# Crawling demonstration



Video.mp4

[CLICK FOR VIDEO](#)

- Water tank for coupling
- Water pump
- Motors
- Adjustable arm
- UT Probes



# ARTiS Technical specifications

Parameter	Value
Scanning speed	2 to 5 minutes per 10 meters – adjustable
Scanning resolution	100 mm
Fixing time of Crawler	3 minutes
Flexible UT probe adjustment	Tube OD: 130 to 180 mm Tube thickness: 8 to 20 mm
Adoptability (tube outer diameter)	Minimum 125mm Maximum 195mm
Climbing height	Maximum 15000 mm
DM Water consumption	500 ml per 10 meters
Outer diameter measurements	IR Distance sensors – resolution 0.5% of OD
Tube bowing	Gyros sensors – minimum detection 5mm.
UT Probe	Diameter: 25mm Frequency: 1 MHz
Range / resolution	30 to 100 dB / 0.1 dB
Operating conditions	Max. temperature 10 to 40°C Max humidity 20 to 80 RH

# List of the clients

## **Condition Assessment with Automated UT**

- GNFC Bharuch Through: Spic India.( ARTiS)
- BPCL, refinery, Through: Radiant engineers ( ARTiS)
- Godrej industries Valia ( Manual)

## **RLA & Failure Investigation :**

CFCL Kota, Indo Gulf Jagdish Pur, GNFC Bharuch, Godrej Ltd. Valia. Althuriya, kuwait , Maden , Saudi Arabia.

## **In situ metallography**

GNFC Bharuch, GSFC Vadodara, CFCL Kota, IOCL Vadodara, BPCL Cochin, BPCL Mumbai, RIL Jamnagar, RIL Vadodara, RIL Hazira, Deepak Fertilizers, RCF Thal, VVF Ltd. Mumbai, Nirma Ltd. Vadodara, NPL Kalyan, Welspun Maxsteel Ltd. Alibaug, Maden , Saudi Arabia

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