Paresh Haribhakti

Present Affiliation & Organization	Managing Director TCR Advanced Engineering Pvt. Ltd., Vadodara
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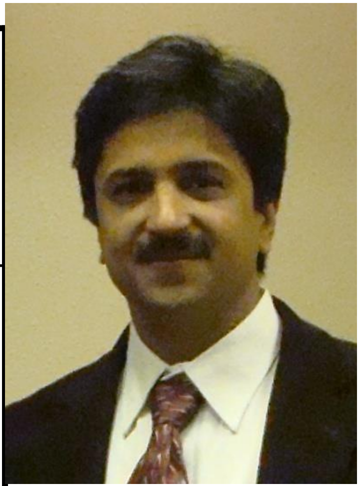
Title of paper	Root cause Failure Investigation and Remaining life assessment of Reformer tubes
Authors	Paresh Haribhakti and V. K. Bafna



Root cause Failure Investigation and Remaining life assessment of Reformer tubes

Paresh Haribhakti and V K Bafna
TCR Advanced Engineering Pvt. Ltd.,
Vadodara and Mumbai

DATA REQUIREMENT FOR LIFE ASSESSMENT

Item	Level – I	Level – II	Level – III
Feature	Least detail	More detail	Most detail
Failure history	Plant records	Plant records	Plant records
Dimensions	Design or nominal	Measured or nominal	Measured
Condition	Records or nominal	Inspection	Detailed inspection
Temperature and pressure	Design operational	Operational or measured	Measured
Stresses	Design or operational	Simple calculation	Refined analysis
Material properties	Minimum	Minimum	Actual material
Material samples required?	No	No	Yes

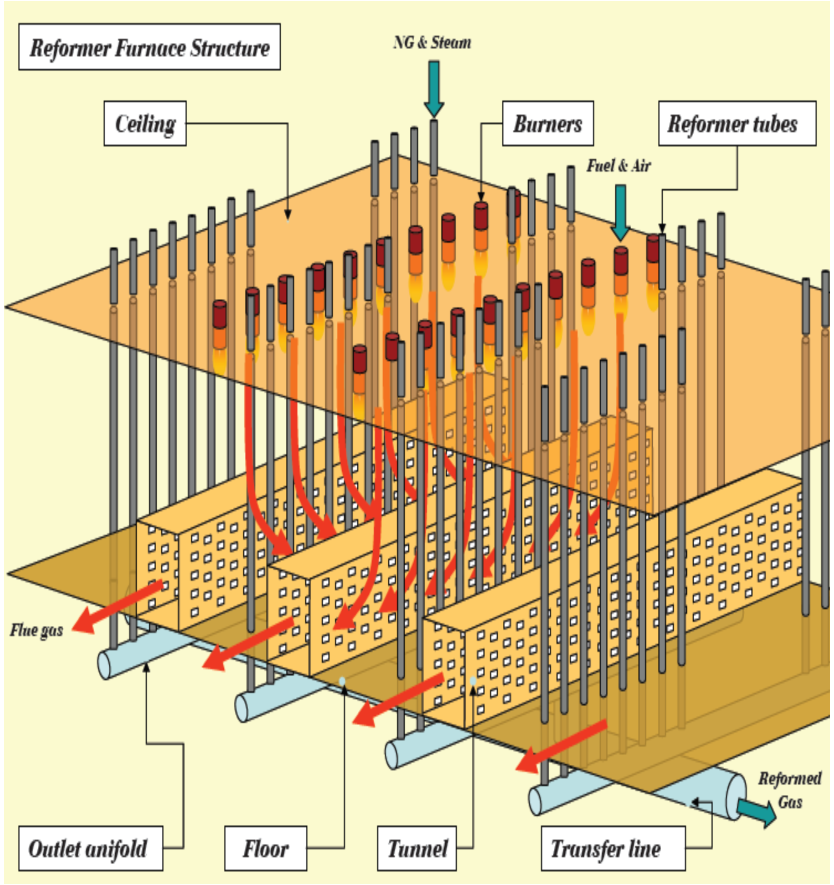
CALCULATION BASED APPROACH

Calculation procedures are often employed to determine the expanded lives of components under creep, fatigue and creep fatigue conditions. From plant records, information on temperature and cycling history is gathered. By use of standard material properties and damage rules, the fractional life expended up to a given point in time can be estimated.

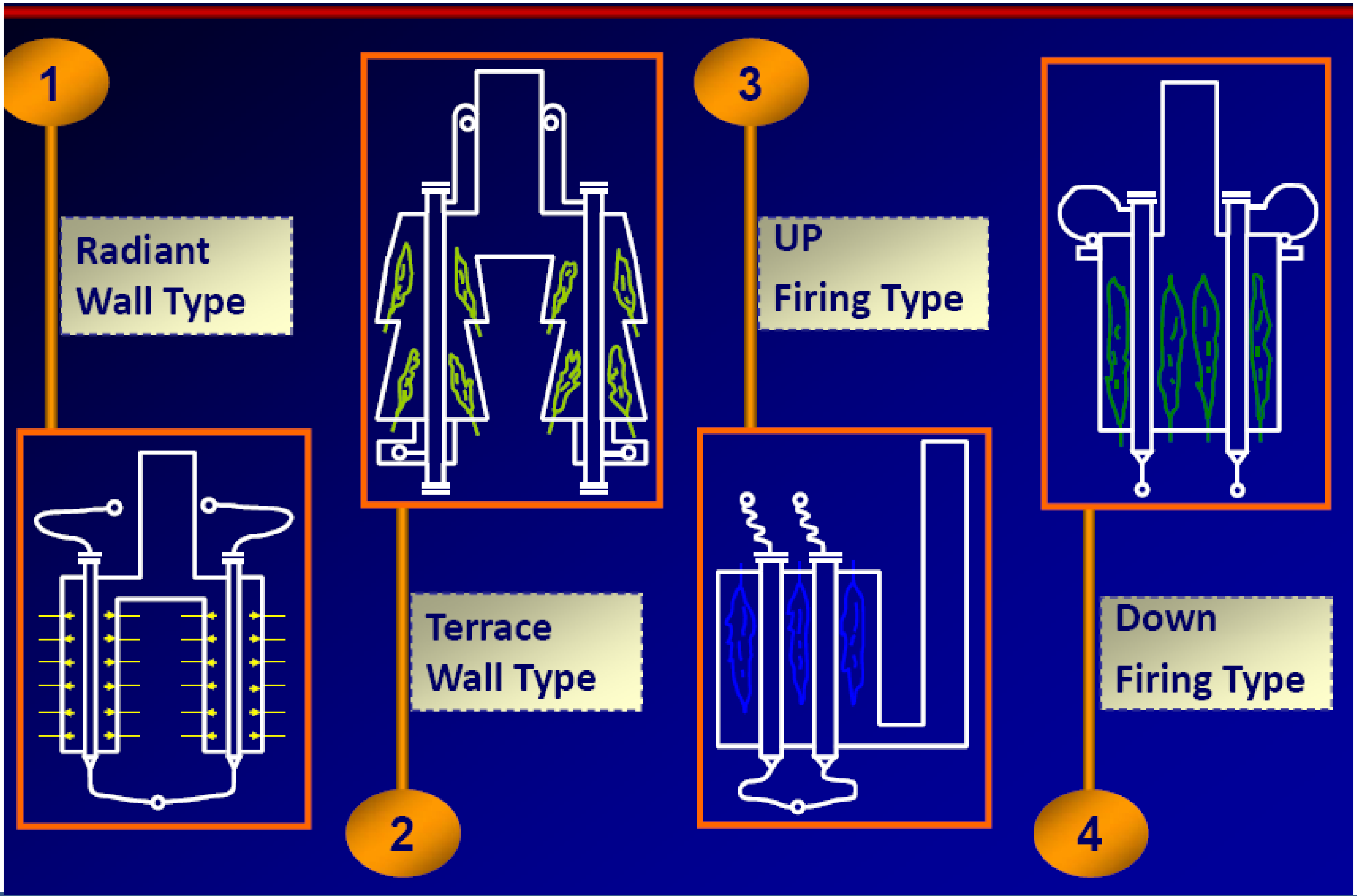
Unfortunately, histories of plant are usually not available in sufficient detail. Errors of as little as 14°C in assumed temperature and small errors in assumed stress can lead to errors.

Reformer lay out

Reformer tubes are used for cracking hydrocarbon in presence of steam to liberate Hydrogen and CO_2. Hydrogen has wide applications for chemical process. Normally, hydrogen generation requires a temperature range between 840° to 880° C under catalytic endothermic reaction. The temperature overshoot lowers the tube life.



Different firing positions



METALLURGY DEVELOPMENT

DATE	COMMON NAME	Cr %	Ni %	Nb %	OTHERS	RELATIVE STRENGTH
1960s	HK40	25	20	---	---	1.0
1970s	[illegible]	25	24	1	---	1.4
Early 80s	BST	23	22	1	Ti	1.7
Mid 80s	HP – BST	25	35	1	Ti	1.9
Late 80s	HP Micro-alloy	25	35	1	Ti, Zr, W, Cs	2.2

03. AAP TO AISE NA THE

Table III Nominal composition and mean stress to rupture in 100,000 hours for those heat resistant cast alloys most commonly used in refining and petrochemical applications

	Nominal Composition				Rupture Stress, psi		
Grade	C	Cr	Ni	Other	1600F (871C)	1800F (982C)	2000F (1093C)
HK40	0.4	25	20		2700	1200	450
HP-45 Nb	0.45	25	35	Nb 1.5	4300	1750	460
HP-45 Nb MA	0.45	25	35	Nb 1.5, Ti, Zr	4700	1850	460
HP-45Nb W	0.45	25	35	Nb 1.5, W 1.5	4400	1850	500
HP-45W	0.45	25	35	W 4	4200	1450	420
HP-45Mo	0.45	25	35	Mo 1.5	3400	1750	500
45Ni-35Cr,MA	0.45	35	45	Nb 1.5, Ti, Zr	4500	1700	600
HP-15Nb	0.15	25	35	Nb 1.5	3500	1500	300

MA=Micro-alloyed

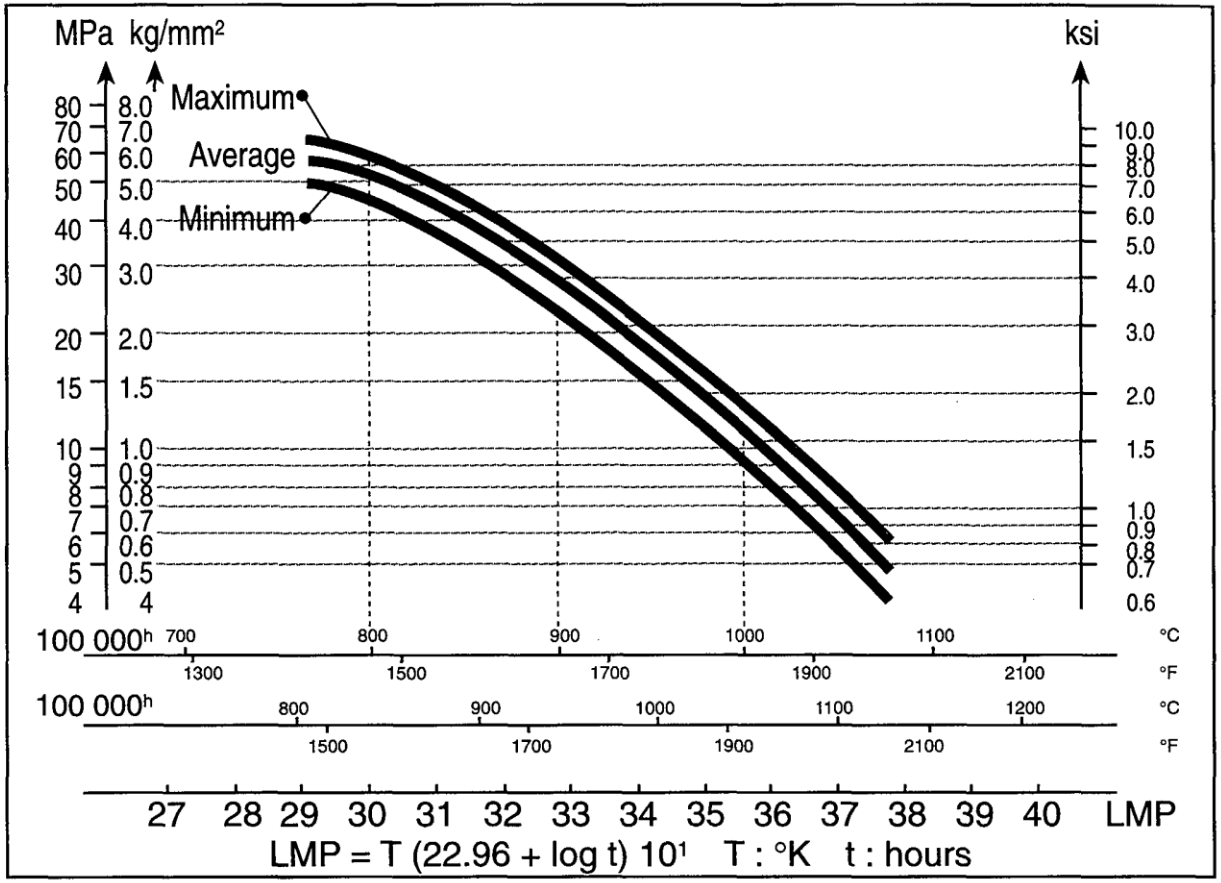


Figure 1 One manufacturer's format for presenting creep-rupture data for a centrifugally cast heat resistant HP-type alloy. (LMP = Larson-Miller Parameter). Source: Manoir Industries

Common damage mechanism observed in Reformer tube

- 1. Overheating (Cumulative)
- 2. Thermal Cycling (cyclic operation)
- 3. Tube Bending (improper counter weight balance
- for tube linear will increase stress on tube)
- 4. Thermal shock
- 5. Stress Corrosion Cracking

Common cause of the over heating

- **Temperature Increase To Maintain Yield When Catalyst Becomes**
- **Less Active. 1**
- **2 Feedstock Or Steam Supply Failure**
- **3 The Absence Of Cooling Effect Of The Endothermic Reaction**
- **4 Burner Misalignment Can Result In Over Temperature**
- **5 Restricted Flow Of Process Due Catalyst Choking**

- **Through Wall Stresses are Temporarily Increased during start up and shut downs**
- **Tube Wall Temperature Gradients Can Be Significant**
- **During Operation , The Stress Produced By Different Expansion Relaxes Through Creep**
- **Temperature Changes Up Down Will Reintroduce Some Stress**

- **Creates Extremely High Stresses As The Tube Attempts To Contract Under Restraint .**
- **Sudden heating or cooling**
- **Can Occur Through Boiler Water Carry Over On Inside The Tubes**

Non destructive methods for damage evaluation

- **Dimensional changes; diameter and wall thickness due to creep**
- **Replica metallography; spot check for micro structural changes due to overheating and some times creep damage**
- **Radiography; large voids and micro cracks**
- **Eddy current; chromium migration due overheating and conductivity changes**
- **Ultrasonic; attenuation and scattering**
- **New techniques such as LOTIS and IESCO ‘H’ SCAN**

To undertake a furnace life assessment the following input information is required …

- **Furnace design drawings / material records / Operation**
- **history (turn-around and process conditions)**
- **Process temperature and pressure records as available**
- **Tube samples for material specific assessment**
- **Appropriate NDT techniques data**

Parameter to Monitor	Dimensioning	UT	RT	Eddy Current
Creep Strain	√	x	x	√
Damage under 30% Thickness	x	x	x	√
Sever damage >30% Thk.	x	√	√	√
Wall Thickness reduction	x	√	√	x

Severity Classification (Statistics based on general Reformer Tube grade material)

Class - 1	Class - 2	Class - 3	Class - 4	Class - 5
Sound Metal (in as cast condition)	Creep Voids Micro Fissures Inner Wall	Aligned voids & fissures between ID & mid-wall	Voids & creep Fissures mid-wall to OD, greater	Macro cracking with > 75% through wall thickness
No Damage	Slight Damage	Moderate Damage	Severe Damage	Critical Replacement needed
When found ? Before commissioning	After 40% Life.	After 55% Life	After 75% Life	After 100% Life
Class - 1	Class - 2	Class - 3	Class - 4	Class - 5

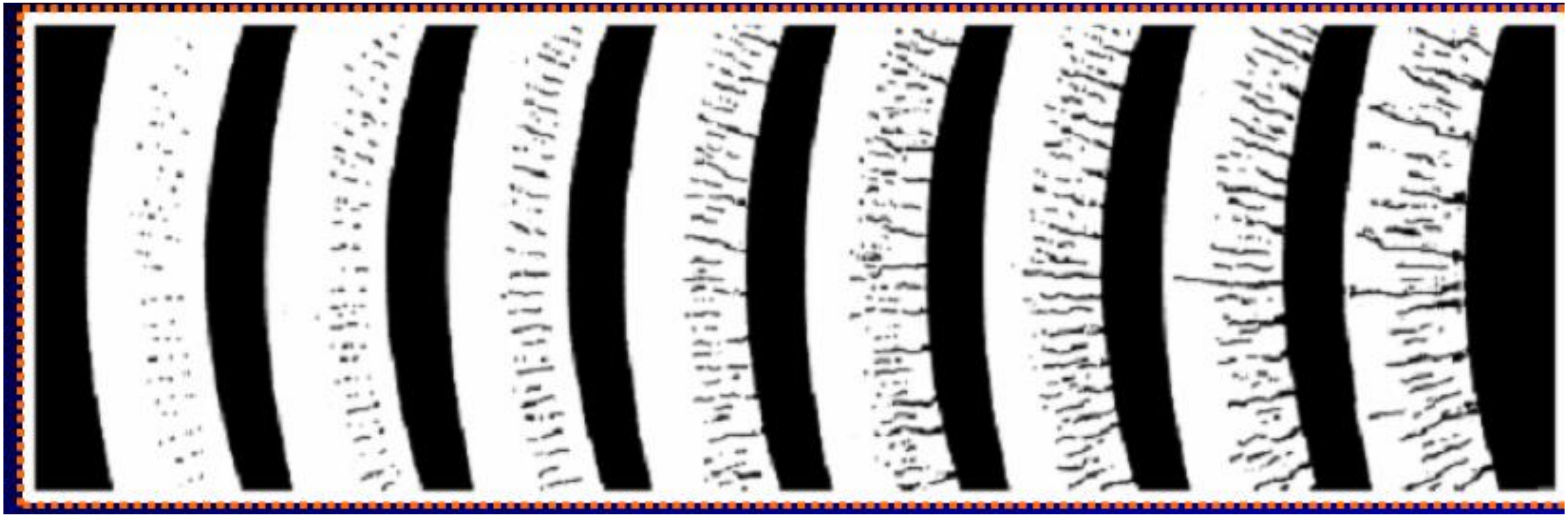


Figure 1. Steam methane reformer, typical for hydrogen production

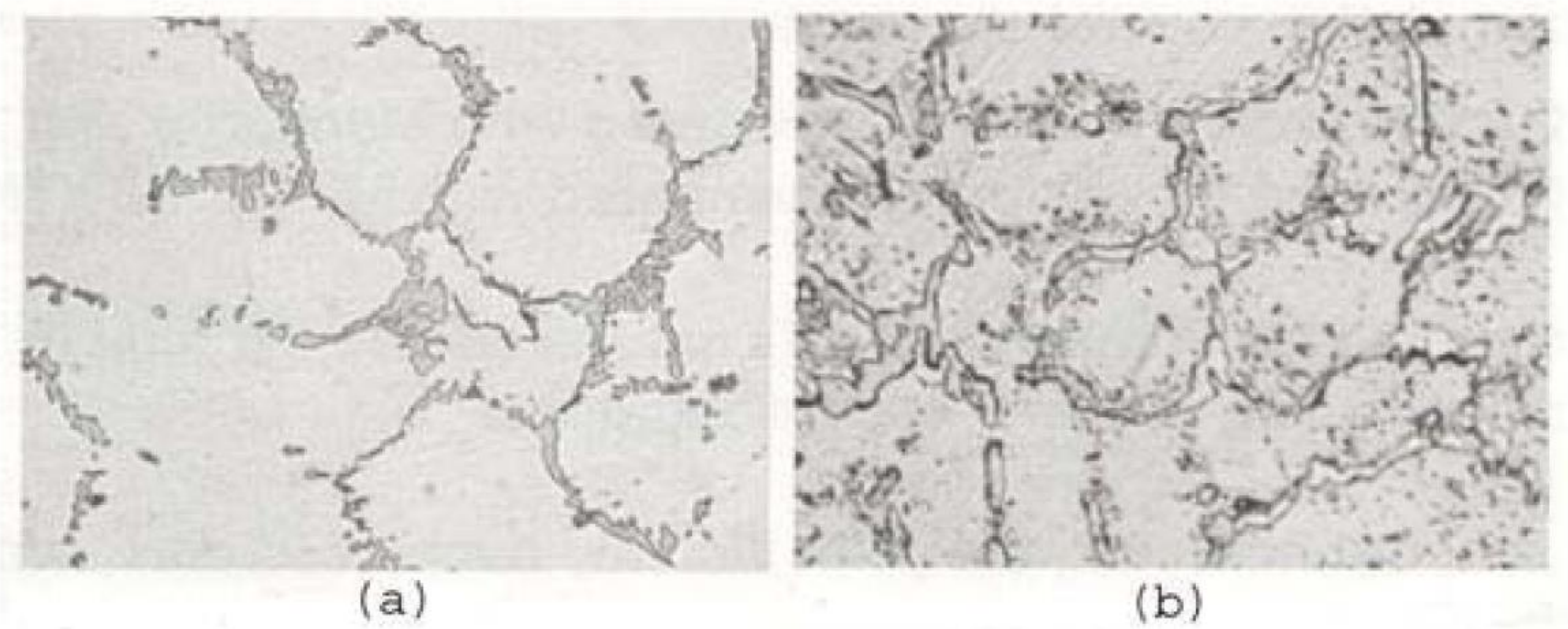
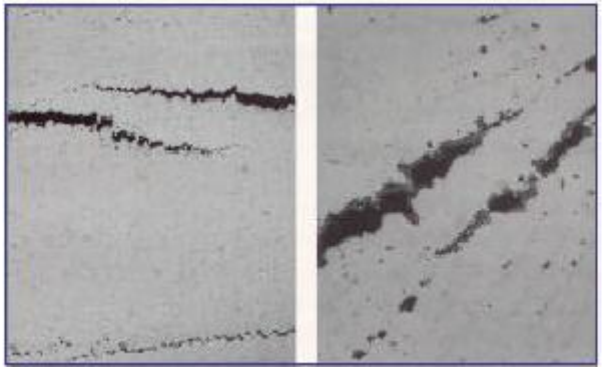
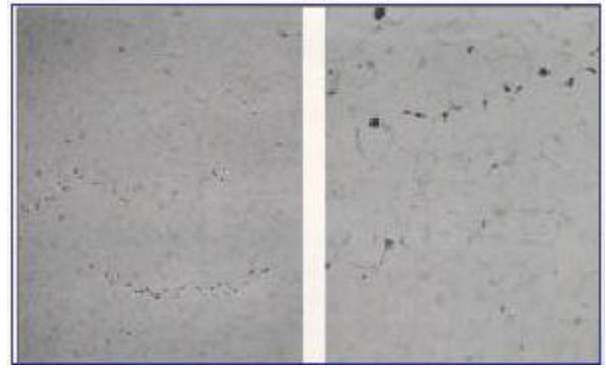


Figure 2. (a) Primary Carbides, (b) Primary and Secondary Carbides

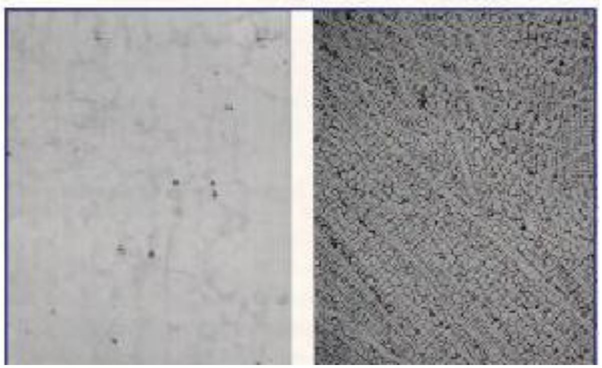
Micrograph of 0.4m test coupon sections
(Magnification: x 50 / 200)



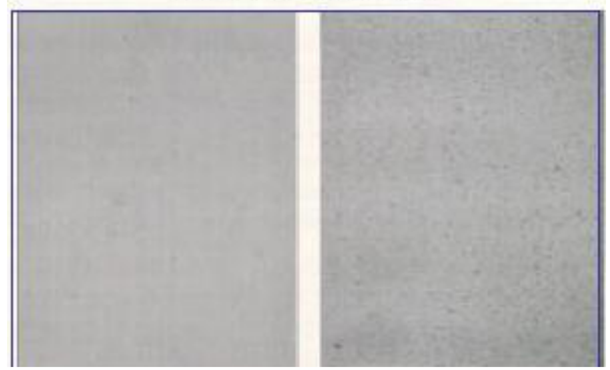
Micrograph of 1m test coupon sections
(Magnification: x 50 / 200)



Micrograph of 7m test coupon sections
(Magnification: x 50 / 200)



Micrograph of 11m test coupon sections
(Magnification: x 50 / 200)



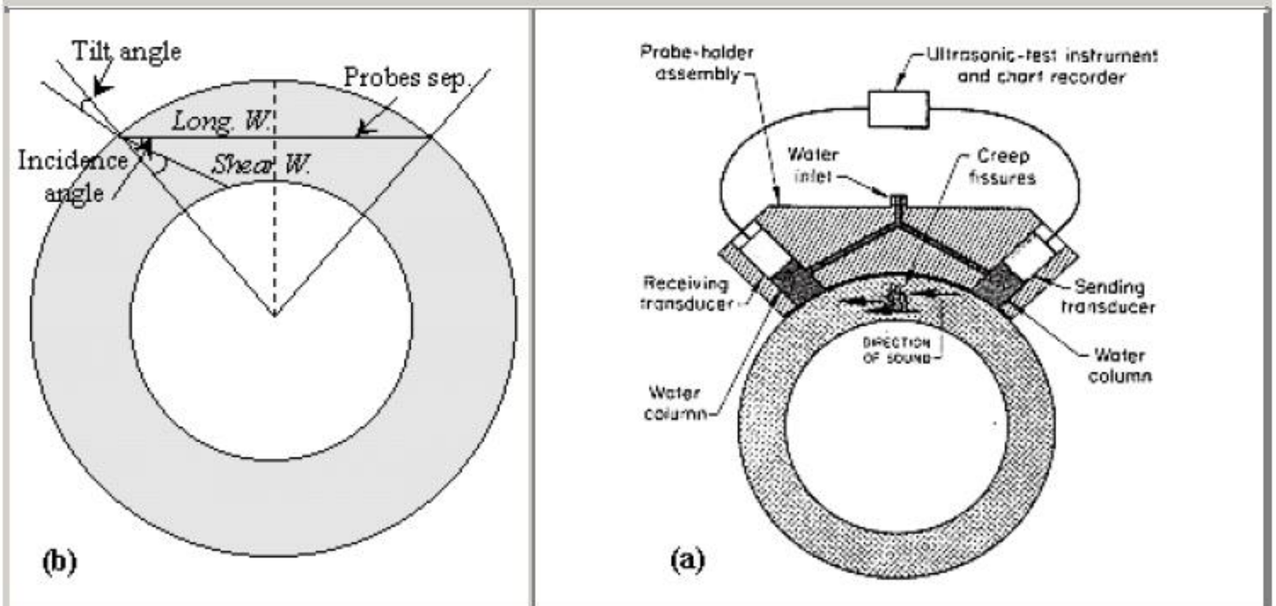
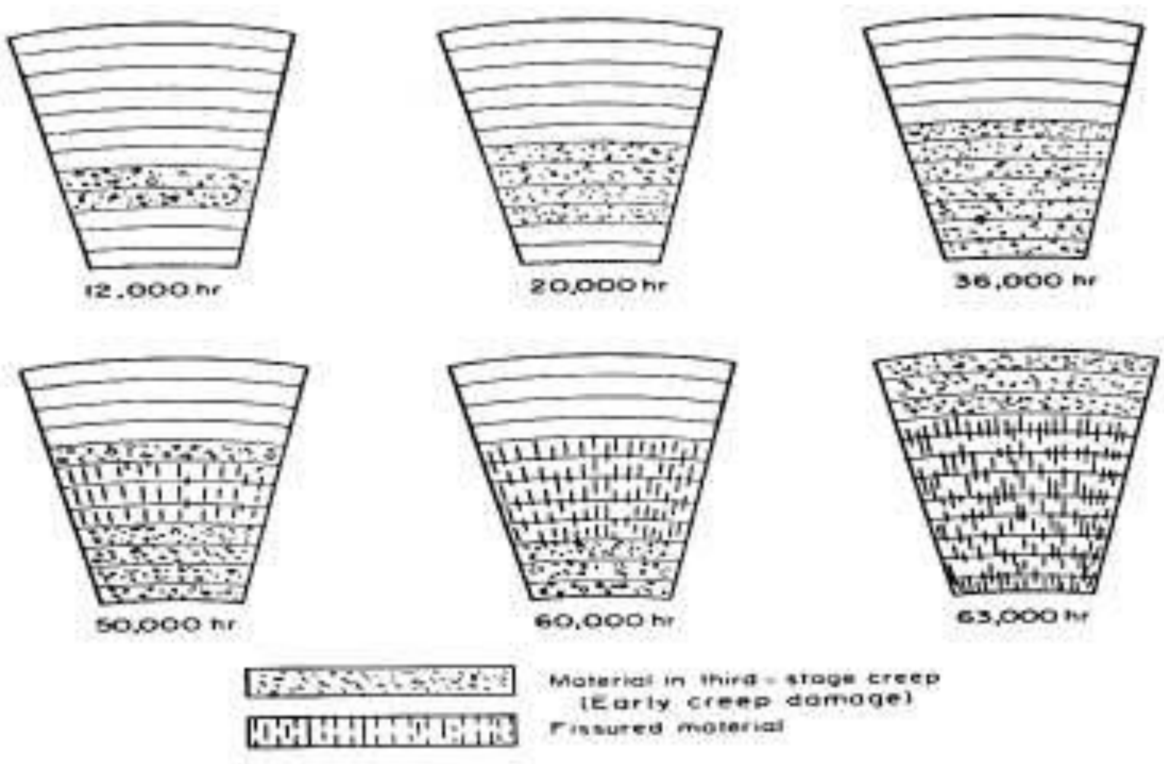
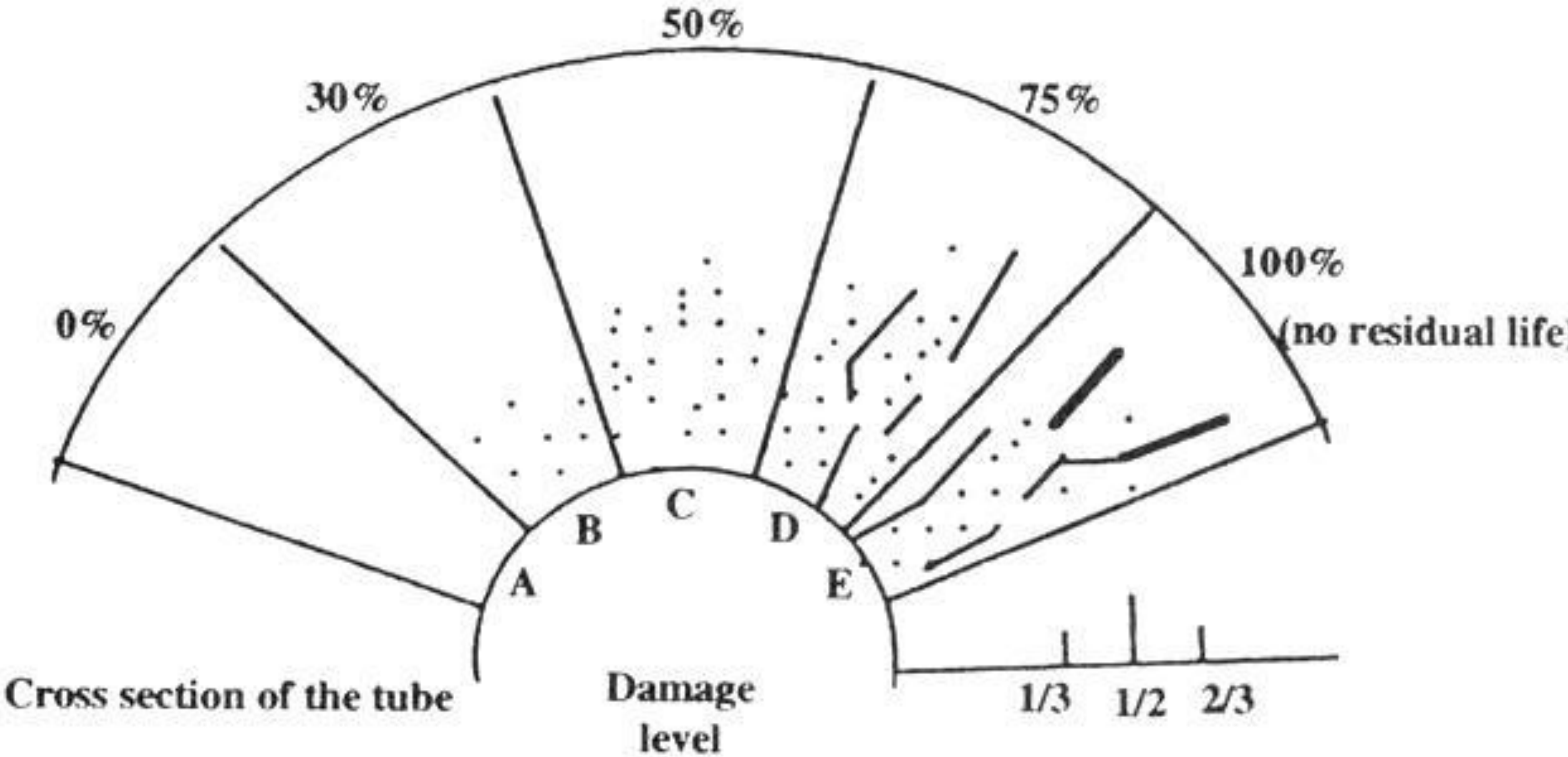
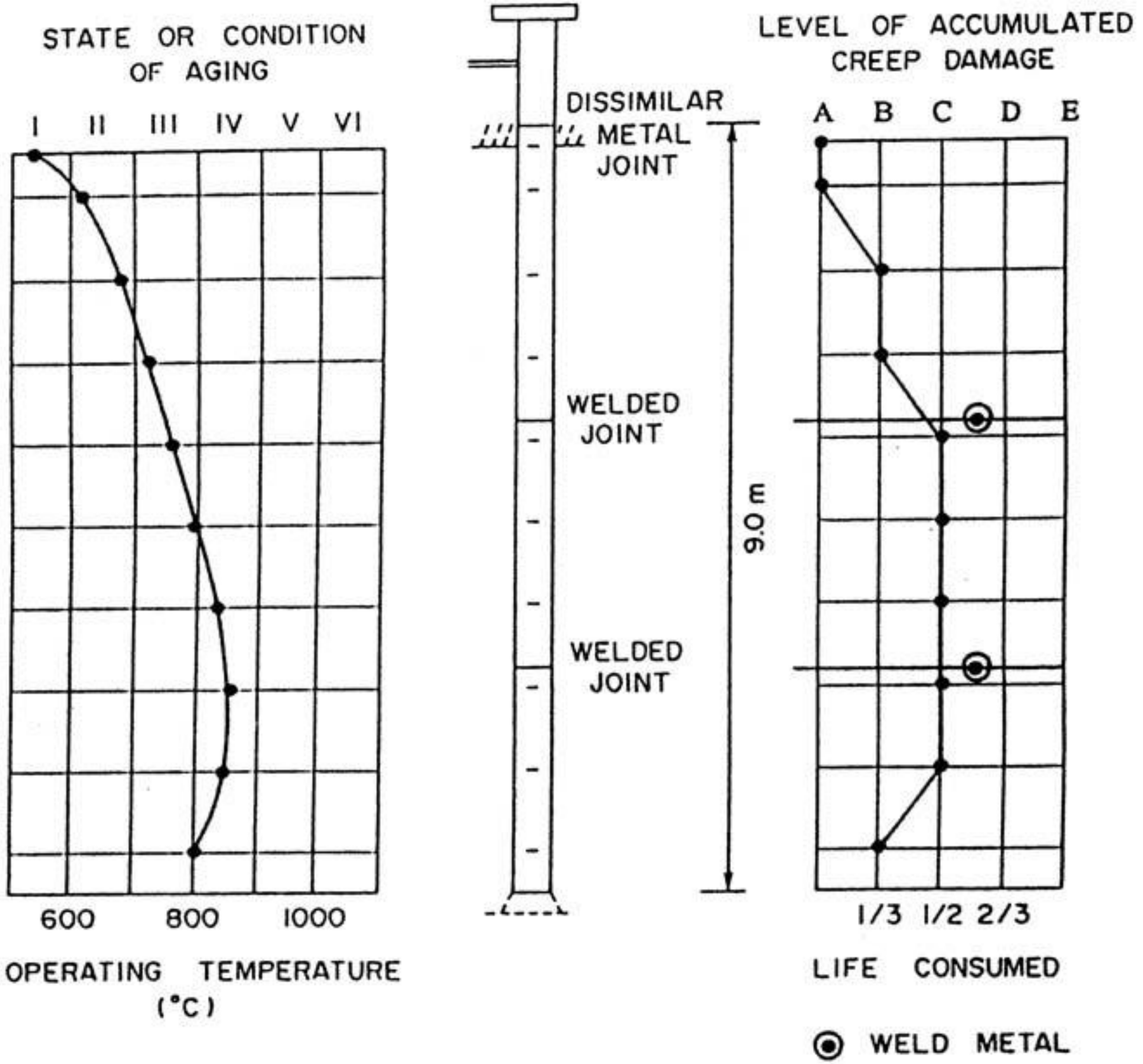
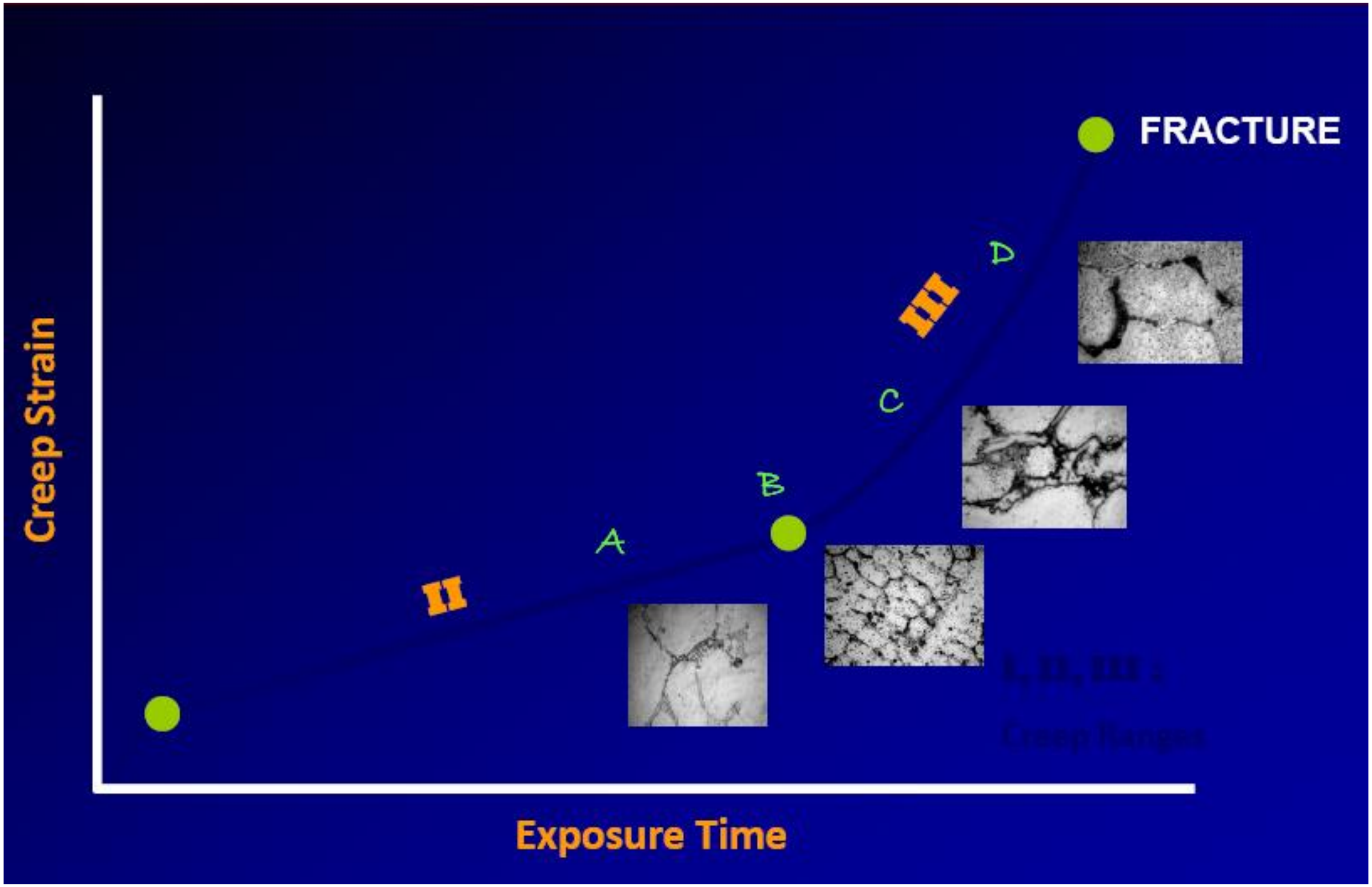


Fig 2: Scheme of ultrasonic method for detection of creep damage: a) inspection device for in-service inspection; b) fundamentals of the UT technique for reformer tubes inspection[4]


12,000 hr
20,000 hr
36,000 hr
50,000 hr
60,000 hr
63,000 hr
Material in third - stage creep
(Early creep damage)
Fissured material


50%
30%
75%
0%
100%
(no residual life)
A
B
C
D
E
Cross section of the tube
Damage
level
1/3
1/2
2/3


STATE OR CONDITION OF AGING
I
II
III
IV
V
VI
600
800
1000
OPERATING TEMPERATURE (°C)
DISSIMILAR METAL JOINT
WELDED JOINT
WELDED JOINT
9.0 m
LEVEL OF ACCUMULATED CREEP DAMAGE
A
B
C
D
E
1/3
1/2
2/3
LIFE CONSUMED
WELD METAL


FRACTURE
D
III
C
B
A
II
Creep Strain
Exposure Time

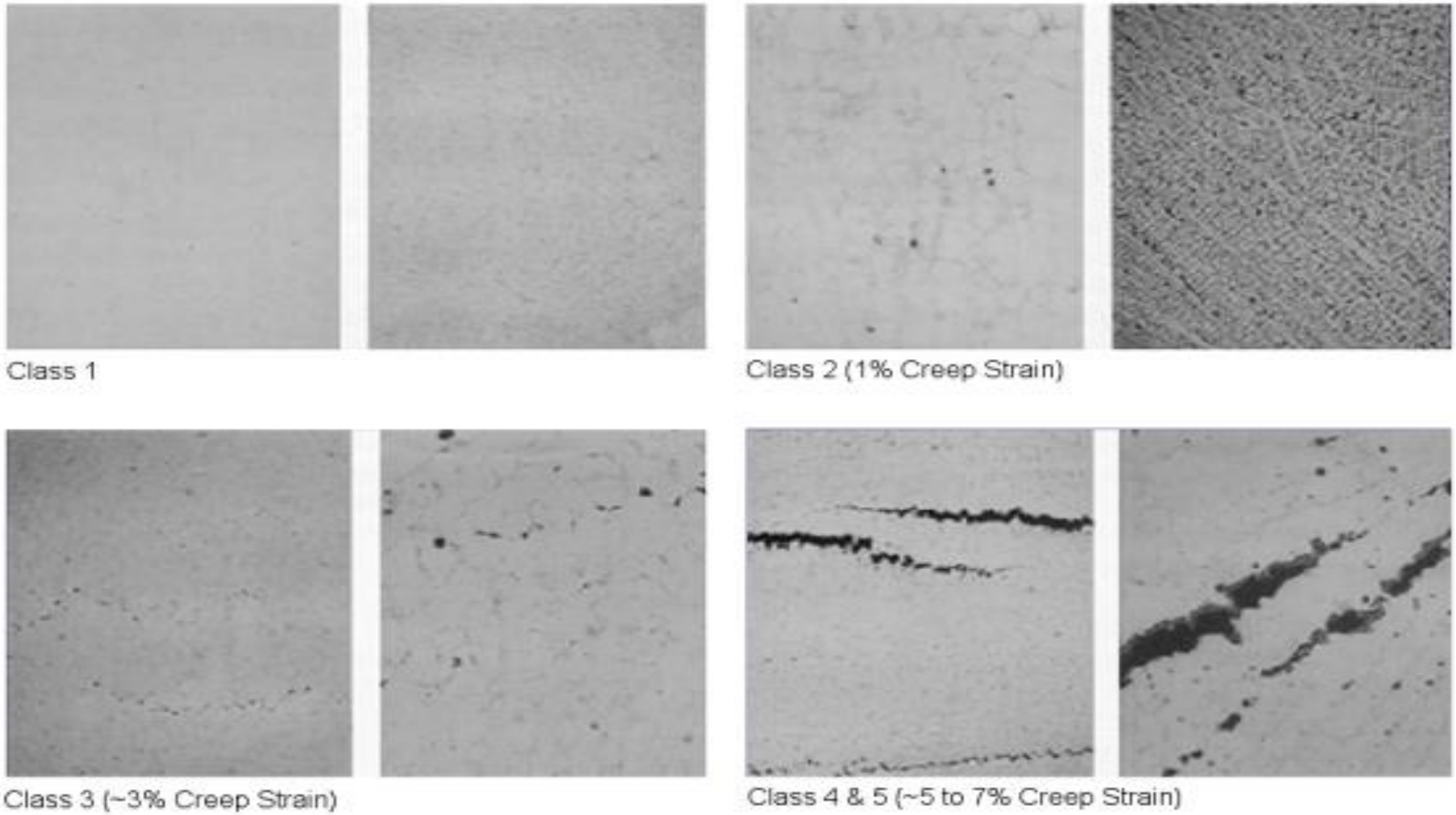


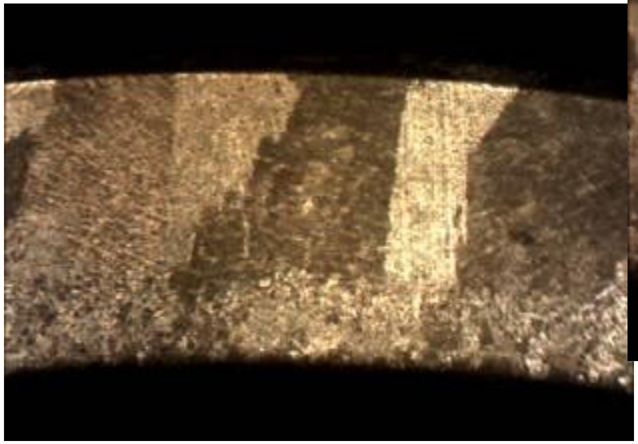
Figure 3: Classification based on Metallorgraphy

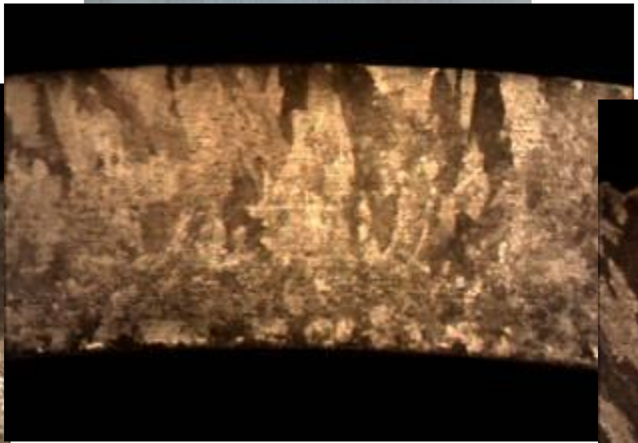
Macrostructure Examination

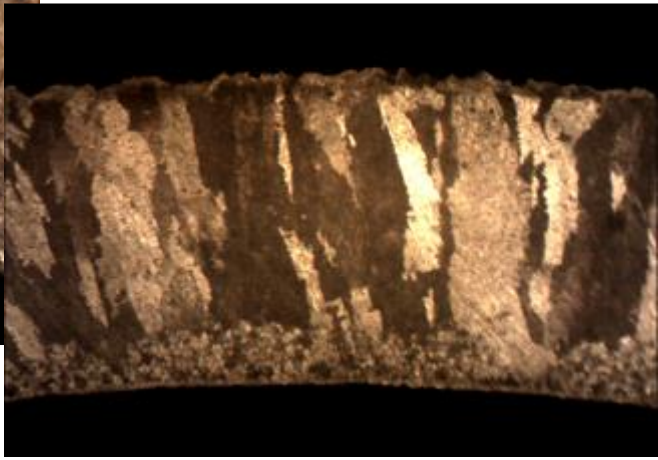
TOP

MIDDLE

BOTTOM





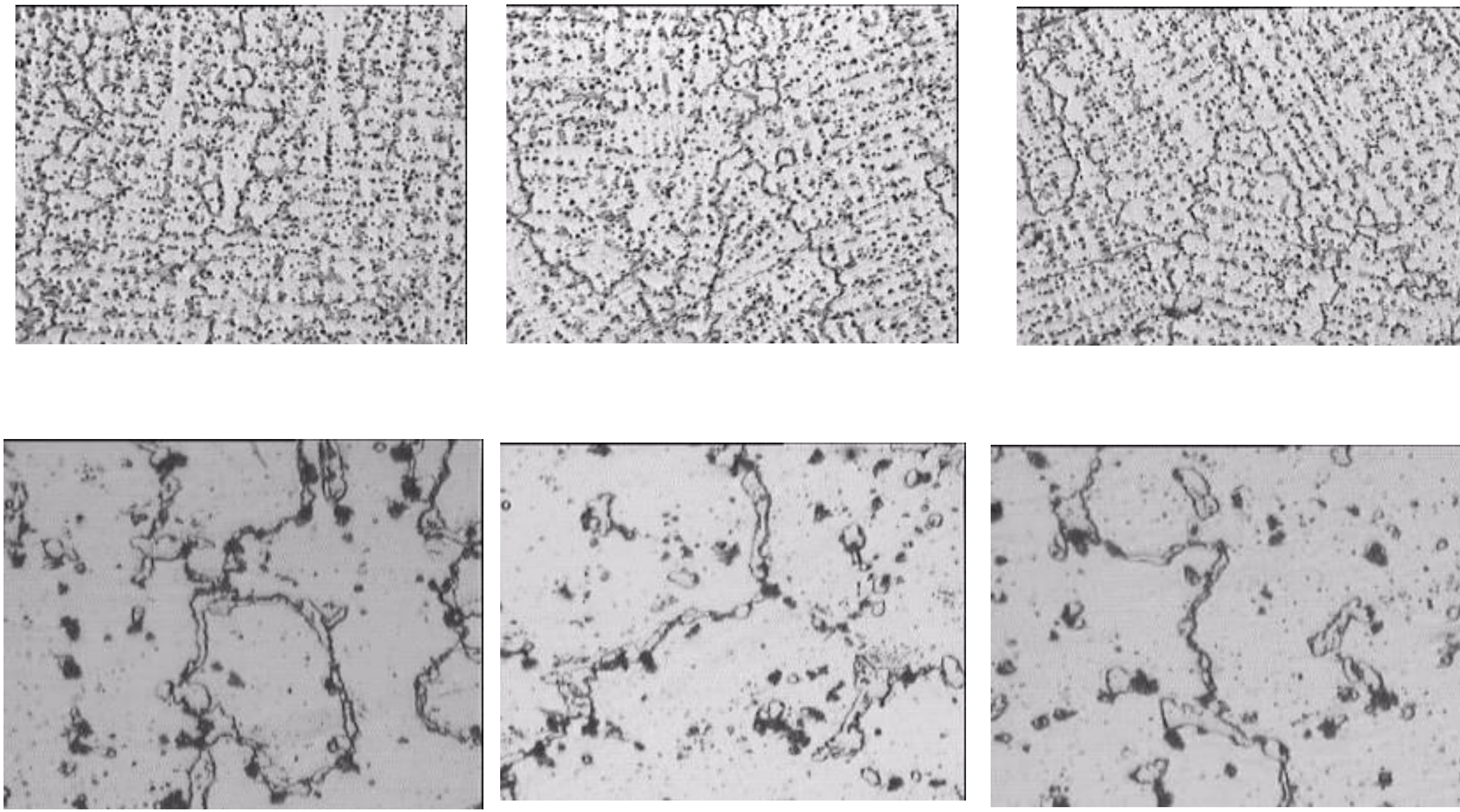


Microstructure Examination

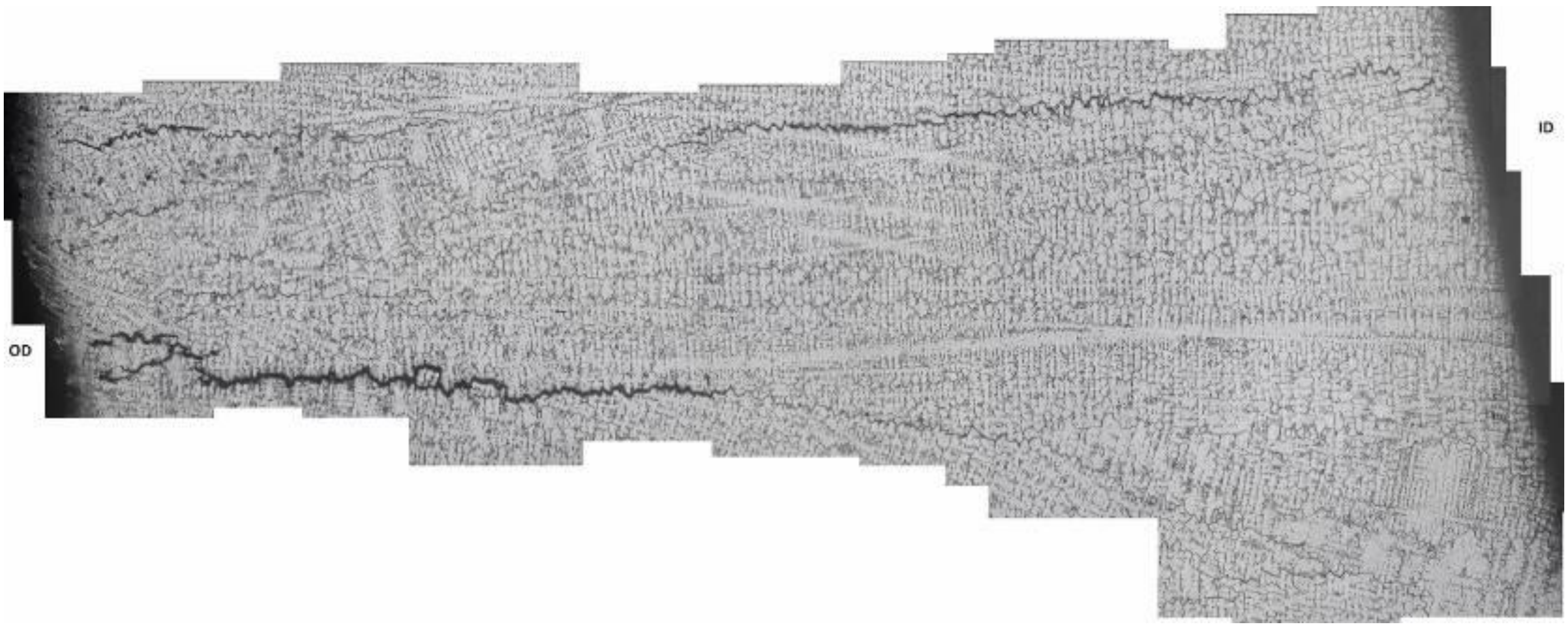
TOP MIDDLE BOTTOM

100X

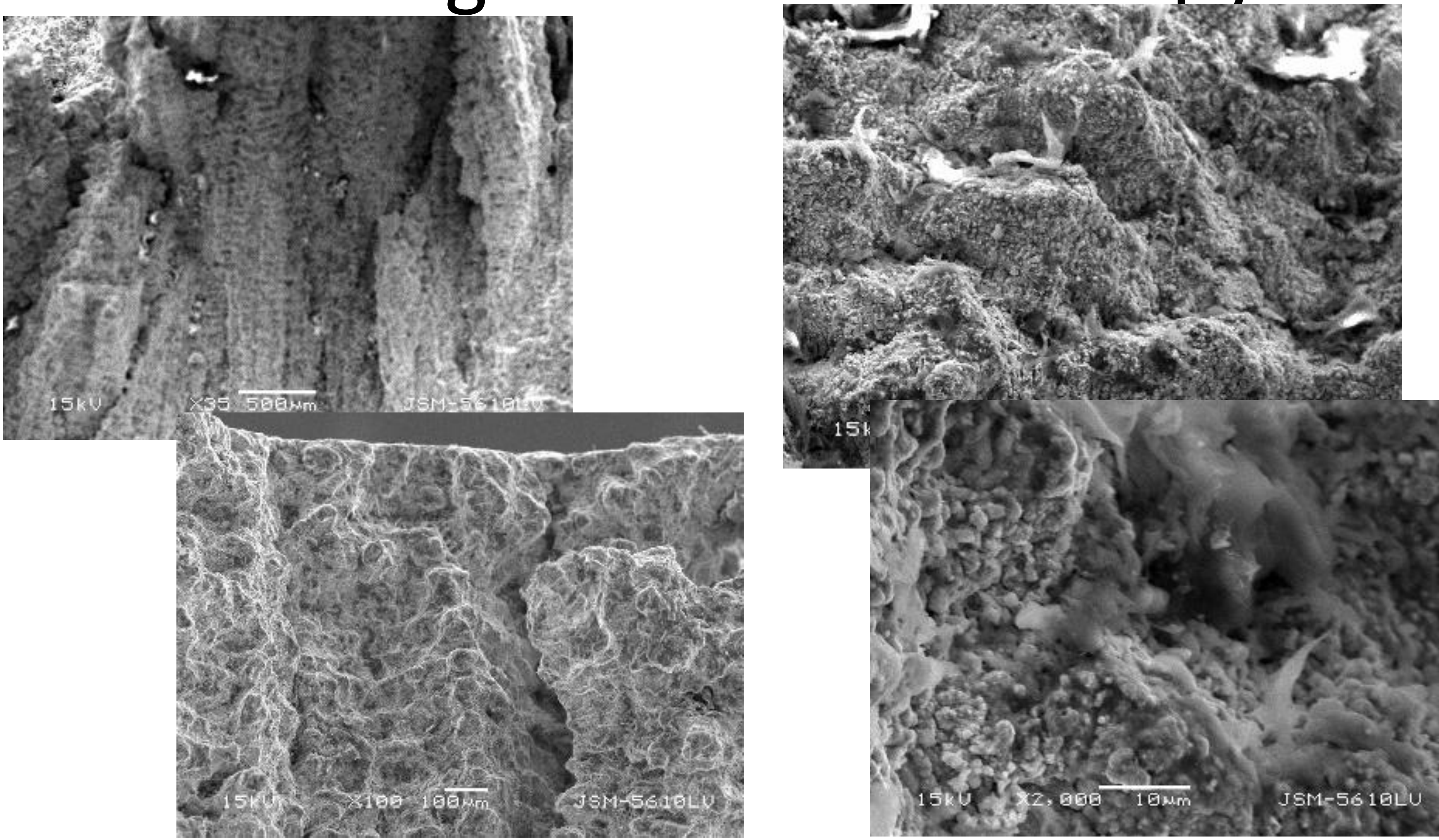
400X



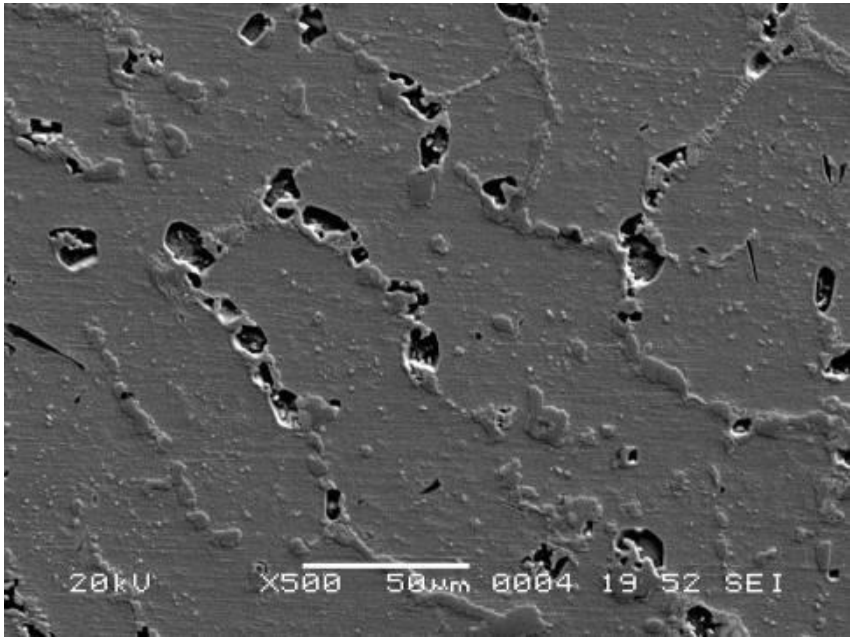
Panoramic view of crack at OD to ID

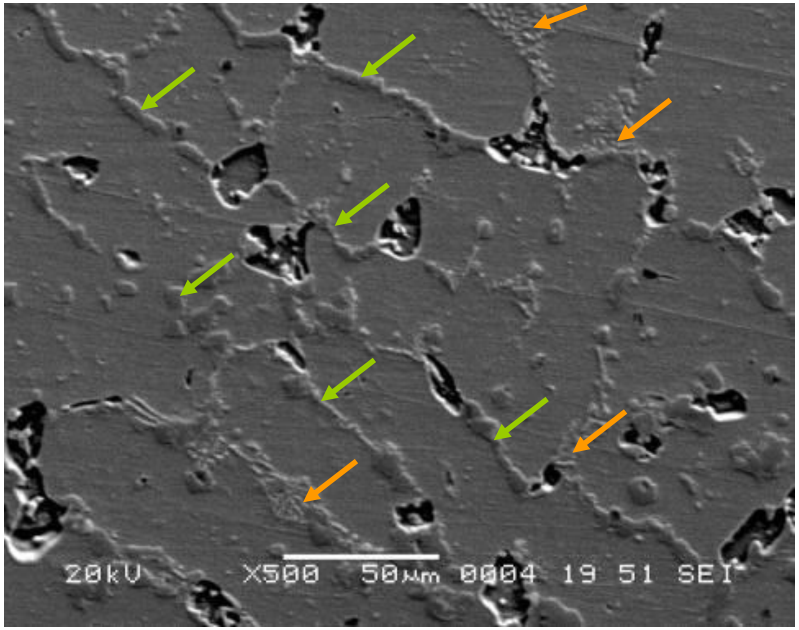


Scanning Electron Microscopy



IN 519 modified tube





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