Risk Based Inspection of Pressure Equipment in Anglo American

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Anglo American

Anglo Field Services

Order of Presentation

- Current inspection approach
- Comparison of MHSA & OHSA Regulations
- Risk Based Inspection
  - Overview
  - Process
  - Outcome
- Benefits of RBI
- Intention

Current Pressure Vessel Inspections

- In-service inspection:
  - traditionally been driven by prescriptive regulatory requirements
  - fixed locations, fixed frequency (calendar-based)
  - fixed methods of inspection (pressure test & visual)
  - No encouragement to analyse:
    - threats to structural integrity
    - consequences of failure
    - risks created by each item of equipment

- **Do we inspect what needs to be inspected?**

Comparison – MSHA & OHSA

MHSA Requirements	OHSA Requirements
• PV's – kPa(g) x m^3 < 30 • Inspected before use only – kPa(g) x m^3 > 30 • Annual Internal & External Examination • Pressure test to 1.3 DP 2-yearly	• PV's – Everything > 50 kPa(g) • Internal & External Examination 3-yearly • Pressure test to 1.25DP 3-yearly or – Implement Risk Based Inspection Management system

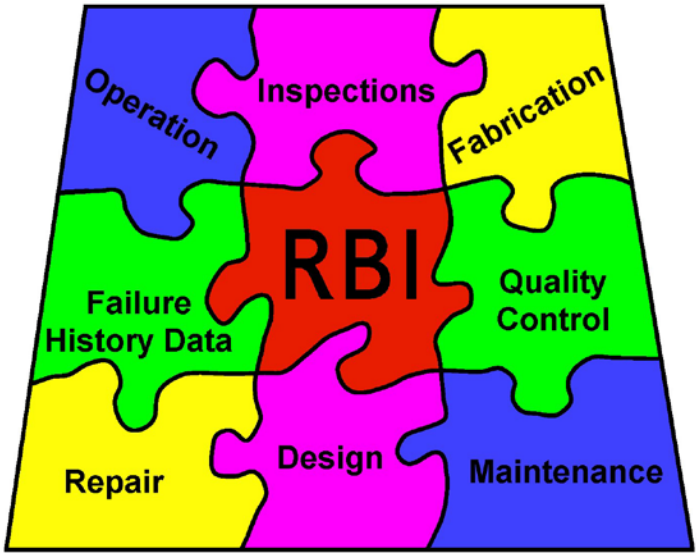
Comparison – MSHA & OHSA

MHSA Requirements	OHSA Requirements
• Piping – No defined requirements	• Piping – Implement Risk Based Inspection Management system
• Tanks – No defined requirements	• Tanks – If DP > 50kPa(g) then PV – Implement Risk Based Inspection Management system

Draft MHSA PV Regulations are similar to OHSA PER

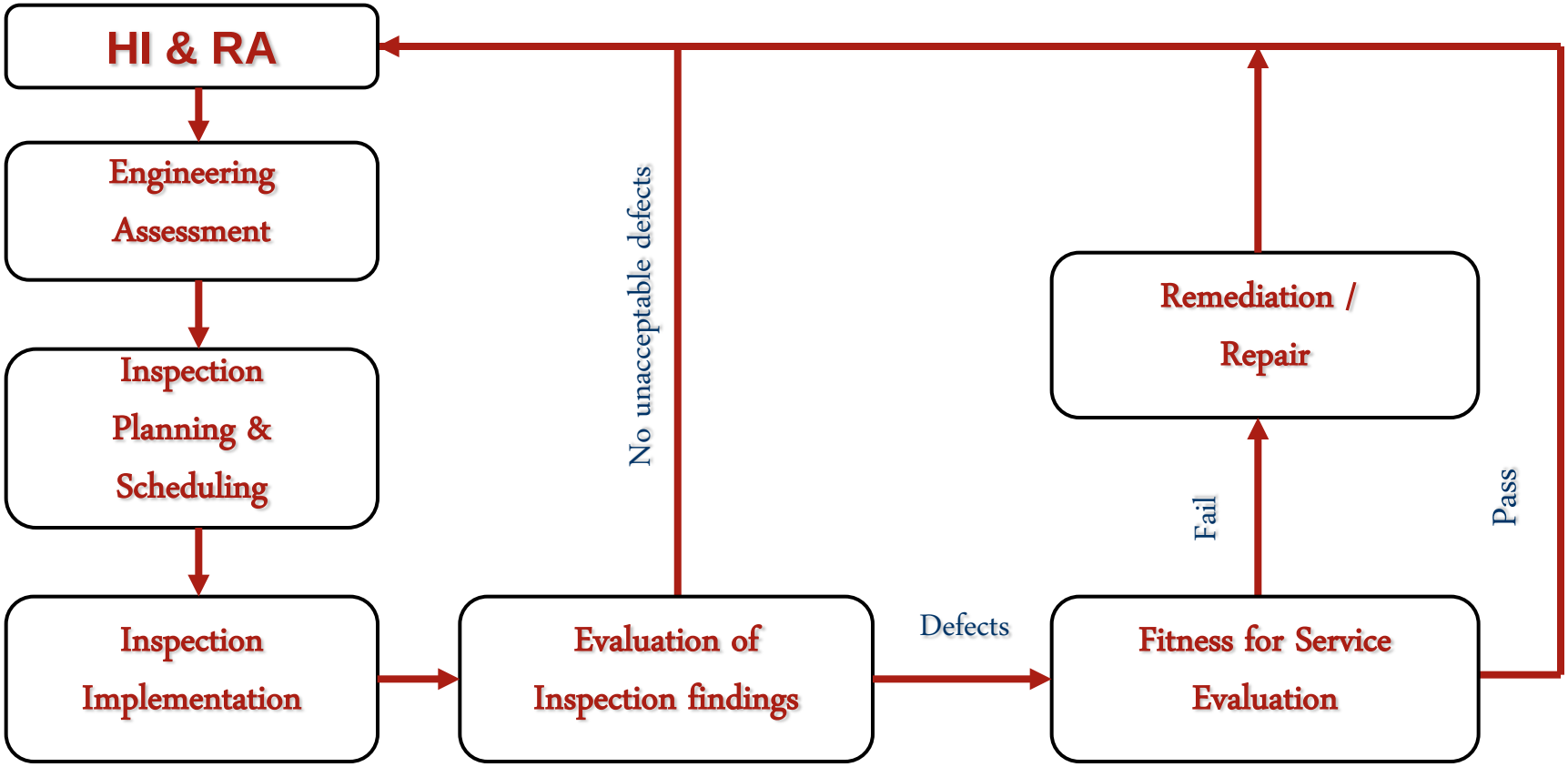
Risk Based Inspection – Best Practice

- Inspection strategies based on risk of failure and consequences.
- WSE developed for each vessel / piping
- Combination of various inspection technologies
- Engineering assessment of all inspection results
- Intervals set according to current condition
- Continued Fitness-for-Service assessments



RBI Process

- RBI is a combination of the following processes:



RBI Process

HI & RA

- RA Team:
  - RBI Specialist / Engineer
  - Plant Management
  - Maintenance / operating personnel
  - Inspection personnel

Plant Item Number	Vessel Description	Safety Risk Rating	Enviro Risk Rating	Fin Risk Rating	Risk Rating
K-AB-CRU-498-VS-001	Matte & Reverts Transfer Vessel No. 1	10	8	11	11
K-AB-CRU-498-VS-002	Matte & Reverts Transfer Vessel No. 2	10	8	11	11
K-AB-DRY-492-VS-001	F/D No. 1 Dry Conc. Transfer Vessel No. 1	10	8	11	11
K-AB-DRY-492-VS-002	F/D No. 1 Dry Conc. Transfer Vessel No. 2	10	8	11	11
K-AB-DRY-493-VS-006	F/D No.1 Sand Cleaning Transfer Vessel	8	8	10	10
K-AB-DRY-492-VS-004	F/D No.1 Sand Cleaning Transfer Vessel	8	8	10	10
K-AB-DRY-492-VS-005	F/D No.1 Sand Cleaning Transfer Vessel	8	8	10	10
K-AB-DRY-492-VS-003	Plant Air / Instr. Air Receiver	8	8	10	10

Unit	Equipment Description	Safety Risk Rating	Environ Risk Rating	Finance Risk Rating
	75' Thickener Tank	5	9	11
	Larox Feed Tank	5	8	10
	Spare Stack	5	8	10
	UG2 Browns Tank	6	8	10
	UG2 Goldfields Tank	5	8	10
	Merensky Goldfields Tank	5	8	10
	Slag Goldfields Tank	6	8	10

RBI Process

HI & RA

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Engineering Assessment

- RBI Specialist / Engine

Required Thickness, MAWP & Stress Calculations

Circumferential Stress (Longitudinal Joints):

$$t_{cmin} := \frac{P \cdot R_c}{S \cdot E - 0.6 \cdot P} \qquad t_{cmin} = 11.979$$

$$MAWP_c := \frac{S \cdot E \cdot t_c}{R_c + 0.6 \cdot t_c} \qquad MAWP_c = 2.379$$

$$\sigma_{cm} := \frac{P}{E} \cdot \left(\frac{R_c}{t_c} + 0.6 \right) \qquad \sigma_{cm} = 88.653$$

Longitudinal Stress (Circumferential Joints):

$$t_{lmin} := \frac{P \cdot R_c}{2 \cdot S \cdot E + 0.4 \cdot P} \qquad t_{lmin} = 5.895$$

$$MAWP_1 := \frac{2 \cdot S \cdot E \cdot t_c}{R_c - 0.4 \cdot t_c} \qquad MAWP_1 = 4.871$$

$$\sigma_{lm} := \frac{P}{2 \cdot E} \cdot \left[\frac{R_c}{\left(t_c - t_{sl} \right)} - 0.4 \right] \qquad \sigma_{lm} = 43.306$$

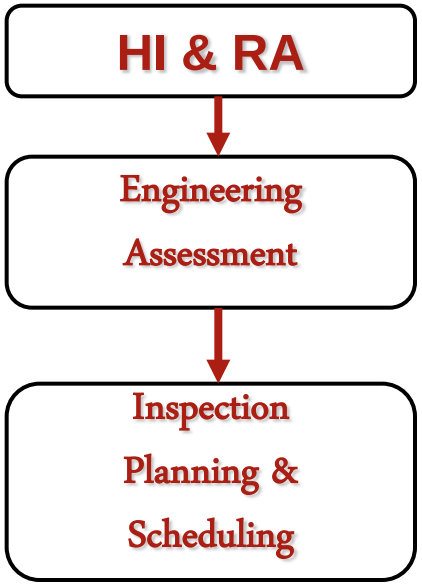
Final Values including Par. UG16 (b) check:

$$t_{min} := \begin{bmatrix} t_{cmin} \\ t_{lmin} \end{bmatrix} \qquad t_{min} := \max(t_{min}) \qquad t_{min} = 11.979$$

$$MAWP := \begin{bmatrix} MAWP_c \\ MAWP_1 \end{bmatrix} \qquad MAWP := \min(MAWP) \qquad MAWP = 2.379$$

$$\sigma_{max} := \begin{bmatrix} \sigma_{cm} \\ \sigma_{lm} \end{bmatrix} \qquad \sigma_{max} := \max(\sigma_{max}) \qquad \sigma_{max} = 88.653$$

RBI Process



- RBI Specialist / Engineer
- Site personnel
- Inspection personnel

- ***Written Scheme of Examination***

showing what & how it should be inspected.

Feature	*Inspection Type*	*Inspection Scope*
Shell	B-Scan External	4 longitudinal wall thickness profiles. 2 circumferential wall thickness profiles. Original wall thickness = 12 mm. Minimum allowable wall thickness = 11.8 mm.
Dished End	B-Scan External	2 circumferential wall thickness profiles (as an alternative a minimum of 8 point thickness measurements). Original wall thickness = 17 mm. Minimum allowable wall thickness = 7.9 mm.
Nozzles	Point Thickness	4 thickness measurements on each of the nozzles.
Shell welds	Surface Eddy Current	10% of all longitudinal welds. 10% of all circumferential welds. Alternative method of inspection – Magnetic Particle Inspection
Bolts	Visual External	Inspect bolts for tightness and corrosion.
Shell	Visual External	General condition of shell and attachments. Special attention to be given to welded attachments and condition of paint at the welds.
Supports	Visual External	General condition of support structures, concrete and steel.

RBI Process

HI & RA

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Engineering Assessment

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Inspection Planning & Scheduling

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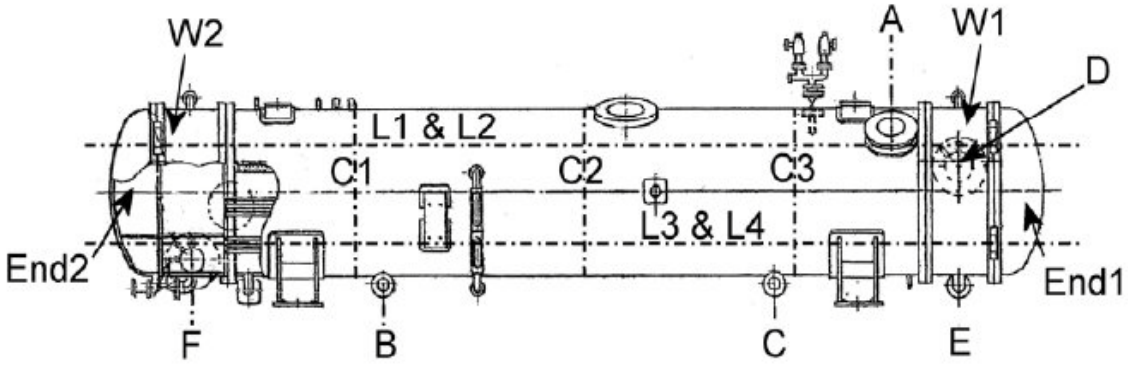
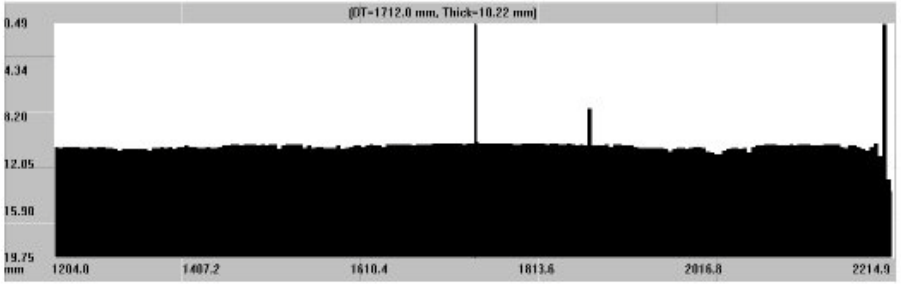
Inspection Implementation



Scan L1:

Maximum:	11.66mm	Minimum:	10.22mm	Minimum Position:	1712.0mm
				Minimum Ref File:	Con L1

Minimum Thickness Scan:



- Inspection personnel

RBI Process

Assessment results:

Minimum req'd thickness (mm):	$t_{min} = 8.756$	Level 1 Assessment:	Level $_1$ = "Acceptable"
MAWP (MPa):	MAWP = 16.135	Level 2 Assessment:	Level $_2$ = "Acceptable"
Maximum stress:	$\sigma_{max} = 89.109$	Level 3 Assessment:	Level $_3$ = "Acceptable"
Length for thickness averaging (mm):	L = 2310.276	Remaining Life (years):	$R_{life} = 31.669$

HI & RA

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Engineering Assessment

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Inspection Planning & Scheduling

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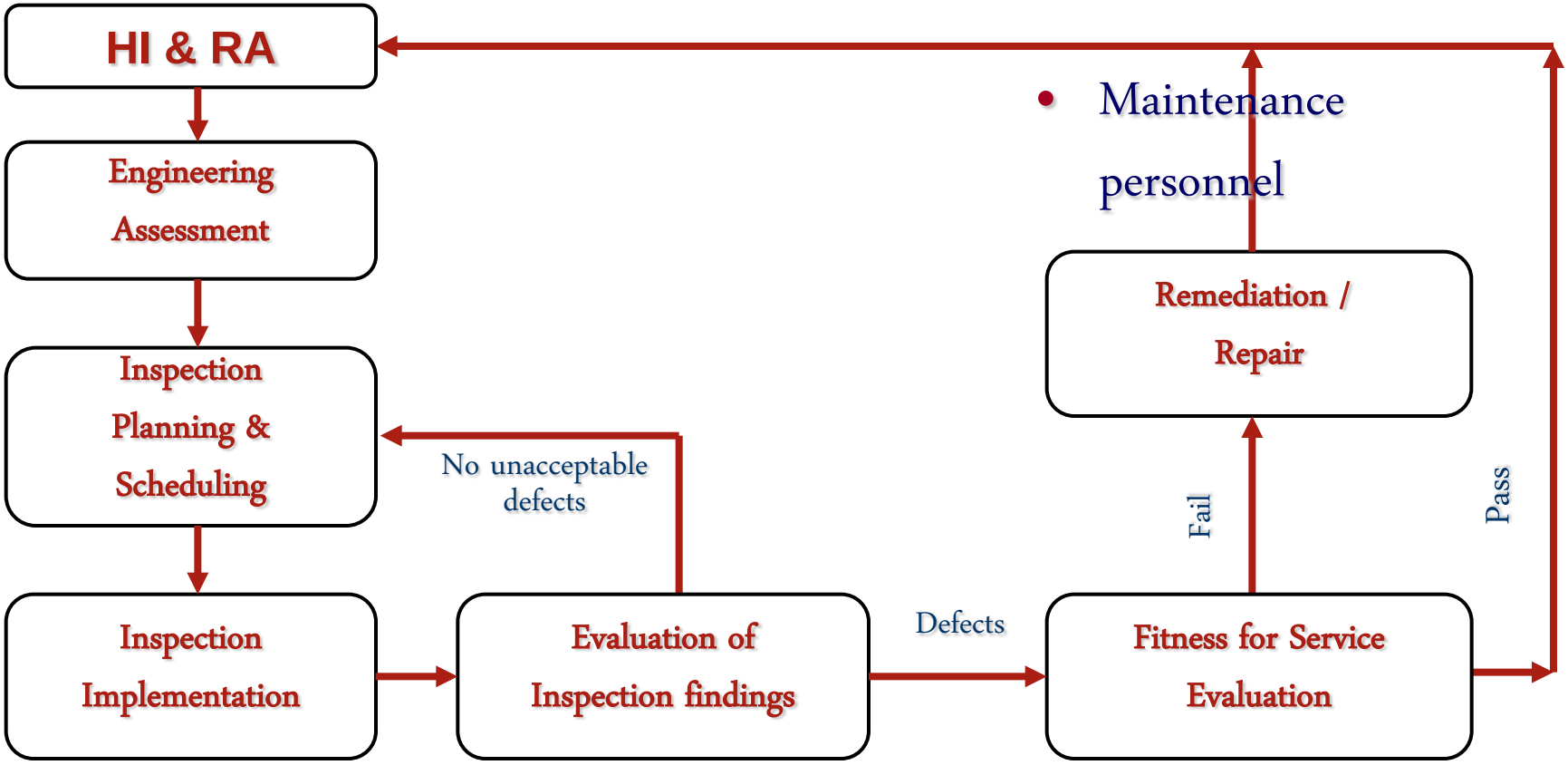
Inspection Implementation → Evaluation of Inspection findings → Defects → Fitness for Service Evaluation

Vessel Description	Life – Corrosion (years)		
	<4	4-8	>8
Matte & Reverts Transfer Vessel No. 1			×
Matte & Reverts Transfer Vessel No. 2			×
F/D No. 1 Dry Conc. Transfer Vessel No. 1			×
F/D No. 1 Dry Conc. Transfer Vessel No. 2			×
F/D No.1 Sand Cleaning Transfer Vessel			×
F/D No.1 Sand Cleaning Transfer Vessel			×
F/D No.1 Sand Cleaning Transfer Vessel			×
Plant Air / Instr. Air Receiver			×

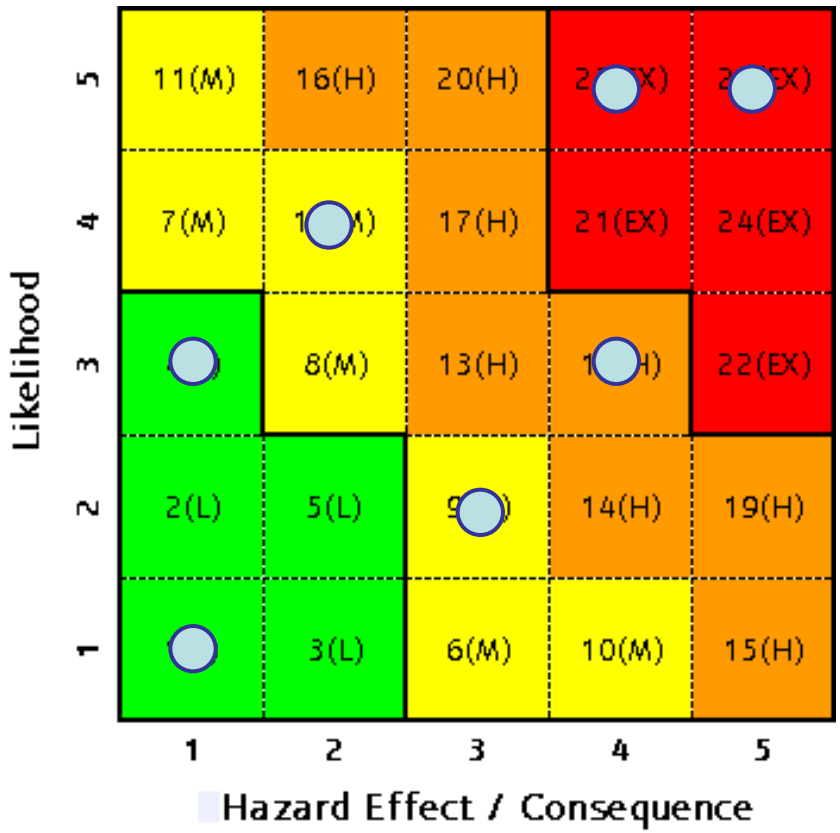
t Description	Shell side Life – Corrosion (years)		
	L<4	4>L<8	L>8
ɔmiser 1A			14
ɔrator 1A		5	
enser 1A	2		
ɔmiser 1B			46
ɔrator 1B	2		
enser 1B			13
ɔmiser 2A			49
ɔrator 2A		7	
enser 2A			16
York Economiser 2B			57

- RBI Specialist / Engineer

RBI Process

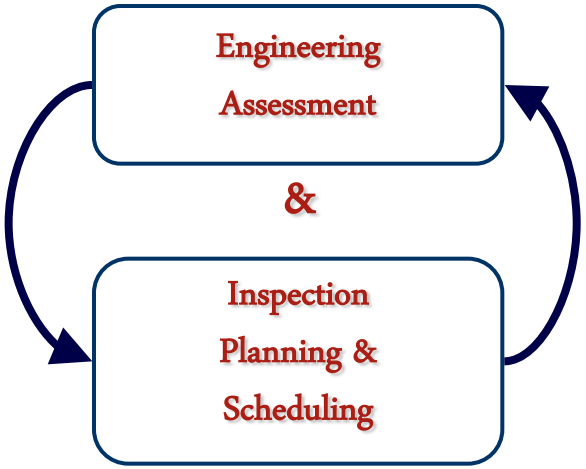

HI & RA
Engineering Assessment
Inspection Planning & Scheduling
Inspection Implementation
Evaluation of Inspection findings
No unacceptable defects
Defects
Fitness for Service Evaluation
Fail
Remediation / Repair
Pass
• Maintenance personnel

Reduction of safety and operational risk



through

scientifically based



RBI Outcome & Benefits Summary

- Equipment Hazard Identification & Risk Assessment
- Written Scheme of Examination
- Fitness-for-Service & Remaining Life
- Inspection Intervals based on actual condition
- Mitigating Actions
- Documentation

Intention

- Manage all pressure equipment on RBI methodology
- Implement RBI on all Anglo American operations
- Involve DME and others in implementation