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CYANIDE OPTIMIZATION AND THE USE OF OZONE FOR WAD CYANIDE DESTRUCTION

South Deep Gold Mine

Metallurgical Plant

2009

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AGENDA

1. Introduction
2. Metallurgical Plant
3. ICMI Code and Implications
4. Initiatives
    - 4.1. Cyanide Reduction
        - 4.1.1. Oxidation Trial
        - 4.1.2. Two Stage cyanide control
    - 4.2. WAD Cyanide Destruction
        - 4.2.1. Hydrogen Peroxide (H_2O_2) Trial
        - 4.2.2. Ozone Trial
5. Conclusion

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1. INTRODUCTION

- Gold Fields South Deep is Located in the South West Rand
- New gold plant was commissioned in 2002
- Design capacity of 220 000 t/month
- The mining method by Trackless mining
- Gold recovery achieved by Milling, Classification (cyclones),Gravity gold, Thickening, Leaching, CIP, Elution, Electro-wining and Smelting

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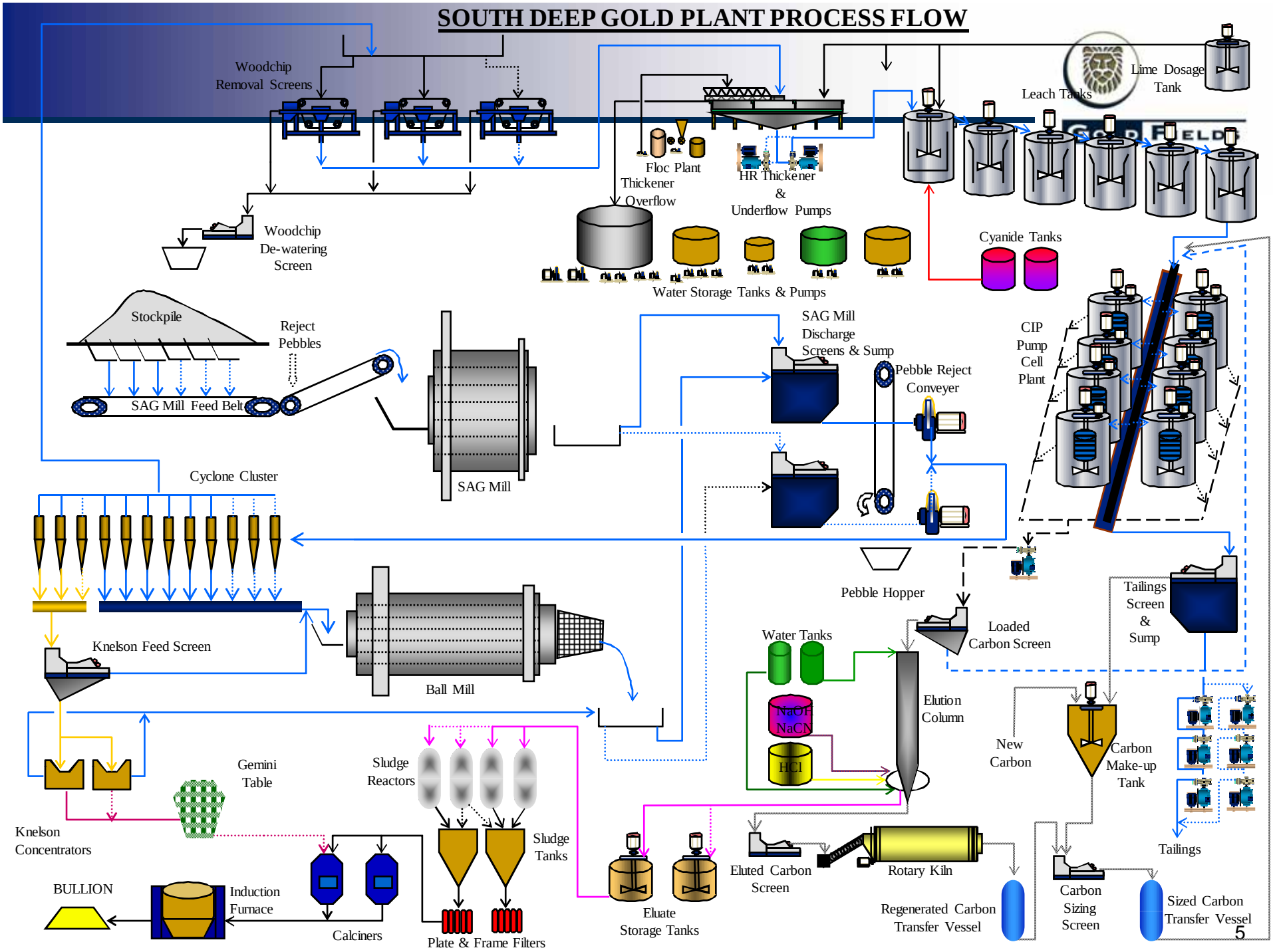
2. METALLURGICAL PLANT

SOUTH DEEP GOLD PLANT PROCESS FLOW



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3. ICMI CODE AND IMPLICATIONS

- In the year 2000 the ICMI (International Cyanide Management Institute) Code was developed after an accidents in *Baia Mare*

- Mines that are compliant with the ICMI code they have to implement the Principles and Standard of practice
  - *Production*
  - *Transportation*
  - *Handling and storage*
  - *Operation*
  - *Decommissioning*
  - *Workers safety*
  - *Emergency response*
  - *Training*
  - *Dialogue*

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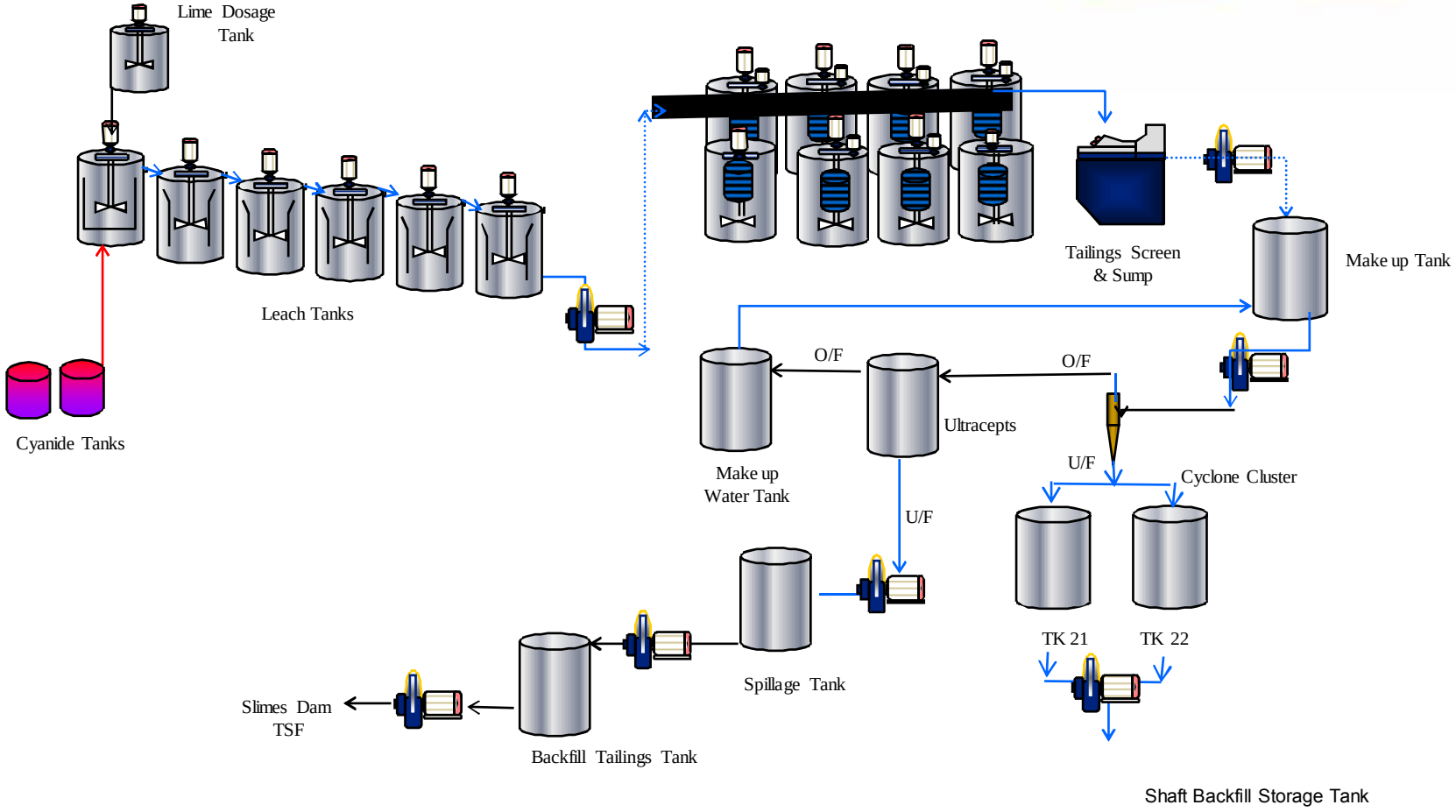
- Gold Fields South Deep Gold Mine has been certified as fully compliant with the ICMI Code as from the 1 April 2009
- The Metallurgical Plant had to demonstrate that it has implement programs, procedures and practises as required by ICMI
- Principle 4**: Standard of Practice 4.2 of the code "*Has the operation introduced management and operating systems to minimize cyanide use, thereby limiting concentrations of cyanide in mill tailings*"**
- **Standard of Practice 4.6.3 "*Has the potential impacts to workers health and the beneficial uses of ground water been evaluated and have been measures been implemented as necessary to address them*?"**

Cyanide Addition and Monitoring



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Areas of concern (Underground and Slimes dam)

- Possibility of HCN gassing
- No CN monitors
- “Cyanide tracking underground as a function of backfill seepage”
  P. W. Lotz

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Cyanide Addition

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TAC 2000

- Leach TK 1
- TK1 Cyanide addition Set Point 200ppm
- TK4 Cyanide addition Set Point 90ppm

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WAD Cyanide Monitoring

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WAD 1000 (Plant and Backfill)

- Pump
- Probe at Tailings Sump
- Analyser for Analysis and Data collection

4. INITIATIVES

4.1. CYANIDE REDUCTION

4.1.1.Oxidation Trial

- Oxygen from Air Products was used to improve
  - Recoveries
  - Leach kinetics
  - Dissolved oxygen levels
  - Lower cyanide consumption

- First phase of the trial
  - Oxygen added in TK 1 together with cyanide and lime
- Second phase
  - Pre-Oxidation in TK 1 leach tank prior to adding cyanide and Lime in TK 2

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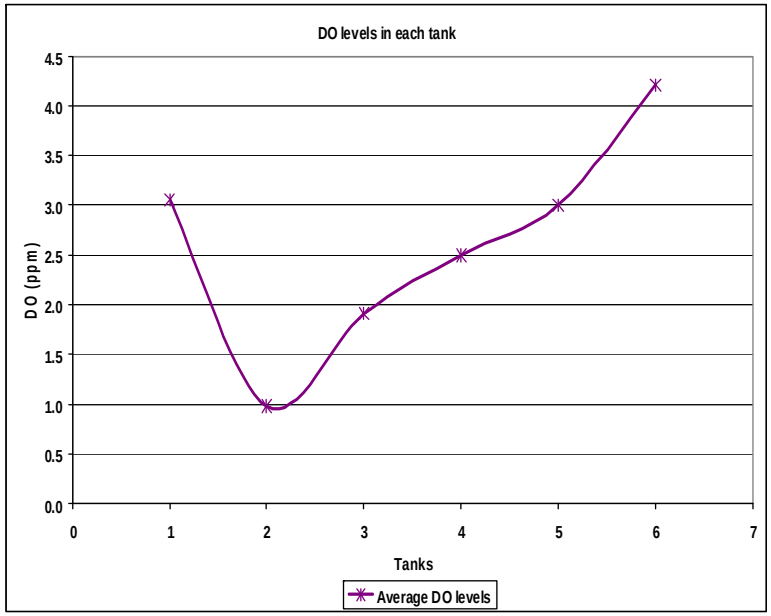

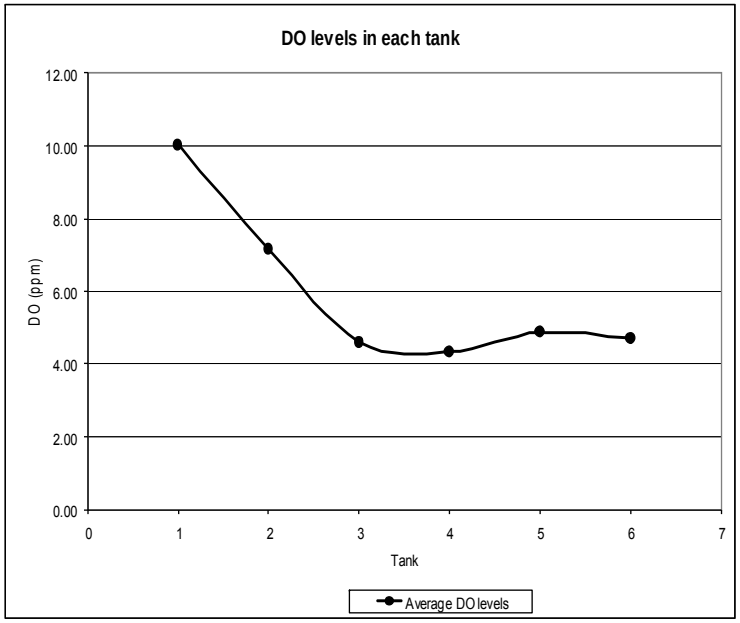

$$4\,Au + 8\,CN^- + O_2 + 2\,H_2O = 4\,Au(CN)^-_2 + 4\,OH^-$$

- The DO level during P1 was <4.2ppm and during P2 the DO levels increased in TK 1 and TK 2 to 10.02ppm and 7.16ppm

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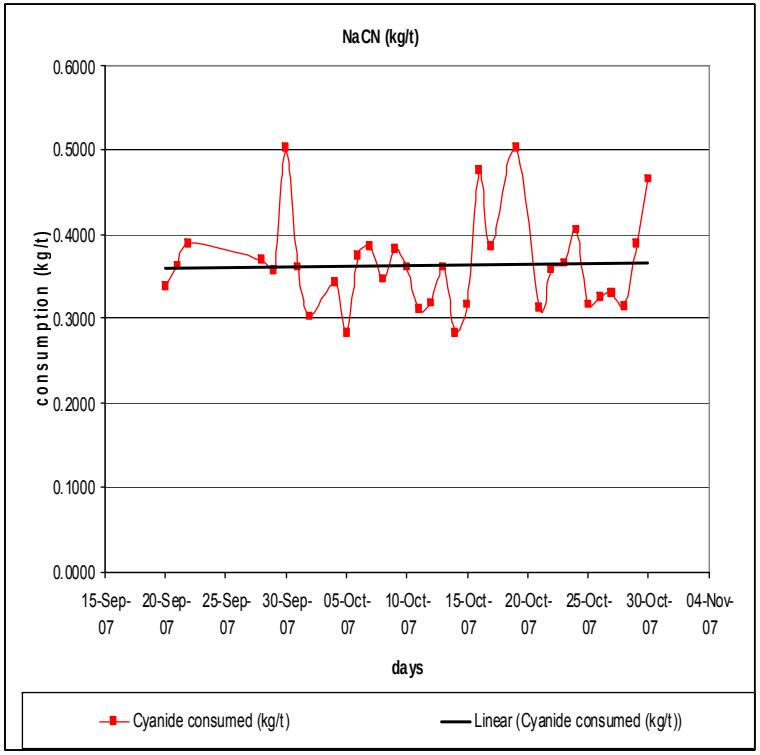
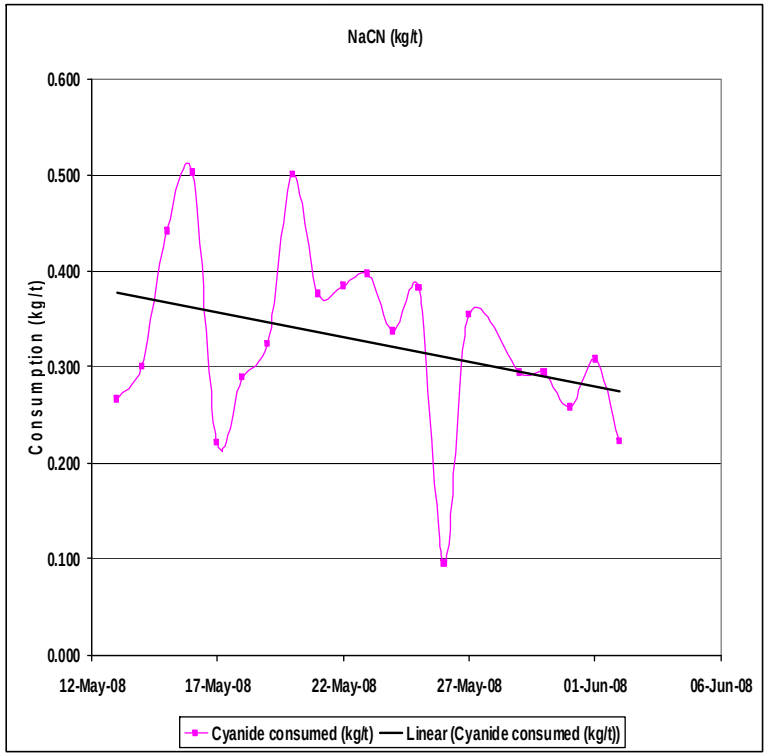
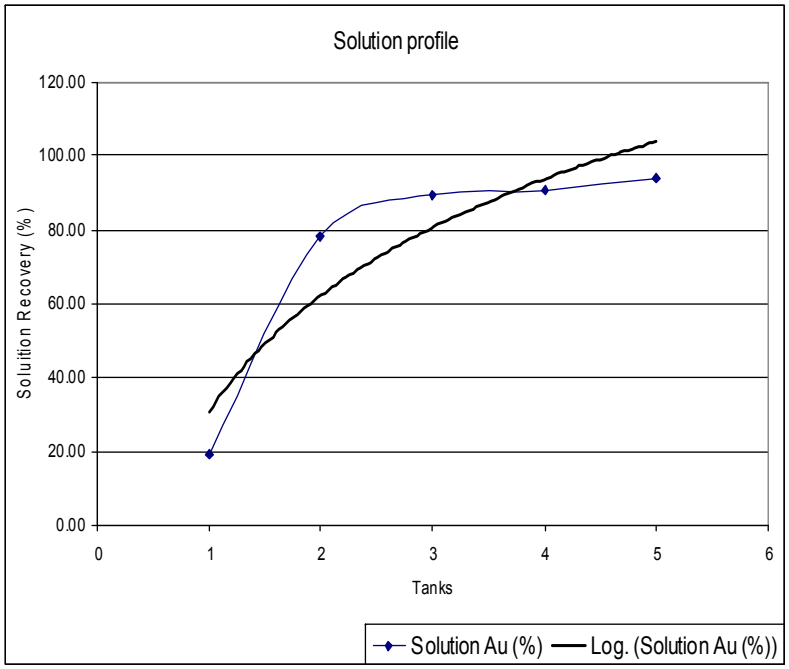




- Cyanide consumption during P1 was 0.366kg/t and was 0.270kg/t during P2



- During P1 and P2 there was a rapid increase in dissolution of gold within the first three tanks which resulted in increased leach kinetics

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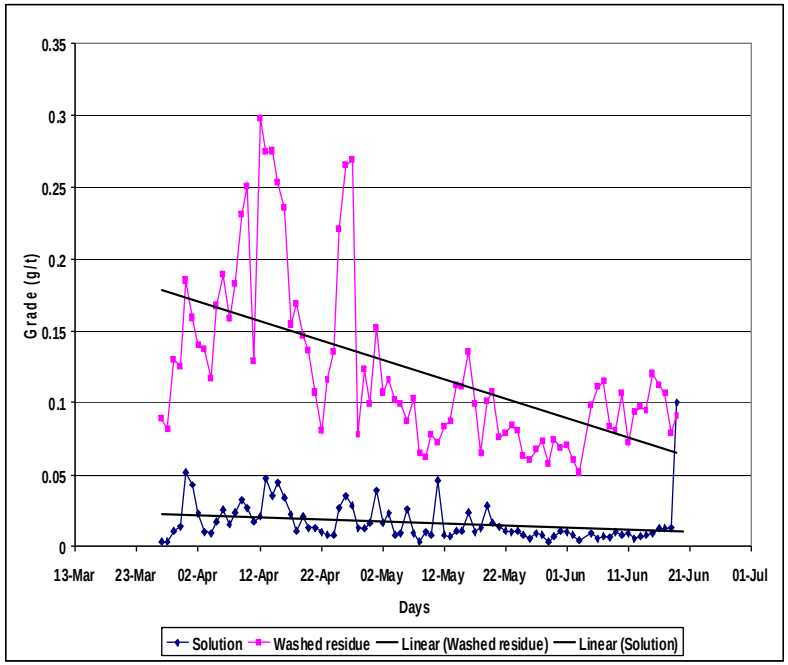

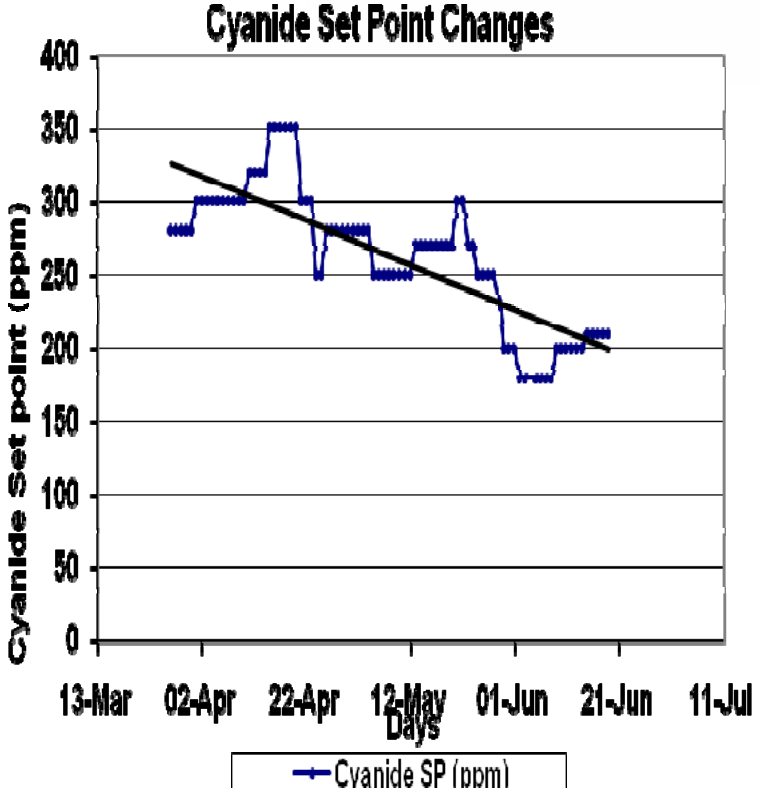

- The increase in residue resulted in increase cyanide set point
- During P2 residues dropped for both solution and washed solids and that resulted in cyanide addition set points from 350ppm to 180ppm

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- Phase 1 results
  - Oxygen trial improved
  - Dissolved Oxygen levels
  - No changes in cyanide consumption
  - Leach profiles indicated faster leach kinetics

- Phase 2 results
  - Pre-oxidation resulted in reduction in cyanide consumption from 0.366 kg/t to 0.270kg/t
  - Increased leach kinetics
  - Dissolved oxygen levels
  - Leach could be operated with less tanks resulting in reduction in gold lock up and maintenance cost
  - Cyanide set point was reduced from 350ppm to 180ppm

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4.1.2. Two Stage cyanide control

- The aim
  - Optimize the cyanide addition at the Leach circuit
  - To reduce cyanide cost
  - Reducing the WAD cyanide leaving the Plant to < 50ppm as required by the ICMI

- The cyanide is dosed at TK 1 using TAC 2000
  - Cyanide set point in TK 1 is 200ppm and at TK 4 is 90ppm
  - The WAD Cyanide leaving the Plant is currently 28ppm which is bellow ICMI requirement of 50ppm WAD

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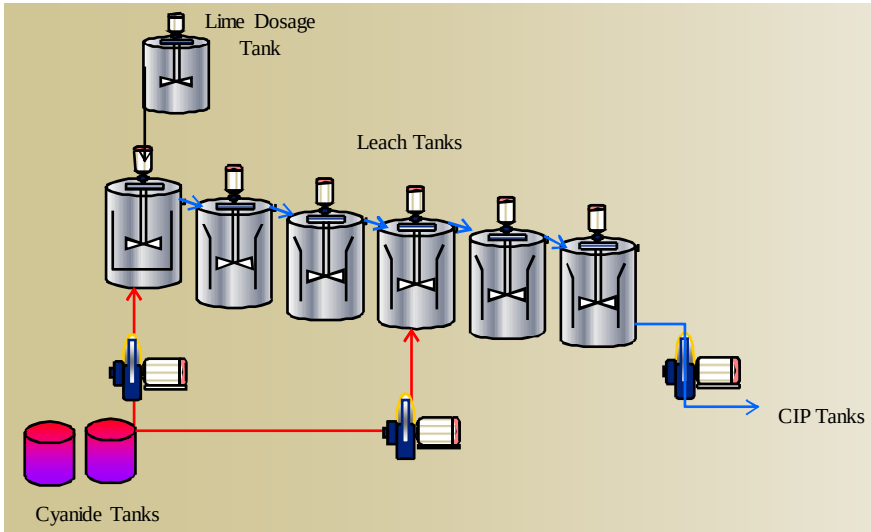

- TK 4 has been identified as the cyanide second stage addition point
- The installation of the second stage at TK 4 has been completed
- The cyanide reduction should impact the WAD cyanide to levels lower than 28ppm thus reducing cyanide consumption and cost

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4.2. WAD CYANIDE DESTRUCTION

4.2.1. Hydrogen Peroxide (H_2O_2) Trial

- The aim
  - Determine the effectiveness of Hydrogen peroxide (H_2O_2) with regard to WAD cyanide destruction to levels <20ppm
  - Determine if Hydrogen peroxide could be used as an alternative to Ferrous sulphate that is currently used

$$Fe^{+2} + 6\,CN^{-} + \tfrac{1}{4}\,O_2 + H^{+} = Fe(CN)^{-3}_{6} + \tfrac{1}{2}\,H_20$$

$$4\,Fe^{+2} + 3\,Fe(CN)^{-3}_{6} + \tfrac{1}{2}\,O_2 + H^{+} = Fe_4[Fe(CN)_6]_3 + \tfrac{1}{2}\,H_20$$

- The test works were done Plant scale and Lab scale

Table 2: WAD destruction results summary using Hydrogen Peroxide

	Test 1	Test 2	Test 3	Test 4	Test5
Density of Slurry (kg/l)	1.82	1.6	1.75	1.75	1.92
Volume of Slurry (l)	215000	5	5	5	96000
Mass of Slurry (kg)	391300	8	8.75	8.75	184320
Density of Hydrogen peroxide (kg/l)	1.2	1.2	1.2	1.2	1.2
Volume of Hydrogen peroxide (l)	150	0.5	0.05	0.01	200
Mass of Hydrogen peroxide (kg)	180	0.6	0.06	0.012	240
Consumption (kg/t)	0.46	75.00	6.86	1.37	1.30
Duration (hr)	32	2	2	2	2
WAD first value (ppm)	52.8	19.6	23.6	21.6	31.5
WAD Last value (ppm)	20.1	0.1	2.7	4.3	3.3
Efficiency	61.9	99.5	88.6	80.1	89.52
Cost per ton (R/t)	3.86	629.38	57.54	11.51	10.93

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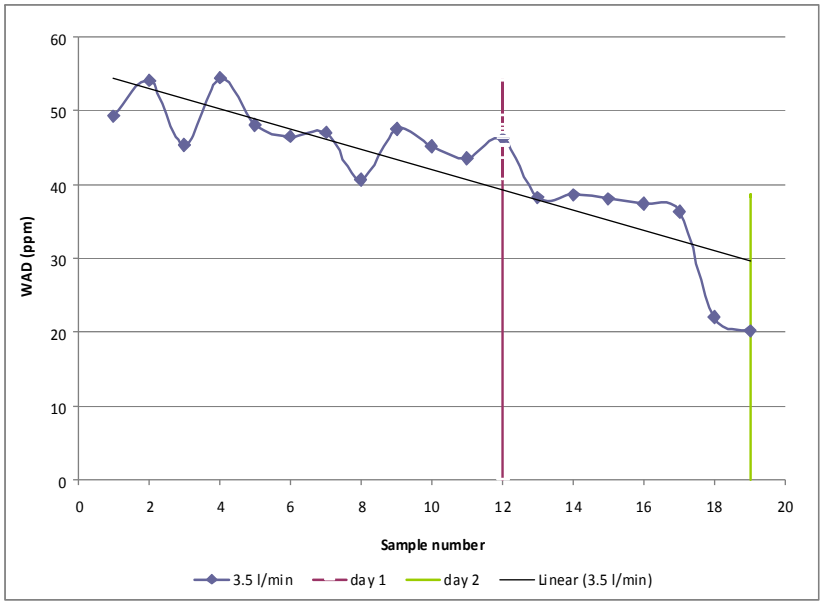

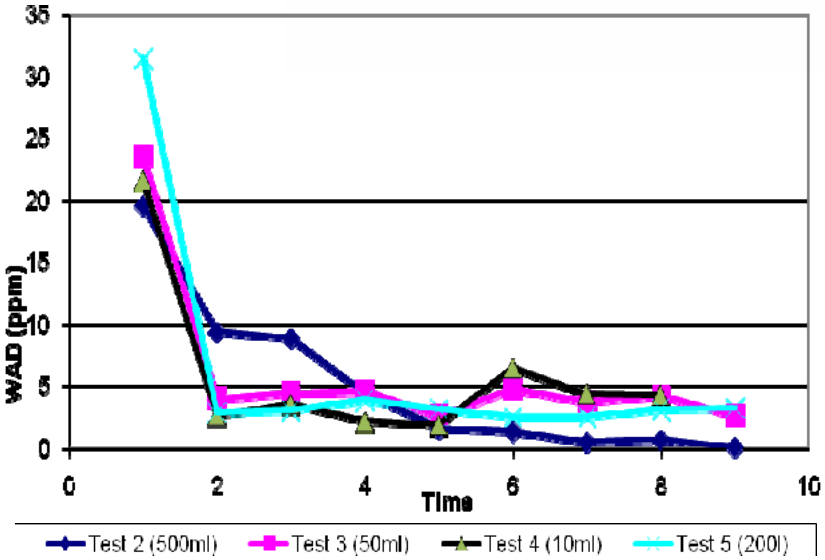

- The results indicates that WAD cyanide was best reduced in Test 2 followed by 3 and 4 although Hydrogen peroxide consumption was high for Test 2, 3 than 4

$$CN^- + H_2O_2 = OCN^- + H_2O$$

- Hydrogen Peroxide does reduce the WAD cyanide levels to <5ppm in 2 hours

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- It was concluded
  - Hydrogen Peroxide does reduce the WAD cyanide levels to even <5ppm effectively
  - Hydrogen Peroxide can be used as an alternative to ferrous sulphate
- It was recommended
  - Attempts be made to lower consumptions to minimize operational cost
  - WAD Cyanide be destroyed at Metallurgical Plant Tailings to levels <50ppm

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4.2.2. Ozone Trial

- The cyanide destruction using Ozone is done to reduce the WAD cyanide leaving the Plant to Slimes dam and Underground
- The Ozone is a powerful oxidant and highly destructive toward WAD cyanide according to Lab test results

$$CN^- + O_{3\,(aq)} = OCN^- + O_{2\,(aq)} \quad (1)$$

$$3CN^- + O_{3\,(aq)} = 3\,OCN^- \quad (2)$$

$$OCN^- + 3O_{3\,(aq)} + H_2O = 2HCO_3^- + N_{2\,(g)} + 3O_{3\,(aq)} \quad (3)$$

- These are initiatives taken to protect the people and the environment

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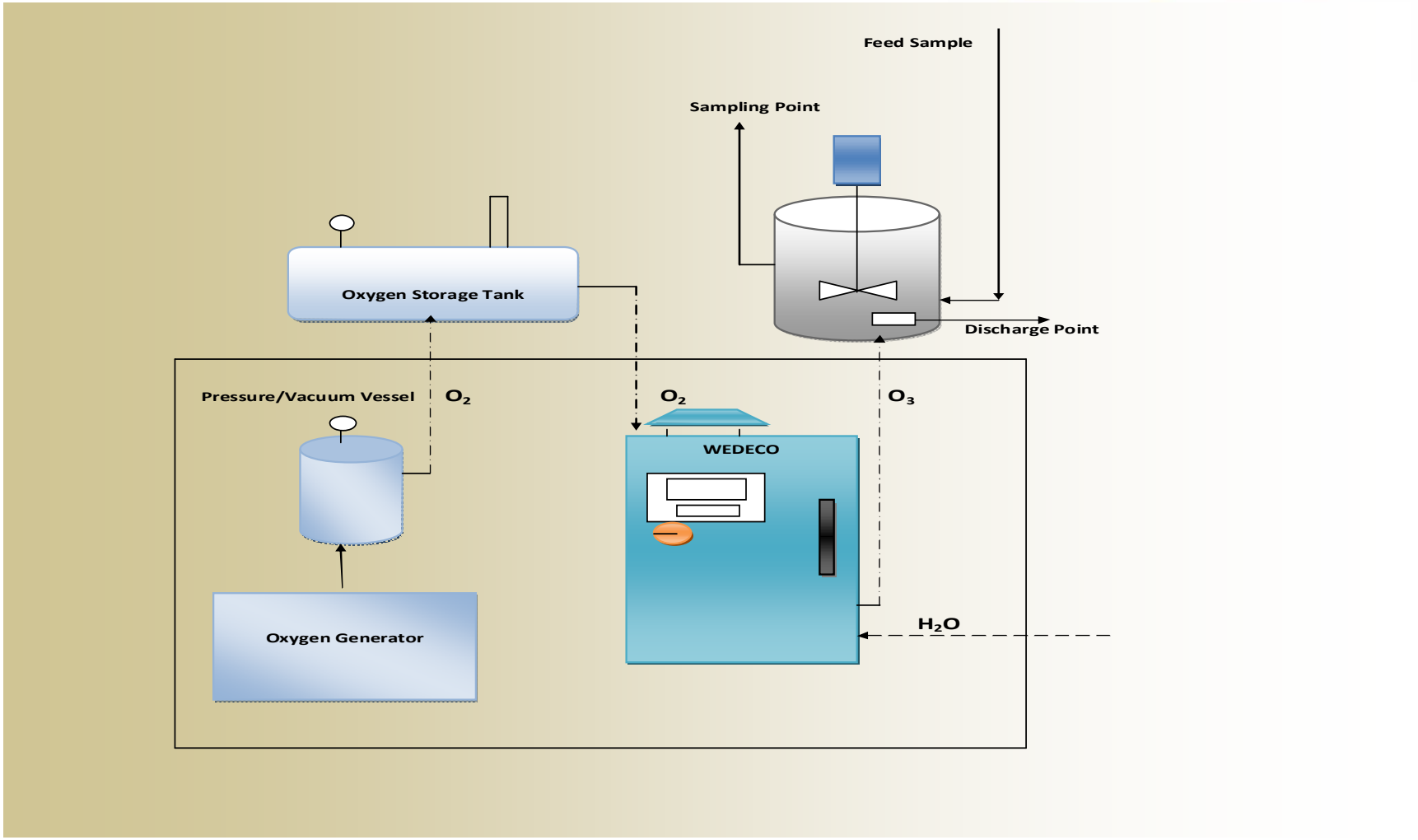
Ozone skid/generation



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Oxygen Buffer Vessel

VSA Generator

WEDECO Ozone Generator

Mixing vessel

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- The Ozone Trial was planned for 3 months at following streams
  - Backfill Tailings to Slime dam
  - Backfill to underground
  - Ultracep underflow
  - Ultracep overflow
  - Spent sample
- WAD cyanide was analysed using WAD 1000

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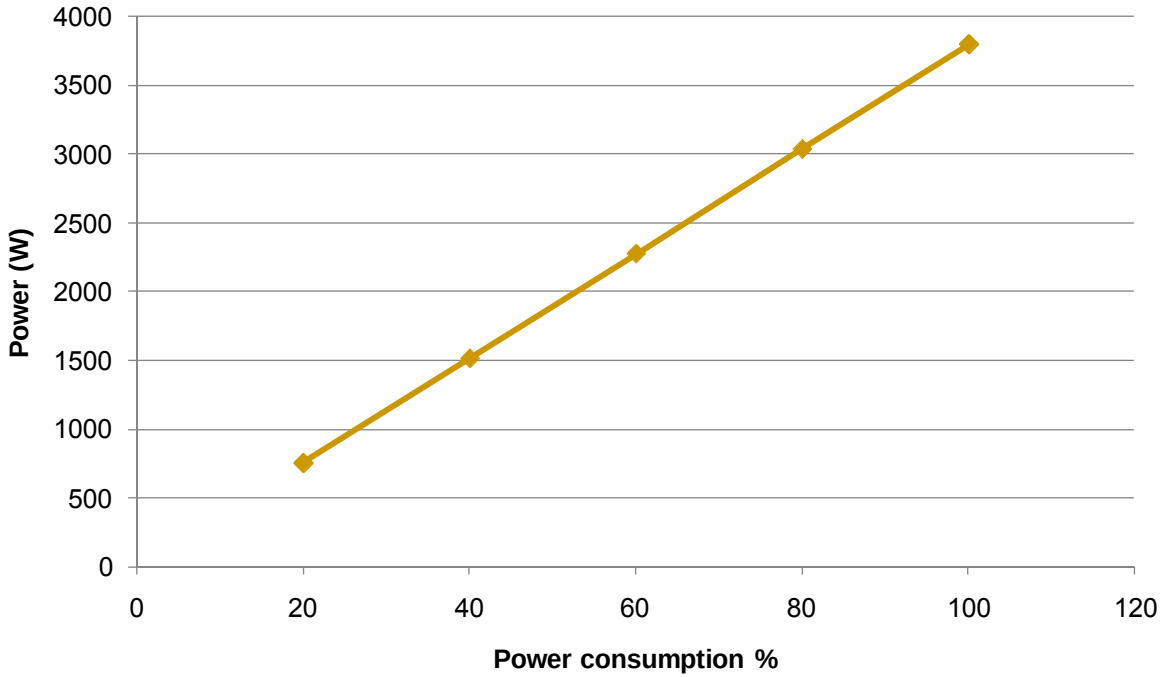
Achievement



Relationship between Power (W) and Power consumption % is linear

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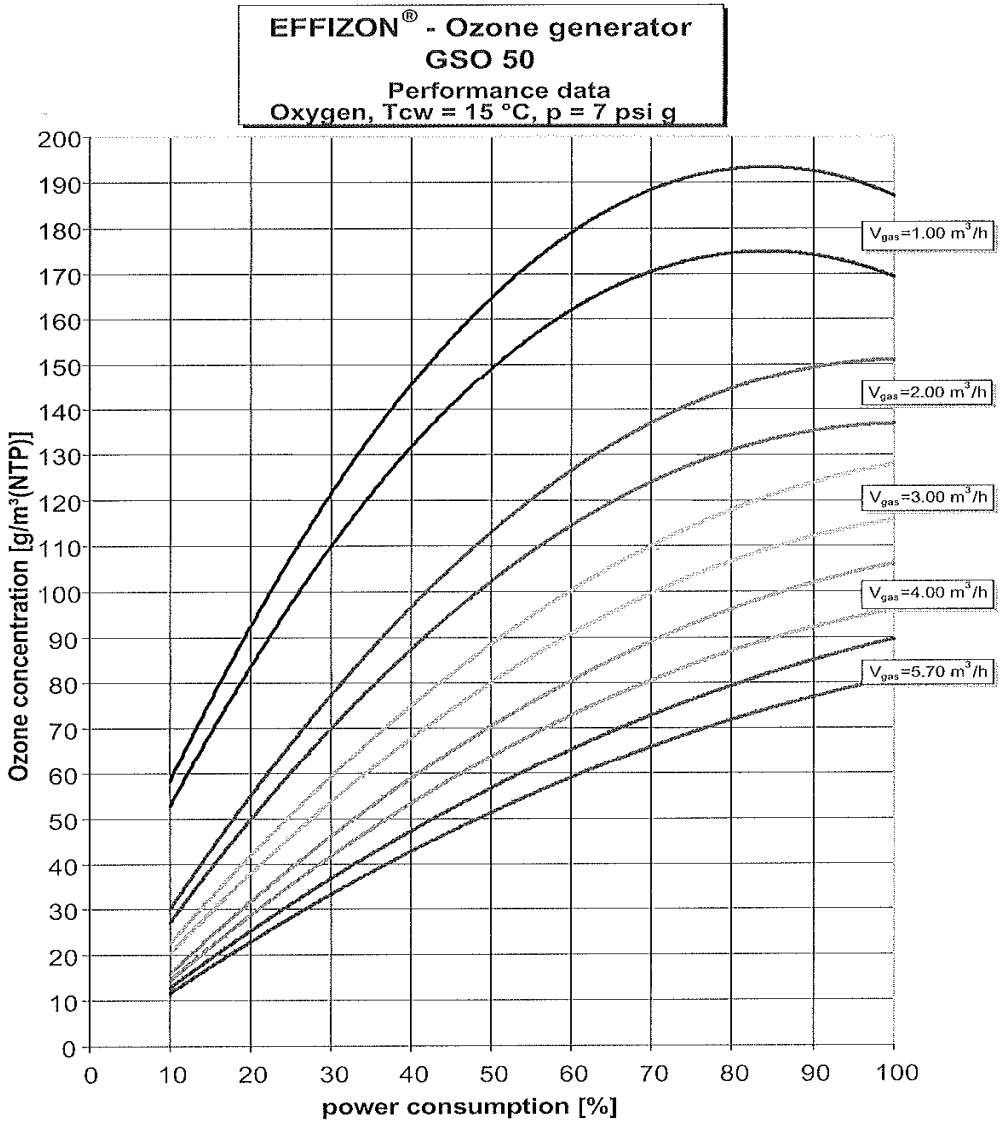

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Power consumption %	Ozone concentration (g/m³)
20	24
40	44
60	59
80	73
100	80

Relationship between Power consumption % and Ozone concentration

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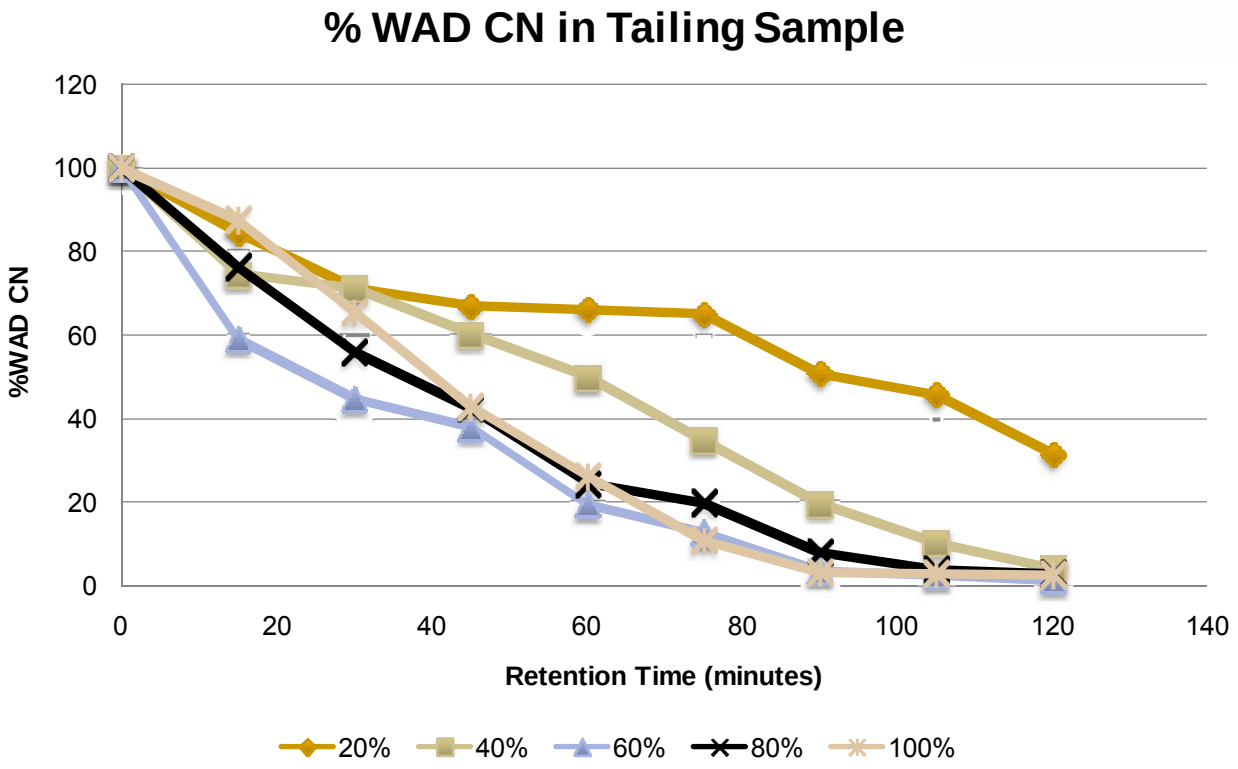

- WAD cyanide reduction of 98.7% for the slurry pumped from Backfill Tailings to Slimes dam at 60% power consumption

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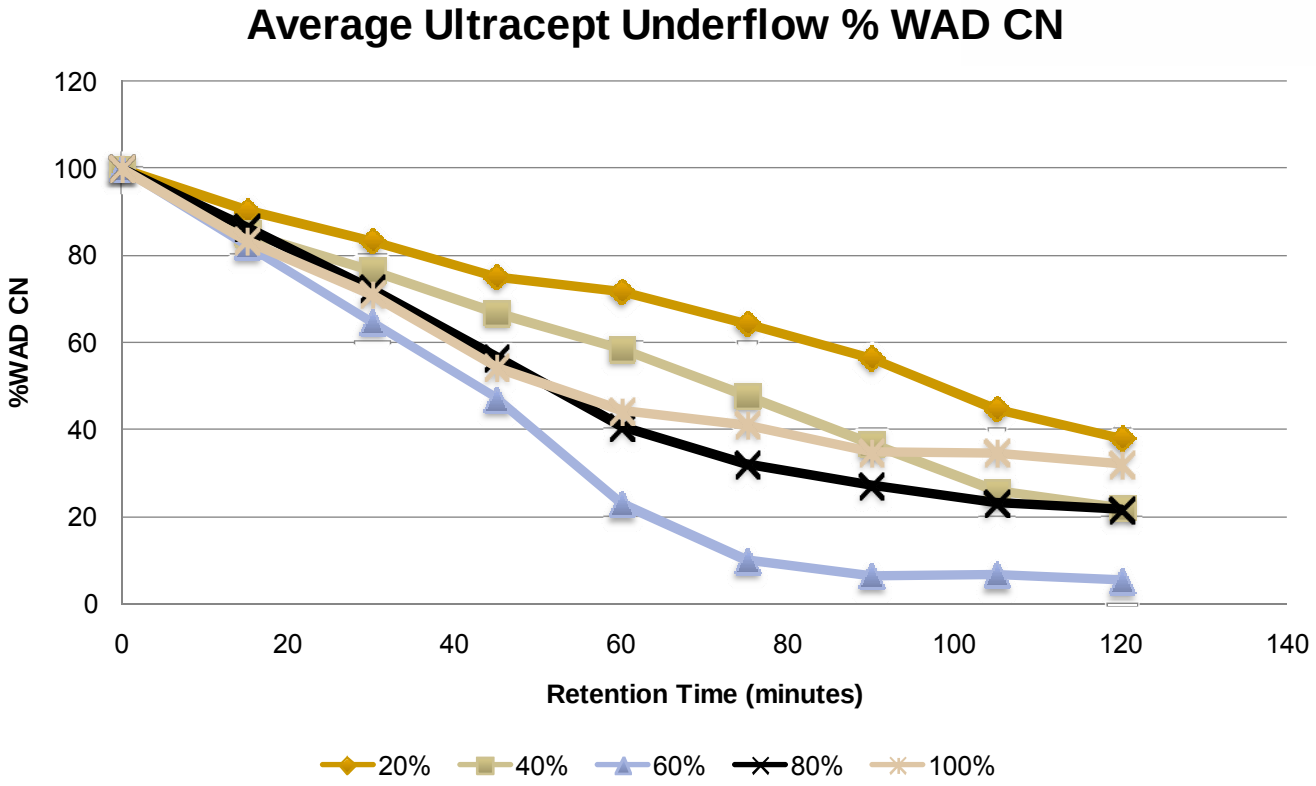

- Ultracep underflow WAD cyanide was reduced by 94.6% at 60% power consumption

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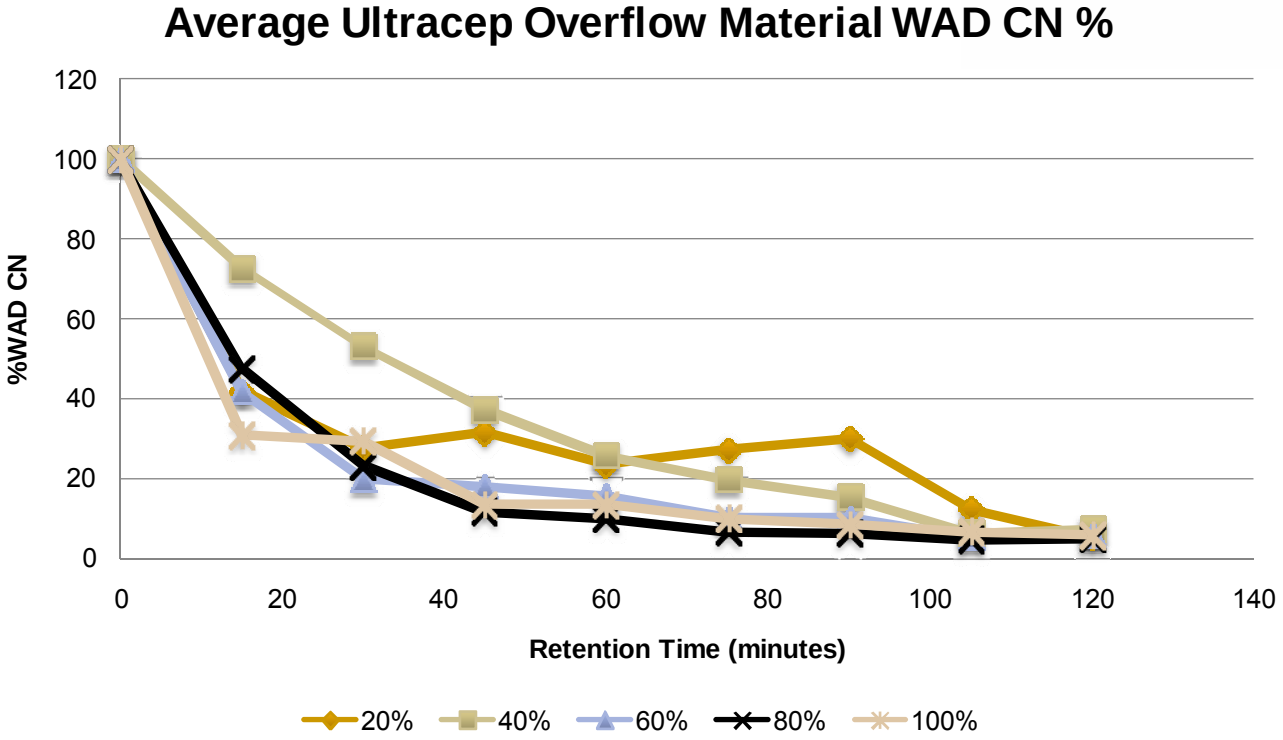

- Ultracep overflow WAD cyanide was reduced by 94.7% at 20% power consumption

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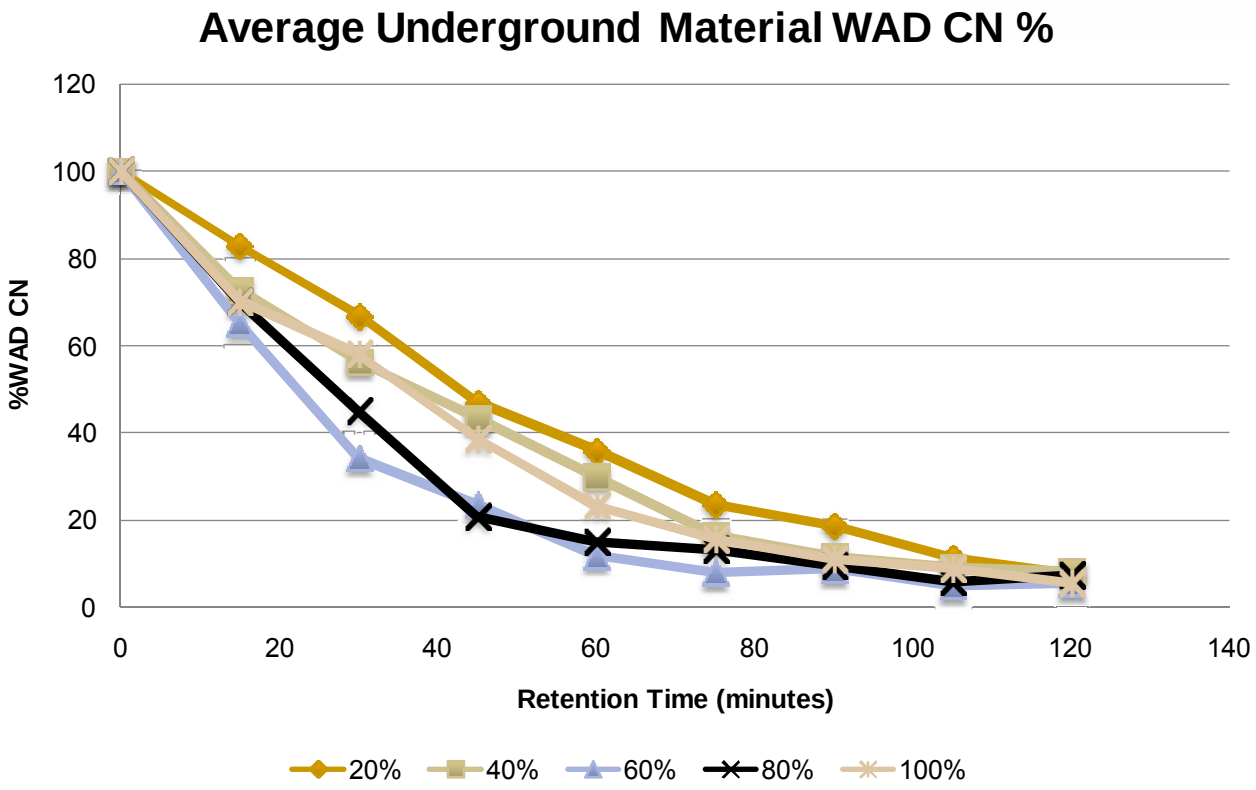

- Backfill to underground WAD cyanide was reduced by 94.5% at 60% power consumption

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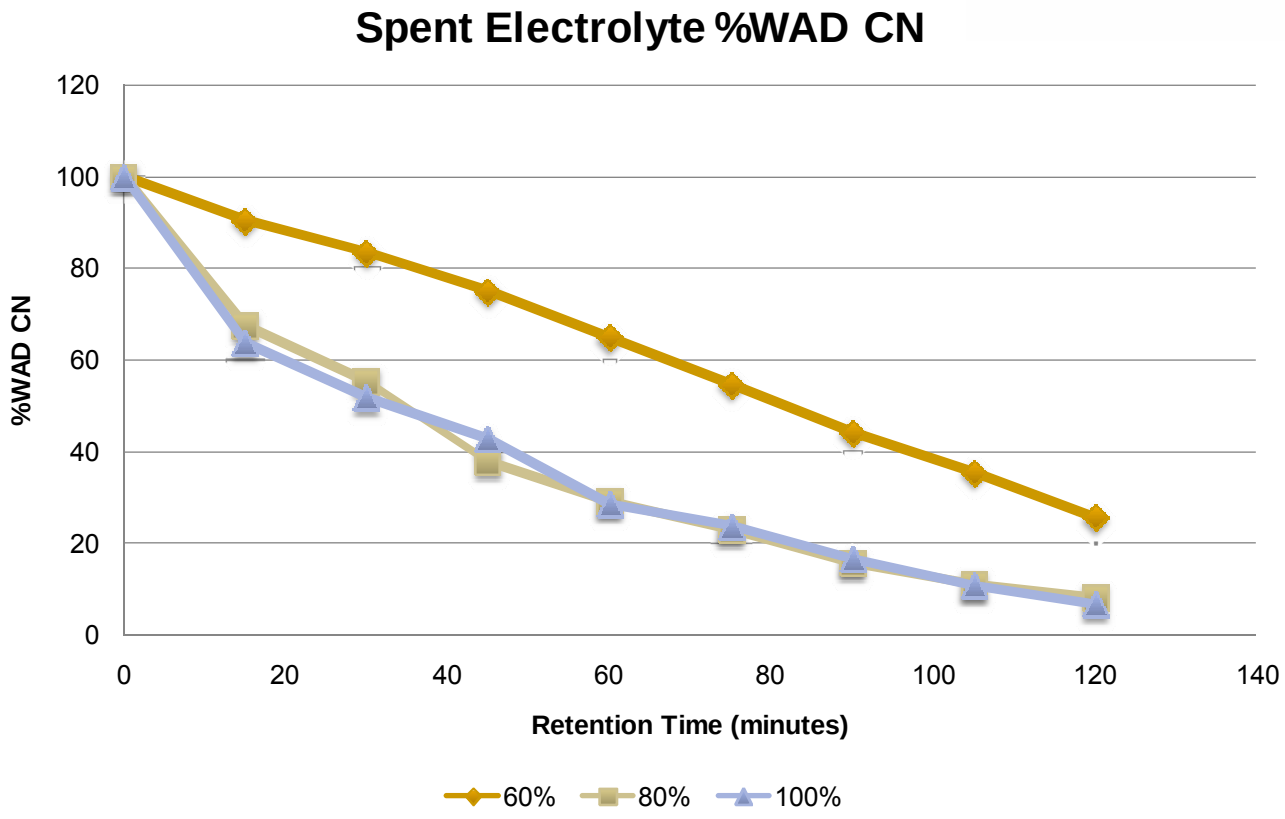

•Spent sample WAD cyanide was reduced by 92% at 80% power consumption

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- Ozone trial was successful in WAD cyanide destruction for all the streams tested as >92% destruction at optimum condition
- Alternative method to destroy WAD cyanide
- WAD levels < 50ppm at all times

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Advantages of the ozone includes

- Rapid WAD cyanide destruction
- No formation of harmful off gases

Cost

- Operating cost associated with ozone to be further investigated

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5. CONCLUSION

- South Deep has achieved WAD <50ppm
- Compliant with the ICMI Code
- Reduced and maintained cyanide addition levels from 0.366kg/t to 0.270kg/t
- Initiatives successful in WAD cyanide destruction to lower levels
- Alternative in both cyanide reduction and WAD cyanide destruction
- Prepared for the future changes in legislation

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QUESTIONS?