IMPLEMENTATION OF HIGH FREQUENCY POWER SUPPLIES AND DUAL FLUE GAS CONDITIONING IN PARTICULATE MATTER ABATEMENT IN THE PGM INDUSTRY

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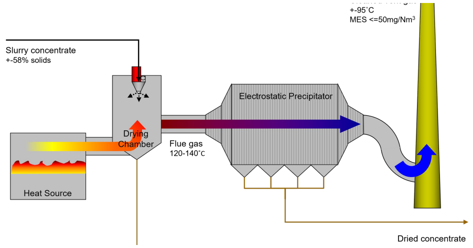
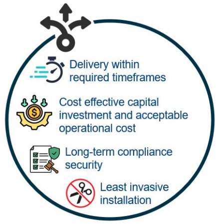
PRESENTATION LAYOUT

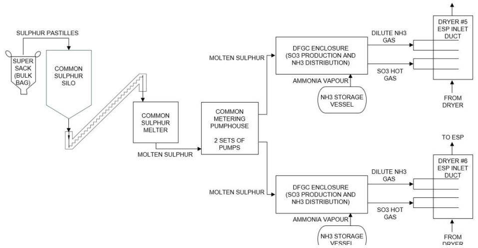
01 Introduction and background



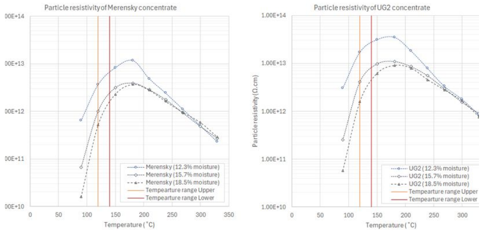
02 Technology Selection



03 Technology Description



04 Results and Lessons Learnt

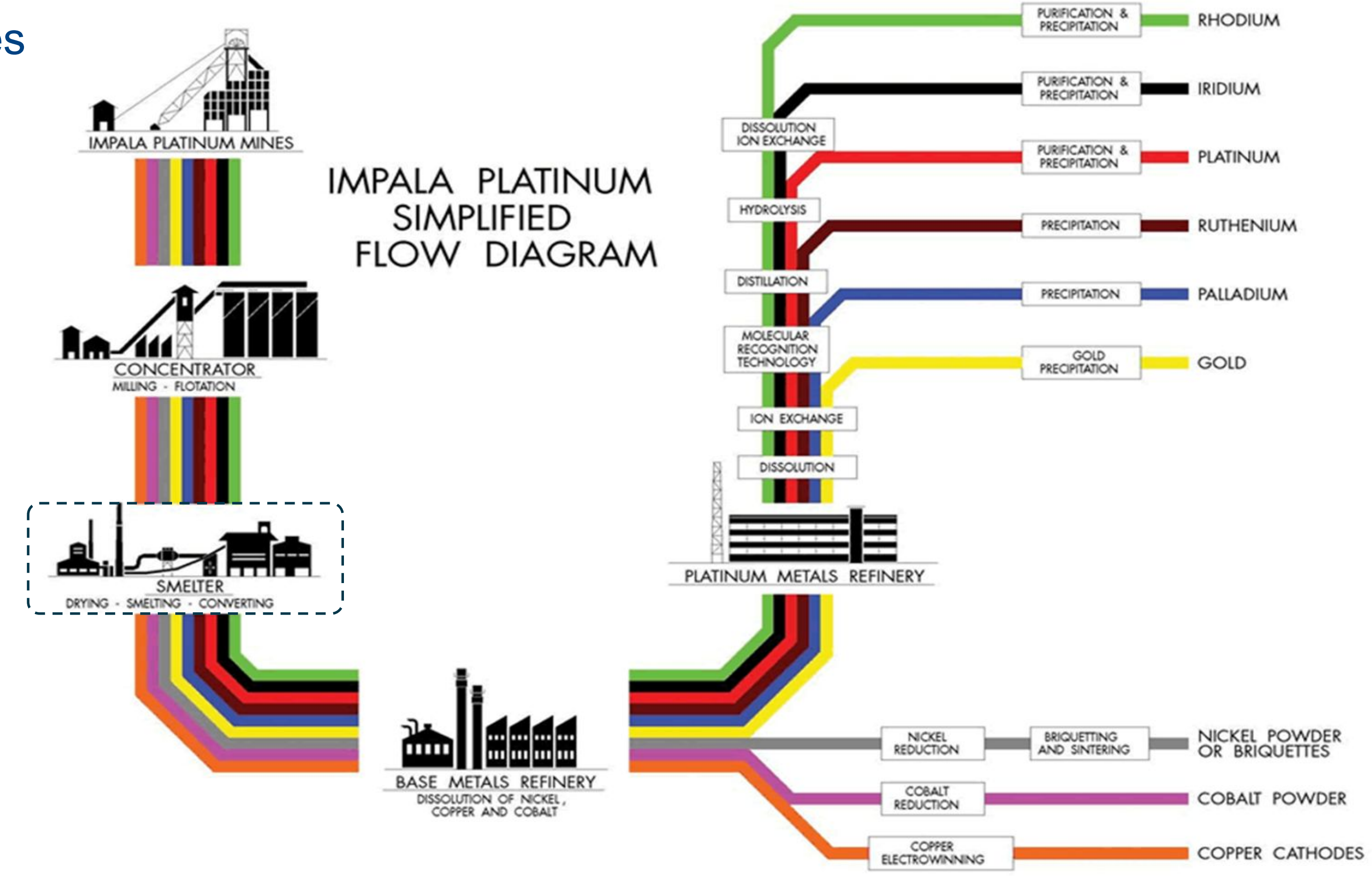


05 Acknowledgements

INTRODUCTION

Mine to market operations

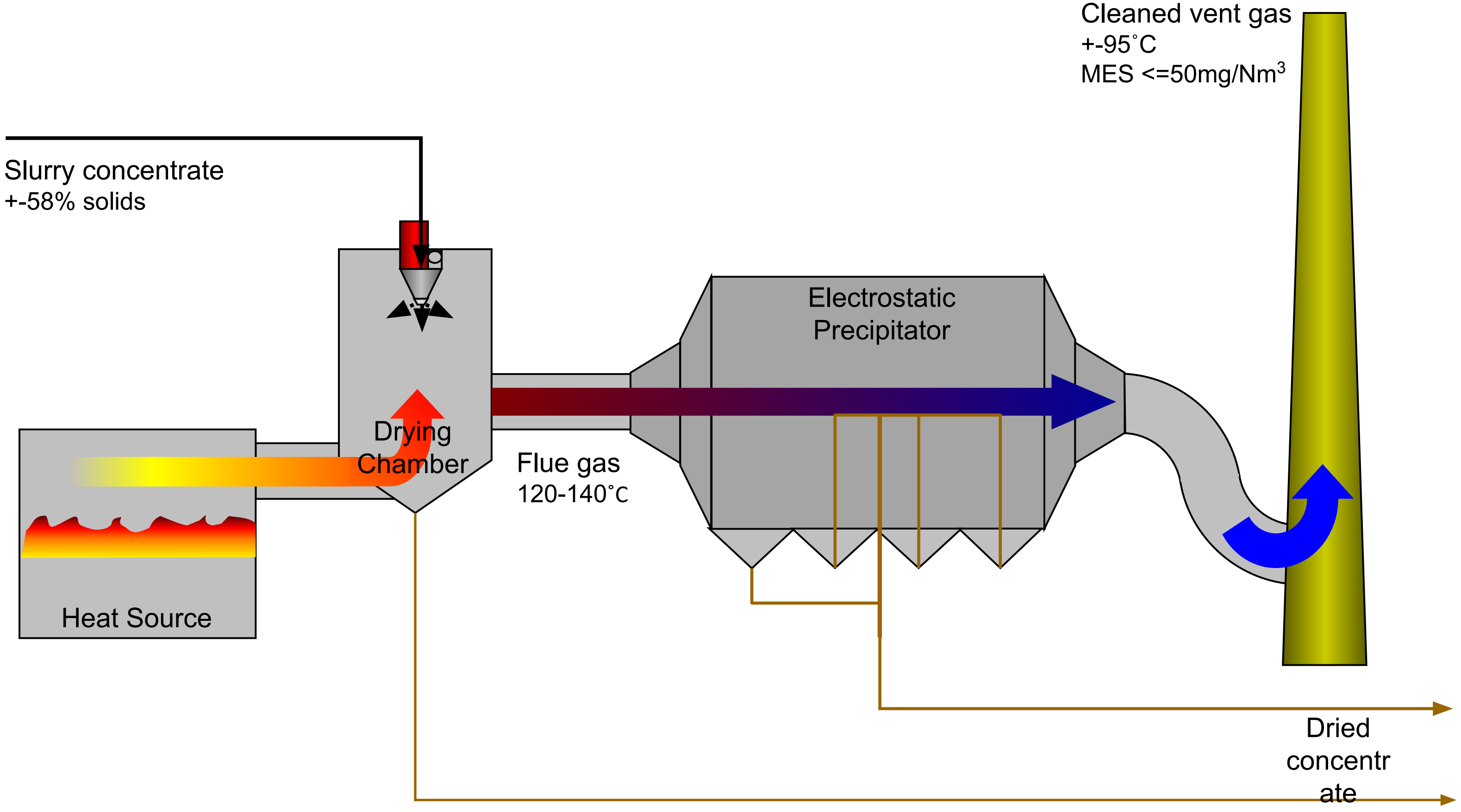
- Smelter operations involve two listed activities in terms of the National Environmental Management: Air Quality Act
  - Subcategory 4.1: Drying and Calcining
  - Subcategory 4.16: Smelting and converting of Sulfide ores
- Impala remains fully committed to maintain world class environmental performance
  - Strict adherence to South African Minimum Emission Standards



INTRODUCTION: DRYING OPERATIONS

Drying process incorporates flash- and spray drying technologies

- Niro spray drying dates back to the 1970's
- Thickened PGM concentrate pulp is dried to a bone-dry product
  - Dryer outlet temperature controlled between 120˚C - 140˚C
  - Primary abatement of particulate matter (PM) by means of an electrostatic precipitator



TECHNOLOGY SELECTION

Road map involved phased programme

- Pre-feasibility assessments
- Selection and scoping
- Detail design and implementation

Delivery within required timeframes

Cost effective capital investment and acceptable operational cost

Long-term compliance security

Least invasive installation

Two-stage ESP upgrade project

- Installation of Switch Mode Power Supplies (also referred to as High Frequency Power Supplies)
- Introduction of Dual Flue Gas Conditioning (DFGC)

TECHNOLOGY DESCRIPTION

High Frequency Power Supplies

- Well established upgrade solution
- Enhanced particle collection due to
  - Increase in average voltage

$$\omega \sim K_2 (kV_{dc})(kV_{peak})$$

- $K_2 = a/2\pi\theta$ (Considered a constant for a given ESP)
- ω = particle migration velocity
- a = particle radius
- θ = gas viscosity or frictional resistance coefficient of the gas
- kV_{dc} = output voltage
- kV_{peak} = peak voltage

  - Improved spark response control
    - Detect and quenching a spark and start recovery within 4.03milliseconds
- Expected reduction in PM emissions of 21%

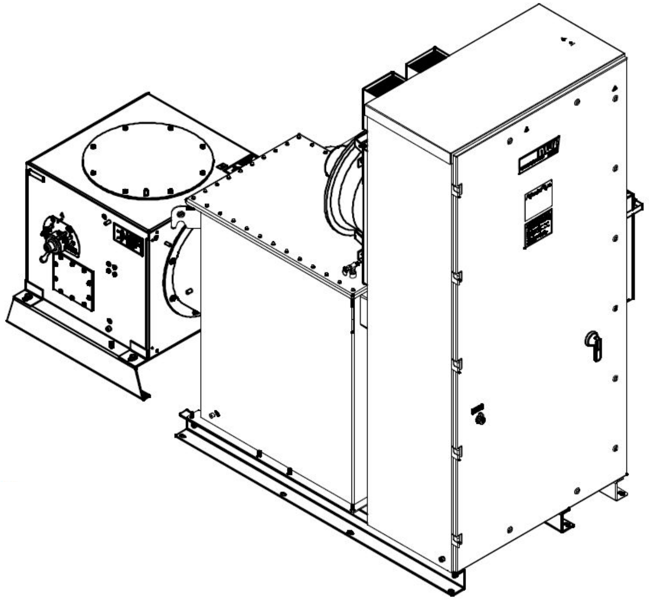
Farmer *et al.*, 2018
Krigmont *et al.*, 2020

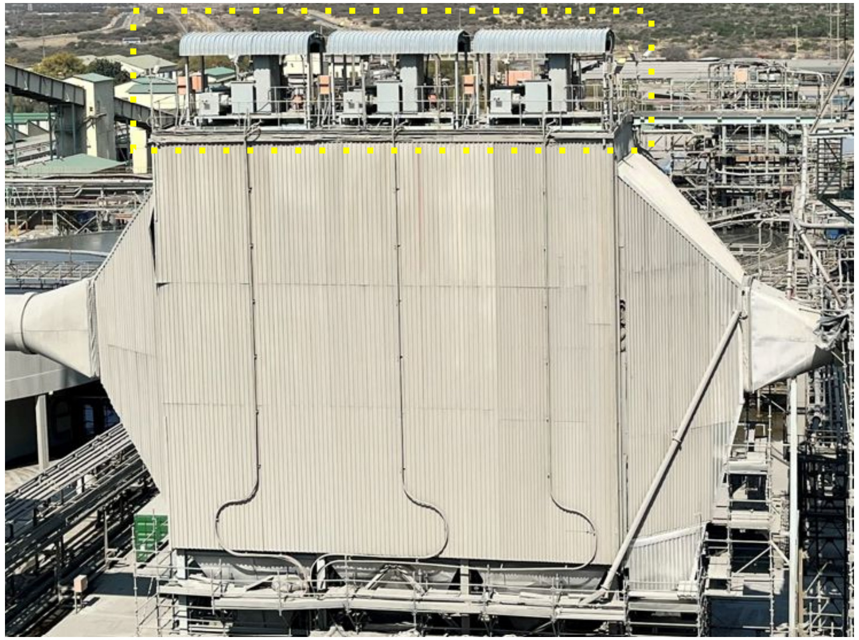
TECHNOLOGY DESCRIPTION

High Frequency Power Supplies

- NWL Series 7.5 PowerPlus Power Supplies

Output Voltage	*83 kV*	Switching Frequency	*25 kHz*
Output Current	*1930 mA DC mean*	Output Power	*160 kW*





TECHNOLOGY DESCRIPTION

Dual Flue Gas Conditioning

- Involves alteration of physico-electrical properties of particles through injection of chemical additives
  - Modification of surface electrical conductivity
  - Increase inter-electrode space charge
  - Increase dust cohesion to reduce rapping losses
  - Reduce back-corona problems
- SO_3 forms sulfuric acid, which is adsorbed on particle surface, coating the surface with thin conducting film
- NH_3 improves space charge effect and increase agglomeration and cohesiveness
  - Acts as scavenger, selectively combining with free SO_3/H_2SO_4 molecules

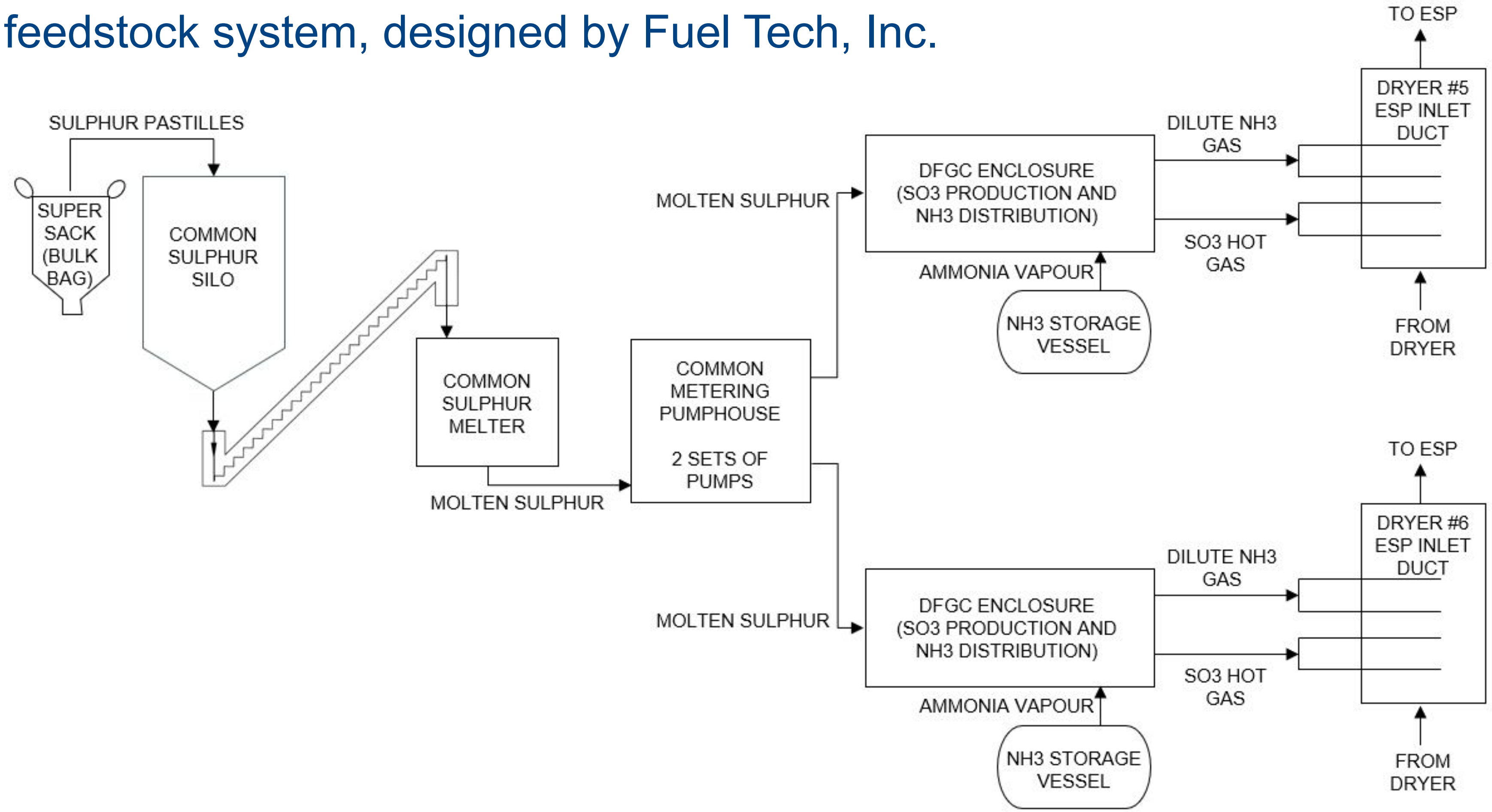
Correlation between SO_3 in converter off gas and ESP efficiency was discovered in 1912

Shanthakumar *et al.*, 2008
Trivedi and Phadke, 2008
Krigmont and Ferrigan, 2018
Krigmont, 2021

TECHNOLOGY DESCRIPTION

Dual Flue Gas Conditioning

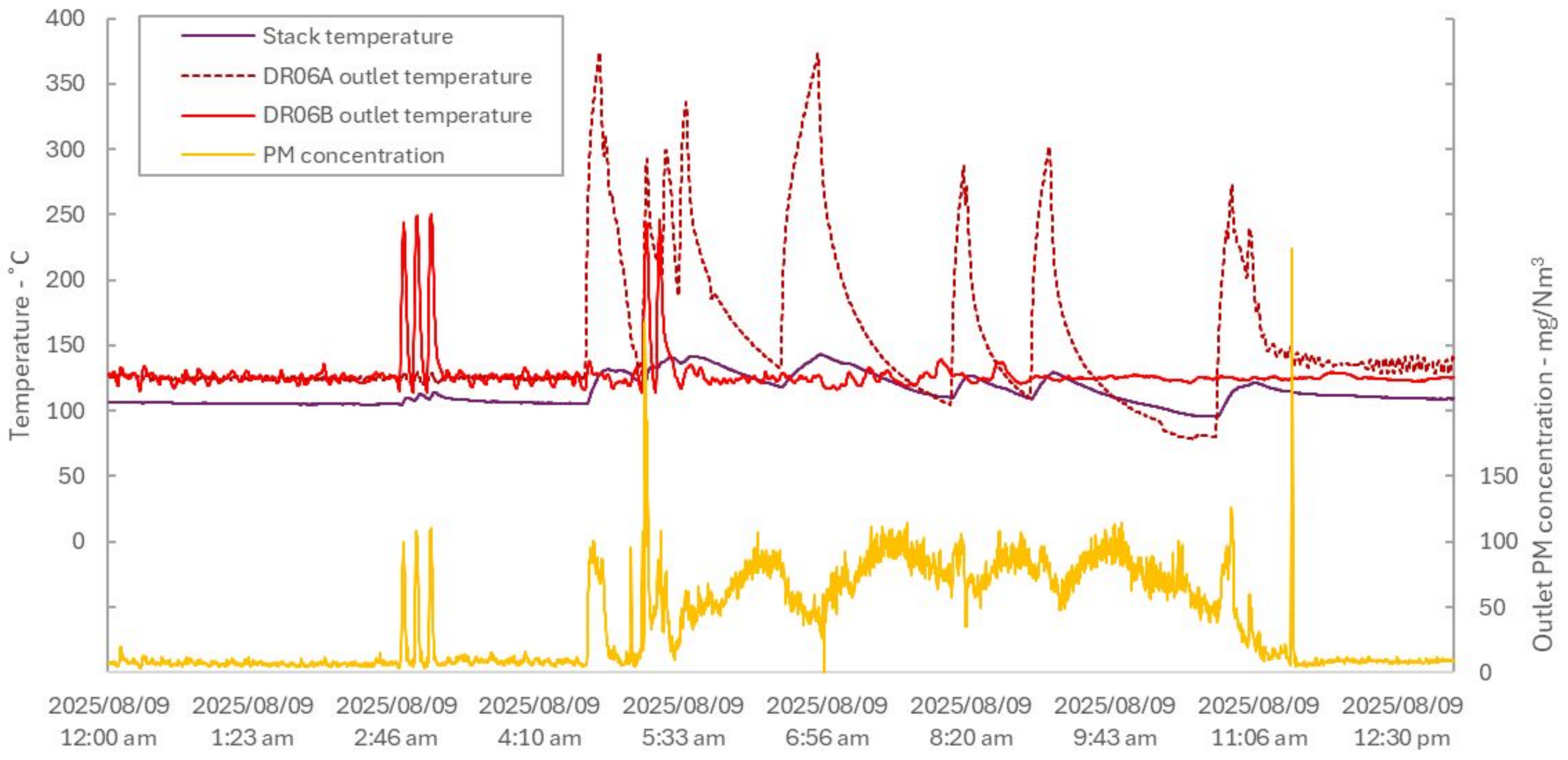
- Dry sulfur feedstock system, designed by Fuel Tech, Inc.



INITIAL PERFORMANCE

High Frequency Power Supplies

- Fairly consistent operation below MES of 50mg/Nm^3

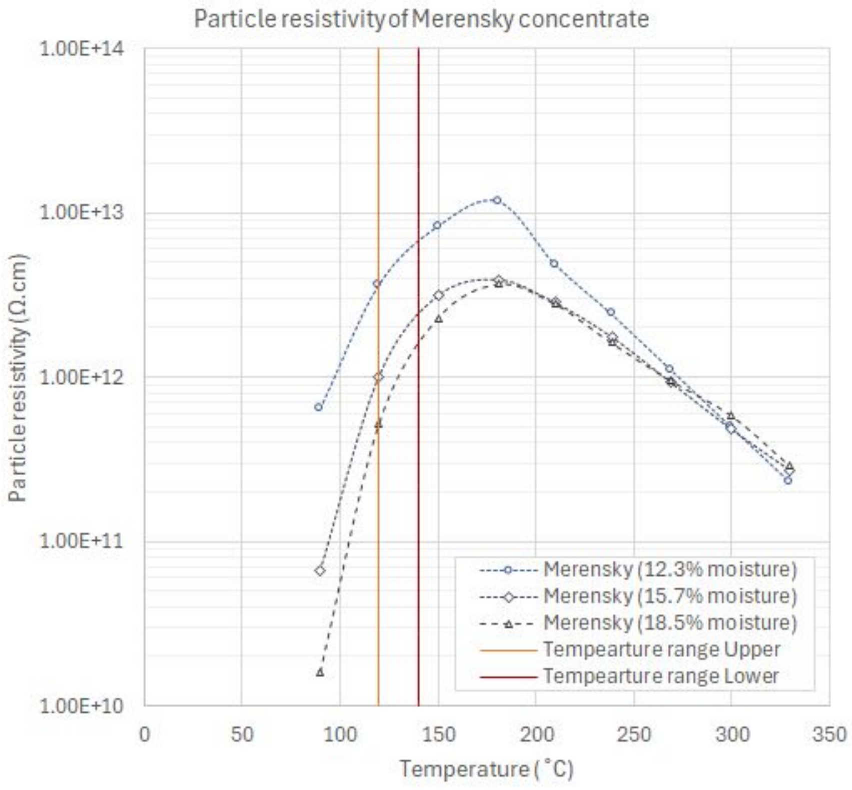


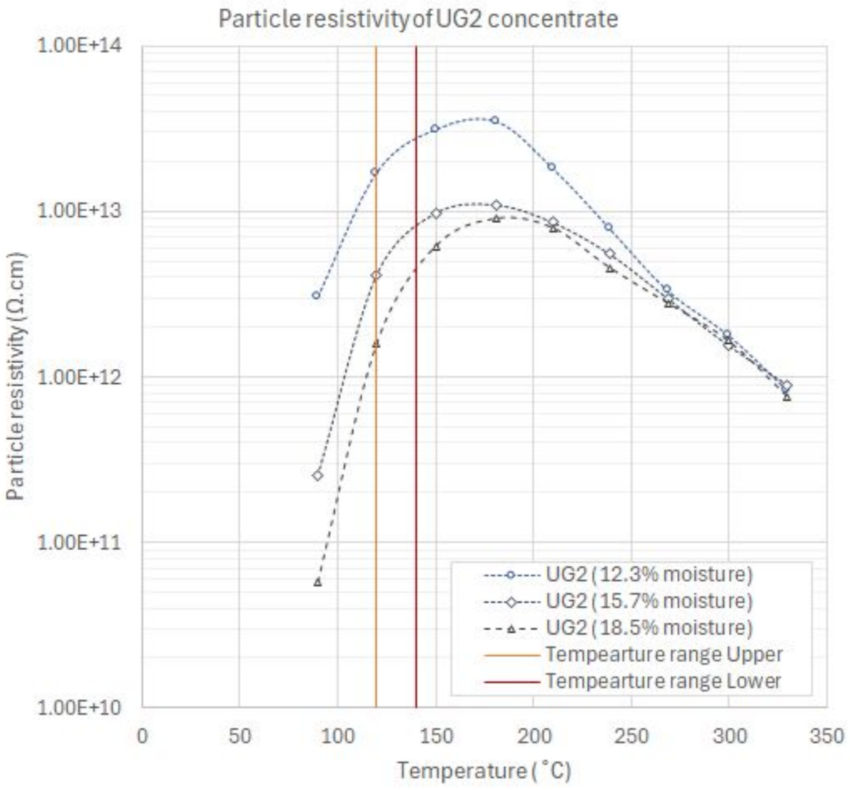
Emission measurement sensitive to gas temperature

- Particle resistivity is a function of temperature
- Charge is not readily accepted or released
- Promotes conditions leading to *back corona* discharge

Trivedi and Phadke, 2008
Krigmont and Ferrigan, 2025

INITIAL PERFORMANCE





Emission measurement sensitive to gas temperature

- *Back corona* discharge countered by activating Intermittent Energising
- Limits electrical input to reduce spark rate

Resistivity Ranges	Classification	ESP Performance
$10^4 - 10^8$ Ω.cm	Conductive dust or ash	Low Collection Efficiency
$10^8 - 10^{10}$ Ω.cm	Normal resistivity	Moderate Collection Efficiency
$10^{10} - 10^{11}$ Ω.cm	Moderate resistivity	High Collection Efficiency
$10^{11} - 10^{13}$ Ω.cm	High resistivity	Low Collection Efficiency

Okolo, 2019

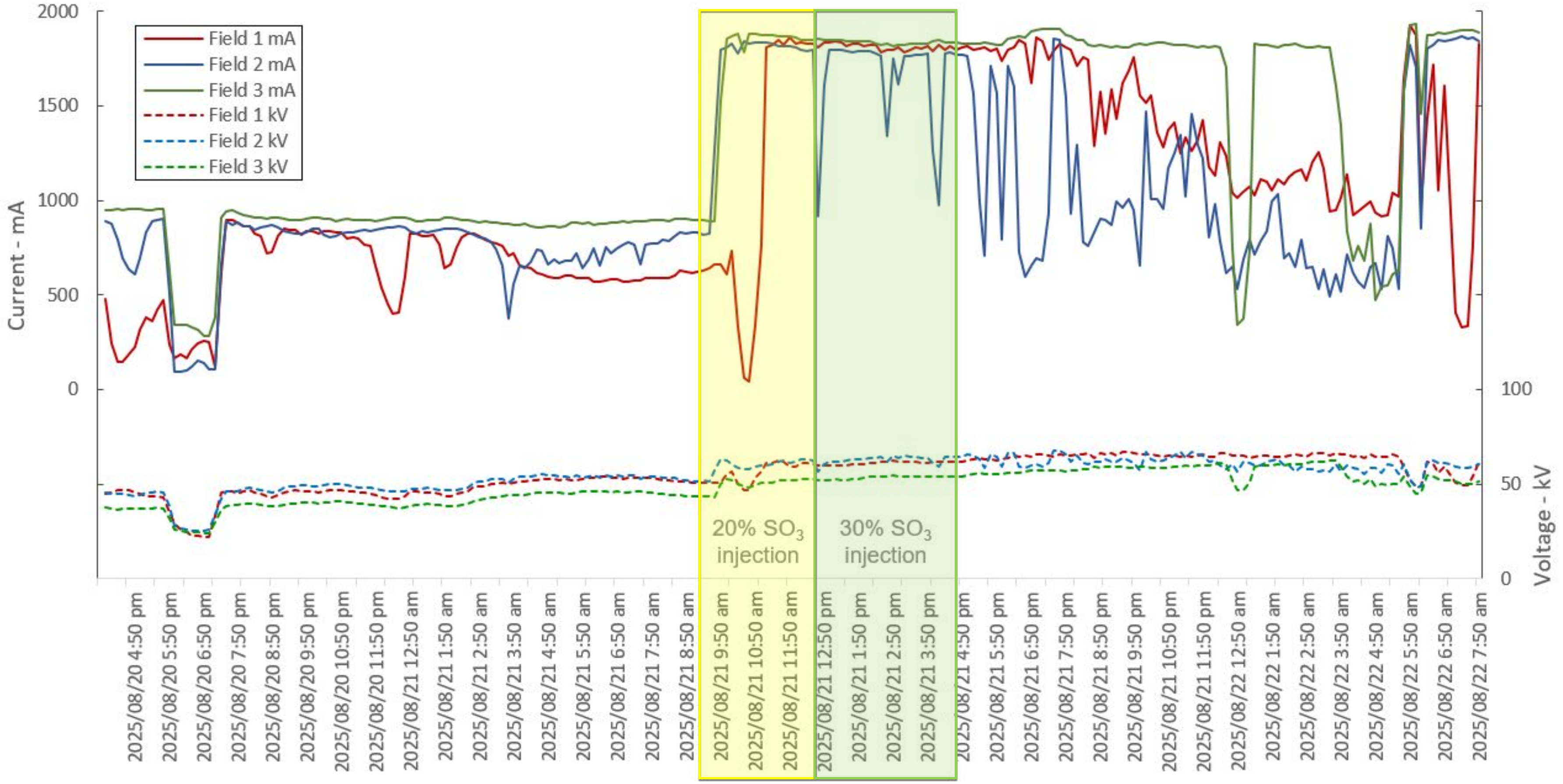
INITIAL PERFORMANCE

Dual Flue Gas Conditioning

- Hot commissioning and performance evaluation of the DFGC circuit was still underway at the time of submission of this paper.
- This section will thus cover initial observations pertaining to ESP performance with SO_3 injection

INITIAL PERFORMANCE

Dual Flue Gas Conditioning



- SO_3 injection performed without IE control
  - Power input improved
  - Spark rates reduced

INITIAL PERFORMANCE

Dual Flue Gas Conditioning

Parameter		Unit	Prior to injection	Injection at 20%	Injection at 30%	After injection
Dryer load	**Slurry feed**	*m^3/hr*	32.5	35.1	33.6	30.9
Voltage	**Field 1**	*kV*	45.9	55.0	61.0	63.4
	Field 2	*kV*	47.7	58.5	62.8	60.9
	Field 3	*kV*	39.8	48.9	53.4	56.1
Current	**Field 1**	*mA*	616	1018	1813	1360
	Field 2	*mA*	728	1545	1661	1070
	Field 3	*mA*	852	1566	1837	1644
Spark rate	**Field 1**	*SPM*	15.9	10.3	0.2	7.2
	Field 2	*SPM*	6.9	0.1	1.6	10.1
	Field 3	*SPM*	2.0	0.0	0.0	2.3
Power input	**Field 1**	*kW*	29.4	60.0	111.6	88.2
	Field 2	*kW*	36.2	93.0	106.2	69.2
	Field 3	*kW*	34.9	79.0	99.1	94.4

LESSONS LEARNT

This paper serves to introduce a proven technology in a new industrial sector.

The following aspects can be shared to benefit future projects of a similar nature.

- Standard equipment or parts, readily available in the USA are uncommon in South Africa.
- Plant layout and positioning within a brownfields project site face various constraints.
  - As such, additional control measures and design adjustments were required to manage accessibility and particulate ingress risks.
- Steam generation and steam circuit control is sensitive to correct and complete insulation of the relevant piping and equipment.
  - The placement and positioning of steam traps is also crucial to system operability and maintenance.

LESSONS LEARNT

This paper serves to introduce a proven technology in a new industrial sector.

The following aspects can be shared to benefit future projects of a similar nature.

- A balance between pre-manufacturing and on-site manufacturing of mechanical components, specifically piping, was required to ensure optimal utilisation of on-site resources.
  - The adoption of a flanged steam cladded pipe design can be considered a success.
- Even though sulfur is readily available within the country, the specification called for in this design is not.
  - Sulfur pastilles of the required quality and form are readily available in US and Asian markets and are therefore an import requirement.

CONCLUSIONS

- Newer generation High Frequency Power Supplies successfully improve ESP operation and lower PM emissions
- Particle resistivity remains a limiting factor, affecting ESP performance at elevated process temperatures.
- SO_3 injection serves to counter the effects of high resistivity particulate and secure electrical stability within the ESP.
- Even though limited data is available, initial observations indicate that SO_3 injection into an ESP that recovers PGM concentrate particulate mirror efficiency improvements realised in the utility sector.

ACKNOWLEDGEMENTS

- Co-authors
  - Eric Eichler
  - Hilgard Heller
- Impala Platinum Limited for being afforded the opportunity of presenting this paper.
- Support of senior management at Impala, Lesedi NS and Fuel Tech, Inc. during an extended commissioning period and ongoing finalisation and optimisation of the new plant.
- Impala engineering and production staff, for their continued support, especially the development and fine-tuning of control philosophies and systems.

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