



Application for Works Approval

Division 3, Part V *Environmental Protection Act 1986*

Works Approval Number W6275/2019/1

Applicant BHP Billiton Nickel West Pty Ltd

ACN 004 184 598

File Number DER2019/000398

Premises Kwinana Nickel Refinery
270 Patterson Road, Kwinana Beach WA 6167
Legal description -
Lot 89 on Deposited Plan 411084 and
Lot 820 on Deposited Plan 77252
Certificate of Title: Volume 2958/Folio 292
Volume 2841/Folio 582

Date of Report 25/09/2020

Status of Report Final

Table of Contents

1. Definitions of terms and acronyms	4
2. Purpose and scope of assessment	5
2.1 Application details	5
3. Background	5
4. Overview of Premises	6
4.1 Operational aspects	6
4.2 Proposed works	6
4.3 Discharges to air major emission sources	7
4.4 Air emissions modelling	10
4.4.1 Model setup	10
4.4.2 Ambient ground level values	10
4.4.3 Modelling assessment	11
4.5 Noise Modelling	12
5. Legislative context	12
5.1 Part V of the EP Act	12
5.1.1 Applicable regulations, standards and guidelines	12
5.1.2 Works approval and licence history	13
5.1.3 Key and recent works approvals	13
6. Consultation	13
7. Location and siting	13
7.1 Siting context	13
7.2 Residential and sensitive premises	13
7.3 Meteorology	14
8. Risk assessment	15
8.1 Determination of emission, pathway and receptor	15
8.2 Consequence and likelihood of risk events	16
8.3 Acceptability and treatment of Risk Event	17
8.4 Risk Assessment – Risk Event 1: nickel emissions	17
8.4.1 Description of Risk Event 1	17
8.4.2 Identification and general characterisation of emission	17
8.4.3 Description of potential adverse impact from the emission	17
8.4.4 Criteria for assessment	17
8.4.5 Applicant controls	18
8.4.6 Consequence	18
8.4.7 Likelihood of Risk Event	18

8.4.8	Overall rating of Risk Event 1	18
8.5	Risk Assessment – Risk Event 2: ammonia emissions	18
8.5.1	Description of Risk Event 2	18
8.5.2	Identification and general characterisation of emission.....	18
8.5.3	Description of potential adverse impact from the emission	18
8.5.4	Criteria for assessment.....	19
8.5.5	Applicant controls for Risk Event 2	19
8.5.6	Consequence of Risk Event 2	19
8.5.7	Likelihood of Risk Event 2	19
8.5.8	Overall rating of Risk Event 2	19
8.6	Summary of acceptability and treatment of Risk Events	19
9.	Regulatory controls	20
9.1	Works approval controls	20
9.1.1	Construction - Infrastructure design and construction	20
9.1.2	Time limited operation – Ambient monitoring.....	21
9.1.3	Specified action – Emission verification and management plan.....	21
9.1.4	Reports	21
10.	Determination of works approval conditions	21
11.	Applicant’s comments.....	22
12.	Conclusion	22
	Appendix 1: Key documents	23
	Appendix 2: Summary of applicant’s comments on risk assessment and draft conditions	24
	Attachment 1: Works Approval W6275/2019/1	26
	Attachment 2: BHP Nickel West Kwinana Licence L8437/2010/3 Process Description, 17 July 2019	27
	Table 1: Definitions	4
	Table 2: Documents and information submitted during the assessment process.....	5
	Table 3: Prescribed premises categories in the existing licence	6
	Table 4: Proposed major works.....	6
	Table 5: Major emission points of the Premises (excl. PLNSP emission points).....	8
	Table 6: AGVs for this assessment	11
	Table 7: Modelled ambient ground level concentration at 90 ktpa (including PLNSP)	12
	Table 8: Works approval and licence history	13
	Table 9: Receptors and distance from activity boundary	13
	Table 10. Identification of emissions, pathway and receptors during operation	15

Table 11: Risk rating matrix.....	16
Table 12: Risk criteria table.....	16
Table 13: Risk treatment table	17
Table 14: Risk assessment summary.....	20
Table 15: Summary of regulatory controls to be applied.....	20
Table 16: Summary of conditions to be applied.....	22

1. Definitions of terms and acronyms

In this Decision Report, the terms in Table 1 have the meanings defined.

Table 1: Definitions

Term	Definition
ACN	Australian Company Number
AGV	air quality guideline value
Applicant	BHP Billiton Nickel West Pty Ltd
ATSDR	US Department of Health and Human Services Agency for Toxic Substances and Disease Registry
Category/ Categories/ Cat.	Categories of Prescribed Premises as set out in Schedule 1 of the EP Regulations
dB	(decibel) The scale on which sound pressure level is expressed
Decision Report	refers to this document
Delegated Officer	an officer under section 20 of the EP Act
Department	means the department established under section 35 of the <i>Public Sector Management Act 1994</i> and designated as responsible for the administration of Part V, Division 3 of the EP Act
DoH	Department of Health
DWER	Department of Water and Environmental Regulation
EP Act	<i>Environmental Protection Act 1986 (WA)</i>
EP Regulations	<i>Environmental Protection Regulations 1987 (WA)</i>
Existing Licence	the Licence issued under Part V, Division 3 of the EP Act and in force prior to the commencement of, and during this Review
g/s	grams per second
HCIS	Safe Work Australia Hazardous Chemical Information System
ktpa	kilo tonnes per annum
LA ₁₀	is sound level exceeded for 10% of the time and as such can be regarded as the "average maximum level"
micron	unit of length equalling 1x10 ⁻⁶ metre
MRL	minimum risk level
PM _{2.5} and PM ₁₀	used to describe particulate matter that is smaller than 2.5 or 10 microns (µm) in diameter
Premises	refers to the premises to which this Decision Report applies, as specified at the front of this Decision Report

Term	Definition
Risk Event	As described in <i>Guidance Statement: Risk Assessment</i>
TSP	total suspended particulates
µg/m ³	micrograms per cubic metre

2. Purpose and scope of assessment

BHP Billiton Nickel West Pty Ltd (the Applicant) applied for a Works Approval on 18 July 2019 to undertake a series of individual works projects that are part of de-bottlenecking production at the Kwinana Nickel Refinery (KNR). These work projects are collectively referred to as the Capacity Uplift Project. The Capacity Uplift Project is expected to increase nickel production capacity from 75 ktpa to 90 ktpa. The works projects are planned over a period of approximately five years.

This Decision Report documents the Delegated Officer's assessment and determination of the application consistent with DWER's Regulatory Framework. The scope of risk assessment includes potential impacts from emissions and discharges during the construction and operational phases, whilst acknowledging that the emissions from all new infrastructure and equipment constructed under this works approval is through authorised emission sources on the existing licence

As the upgrades relate to multiple areas of the KNR and these upgrades impact the overall emissions and discharges of the premises, the scope of the assessment considers the environmental impact of the KNR after the upgrades have been completed.

2.1 Application details

The Applicant submitted the application form and additional information on 18 July 2019. Table 2 lists the documents submitted during the assessment process.

Table 2: Documents and information submitted during the assessment process

Document/information description	Date received
Works Approval Application with supplementary information (DWER record FA245429)	18 July 2019
Email from the Applicant with information about the Applicant's ambient ammonia monitoring program (DWER record A1911990)	19 June 2020
Email from the Applicant with an updated list of major works grouped in stages (DWER record A1911988)	19 June 2020

3. Background

The KNR has been operating since the 1970s and is located within the heavy industrial area of Kwinana.

The Capacity Uplift Project is driven by the need for nickel sulfate in the production of lithium batteries. The Applicant is nearing construction completion of a new Powder Leach Nickel Sulfate Plant (PLNSP) that is subject to works approval W6117/2018/1. Following the completion of the PLNSP, nickel from the KNR will be used to produce nickel sulfate. Other nickel products will still be produced at the KNR.

Table 3 lists the prescribed premises categories for the KNR.

Table 3: Prescribed premises categories in the existing licence

Classification of Premises	Description	Assessed Capacity
Category 31	Chemical manufacturing	2,701 tonnes of hydrogen sulfide gas per annum
Category 34	Oil or gas refining	5,840 tonnes of hydrogen gas per annum
Category 44	Metal smelting or refining	90 ktpa of nickel metal per annum
Category 67	Fuel burning	7,500 kilograms per hour

4. Overview of Premises

4.1 Operational aspects

The KNR is a hydrometallurgical refinery for nickel. The Applicant submitted a full process description, which is Attachment 2.

4.2 Proposed works

The Applicant has submitted information on the type of works it believes are needed to achieve an annual nickel production of 90 ktpa. The major works are described in Table 4 below.

Table 4: Proposed major works

Infrastructure name	Description	Design/construction specification
High rate thickener	Installation of a new thickener	<ul style="list-style-type: none"> Thickener will have a maximum diameter of 12 m Emissions from the thickener are directed to the existing vent system
Wet metals upgrade	Replacement of Driers, Pan Filters and Screw Classifiers with larger units	<ul style="list-style-type: none"> Optional replacement of existing venturi scrubber
Ammonium sulfate drier replacement	Driers replaced with larger capacity driers New Ammonium sulfate cooler	<ul style="list-style-type: none"> Waste gas stream to be treated by a wet gas cyclone (or equivalent) No increase of particulate emissions from the Ammonium sulphate plant
Adjustment thickener	Thickener with a maximum 12m diameter	<ul style="list-style-type: none"> Emissions to be directed to existing vent system.
4D-1 Tank	Ammonium sulphate plant feed storage tank	<ul style="list-style-type: none"> Tank vent system discharges into Amsul Cooling tower for water scrubbing of emissions Tank volume to be optimised to maximum average utilisation of ammonium sulphate evaporative and solids handling system
7 th Leach autoclave	Installation of an additional Leach autoclave	<ul style="list-style-type: none"> Replicate of existing leach autoclaves Waste gasses to be treated by the existing tail gas scrubber (no modification needed).
No.3 Boiler de-bottleneck	Replace fans and upgrade burner management system	<ul style="list-style-type: none"> De-bottleneck No. 3 Boiler to produce more steam. More natural gas consumption and more wastewater effluent produced.
Brine crystalliser	Ammonium sulphate crystalliser	<ul style="list-style-type: none"> Additional evaporative capacity required to process effluent streams and peak flows from Reduction

4.3 Discharges to air major emission sources

The Applicant has provided a list of all major emission sources, along with current emissions at 75 ktpa and the predicted emissions for 90 ktpa (+20% increase). The key emissions of concern are emissions of TSP, Ni and NH₃.

Table 5 shows the main emission sources and current and proposed emissions in g/s for TSP, Ni and NH₃ and the percentage of change. Emissions from the PLNSP have not been included in this table, as these are detailed in the documentation of W6117/2018/1.

It should be noted that although a comparison has been made between the current and proposed production rate emissions, the manner of how the emission rates were derived was different between these two scenarios and therefore comparison is only indicative of the change.

Table 5: Major emission points of the Premises (excl. PLNSP emission points)

Emission Point Source name	TSP emissions			Nickel emissions			Ammonia emissions		
	In g/s at 75 ktpa	In g/s at 90 ktpa	% change	In g/s at 75 ktpa	In g/s at 90 ktpa	% change	In g/s at 75 ktpa	In g/s at 90 ktpa	% change
Reduction Flash Tanks combined	0.000285	0.00034	+19.30%	0.00029	0.00034	+17.24%	49.2	54.8	+11.38%
Tail gas scrubber vent	0	0	-	0	0	-	17.5	56	+220%
Vent gas scrubber	0	0	-	0	0	-	11.0	7.5	-31.82%
Reduction Plate Leach vent	0	0	-	0	0		0.39	0.477	+22.31%
Nucleation flash tanks	0	0	-	0	0	-	0.50	0.6	+20%
Oxy overheads	0	0	-	0	0	-	5.8	0.00	-100%
Oxydrolysis Feed Tank	0	0	-	0	0	-	0.088	0.088	-
Copper Sulfide handling vent E2D-58	0	0	-	0	0	-	0.067	0.075	+11.94%
Copper Sulfide Handling vent E2D-2	0	0	-	0	0	-	0.20	0.20	-
Copper Sulfide Handling vent E2D-26	0	0	-	0	0	-	0.083	0.083	-
DTO Tank (11D-7) Vent	0	0	-	0	0	-	0.22	0.22	-
Wet Metals Scrubber A	0.00085	0.0010	+17.65%	0.00085	0.001	+17.65%	0	0	-
Wet Metals Scrubber B	0.00054	0.00065	+20.37%	0.00054	0.00065	+20.37%	0	0	-

Emission Point Source name	TSP emissions			Nickel emissions			Ammonia emissions		
	In g/s at 75 ktpa	In g/s at 90 ktpa	% change	In g/s at 75 ktpa	In g/s at 90 ktpa	% change	In g/s at 75 ktpa	In g/s at 90 ktpa	% change
Pre-Oxidation Stack 1	0.0039	0.0039	-	0.0012	0.0012	-	0	0	-
Pre-Oxidation Stack 2	0.0039	0.0039	-	0.0012	0.0012	-	0	0	-
Pre-Oxidation Stack 3	0.0039	0.0039	-	0.0012	0.0012	-	0	0	-
Sinter Furnace 1	0.0073	0.0088	+20.55%	0.0016	0.0019	+18.75%	0	0	-
Sinter Furnace 2	0.0068	0.0082	+20.59%	0.0016	0.0020	+25%	0	0	-
Sinter Furnace 3	0.0048	0.0058	+20.83%	0.0008	0.0010	+25%	0	0	-
Baghouse 3T-10	0.0004	0.00044	+10%	0.0003	0.0003	-	0	0	-
Baghouse 3T-156	0.0029	0.0029	-	0.0033	0.0033	-	0	0	-
Baghouse 3T-306	0.0024	0.0024	-	0.0015	0.0015	-	0	0	-
Baghouse 3T-308	0.0019	0.0019	-	0.0012	0.0012	-	0	0	-
Mixed Sulfides Packaging	0.011	0.011	-	0.0038	0.0038	-	0	0	-
Total	0.050875	0.05513	+8.36%	0.01938	0.02059	+6.24%	85.048	120.043	+41.15%

4.4 Air emissions modelling

4.4.1 Model setup

The Applicant provided modelling of the air emissions from the Premises. The modelling was conducted for 75 ktpa and 90 ktpa scenarios using meteorological data from Swanbourne and Kwinana Industries Council (KIC) monitoring locations.

The Applicant used the manufacturers' design specifications of some pollution control equipment or used monitoring data of the emission sources for the modelling when these were available. If either of the two was not available, the Applicant used estimation techniques for the emission sources.

The Applicant used process simulation software to model worst case emission from the tail gas scrubber at 90 ktpa, which is different to what was used when modelling ammonia emission rates at 75 ktpa. The 75 ktpa emission rates were based on 2017 National Pollution Inventory reporting and reflects the annual average emissions during actual operations.

The modelling of intermittent emissions (from batch operated sources) was performed at a constant emission rate to model the worst-case scenario.

For this application, the Applicant modelled all existing emission sources from the KNR and excluded proposed new emission sources of the PLNSP. Emissions from the PLNSP were modelled separately and used for the assessment of the recent amendment of works approval W6117/2018/1.

To aid its assessment of air emissions from the whole refinery post-Capacity Uplift Project and PLNSP completion, DWER combined the modelling results of the PLNSP with the modelling results for this application.

DWER undertook a technical review of the Applicant's modelling and found that results using the meteorological data from KIC's monitoring location in Kwinana were significantly closer to the monitored values from a recently completed monitoring campaign that DWER undertook at North Rockingham, than the modelling results from the Swanbourne meteorological data set.

4.4.2 Ambient ground level values

DWER initially compared modelling results to ambient ground level values (AGV) in its *draft Guideline: Air Emissions* (October 2019). It was noted TSP emissions are modelled to be less than 1% of the set AGV and therefore TSP was screened out from further detailed analysis.

It was also noted that the model predicted potential nickel and ammonia levels above the respective AGV from the department's *draft Guideline: Air Emissions*. Further analysis and consultation with the Department of Health (DoH) was undertaken to ascertain the appropriateness of the draft AGV for nickel and ammonia to this assessment.

In respect of nickel, it is understood a key health risk of air emissions is associated with long term exposure (i.e. annual average and above). As such the annual AGV for nickel is the most appropriate to determine the consequence of the nickel emissions. The *draft Guideline: Air Emissions* provides an annual nickel (nickel and its compounds) AGV of 0.003 µg/m³. DoH took account of the analysis of the modelling and results of the department's ambient nickel monitoring program, which was conducted in 2019 in North Rockingham. It also reviewed submissions on the draft nickel AGV and indicated that evidence supports a review of the guideline in support of the 0.02 µg/m³ annual value provided by the European Union (source: <https://ec.europa.eu/environment/air/quality/standards.htm>) for the protection of short term and long term health.

Therefore, a revised AVG of 0.02 µg/m³ (annual average) for nickel has been used for this assessment, measured as the PM₁₀ fraction.

In respect of ammonia, it is understood a key health risk of air emissions is associated with acute, short term (i.e. 1 hour) exposure. The department's draft AVG in its *draft Guideline: Air Emissions* is 330 µg/m³ (1 hour average). This was sourced from the New South Wales Environment Protection Authority (NSW EPA) "*Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (2016).

The department commissioned a consultant in 2011 to provide advice on the appropriate ammonia AGV for the protection of human health. The recommendation for the ammonia threshold was to use the Minimum Risk Level (MRL) as documented in "*Toxicological Profile for Ammonia*" from the U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, September 2004 (ATSDR 2004 Ammonia).

In the ATSDR 2004 Ammonia report, a MRL of 1.7 ppm (1,184 µg/m³) has been derived for acute-duration inhalation exposure (14 days or less) to ammonia. The findings also noted that there is no cumulative effect at this MRL. While the department's draft *Guideline: Air emissions* puts forward a proposed AGV of 330 µg/m³, the Delegated Officer has further considered the applicability and appropriateness of that proposed value to the KNR and this assessment.

The Delegated Officer assessed the modelled ammonia emissions against the 1-hour AGV as per the department's *draft Guideline: Air Emissions* and it was determined that ammonia emissions are not deemed insignificant. The Delegated Officer then assessed ammonia against the ATSDR 2004 Ammonia MRL.

Table 6 summarises the used Assessment AGV for nickel and ammonia in this assessment.

Table 6: AGVs for this assessment

Pollutant	Averaging time	Assessment AGV at 0 °C and 101.325 kPa	Notes
Nickel and its compounds	Annual	0.02 µg/m ³	Assessment against the AGV to occur based upon 99.9 percentile of the modelling result at a residential receptor.
Ammonia	1 hour	1,184 µg/m ³	Nickel and its compounds means that the g/s emission rate of a nickel compound such as nickel sulfate is to be used and not to be adjusted to only reflect the nickel portion of the compound.

4.4.3 Modelling assessment

The modelling results have been assessed against the AGVs as established under paragraph 4.4.2. The results of this assessment are shown in Table 7.

Table 7: Modelled ambient ground level concentration at 90 ktpa (including PLNSP)

Pollutant and average time*1	Ambient ground level value	% AGV at residential receptor as the 99.9 percentile of the modelling results
		North Rockingham
Nickel and its compounds - Annual	0.02 µg/m ³	68%
Ammonia - 1 hour	1,184 µg/m ³	54%

4.5 Noise Modelling

The Applicant undertook noise modelling using 215 noise sources from the KNR to establish a new baseline model of noise emissions of the KNR for 90 ktpa. The noise modelling in the Application is not comparable to previous limited noise modelling the Applicant has prepared using nine noise sources. Neither is it possible to make a comparison of the “before” and “after” the capacity upgrade scenarios.

The noise model was found to be technically sound and predicted an exceedance (max modelled exceedance 2.8 dB at one of the 5 assessment locations, residential areas) of the nighttime LA₁₀ assigned noise levels at the sensitive receptors under worst case weather conditions. The model predictions have not been validated with actual monitoring and are therefore a conservative worst case indicator of predicted noise impacts from the whole of the KNR (including the PLNSP, which is still under construction).

It is noted that the Applicant has submitted a Noise Monitoring and Validation Plan on 27 September 2019 as a requirement of Works Approval W6117/2018/1 for the PLNSP and the plan is now in its implementation phase. It is expected the results of this study will better inform understanding of noise emissions and noise impacts from the KNR.

The Applicant has also committed to preparing a Noise Reduction Management Plan. It is expected this will follow and be informed by the results of the Noise Monitoring and Validation Plan. The department will further review the noise risk profile once this information is available, and consider the adequacy of controls in the existing licence.

Noise has not been further assessed in detail for this report, noting that broader noise investigations have been initiated through other regulatory mechanisms.

5. Legislative context

5.1 Part V of the EP Act

5.1.1 Applicable regulations, standards and guidelines

The overarching legislative framework of this assessment is the EP Act and EP Regulations. The guidance statements which inform this assessment are listed in Appendix 1.

5.1.2 Works approval and licence history

Table 8 summarises the works approval and licence history for the premises.

Table 8: Works approval and licence history

Instrument	Issued	Nature and extent of works approval, licence or amendment
L8437/2010/3	30/10/2015	Licence reissued
L8437/2010/3	20/04/2016	Notice of amendment of licence expiry dates Section 59B(9) and Section 59(1)(k) <i>Environmental Protection Act 1986</i> Licensed Prescribed Premises Licence duration extended to 30 October 2021
W6117/2018/1	13/07/2018	Works Approval issued for the construction of the powder leach nickel sulfate plant
W6117/2018/1	16/04/2020	Amendment to Works Approval W6117 to reflect the detailed design of the powder leach nickel sulfate plant

5.1.3 Key and recent works approvals

Works Approval W6117/2018/1 and the subsequent amendment are relevant to this application. As part of Works Approval W6117/2018/1 the Applicant is to conduct ambient monitoring for nickel, including in North Rockingham.

6. Consultation

The works approval application was advertised on the department's website on 16 August 2019 and in the West Australian on 19 August 2019. No comments were received on the application.

7. Location and siting

7.1 Siting context

The KNR is located within the Kwinana Industrial Area, which is located approximately 30 km south of Perth. There are several heavy industrial premises to the north of the Premises, but only the CBH Grain Terminal is between the KNR and residents in North Rockingham.

7.2 Residential and sensitive premises

The distances to residential and sensitive receptors are detailed in Table 9.

Table 9: Receptors and distance from activity boundary

Sensitive Land Uses	Distance from Prescribed Activity
Residents in North Rockingham	Approximately 1.6 km to the south - south west
Residents in Hillman	Approximately 2.6 km to the south
Community recreation area (Wells Park)	Approximately 600 m to the west - north west

7.3 Meteorology

The Applicant used the data from the KIC monitoring location for the modelling of air emissions. This is the most appropriate dataset for modelling of emissions from the Premises. As such no generic information about meteorology will be presented here. It is noted that the Applicant has installed their own meteorological station just south of their Premises to create a site specific dataset.

8. Risk assessment

8.1 Determination of emission, pathway and receptor

In undertaking its risk assessment, DWER will identify all potential emissions pathways and potential receptors to establish whether there is a Risk Event which requires detailed risk assessment.

To establish a Risk Event there must be an emission, a receptor which may be exposed to that emission through an identified actual or likely pathway, and a potential adverse effect to the receptor from exposure to that emission. Where there is no actual or likely pathway and/or no receptor, the emission will be screened out and will not be considered as a Risk Event. In addition, where an emission has an actual or likely pathway and a receptor which may be adversely impacted, but that emission is regulated through other mechanisms such as Part IV of the EP Act, that emission will not be risk assessed further and will be screened out through Table 10.

The identification of the sources, pathways and receptors to determine Risk Events during operation is set out in Table 10 below. As the Capacity Uplift Project works are occurring during normal operation of the Premises, the potential impacts of the construction of the works are not separately assessed but included in the assessment of the operational phase.

Table 10. Identification of emissions, pathway and receptors during operation

Risk Events					Continue to detailed risk assessment	Reasoning
Sources / Activities	Potential emissions	Potential receptors	Pathway	Potential adverse impacts		
Operation of the KNR	Emissions of nickel and ammonia to air	Residents in North Rockingham	Air / wind dispersion	Short term acute and/or long term health impacts	Yes	See paragraph 9.4 and 9.5
	Noise	Residents in North Rockingham	Air	No negative impacts expected	No	Based upon noise modelling no negative impacts on sensitive receptors expected from the proposed increase in production. <i>Environmental Protection (Noise) Regulations 1997</i> apply.

8.2 Consequence and likelihood of risk events

A risk rating will be determined for risk events in accordance with the risk rating matrix set out in Table 11 below.

Table 11: Risk rating matrix

Likelihood	Consequence				
	Slight	Minor	Moderate	Major	Severe
Almost certain	Medium	High	High	Extreme	Extreme
Likely	Medium	Medium	High	High	Extreme
Possible	Low	Medium	Medium	High	Extreme
Unlikely	Low	Medium	Medium	Medium	High
Rare	Low	Low	Medium	Medium	High

The department will undertake an assessment of the consequence and likelihood of the Risk Event in accordance with Table 12 below.

Table 12: Risk criteria table

Likelihood		Consequence		
The following criteria has been used to determine the likelihood of the Risk Event occurring.		The following criteria has been used to determine the consequences of a Risk Event occurring:		
			Environment	Public health* and amenity (such as air and water quality, noise, and odour)
Almost Certain	The risk event is expected to occur in most circumstances	Severe	<ul style="list-style-type: none"> onsite impacts: catastrophic offsite impacts local scale: high level or above offsite impacts wider scale: mid-level or above Mid to long-term or permanent impact to an area of high conservation value or special significance[^] Specific Consequence Criteria (for environment) are significantly exceeded 	<ul style="list-style-type: none"> Loss of life Adverse health effects: high level or ongoing medical treatment Specific Consequence Criteria (for public health) are significantly exceeded Local scale impacts: permanent loss of amenity
Likely	The risk event will probably occur in most circumstances	Major	<ul style="list-style-type: none"> onsite impacts: high level offsite impacts local scale: mid-level offsite impacts wider scale: low level Short-term impact to an area of high conservation value or special significance[^] Specific Consequence Criteria (for environment) are exceeded 	<ul style="list-style-type: none"> Adverse health effects: mid-level or frequent medical treatment Specific Consequence Criteria (for public health) are exceeded Local scale impacts: high level impact to amenity
Possible	The risk event could occur at some time	Moderate	<ul style="list-style-type: none"> onsite impacts: mid-level offsite impacts local scale: low level offsite impacts wider scale: minimal Specific Consequence Criteria (for environment) are at risk of not being met 	<ul style="list-style-type: none"> Adverse health effects: low level or occasional medical treatment Specific Consequence Criteria (for public health) are at risk of not being met Local scale impacts: mid-level impact to amenity
Unlikely	The risk event will probably not occur in most circumstances	Minor	<ul style="list-style-type: none"> onsite impacts: low level offsite impacts local scale: minimal offsite impacts wider scale: not detectable Specific Consequence Criteria (for environment) likely to be met 	<ul style="list-style-type: none"> Specific Consequence Criteria (for public health) are likely to be met Local scale impacts: low level impact to amenity
Rare	The risk event may only occur in exceptional circumstances	Slight	<ul style="list-style-type: none"> onsite impact: minimal Specific Consequence Criteria (for environment) met 	<ul style="list-style-type: none"> Local scale: minimal to amenity Specific Consequence Criteria (for public health) met

[^] Determination of areas of high conservation value or special significance should be informed by the *Guidance Statement: Environmental Siting*.

* In applying public health criteria, DWER may have regard to the Department of Health's *Health Risk Assessment (Scoping) Guidelines*.

"onsite" means within the Prescribed Premises boundary.

8.3 Acceptability and treatment of Risk Event

The department will determine the acceptability and treatment of Risk Events in accordance with the Risk treatment Table 13 below:

Table 13: Risk treatment table

Rating of Risk Event	Acceptability	Treatment
Extreme	Unacceptable.	Risk Event will not be tolerated. DWER may refuse application.
High	May be acceptable. Subject to multiple regulatory controls.	Risk Event may be tolerated and may be subject to multiple regulatory controls. This may include both outcome-based and management conditions.
Medium	Acceptable, generally subject to regulatory controls.	Risk Event is tolerable and is likely to be subject to some regulatory controls. A preference for outcome-based conditions where practical and appropriate will be applied.
Low	Acceptable, generally not controlled.	Risk Event is acceptable and will generally not be subject to regulatory controls.

8.4 Risk Assessment – Risk Event 1: nickel emissions

8.4.1 Description of Risk Event 1

Risk Event 1 is described as follows:

Nickel is released from the KNR to atmosphere where it is dispersed in the air causing long term exposure health impacts on residents in North Rockingham.

(Please note the wording of the above statement is such so that it can be assessed, not that it is a statement of truth)

8.4.2 Identification and general characterisation of emission

Nickel emissions (including nickel sulfate and other nickel compounds) are emitted from several stacks within the KNR. These have been modelled and results of ground level concentrations are shown in Table 5. Emissions from the PLNSP were modelled for the recent amendment to Works Approval W6117/2018/1.

8.4.3 Description of potential adverse impact from the emission

Nickel emissions to air are generally between 2.5 and 10 micron in size. Nickel particulate matter, like other chemicals or metals of this size, can be inhaled by people and can travel to the lungs. Long term exposure to higher levels of nickel in the air can cause chronic bronchitis, reduced lung function and cancer of the lung and nasal sinus.

8.4.4 Criteria for assessment

The criterion for assessment of nickel emissions is detailed in Paragraph 4.4.2.

8.4.5 Applicant controls

The Applicant did not propose additional controls to reduce nickel emissions to atmosphere in the works approval application. Existing controls such as bag house filters will continue to be used in the process. It may be that an existing scrubber will need to be replaced for a similar kind of scrubber, however that is currently not certain and emissions are expected to be similar. In addition to emission controls the Applicant has commenced ambient monitoring of nickel in compliance with conditions of Works Approval W6117/2018/1 for the PLNSP. The ambient monitoring of nickel is designed to measure the impact of nickel on the residents of North Rockingham and the results will be reviewed annually by the department and DoH.

8.4.6 Consequence

The Delegated Officer has determined that the impact of the nickel emissions from KNR on residential receptors will likely meet the public health standards at the receptors. Therefore, the Delegated Officer considers the consequence of Risk Event 1 to be **Minor**.

8.4.7 Likelihood of Risk Event

The Delegated Officer has determined that Risk Event 1 will probably not occur in most circumstances. Therefore, the Delegated Officer considers the likelihood of Risk Event 1 to be **Unlikely**.

8.4.8 Overall rating of Risk Event 1

The Delegated Officer has compared the consequence and likelihood ratings described above with the risk rating matrix (Table 11) and determined that the overall rating for the risk of Risk Event 1 is **Medium**.

8.5 Risk Assessment – Risk Event 2: ammonia emissions

8.5.1 Description of Risk Event 2

Risk Event 2 is described as follows:

Ammonia is released from the KNR to atmosphere where it is dispersed in the air causing short term, acute health impacts and/or odour impacts on residents in North Rockingham.

(Please note the wording of the above statement is such so that it can be assessed, not that it is a statement of truth)

8.5.2 Identification and general characterisation of emission

Ammonia emissions are emitted from several stacks within the KNR. These have been modelled and are shown in Table 5. Although several emission sources are intermittent, they have been modelled as continuous sources and thus resulting in a worst case scenario for the modelling.

8.5.3 Description of potential adverse impact from the emission

Exposure to typical environmental concentrations of ammonia will not affect humans. Exposure to high levels of ammonia can cause irritation and serious burns on the skin, and in the mouth, throat (laryngitis), lungs (pulmonary oedema) and eyes (conjunctivitis). Exposure to very high levels of ammonia can lead to death (information from www.npi.gov.au). Ammonia has a distinct odour which is experienced by many people as a nuisance and thus impacting on their amenity. Individual responses to odour emissions may vary depending on age, health status, sensitivity, and odour exposure patterns. Perceived odour intensity may increase or decrease on exposure. Community response to an odour can include annoyance, potentially leading to stress and loss of amenity. Exposure to repeated odour events can create a

nuisance effect.

Exposure times and frequency of odour emissions depend on day to day activities and weather conditions.

8.5.4 Criteria for assessment

The selection of the criterion for assessment of ammonia emissions is detailed in Paragraph 4.4.2. The odour threshold for ammonia seems to be between 28 µg/m³ to 13,930 µg/m³. This means that highly sensitive individuals may detect ammonia odour at very low levels, whereas the threshold for other individuals may be much higher. The point at which detecting odour becomes perceived as impacting comfort, amenity or convenience is highly subjective.

8.5.5 Applicant controls for Risk Event 2

The Applicant did not propose additional controls for ammonia emissions to atmosphere in the works approval application. Work is proposed to try to optimise the Tail Gas Scrubber to ensure that will have the same efficiency when it is processing more waste gases. The overall emissions of ammonia are expected to increase due to the increased production. The Applicant has initiated ambient monitoring of ammonia at places beyond, but relatively close to the Premises. The aim of the monitoring is to verify the modelling. The Applicant has a management plan in place to respond to ammonia complaints.

8.5.6 Consequence of Risk Event 2

The Delegated Officer has determined that the impact of the ammonia emissions from KNR on residential receptors is likely to meet the specified health criterion, however low level impact to amenity may be experienced due to the lower odour threshold. Therefore, the Delegated Officer considers the consequence of Risk Event 2 to be **Minor**.

8.5.7 Likelihood of Risk Event 2

The Delegated Officer has determined that it is unlikely that short term, acute health impacts will occur on residential receptors. The Delegated Officer also has determined that it may be possible that a short term amenity impact, due to the lower odour threshold, could occur at some time. Therefore, the Delegated Officer considers the likelihood of Risk Event 2 to be **Possible**.

8.5.8 Overall rating of Risk Event 2

The Delegated Officer has compared the consequence and likelihood ratings described above with the risk rating matrix (Table 11) and determined that the overall rating for the risk of Risk Event 2 is **Medium**.

8.6 Summary of acceptability and treatment of Risk Events

A summary of the risk assessment and the acceptability or unacceptability of the risk events set out above, with the appropriate treatment and control, are set out in Table 14 below. Controls are described further in section 9.

Table 14: Risk assessment summary

	Description of Risk Event	Applicant controls	Risk rating	Acceptability with controls (conditions on instrument)
1.	Nickel is released from the KNR to atmosphere where it is dispersed and long term exposure causes health impacts on residents in North Rockingham.	Existing infrastructure within the Premises. Ambient nickel monitoring in North Rockingham	Minor consequence Unlikely Medium Risk	Acceptable subject to regulatory controls
2.	Ammonia is released from the KNR to atmosphere where it is dispersed and short term, acute exposure causes health impacts and/or odour impacts on residents in North Rockingham.	Existing infrastructure within the Premises. Efficiency upgrade for the Tail Gas Scrubber. Ambient ammonia monitoring outside the Premises.	Minor consequence Possible Medium risk	Acceptable subject to regulatory controls

9. Regulatory controls

A summary of regulatory controls determined to be appropriate for the Risk Event is set out in Table 15. The risks are set out in the assessment in section 8 and the controls are detailed in this section. The department will determine controls having regard to the adequacy of controls proposed by the Applicant. The conditions of the Works Approval will be set to give effect to the determined regulatory controls.

Table 15: Summary of regulatory controls to be applied

Risk Events	Controls (references are to sections below, setting out details of controls)			
	9.1.1 Construction	9.1.2 Time limited operation	9.1.3 Specified Action	9.1.4 Reporting
Nickel is released from the KNR to atmosphere where it is dispersed and long term exposure causes health impacts on residents in North Rockingham.	●	●	●	●
Ammonia is released from the KNR to atmosphere where it is dispersed and short term, acute exposure causes health impacts and/or odour impacts on residents in North Rockingham.	●	●	●	●

9.1 Works approval controls

9.1.1 Construction - Infrastructure design and construction

Proposed works that are directly related to emissions and discharges will be specified with associated design and construction requirements consistent with the Applicant's controls.

9.1.2 Time limited operation – Ambient monitoring

Following completion of infrastructure / equipment as shown in Table 4, the Applicant will be required to provide evidence that the works have been completed in accordance with the specifications.

The Applicant's ambient ammonia monitoring will not be prescribed in the conditions of the works approval as the monitors that are being used for this purposes do not comply with an appropriate standard that can be referred to for compliance. Furthermore, the locations of the monitors may not reflect the potential impact of ammonia emissions at residential receptors.

However, consistent with the conditions relating to ambient nickel monitoring on works approval W6117/2018/1 for the PLNSP, the Delegated Officer specified ambient ammonia monitoring in the conditions for this works approval.

9.1.3 Specified action – Emission verification and management plan

The Delegated Officer has required the Applicant to prepare and submit an emission verification and management plan within 12 months of granting the works approval. The plan will require the Applicant to undertake emission source, control, verification and reduction investigations for nickel and ammonia.

It is expected that this information will increase the level of certainty within the Applicant's conservative emission estimations and allow for DWER to undertake further review of the risk profile of nickel and ammonia emissions from the whole of KNR and the appropriateness and adequacy of controls on the licence.

9.1.4 Reports

The Applicant will be required to provide the monitoring results and evidence of compliance with the works approval conditions to the CEO in writing for each stage. Reporting of the ambient ammonia ground level concentrations measured by the ambient ammonia monitor will also be required.

10. Determination of works approval conditions

The conditions in the works approval in Attachment 1 have been determined in accordance with the *Guidance Statement: Setting Conditions*.

Note that risk assessment has considered the construction and operational phase potential impacts associated with the application. The works approval and its conditions will apply to the construction phase only. Taking into consideration the nature of proposed works and the risk assessment outcomes, the Delegated Officer considers that the emissions from the Capacity Uplift Project once operational, will be via emission points on the existing licence that are subject to existing controls. The Delegated Officer has not included time limited operations conditions on the basis that once the Applicant has completed works and submitted relevant Environmental Compliance Reports, it can transition straight to operating that new infrastructure and equipment under the existing licence and licence amendments for this purpose are not expected to be necessary.

However, the Applicant will be required to undertake ammonia and nickel investigations under this works approval, and the Delegated Officer expects that the results will inform further review of the air emissions risk profile and consideration of the ongoing adequacy and appropriateness of the conditions of the existing licence.

Table 16 provides a summary of the conditions to be applied to this works approval.

Table 16: Summary of conditions to be applied

Condition Ref.	Grounds
Infrastructure and equipment 1	This condition specifies environmental requirements regarding the proposed infrastructure to be constructed under the works approval.
Compliance reporting 2 and 3	These conditions relate to condition 1 to ensure that the works are constructed in accordance with the specification of condition 1.
Time limited operations phase 4	These conditions allow for the works to be operated following compliance reporting. As works are part of de-bottlenecking and may not individually require an amendment to the licence there is no time restriction on the time limited operation as emissions are captured under the licence.
Ambient ammonia monitoring 5 and 6	These conditions are a result of the risk of short-term ammonia impacts on residents in North Rockingham. Continuous ambient ammonia monitoring is required to be conducted within the residential area of North Rockingham.
Specified action – emission verification and management plan 7	This condition requires the submission of an emission verification and management plan for ammonia and nickel of KNR’s emission sources.
Compliance reporting – time limited operation 8	This condition requires the submission of the results of the ambient ammonia monitoring to the CEO.
Records and reporting 9, 10 and 11	These conditions are standard in nature to record complaints and keep books about the environmental performance of the Premises.

The Delegated Officer notes that DWER may review the appropriateness and adequacy of controls at any time and that, following a review, DWER may initiate amendments to the works approval under the EP Act.

11. Applicant’s comments

The Applicant was provided with the draft Decision Report and draft Works Approval on 13 August 2020. The Applicant submitted comments and the Delegated Officer’s response to these are outlined in Appendix 2.

12. Conclusion

This assessment of the risks of activities on the Premises has been undertaken with due consideration of a number of factors, including the documents and policies specified in this Decision Report (summarised in Appendix 1).

Based on this assessment, it has been determined that the works approval will be granted subject to conditions commensurate with the determined controls and necessary for administration and reporting requirements.

James Milne

A/Senior Manager, Process Industries

Officer delegated under section 20 of the *Environmental Protection Act 1986*

Appendix 1: Key documents

	Document title	In text ref	Availability
1.	Application for works approval with attachments	Application	DWER record A1808976
2.	Email from BHP regarding a change of proposed works and clarification of stages dated 19 June 2020	-	DWER records A1911988
3.	Email from BHP regarding their ambient ammonia monitoring program dated 19 June 2020	-	DWER records A1911990
4.	DER, July 2015. <i>Guidance Statement: Regulatory principles</i> . Department of Environment Regulation, Perth.	DER 2015a	accessed at www.dwer.wa.gov.au
5.	DER, October 2015. <i>Guidance Statement: Setting conditions</i> . Department of Environment Regulation, Perth.	DER 2015b	
6.	DER, May 2016. <i>Guidance Statement: Publication of Annual Audit Compliance Reports</i> . Department of Environment Regulations, Perth.	DER 2016a	
7.	DER, August 2016. <i>Guidance Statement: Licence duration</i> . Department of Environment Regulation, Perth.	DER 2016b	
8.	DER, September 2016. <i>Guidance Statement: Environmental Standards</i> . Department of Environment Regulation, Perth.	DER 2016c	
9.	DER, November 2016. <i>Guidance Statement: Environmental Siting</i> . Department of Environment Regulation, Perth.	DER 2016d	
10.	DER, February 2017. <i>Guidance Statement: Risk Assessments</i> . Department of Environment Regulation, Perth.	DER 2017b	
11.	DWER, June 2019. <i>Guidance Statement: Decision Making</i> . Department of Water and Environmental Regulation, Perth.	DER 2019a	
12.	DWER, June 2019. <i>Guideline: Industry Regulation Guide to Licensing</i> . Department of Water and Environmental Regulation, Perth.	DER 2019b	
13.	DWER, June 2019. <i>Guideline: Odour emissions</i> . Department of Water and Environmental Regulation, Perth.	DER 2019c	
14.	National Environment Protection Assessment of Site Contamination Measure (ASC NEPM)	ASC NEPM 1999	

Appendix 2: Summary of applicant’s comments on risk assessment and draft conditions

Condition/aspect	Summary of Licence Holder comment	Delegated Officer’s response
Works Approval Duration	Request to have the duration of the Works Approval extended to at least 5 years	The works approval duration was updated to 5 years.
Infrastructure table	<p>The requested detailed design specification for the infrastructure is not available at the moment. The Applicant provided further context and detail as much as possible. Emission profile of all infrastructure combined when completed will be consisted with the figures used in the air emission modelling for 90 ktpa.</p> <p>The Applicant requested to remove the stages of the infrastructure to allow for the individual infrastructure items to be completed and used.</p>	<p>The response from the Applicant was noted. The Delegated Officer took into consideration air emissions modelling and risk assessment outcomes and that the works are expected to occur over a five year period. The department will review the emissions verification and management plan (condition 7) and identify potential changes to the risk profile and the need for licence amendments.</p> <p>The removed the stages of construction and the works were listed individually.</p>
Compliance reporting - Infrastructure	The Applicant reiterated that the works are part of de-bottlenecking and as such the works proposed will be constructed and then they will need to be tied-in to the existing infrastructure, which will occur during planned shut-downs. The Applicant requested a 90 calendar day period for the compliance reporting, following the commissioning of that infrastructure (tie-in)	Condition 2 was updated to allow 90 calendar days for compliance reporting.
Commissioning	The Applicant requested that the term “commissioning” be included and used in the conditions. The Applicant provided a definition for “commissioning”.	The Applicant’s comments were noted. On consideration of the nature of works, this risk assessment and the existing licence, the Delegated Officer determined that time limited operational phase conditions are not required. Emissions from the new infrastructure / equipment is via emission points on the existing licence that are subject to conditions. This assessment has not identified specific

Condition/aspect	Summary of Licence Holder comment	Delegated Officer's response
		<p>changes to the licence that are needed in order for the Applicant to be able to transition to the existing licence once a compliance report(s) are submitted. However, the information from required nickel and ammonia studies will inform a review of the air emissions risk profile and the licence may be amended following this review.</p> <p>There is therefore considered no need for a commissioning definition and the Delegated Officer has removed time limited operational conditions.</p>
Ambient ammonia monitoring	The Applicant requested changes to this condition as they acquired a monitor that complies with AS3580.14. Also the Applicant requested a change of location and a change to the reporting requirements.	<p>The requested alteration was further discussed with the Applicant. The proposed monitor is noted to be compliant with AS3580.14 therefore the condition was simplified.</p> <p>A monitor location for the first 12 months has been identified (North Rockingham, within the department's ambient monitoring compound). It was accepted that while annual reporting of the ammonia monitoring results may be too infrequent, monthly may be excessive. too frequent. The Delegated Officer therefore opted for quarterly reporting.</p>
Emission verification and management plan	The Applicant requested some changes to the requirement of this plan.	This was further discussed with the Applicant and the Delegated Officer agreed to alter the final condition to include all potential ammonia and nickel emission sources and accept the Applicant's proposed wording changes.
Draft Decision Report	The Applicant requested some wording changes throughout the Draft Decision Report. These were mainly to correct or clarify matters within the report.	The Decision Report was updated and corrected as needed.

Attachment 1: Works Approval W6275/2019/1

Attachment 2: BHP Nickel West Kwinana Licence L8437/2010/3 Process Description, 17 July 2019

BHP

Nickel West Kwinana Licence L8437/2010/3

Process Description

17 July 2019



Contents

Process Description	3	
Purpose of document	3	
Overview	3	
Detailed Process Description	1	
Nickel Refining	1	
Matte Grinding		1
Leach		1
Copper Boil		2
Oxydolysis		2
Nickel Reduction		3
Metals (Wet Metals)		3
Metals (Briquetting)		4
Furnaces		4
Mixed Sulphides		4
Ammonia Recovery		5
Ammonium Sulphate Crystallisation (Amsul Plant)		8
Utility Systems	8	
Hydrogen Plant		8
Old PSA Plant		9
Hydrogen Sulphide (H ₂ S)		9
Boiler		10
Demineralised Water		10

Process Description

Purpose of document

This document provides details of the hydrometallurgical refining process utilised at Nickel West's (NiW) Kwinana Nickel Refinery (NKW). This process description is intended to support the Capacity Uplift licence amendment application and facilitate the Department of Water and Environment Regulation (DWER) review of the NKW licence granted under Part V of the *Environmental Protection Act 1986* (EP Act).

NKW is currently constructing a Powder Leach Nickel Sulfate Plant (PLNSP) at the Refinery site. The PLNSP converts Nickel powder produced by the existing refining process to Nickel Sulfate, a key component of lithium ion batteries. This facility has been assessed by DWER and is being constructed under works approval 6117/2018/1. As the facility is not yet operational, it has not been included in this document.

Overview

NKW produces a refined nickel metal in the form of a metallic powder, or a pillow shaped sintered briquette of approximately 100g. The nickel metal is over 99% pure and exported via Fremantle Port to third parties.

The majority of nickel produced at the NKW Nickel Refinery originates from nickel sulphide ores mined at Mt Keith, Leinster and Kambalda in WA. The mined ore is first processed to produce a nickel sulphide concentrate, which then becomes the primary feedstock for the Kalgoorlie Nickel Smelter (NKS) located on the outskirts of Kalgoorlie. The smelter produces a nickel matte, which becomes the feedstock for NKW.

The granulated nickel matte produced by the NKS is fed into a Grinding Mill and the finely ground product is fed as slurry into a series of Leach Autoclaves. The slurry is mixed with ammonia and air and is subjected to both high temperature and pressure during which most of the metals and sulphur is leached into solution. Three stages of leaching are carried out to maximise metal recoveries. The resulting pregnant solutions are separated from any un-leached materials via use of thickeners.

The pregnant leach solution containing nickel, copper and cobalt is then fed into the Copper Boil circuit to precipitate a copper sulphide via an ammonia distillation process. The precipitates are then separated from the copper-free solution by a thickening and filtration process to produce a clean solution containing nickel, cobalt, ammonia and ammonium sulphate. The precipitate is a copper sulphide material that is filtered, dried and packed for further processing overseas.

The clean solution from Copper Boil then undergoes the Nickel Reduction process where nickel is precipitated from solution by hydrogen in autoclaves as a pure nickel powder. After being washed and dried, the nickel powder is available for sale in this form or alternatively it is pressed into briquettes and sintered by a furnace.

Solution from the Reduction circuit still contains some nickel and most of the cobalt that was dissolved within the Leach circuit. These metals are recovered in a liquor stripping operation using hydrogen sulphide gas. The precipitate, a 'mixed sulphide' of nickel and cobalt, is recovered from the ammonium sulphate solution by a thickening and filtration system prior to being dried and packed for further processing overseas.

The clean ammonium sulphate liquor passes to a crystallising plant. The crystallising plant produces a coarse crystalline ammonium sulphate solid, which is then sold as a fertilizer.

A schematic representation of this process is at Figure 1.

Nickel West Kwinana PROCESS FLOWSHEET

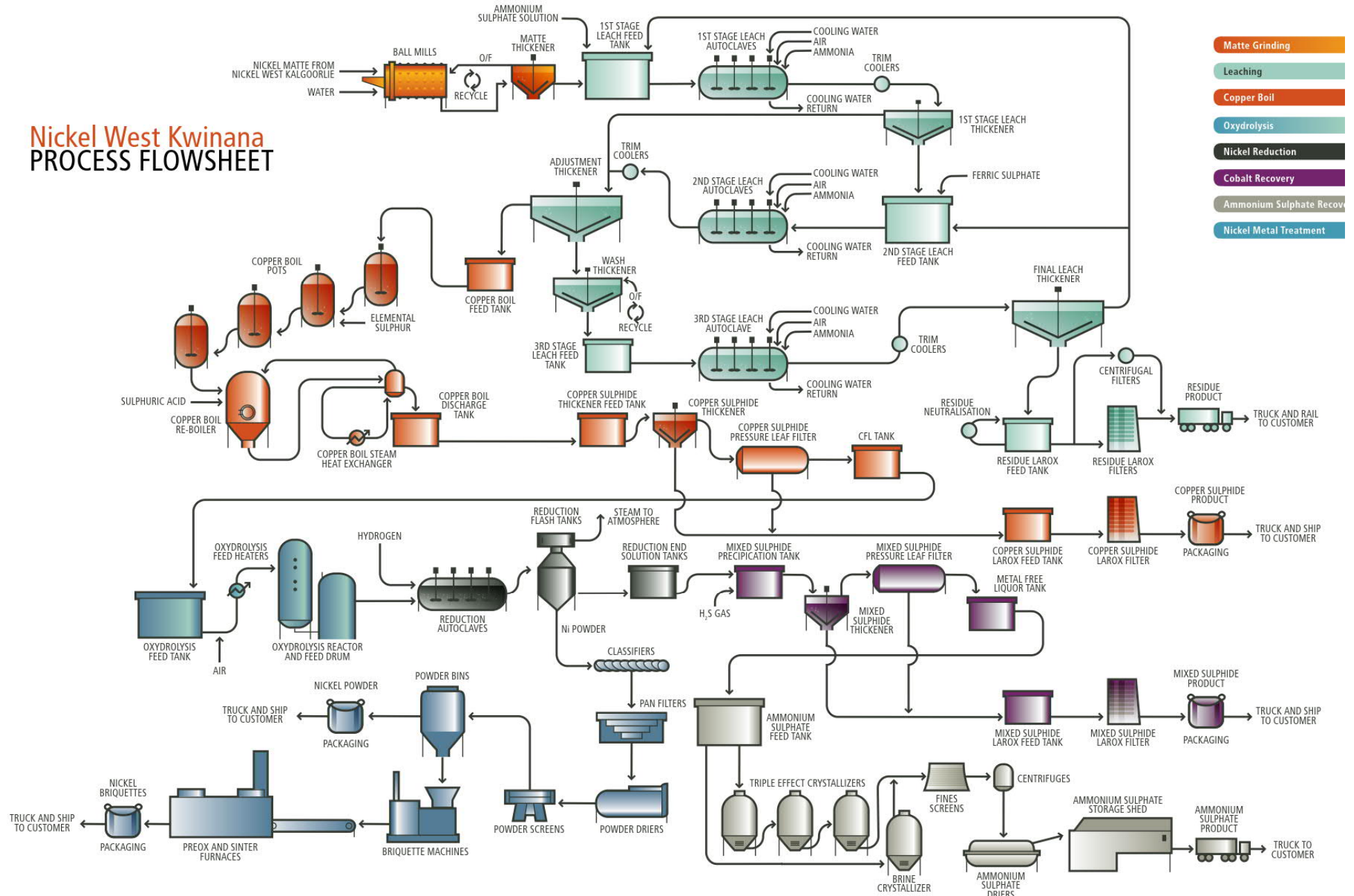


Figure 1: KNR Process Flowchart

Detailed Process Description

Nickel Refining

Matte Grinding

Nickel matte (primary feed to the NKW) is transferred via rail from the NKS to the Kwinana rail terminal and then to NKW by road. Once the matte has been emptied, some containers are back-loaded with residue for transport to Kalgoorlie and ultimately, to another nickel producer in the Northern Goldfields of WA.

Containers transporting matte and residue have been specially designed to meet the requirements of NKW including the following features:

- The containers can be transferred from a railway wagon to a truck (and vice versa) via a forklift;
- The containers are loaded from the top via a front-end loader and emptied via unlocking an end panel and tipping;
- The containers are covered to prevent material being lost, or impacted by rain, during the transportation process; and
- The containers have been constructed to prevent corrosion as a result of contact with residue containing residual amounts of ammonium sulphate salt and moisture.

Due to their special design and method of construction, the containers are purpose built and owned by Nickel West. To maintain a constant supply of feed material, NKW maintains a fleet of approximately 60 containers.

Once received nickel matte is stored at a holding yard until required, or carted directly to the matte unloading ramp and discharged into a hopper. Matte is then transferred via conveyor and a bucket elevator to the matte storage bins.

Matte is then ground in a two stage milling circuit with water to form a slurry. The slurry consisting of fine particles is pumped via a discharge hopper to the Dewatering Thickener.

Flocculant is added to the thickener to assist the settling of ground matte particles in order to produce a clear thickener overflow stream. The thickener underflow is directed to the First Stage Leach Feed Tank. The thickener overflow, which is free of solids, is fed by gravity to the Overflow Tank and pumped back for reuse in the Matte Grinding circuit.

Leach

Leaching involves subjecting the ground matte to air and ammonia at high temperature and pressure. NKW has six leach autoclaves configured to form a three stage leach circuit. Of the six autoclaves two are on a first stage duty, three are on a second stage duty, while one is on a third stage duty. This three stage approach enables an overall nickel extraction of >98%.

To facilitate optimum metals recovery and residence time within the circuit, leaching temperatures within the autoclaves are maintained within a temperature range 85 to 115°C by internal cooling coils. The ammonia feed to leach autoclaves is by direct addition of anhydrous ammonia and also recycled solutions and vapours from the ammonia recovery circuit.

Ground matte is initially fed from the Dewatering Thickener to the First Stage Leach Tank and mixed with barren recycled process liquors. Dosed Thickener Overflow, which has been spiked with magma from the Ammonium Sulfate Crystallisation Plant, is also added to the First Stage Leach Tank to stabilise amine compounds produced in the leach circuit. Contents of the First Stage Leach Tanks are then fed to one of two First Stage Leach Autoclaves.

First stage leach has been designed to target the removal of the easy to leach metallic nickel content of the matte so the autoclaves operate at slightly lower ammonia concentrations and lower oxygen partial pressures than the second and third stage leach autoclaves. The discharge from the first stage leach is fed to First Stage leach Thickener. Underflow from this thickener is fed to the Second Stage Leach Feed Tank, while overflow is fed to Adjustment Thickener.

The Second Stage Leach Feed Tank mixes un-leached solids from the first stage with barren recycled process liquors. As in first stage leach, the blend of recycle process streams is adjusted to manage the amount of ammonium sulphate recycled to the leaching process.

The discharge from the Second Stage Leach Autoclaves is fed to the Adjustment Thickener. Overflow from Adjustment Thickener is fed to the Copper Boil circuit, while underflow from the Adjustment Thickener is fed to the Third Stage Leach Autoclave to extract the maximum amount of valuable metals as possible.

Discharge from the Third Stage Leach Autoclave is fed to the Final Thickener. Overflow from the Final Thickener is usually fed to the Amsul circuit where it is dosed with ammonium sulphate magma to make DTO for reuse in the leach process. Underflow from the Final Thickener which is predominately an iron oxide plus residual quantities of un-leached material, is processed via centrifuges or pressure filters located in the Filter Building prior to the residue being discharged to a storage bunker prior to export.

To reduce fugitive ammonia emissions from the residue filtration process, there is a dedicated circuit that neutralises ammonia contained within the residue slurry.

The spent air from the leach circuit is sent to the ammonia recovery circuit where, as the name suggests, ammonia is recovered from the air before discharging to atmosphere via the Tail Gas Scrubber.

Copper Boil

After leaching, pregnant feed solution enters the copper boil circuit. Copper boil involves precipitating copper as copper sulphide, removal of excess ammonia, increasing ammonium sulphate concentration and adjustment of nickel strength in the feed solution prior to feeding downstream processes.

The pregnant solution produced by the leaching circuit flows against a stream of ammonia and water vapour through five vessels (Copper Boil pots) arranged in a cascade order. Steam generated from an indirectly heated flash stage is injected into the bottom vessel and is gradually enriched with ammonia as it passes up through the system. The feed solution passes down the system and is gradually depleted of ammonia. Ammonia vapour is recovered as aqua and recycled to matte leaching. Sulphuric acid is added to the solution to convert some of the remaining ammonia to ammonium sulphate. Elemental sulphur is added to enable the copper to precipitate as copper sulphide.

The discharge slurry from Copper Boil is fed to the Cusul Thickener via a series of tanks. Overflow from the Thickener is passed through Pressure Leaf Filters (PLFs) to remove solids. The clear liquor is free from copper and is called Copper Free Liquor (CFL) and becomes the feed for the next unit operation (Oxydrolisis).

The solids from the Pressure Leaf Filters are mixed with the underflow from the Cusul Thickener and passed through a Larox Pressure Filter to recover the copper sulphides as a filter cake. The filter cake is then packaged into 2 tonne bulk-a-bags for shipment to customers. The filter cake moisture content is maintained above approximately 10% to prevent auto-ignition of the product during shipment.

Oxydrolisis

Copper Free Liquor (CFL) from the Copper Boil circuit contains dissolved amines of nickel and cobalt along with ammonium sulphate. However, the solution also contains minor amounts of unsaturated sulphur compounds (thiosulphate) and ammonium sulphamate. The first function of the Oxydrolisis circuit is to remove the unsaturated sulphur compounds as they can decompose under the conditions within the Reduction Autoclaves and contaminate the nickel powder with sulphur. The second function of Oxydrolisis is to remove the ammonium sulphamate as it has herbicidal properties and any residual ammonium sulphamate will report in the ammonium sulphate product, which is sold as a fertiliser.

The CFL is stored in the Oxydrolisis Feed Surge Tank before being pumped through the first stage preheater where the temperature of the feed is raised to approximately 115°C by the reactor vapour overheads. The solution then passes through the second stage preheater and high pressure steam heaters to raise the temperature approximately 245°C.

As the solution passes through the circuit, high pressure air is injected at a controlled rate to provide the oxygen necessary for the oxidation of the residual thiosulphates. From the steam heaters, the solution and air pass to the top of the Oxydrolisis reactor. The reactor vessel provides residence time for hydrolysis of the ammonium sulphamate to ammonium sulphate. The exhaust air, which contains water vapour and ammonia, is cooled to recover ammonia as a dilute aqua. The dilute aqua returns to Oxydrolisis Feed Surge Tank while the unused air is directed

to the leach air system where it finally exits to atmosphere via the Tail Gas Scrubber. There is also the capacity to direct the spent air to vent of the Oxydrolisis Feed Tank, which may be required when the leach circuit is shutdown and the Oxydrolisis circuit is still operating.

The treated solution is then drawn from the bottom of the reactor vessel and discharged to the Reduction Feed Drum, which is a high pressure, high temperature storage vessel for feed liquor to the Reduction Autoclaves. When required nitrogen will vent through a control valve to a cooler and then into the vapour space of the Oxydrolisis Feed Tank. The Oxydrolisis Feed Tank has an elevated vent direct to atmosphere.

Nickel Reduction

Liquor from the Reduction Feed Drum is fed to eight nickel Reduction Autoclaves and reacts with hydrogen gas to precipitate nickel from the liquor as nickel powder. The precipitation reaction is a heterogeneous reaction in that the nickel requires a pre-existing solid surface of nickel upon which it can precipitate. As a result, the creation of an initial seed particle and the subsequent growth of the particle through the precipitation reactions are two important parameters in managing the performance of a reduction autoclave.

The reduction process is a batch process, which takes approximately five days to complete. The reduction feed solution from Oxydrolisis is fed in batches into one of eight Reduction Autoclaves which are horizontal, cylindrical vessels with four agitators.

The operation of each autoclave passes through a standard cycle comprising four distinct phases:

- Nucleation;
- Densification;
- Rinsing and purging; and
- Leaching and purging.

Waste gas streams and vapours from the nickel reduction cycle are predominately discharged via the Reduction Flash Tanks. This emission fluctuates and composition is dependent on the stage in the cycle.

Metals (Wet Metals)

The function of the wet metals process is to wash nickel powder of ammonium sulphate and dry the nickel powder prior to briquetting, powder packaging or feeding the Nickel Sulphate Plant.

Nickel powder slurry from the Reduction Autoclaves enters the Reduction Flash Tanks where the solids quickly settle to the bottom in the cone shaped part of the tank. The clear liquor is decanted into the Reduction End Solution Tank from where it proceeds to the Mixsul precipitation and Amsul crystallisation sections of the refining process. The heavy nickel slurry in the cones of the Reduction Flash Tanks is withdrawn by gravity through slurry control valves into a two-stage washing circuit to reduce the sulphate level of the powder to acceptable limits.

The nickel powder slurry flows into a spiral classifier before being transferred onto a vacuum pan filter where it is subjected to washing with raw water. A "scroll" picks up the wet powder from the pan filter and discharges its contents to a nickel powder drier.

The drier, equipped with internal steam tubes, slopes from the horizontal. Wet nickel powder is fed into the drier at its highest point and is dried while passing through to exit at the lowest point. Steam is passed through the internal heating tubes in the opposite direction before being discharged via a steam trap as condensate at the lower end of the drier. The drier is equipped with an induced draft fan, which draws air through the drier and discharges to atmosphere via wet Venturi scrubbers.

From the driers, the powder containing less than approximately 1% moisture is discharged onto screens to remove any large lumps of nickel. The nickel lumps or plate is screened off into drums whilst the finer nickel powder is directed to a powder distribution box from where it is sent to either the Briquette Feed Bin, Powder Packaging Storage Bins or the Nickel Sulphate plant.

Metals (Briquetting)

The purpose of the briquetting process is to convert nickel powder into a form that can be readily stored and handled by the final customers. The briquettes produced at NKW weigh between 80 to 130 grams and are a pillow shape. Once formed, the briquettes are fed to the furnaces.

Depending on which briquette machine is online, the powder is fed via a variable speed screw feeder into a mixing vessel. A binder is added and a vertical screw feeder (force feeder) mixes the binder and powder together. The force feeder forces the mixture into the pockets of a rotary mould (rolls) which creates a "green" briquette that has sufficient strength to hold its shape until it enters the Pre-oxidation furnace.

From the rolls, the briquettes fall onto a discharge conveyor and are directed onto a vibrating screen. This screen separates any chips and powder from the briquettes and recycles them to the hammer mills or premixing vessel. The whole briquettes passing from the vibrating screen then enter the Briquette Surge Bin. Briquettes from this bin can be directed to whichever furnace is online, where they are sintered (hardened) and desulphurised.

Furnaces

The purpose of the furnaces is to strengthen and fuse the briquettes and remove any sulphur, carbon and oxygen. This is a two-step furnace operation that produces a >99.8% purity nickel briquette that meets the specifications for trading on the London Metals Exchange (LME).

There are three furnace lines situated at the south side of the Metals Building. Each furnace line consists of two specialised furnaces, a Pre-oxidation Furnace and a Sinter Furnace. Each furnace line operates in similar manner and the following information is applicable to each furnace.

The Pre-oxidation Furnace is designed to give briquettes a degree of physical strength prior to de-sulphurisation in the Sinter Furnace while also removing the carbon introduced via the briquetting process. The Pre-oxidation Furnace has two heating zones, one containing four natural gas burners and the second containing two. The burners are situated below a wire mesh conveyor belt which runs through the Furnace. The first zone is designed to raise the briquette temperature rapidly to around 800°C, while the second zone maintains the temperature of the briquettes as they pass through to the Pre-oxidation Furnace. Air is injected into the second zone to maintain sufficient oxygen within furnace atmosphere to partially oxidise the briquettes.

The Sinter Furnace consists of an incinerator, four hot zones and a cooling zone comprised of four or six compartments. The Furnace operates under a hydrogen atmosphere, which reacts with sulphur to form H₂S gas. The H₂S gas is subsequently burnt in the incinerator along with the excess hydrogen. The quantities of H₂S produced are small at less than ~1.0 kg/hr per furnace.

The hot zones operate at 800 to 1000°C to assist with the reaction of hydrogen with the sulphur in the briquettes. The cooling zone on the Furnace performs the task of reducing the briquette temperature from approximately 900°C to 60°C in an oxygen-free environment before being packaged ready for distribution to customers.

Mixed Sulphides

Reduction End Solution (RES) discharged from the Reduction Autoclaves contains small amounts of nickel and cobalt in solution. The metals in solution are recovered by a sulphide stripping operation prior to the crystallisation of fertiliser grade ammonium sulphate (Amsul) in the Ammonium Sulphate Plant. The 'stripping' of the metals is accomplished by the addition of H₂S gas to the RES under controlled conditions. The precipitation is carried out to the point where only a trace of metals remain in solution.

RES is pumped at a controlled rate from the Reduction End Solution Clarification Tank into the Mixed Sulphide Precipitation Tank. H₂S gas is sparged into a combination of RES and a continuously circulating mixture of precipitation tank contents that acts as a seed bed for subsequent sulphide particle growth.

The vapour space above the Sulphide Precipitation Tank is connected to its own independent ventilation system. The vent system captures any H₂S, water vapour or inert gases and then directs them to a scrubbing system prior to release to atmosphere via a flare. The system consists of a vapour condenser to remove most of the water vapour followed by a packed column scrubber. The scrubbing system uses a weak ammonia solution to capture any residual H₂S gas. The spent scrubbing solution containing some dissolved H₂S is then returned to the process via the Mixed

Sulphide Precipitation Tank. Under normal operating conditions, the scrubber will remove all the H₂S gas, leaving only nitrogen and water vapour to be directed to the flare.

Following precipitation, the mixed sulphide slurry is transferred to the Mixsul Thickener. The overflow is further processed via Pressure Leaf Filters (PLF) to remove any suspended solids. The clear liquor from the PLF filters is called Metal Free Liquor (MFL) and is further processed in the Amsul plant. Captured solids from the PLFs are combined with the Mixsul Thickener underflow for processing through a Larox Pressure Filter. The filter washes out entrained ammonium sulphate solution before air drying the solids. The Mixsul product is then packaged into 2 tonne bulk-a-bags ready for final shipment.

It is possible to supplement the H₂S gas with a liquid reagent called sodium hydrosulphide (NaHS). The NaHS system can also be used instead of H₂S gas for short periods.

Ammonia Recovery

The primary purpose of the ammonia recovery system is to recover ammonia from the leach and copper boil process vapours through a combination of condensing and water scrubbing. The system also recovers minor amounts of ammonia from ventilation gases collected from various tanks and thickeners through the Vent Gas Scrubber. The recovery of the ammonia is desirable for both environmental and economic point of view. A schematic of the Ammonia Recovery Circuit is at Figure 2.

Tail Gas Scrubber

The TGS removes ammonia from leach off-gas through contact with process water. The original scrubber was equipped with 30 valve trays to provide intimate contact between the off-gas and water. The replacement scrubber (installed in 2012; described here) adopted a five stage or sectionalised packed bed design.

The absorption of ammonia is an exothermic reaction; the rising temperature of the water decreases its ability to absorb ammonia. To overcome this issue, the water/aqua solution is collected at various points down the scrubber and diverted into intercoolers where the aqua is cooled and then returned to the column, just below the take-off point.

The pressure inside the TGS is controlled by a control valve located on the TGS gas outlet line. After passing through the control valve, the clean gas then exits to atmosphere via a Muffler (F2T-88).

The solution collected at the bottom of the TGS contains approximately 65 gpL ammonia and is called medium aqua. From the TGS, it flows to the Medium Aqua Tank where it combined with the condensed ammonia vapour from the copper boil overhead vapour circuit.

Ammonia Still

From the Medium Aqua Tank, the liquor is fed to the Ammonia Still where it is first pre-heated to approximately 135°C using heat recovery heat exchangers. The resulting hot aqua then enters the Still at the top above the internal packing.

The Ammonia Still is a sectionalised packed column containing three beds of stainless steel pall rings. The physical chemistry is the reverse of the other ammonia recovery unit operations. That is, ammonia is stripped out of the feed solution and rises with some water to the top of the column where it is condensed as a ~455 gpL ammonia solution. The resulting solution is then collected in a Condensate Drum from where it is returned to the leach autoclaves.

The bottoms from the Still consisting of recovered process water with traces of ammonia is cooled by first passing through some heat recovery heater exchanges and then a water cooled exchanger. Once cooled, the process water is directed to a storage tank.

Vent Gas and Vacuum Gas Scrubbers

The Vent Gas and Vacuum Gas Scrubber remove ammonia from ammonia bearing ventilation gases collected from various tanks and thickeners within the refinery. The Vacuum Gas Scrubber has been decommissioned and there are no plans to reinstate this equipment.

The Scrubber is sectionalised packed columns containing three beds packed with pall rings for intimate contact between the gas and the absorbing medium which is water. The ammonia-rich gases pass up through the column where the ammonia is absorbed in the water and the resulting ammonia free gas is vented directly to atmosphere.

Process water from the Process Water Tank enters the Scrubber above the top packed section. As the water flows down through the two upper packed sections, it is collected internally in draw-off trays and flows by gravity through intercoolers. As in the TGS, intercoolers are used between the packed sections to remove the heat evolved from the absorption of ammonia into water.

The cooled water from the intercoolers is returned to the Scrubber just below the draw-off tray from which it was collected and circulated through the column packed bed.

The amount of ammonia collected by the Vent Gas Scrubber is much smaller than the TGS. Consequently, the aqua produced at the bottom of the column contains approximately 25 gpL ammonia ("weak aqua") and is pumped from the Scrubbers via a heat exchanger to the Weak Aqua Tank.

The main use of weak aqua is for scrubbing H₂S gases from the vent gases generated by the Mixed Sulphide Precipitation Tank. It is also used to by the Ammonia Absorber to remove ammonia vapour from the Copper Boil Overheads circuit.

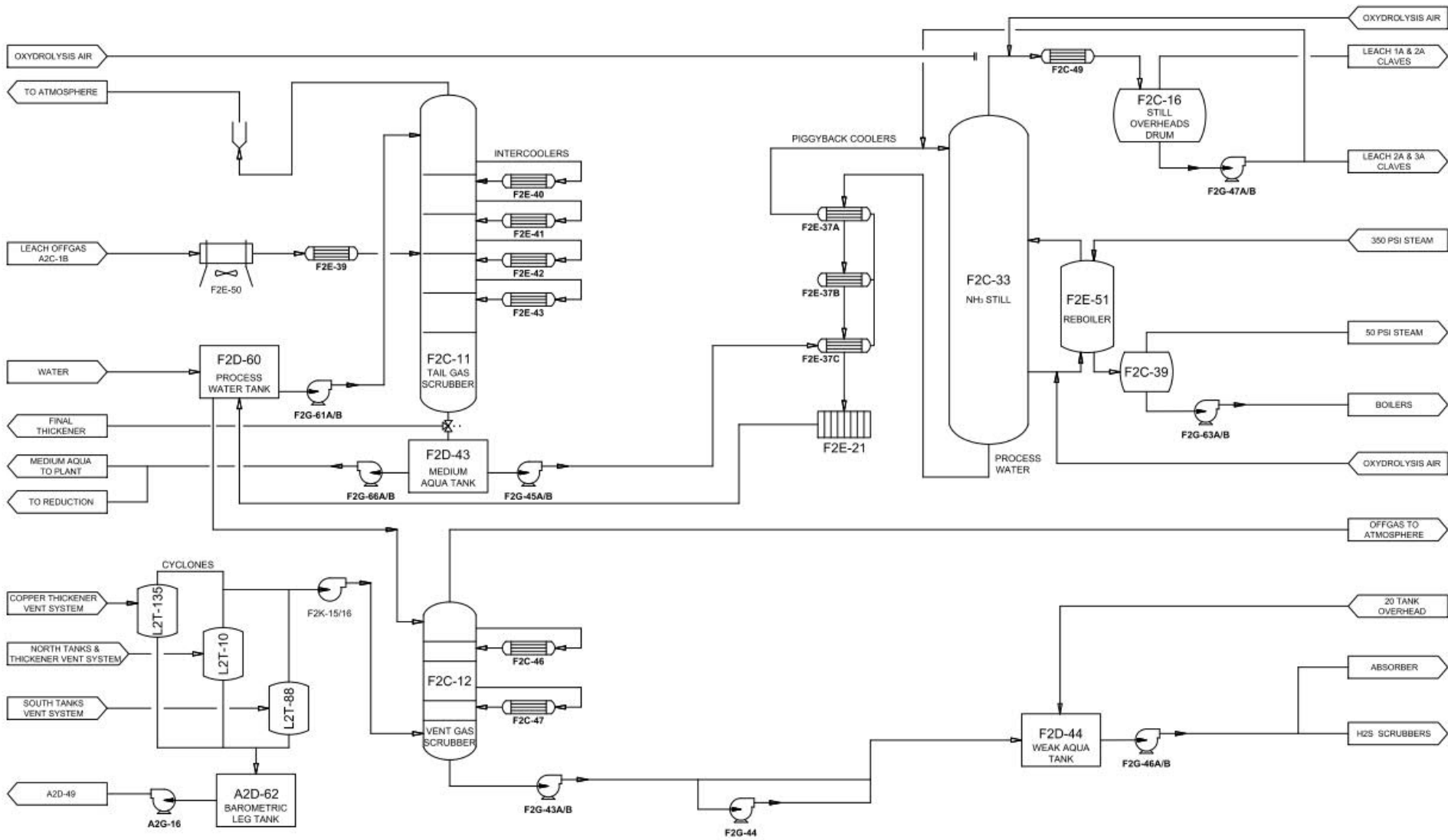


Figure 2: NKW Ammonia Recovery Circuit

Ammonium Sulphate Crystallisation (Amsul Plant)

The Amsul Plant produces dry ammonium sulphate crystals using MFL from the Mixed Sulphides circuit. MFL produced by the Pressure Leaf Filers (PLFs) is first directed to a Storage Tank. From this tank, most of the MFL is pumped to the Amsul plant, while some is directed to the reduction and leach areas for various operating purposes.

Typically, liquor exiting the Storage Tank contains >500 gpL dissolved ammonium sulphate along with residual levels of nickel and cobalt. It also contains trace amounts of other elements including calcium, sodium and chlorides.

The Amsul Plant consists of two different crystalliser types, namely the Triple Effect Crystalliser (TEC) and Brine Crystalliser (BC). The TEC comprises three interdependent crystallisers operating as one system. The BC is a stand-alone crystalliser designed to produce a large average crystal size.

Each crystalliser is designed to evaporate water. As the water is removed, the ammonium sulphate solution present within the crystallisers becomes more and more concentrated. Eventually a point is reached where the solution becomes supersaturated, causing some of the contained ammonium sulphate to precipitate and form a solid crystal. The challenge for a crystalliser is to form a consistent size and shape of crystal.

The heat exchanger used to evaporate the water within the BC has a non-condensable vent. This stops the accumulation of gases such as air and/or carbon dioxide within the crystalliser. Failing to remove these gases will eventually cause the crystallisation process to stop as it prevents the heat exchanger from producing steam (i.e. system binding). In venting the non-condensables to atmosphere, a small amount of steam is also released. The TEC also has a non-condensable vent for the same reason. However, as the vent needs to be capable of removing non-condensables from the last evaporator (which operates under a vacuum) a steam educator is required to provide the necessary motive force. This educator vents straight to atmosphere.

Once formed, the ammonium sulphate crystals are separated from their mother solution by a wire screen. From the screen, the solid particles are dried by first passing through a centrifuge; which removes the bulk of the entrained moisture, before passing onto a hot air drier.

Utility Systems

Hydrogen Plant

Hydrogen is produced on site by a dedicated Hydrogen Plant from which hydrogen is distributed via either a high pressure or low pressure system.

In 2012, NKW commissioned a new hydrogen plant, which was designed and constructed by Technip S.A, a French-based engineering design and construction company. The plant utilises Steam Reforming technology and is designed to produce 688 kg/h of hydrogen at a purity of >99%. The Steam Reforming process involves the conversion of natural gas (methane) in the presence of steam, to a hydrogen-rich gas, which is then purified in a Process Swing Adsorption (PSA) unit.

The process starts with natural gas being mixed with recycled hydrogen and then pre-heated by heat recovered from the process gas leaving the High Temperature (HT) Shift Reactor. The hot feed gas is then fed to the Hydrodesulphurizer Reactor where contained sulphur is removed via a series of different catalysts.

The clean feed gas is then mixed with a controlled quantity of steam before being pre-heated in the convection section of the Steam Reformer. After pre-heating, the heated gas passes through a series of tubes containing a nickel catalyst where the methane is converted to hydrogen, carbon monoxide and carbon dioxide in the presence of steam. The steam reforming reactions are strongly endothermic and heat has to be supplied externally to achieve the required conversion rate. This heat is provided by combustion of PSA purge gas as priority fuel and natural gas as make-up fuel.

Waste gases from the Reformer are cooled in the Process Gas Boiler and then fed under temperature control to the HT Shift Reactor, where the major portion of carbon monoxide reacts with steam to produce hydrogen and carbon dioxide. The heat content of the process gas leaving the HT Shift Reactor (higher in temperature due to the exothermic shift reaction) is recovered by pre-heating feed gas and then pre-heating the boiler feed water.

The process gas is finally cooled in a trim cooler. After removing process condensate, the gas is sent to the PSA plant where the impurities are captured on an adsorbent at a pressure of approximately 2280 kPa(g). Once the adsorbent is fully loaded with impurities, the vessel is taken offline to regenerate the adsorbent by reducing the system pressure. The impurities and contained hydrogen within the vessel are collected to form a purge gas stream which is delivered to the Reformer as a fuel at approximately 30 kPa(g). Approximately 80 to 85% of the hydrogen present in the PSA feed is recovered as pure hydrogen.

Steam production within the plant is sufficient to satisfy the Reformer requirements along with a small excess that is exported to the NKW steam system. The process condensate is recovered and recycled back to the steam generation system via the Deaerator.

For the heat to be released by combustion in the Reformer Furnace, two fuel gases are utilised:

- Purge gas from the PSA unit; and
- Natural gas from the battery limit as make up fuel.

Flue gases are drawn from the furnace by the flue gas fan such that a negative pressure is always maintained in the reformer furnace. The flue gases are discharged to atmosphere through a stack.

Old PSA Plant

At the time of writing, the Old PSA plant (formally called the SAS plant) is only used where there is a requirement to import a supplementary source of hydrogen into NKW. The Old PSA plant purifies a crude hydrogen stream from the BP Oil Refinery or Syngas from CSBP via Pressure Swing Adsorption. The technology is the same as that used within the new hydrogen plant PSA. The key difference, however, is that it is not possible to utilise the waste impurities collected within the absorption process as a fuel for other unit operations. Consequently, waste gas is directed to a ground-based flare for disposal.

It is worth noting that NKW has not imported supplementary hydrogen since the successful commissioning of the new hydrogen plant.

Hydrogen Sulphide (H₂S)

H₂S gas is produced onsite at the H₂S Plant by reacting hydrogen gas and molten sulphur in a H₂S Reactor.

Molten sulphur is delivered by road tanker and held in the Molten Sulphur Holding Tank which can hold approximately 40 kilolitres of sulphur between 130 to 140°C. From this tank, molten sulphur is pumped to the Day Tank where any impurities settle to the bottom. These impurities are periodically purged from the Tank into a small drum for disposal to landfill. From the Day Tank, molten sulphur is pumped to the H₂S Reactor via the Reactor Quench Column.

Hydrogen gas is supplied to the reactor under pressure control. Hydrogen enters the reactor via a sparger, which forces it to mix intimately with the hot molten sulphur. At the prevailing conditions, hydrogen is converted into H₂S via an exothermic reaction. To remove excess heat from the Reactor, a Sulphur Recycle Pump draws hot sulphur from the Reactor and pumps it through a Molten Sulphur Cooler. The sulphur enters the Cooler at approximately 445°C and is cooled to approximately 138°C by generating steam within the Cooler. The resulting steam from the Cooler is condensed in the Reflux Condenser using cooling water. The temperature of the sulphur exiting the Molten Sulphur Cooler is controlled by the flow of cooling water to the Reflux Condenser. The cooled sulphur is then returned to the H₂S Reactor via the Reactor Quench Column, which acts as a heat exchanger for the H₂S gas produced within the Reactor. It is filled with a stainless steel ring packing which promotes an intimate contact between the returning molten sulphur and exiting H₂S gas. As the H₂S gas rises up through the column, it is cooled to approximately 160°C while the returning molten sulphur is heated to around 440°C. The make-up molten sulphur also enters the reactor via the top of the quench column to replenish the sulphur consumed in the production of H₂S gas.

H₂S gas leaving the quench column is then passed through Water Cooled Gas Coolers, which remove sulphur carried over from the quench column and cool the gas temperature to approximately 50°C. The captured sulphur which has solidified onto the coolers is periodically removed by taking the Cooler out-of-service and substituting the cooling water with (nominal) 345 kPa(g) steam which melts the contained sulphur. The resulting molten sulphur then drains to a knock-out pot.

All of the H₂S gas produced is consumed by the Mixed Sulphide circuit. There is no storage of H₂S gas onsite.

Boiler

Steam requirements are met by the use of an onsite boiler. Originally, two diesel fired package boilers were used before being decommissioned and replaced with a still operating larger boiler, colloquially known as No. 3 Boiler.

Where possible condensed steam (condensate) is recovered from process units around NKW and returned to No. 3 Boiler. There are two condensate collection systems:

- Low pressure condensate which primarily recovers condensate from the Amsul and H₂S plants; and
- High pressure condensate which recovers condensate from Oxydrolisis, Reduction, Ammonia Still and Copper Boil plant areas.

To maintain the quality of the condensate being fed to the boiler a small percentage is discharge to the NKW process water system (i.e bleed). Demineralised Water replaces this loss, along with any steam or other condensate losses.

The NKW steam system has two deaerators. These are designed to remove any non-condensable gases from the steam system. These gases are discharged to atmosphere along with a small amount of steam.

Demineralised Water

NKW has a demineralisation plant to provide high purity water to a number of areas, including the No. 3 Boiler and the H₂ Plant boiler. The plant has three identical trains, each comprising three separate but interconnected pressure vessels. Water from the metropolitan water supply passes through the vessels in series as follows:

- A multiple compartment sand filter which removes any suspended particles;
- A cation exchanger which contains a resin to remove calcium, sodium and magnesium ions from the water; and
- An anion exchanger which contains two beds of resin to remove bicarbonates, sulphates and chlorides from the water.

After a period in service, the resin columns need to be regenerated by washing the cation resins with a weak solution of sulphuric acid, and the anionic resins with a weak solution of caustic soda. The regenerating sulphuric acid and caustic soda solutions are supplied to the required vessel via a mixing tee. The sulphuric acid mixing tee is supplied acid from Sulphuric Acid Tank, while the caustic soda mixing tee is supplied caustic from Caustic Tank. Effluent from the water treatment plant is captured in a neutralisation pit where its pH is adjusted using dilute ammonia solution. Once neutralised the water is then returned to the process via the Water Treatment Plant or Effluent Thickener.

Water generated by the Demineralisation Plant is then stored and distributed from the Demineralised Water Storage Tank.