1.1.1 GES 9: POWDER METALLURGY

A detailed assessment of environmental exposure and risk characterisation is provided in Appendix D3 (section 5). Additional information on occupational exposure for the powder metallurgy is in Appendix D5 (section 2).

In the GES, one exposure scenario is presented for the environment and six occupational exposure scenarios are presented based on six different processing steps (*i.e.*, contributing exposure scenarios ES 9.1-9.6).

1. Title **GES 9 Powder metallurgy**	
Life cycle	End use – DU of Ni metal
Free short title	Use of nickel powder in production of parts (articles)
Systematic title based on use descriptor	SU: SU14 Manufacture of basic metals and alloys PC: Not relevant ERC: ERC 5 Industrial use resulting in inclusion into or onto a matrix PROC: PROC 26: Handling of solid inorganic substances at ambient temperature PROC 14: Production of preparations or articles by tabletting, compression, extrusion, pelletisation PROC 22: Potentially closed processing operations with minerals/metals at elevated temperature PROC 25: Other hot work operations with metals PROC 21: Low energy manipulation of substances bound in materials and/or articles PROC 0: Cleaning and maintenance PROC 8b: Transfer of substance or preparation (charging/discharging) from/to vessels/large containers at dedicated facilities PROC 23: Open processing and transfer operations with minerals/metals at elevated temperature
Processes, tasks, activities covered (environment)	Use of nickel powder in production of parts by pressing, sintering, injection and moulding operations.
Processes, tasks, activities covered (workers)	Contributing scenarios 9.1: PROC 26, PROC 8b: Powder mixing Contributing scenarios 9.2: PROC 14, PROC 8b: Powder pressing Contributing scenarios 9.3: PROC 22: Sintering Contributing scenarios 9.4: PROC 25: Powder injection moulding Contributing scenarios 9.5: PROC 21, PROC 23: Post sintering operations Contributing scenarios 9.6: PROC 0: Cleaning and maintenance
2. Operational conditions and risk management measures	
2.1 Control of environmental exposure	
Environmental related free short title	Use of nickel powder in production of parts by pressing, sintering, injection and moulding operations

Systematic title based on use descriptor (environment)	ERC 5: Industrial use resulting in inclusion into or onto a matrix
Processes, tasks, activities covered (environment)	Use of nickel powder in production of parts by pressing, sintering, injection and moulding operations.
Environmental Assessment Method*	Estimated local concentrations based on measurements by industry and measured regional concentrations are used for calculation of PEC
Product characteristics	
Nickel powder < 200 um, 1-50% nickel in product	
Amounts used	
Maximum daily use at a site	11 tonnes/ day (50^{th} % emission days, 50^{th} % tonnage)
Maximum annual use at a site	2853 tonnes / yr (50^{th} %, 2007)
Frequency and duration of use	
Pattern of release to the environment	248 days per year (50^{th} %)
Environment factors not influenced by risk management	
Receiving surface water flow rate	Not relevant
Dilution capacity, freshwater	Not relevant
Dilution capacity, marine	Not relevant
Other given operational conditions affecting environmental exposure	
None	
Technical conditions and measures at process level (source) to prevent release	
None	
Technical onsite conditions and measures to reduce or limit discharges, air emissions and releases to soil	
Waste water: No discharge via waste water **Air:** Treatment in exhaust system (fabric or bag filters) Release factor after on-site treatment: 0.01 g/T	
Organizational measures to prevent/limit release from site	
None	
Conditions and measures related to municipal sewage treatment plant	
Municipal Sewage Treatment Plant (STP)	Not relevant
Discharge rate of the Municipal STP	Not relevant
Incineration of the sludge of the Municipal STP	Not relevant
Conditions and measures related to external treatment of waste for disposal	
Ni-containing waste shall be handled as hazardous waste and removed by licensed waste removal company, incinerated or recycled	
Conditions and measures related to external recovery of waste	
Not applicable	
2.2 Control of workers exposure, contributing scenario 9.1	
Powder metallurgy, Mixing of nickel and other metallic powders	

Workers related free short title	Mixing of powder
Use descriptor covered	PROC 26: Handling of solid inorganic substances at ambient temperature PROC 8b: Transfer of substance or preparation (charging/discharging) from/to vessels/large containers at dedicated facilities
Processes, tasks, activities covered	Raw materials handling Dispensing Weighing Mixing/blending
Assessment Method*	Estimation of exposure based on measured data

Product characteristic

Powder 1-50% Nickel, in specific cases >50% nickel in finished product

Particle size <200 um – depends on how powder produced and the intended metallurgical use eg:

- Cold pressing typically employs irregularly shaped particles formed by atomisation, particles <10 um in diameter
- Injection moulding typically employs particles <70 um diameter
- Most widely used preparation is nickel powder with particles between 1 and 5 um

The ES excludes powders with median diameters that are <1 um

Amounts used

Not relevant

Frequency and duration of use/exposure

8 hour workday

Human factors not influenced by risk management

Respiration volume under conditions of use	Not relevant
Room size and ventilation rate	Not relevant
Area of skin contact with the substance under conditions of use	Not relevant
Body weight	Not relevant

Other given operational conditions affecting workers exposure

Minimisation of drop heights (eg if powder shovelled into mixing tank)

Technical conditions and measures at process level (source) to prevent release

Enclosure of mixing tank and automation of mixing process where quantities of material processes exceed 100 kg/day

Technical conditions and measures to control dispersion from source towards the worker

LEV is required for all processes involving Ni powder except where Ni powder entirely enclosed (eg delivery and storage of closed drums, automated enclosed transfer of powder to mixing vessel)

Organisational measures to prevent /limit releases, dispersion and exposure

Maintenance of clean workplace to prevent accumulation of powders and dusts on surfaces.

Oral: good workplace hygiene practice

Conditions and measures related to personal protection, hygiene and health evaluation

RPE (P2 or P3) is required when handling fine nickel powder.

2.2 Control of workers exposure, contributing scenario 9.2

Powder metallurgy, pressing of powders into shapes/articles

Workers related free short title	Pressing powder
Use descriptor covered	PROC 14: Production of preparations or articles by tabletting, compression, extrusion, pelletisation. PROC 8b: Transfer of substance or preparation (charging/discharging) from/to vessels/large containers at dedicated facilities
Processes, tasks, activities covered	Transfer of mixed powders to die Pressing and compaction
Assessment Method*	Estimation of exposure based on measured data

Product characteristic

Powder mix 1-5% Nickel

Particle size <200 um – depends on how powder produced and the intended metallurgical use eg:

- Cold pressing typically employs irregularly shaped particles formed by atomisation, particles <10 um in diameter
- Injection moulding typically employs particles <70 um diameter
- Most widely used preparation is nickel powder with particles between 1 and 5 um

The ES excludes powders with median diameters that are <1 um

Amounts used

1 – 1000 kg per shift

Frequency and duration of use/exposure

At least once every shift. Tasks giving rise to potential exposure to Ni powder undertaken for less than one hour each shift

Human factors not influenced by risk management

Respiration volume under conditions of use	Not relevant
Room size and ventilation rate	Not relevant
Area of skin contact with the substance under conditions of use	Not relevant
Body weight	Not relevant

Other given operational conditions affecting workers exposure

Powder is contained in die under pressure. Powder is mixed with a lubricant which reduces the dustiness.

Ambient or elevated temperature

Technical conditions and measures at process level (source) to prevent release

The process step is enclosed and emissions extracted by integrated LEV. LEV is required where powder is handled (charging) except if charging is automated and entirely enclosed (automated enclosed transfer of powder to mixing vessel)

Technical conditions and measures to control dispersion from source towards the worker

LEV is required where powder mix is handled in open air;

LEV is required where fumes are given off during heating.

Organisational measures to prevent /limit releases, dispersion and exposure

Maintenance of clean workplace to prevent accumulation of powders and dusts on surfaces.

Oral: good workplace hygiene practice

Conditions and measures related to personal protection, hygiene and health evaluation

Inhalation: RPE (e.g. P2, APF = 10) is required when handling fine nickel powder

Dermal: Dermal contact is minimised by automation and enclosure of process; Gloves are required where direct contact with powder mix or the finished shape/article is possible

2.2 Control of workers exposure, contributing scenario 9.3	
Powder metallurgy, sintering	
Workers related free short title	Sintering of nickel containing powders and related thermal treatments undertaken within a closed system
Use descriptor covered	PROC 22: Potentially closed processing operations with minerals/metals at elevated temperature Industrial setting
Processes, tasks, activities covered	Transfer of mixed powders to die Sintering at elevated temperatures undertaken in a closed system
Assessment Method*	Estimation of exposure based on measured data
Product characteristic	
Powder mix with 1-5% and in some cases 50% Nickel	
Amounts used	
1 – 1000 kg per shift	
Frequency and duration of use/exposure	
1-2 hours Intermittent exposures associated with loading and unloading furnace per shift	
Human factors not influenced by risk management	
Respiration volume under conditions of use	Not relevant
Room size and ventilation rate	Not relevant
Area of skin contact with the substance under conditions of use	Not relevant
Body weight	Not relevant
Other given operational conditions affecting workers exposure	
Sintering performed at elevated temperatures – conditions depend on alloy composition and intended end product	
Technical conditions and measures at process level (source) to prevent release	
The sintering process and the furnace unit is enclosed and equipped with LEV extracting fumes to prevent release to workplace air; Loading and unloading of the furnace is fully automated.	
Technical conditions and measures to control dispersion from source towards the worker	
LEV is required where powder is handled (charging) except if charging is automated and entirely enclosed (automated enclosed transfer of powder to mixing vessel)	
Organisational measures to prevent /limit releases, dispersion and exposure	
Maintenance of clean workplace to prevent accumulation of powders and dusts on surfaces. Oral: good workplace hygiene practice	
Conditions and measures related to personal protection, hygiene and health evaluation	
Inhalation: RPE (e.g. P2, APF = 10) is required when handling fine nickel powder Dermal: No possibilities for potential dermal contact with sintered material, dust release or possibility of accidental ingestion	
2.2 Control of workers exposure, contributing scenario 9.4	
Powder metallurgy, powder injection moulding	
Workers related free short title	Powder injection moulding
Use descriptor covered	PROC 25: Other hot work operations with metals
Processes, tasks, activities covered	Injection moulding Water debinding or thermal debinding

Assessment Method*	Estimation of exposure based on measured data
Product characteristic	
Powder mix with 10-50% Nickel	
Amounts used	
1 – 1000 kg per shift	
Frequency and duration of use/exposure	
1-2 hours Intermittent exposures associated with loading and unloading furnace per shift	
Human factors not influenced by risk management	
Respiration volume under conditions of use	Not relevant
Room size and ventilation rate	Not relevant
Area of skin contact with the substance under conditions of use	Not relevant
Body weight	Not relevant
Other given operational conditions affecting workers exposure	

Injection moulding

1. Transfer of powder mixes from storage (closed bags or drums) into injection moulding press hopper, transfer of injected parts to other process steps
2. Melting the mix in a hot cylinder, injection of the mass in the steel mould, wait for cooling and solidification, opening of mould, ejection and collection of part
3. Green part inspection, setting into trays, deburring
4. Rejected parts and material solidified in feeding system ground in grinding machines prior to recycling in future mixes
5. Cleaning the press

Thermal debinding

1. Introduction of partially debound parts in protective atmosphere furnace onto stainless steel racks, heating in protective atmosphere in slow cycles (up to 3 days) to about 300oC to decompose most backbone binder. Cool, extract parts and inspect and weigh to establish level of debinding.
2. Cleaning of debinding furnace, removal of waste (broken parts), disposal of condensed binder (wax, polymer)

Water debinidng

1. Immerse green parts (set onto trays in stainless steel racks) into warm water baths (30-70oC) for prolonged time (6-48 hours) to dissolve part of the binder. Extract racks, and dry them in a drawer with warm recirculated air (40-70oC). Inspect and weigh sample parts to check debinding removal.
2. Cleaning the debinding tanks, removal of waste (broken parts), disposal of exhaust water with dissolved binder.

Technical conditions and measures at process level (source) to prevent release
The injection process is automated and enclosed. The sintering process and the furnace unit is enclosed and equipped with LEV extracting fumes to prevent release to workplace air; Loading and unloading of the furnace is fully automated.
Technical conditions and measures to control dispersion from source towards the worker
Enclosure of melting process; enclosure of grinding machine used in recycling of rejected parts, extraction of dust and fumes to prevent discharge into workplace air.
Organisational measures to prevent /limit releases, dispersion and exposure

Maintenance of clean workplace to prevent accumulation of powders and dusts on surfaces. Oral: good workplace hygiene practice	
Conditions and measures related to personal protection, hygiene and health evaluation	
Inhalation: RPE (e.g. P2, APF = 10) is required when handling fine nickel powder Dermal: Use of suitable protective clothing where direct contact with Ni-containing material is possible	
2.2 Control of workers exposure, contributing scenario 9.5	
Powder metallurgy, post sintering treatment	
Workers related free short title	Post sintering treatments
Use descriptor covered	PROC 21: Low energy manipulation of substances bound in materials and/or articles PROC 23: Open processing and transfer operations with minerals/metals at elevated temperature
Processes, tasks, activities covered	Hot re-repressing, hot isostatic pressing, forging, infiltration, impregnation, surface hardening, steam treatment, blueing, grinding, cutting. Packaging of finished product
Assessment Method*	Estimation of exposure based on measured data
Product characteristic	
Sintered metallic shape/ Article with Ni contents range from <10->90%	
Amounts used	
Equivalent to a mass of Ni of 1-100kg/shift	
Frequency and duration of use/exposure	
Near continuous operation during operational hours	
Human factors not influenced by risk management	
Respiration volume under conditions of use	Not relevant
Room size and ventilation rate	Not relevant
Area of skin contact with the substance under conditions of use	Not relevant
Body weight	Not relevant
Other given operational conditions affecting workers exposure	
Conditions including temperature depend on process and intended use of end product	
Technical conditions and measures at process level (source) to prevent release	
Repressing/hot pressing: Full containment of the process or appropriate LEV Mechanical shaping and burring: continuous or over 20% of the time: Full containment of the process or appropriate LEV	
Technical conditions and measures to control dispersion from source towards the worker	
Repressing/hot pressing: LEV is used unless process is fully contained. Forging: LEV required to prevent exposure to metal fume Mechanical shaping and burring: machining over a proportion of most shifts: Full containment of the process or appropriate LEV. Use of gloves is required .	
Organisational measures to prevent /limit releases, dispersion and exposure	
Maintenance of clean workplace to prevent accumulation of powders and dusts on surfaces.	

Oral: good workplace hygiene practice	
Conditions and measures related to personal protection, hygiene and health evaluation	
Where fine nickel powder is used: RPE (P2 or P3) is required in all processes giving rise to dust Forging: gloves required to minimise dermal contact before and after forging, RPE can be used as alternative to LEV at operations giving rise to airborne dust Mechanical shaping and burring: in case of infrequent finishing of product gloves are required and Inhalation: RPE (e.g. P2, APF = 10) is required when handling fine nickel powder	
2.2 Control of workers exposure, contributing scenario 9.6	
Powder metallurgy – cleaning and maintenance	
Workers related free short title	Cleaning and maintenance
Use descriptor covered	PROC 0: Cleaning and maintenance
Processes, tasks, activities covered	Removal of powder residues from process equipment Removal of waste materials Wider cleaning of workplace Spill clean ups Equipment maintenance and repair
Assessment Method*	Estimation of exposure based on measured data
Product characteristic	
Variable includes powders and more coarse residues	
Amounts used	
Not relevant	
Frequency and duration of use/exposure	
Routine cleaning and daily equipment maintenance after use – most shifts – 30-60 minutes Equipment repair – infrequent, 1-10 hours	
Human factors not influenced by risk management	
Respiration volume under conditions of use	Not relevant
Room size and ventilation rate	Not relevant
Area of skin contact with the substance under conditions of use	Not relevant
Body weight	Not relevant
Other given operational conditions affecting workers exposure	
Solid residues may be removed from pipes, moulds and other process equipment using appropriate hand tools. Dust should be removed by hosing down (followed by appropriate waste water treatment) or vacuuming using a cleaner fitted with a High Efficiency Filter.	
Technical conditions and measures at process level (source) to prevent release	
None	
Technical conditions and measures to control dispersion from source towards the worker	
None	
Organisational measures to prevent /limit releases, dispersion and exposure	
Oral: good workplace hygiene practice	
Conditions and measures related to personal protection, hygiene and health evaluation	
Inhalation: RPE (e.g. P2, APF = 10) is required where exposure Ni-powder may take place during cleaning and maintenance. Dermal: Gloves are required to minimise skin contact with powder	
3. Exposure and risk estimation	

Environment

Powder metallurgy: Use of nickel powder in production of parts (articles)

Compartment	Unit	PNEC	$PEC_{Regional}$	C_{local}	PEC	RCR	Methods for calculation of environmental concentrations and PNEC
Freshwater	µg/l						No emission to water
Marine	µg/l						No emission to water
Terrestrial	mg/kg	29.9	16.2	0.001	16.2	0.54	Estimated values, Tier 3-RWC

Workers

GES 9.1. Powder metallurgy: Powder mixing

	Unit	DNEL	Exposure concentration	RCR	Methods for calculation of exposure
Dermal					
Acute systemic	mgNi/kg/day	-	NR		
Acute local	mgNi/cm^2/day	-	NR		
Long-term systemic	mgNi/kg/day	-	NR		
Long-term local	mgNi/cm^2/day	0.015 (Sensitisation)	0.009	0.6	
Inhalation					
Acute systemic	mgNi/m^3	816	1.0	0.0012	Estimate assumes effective LEV.
Acute local	mgNi/m^3	1.6*	1.0	0.62	Estimate assumes effective LEV.
Long-term systemic	mgNi/m^3	0.05**	0.1	2 By use of RPE (P2, APF 10): 0.2	Estimate assumes effective LEV. RPE is required when handling nickel powder (<5µm) The exposure is about 10 times lower where operations are fully enclosed and automated.
Long-term local	mgNi/m^3	0.05**	0.1	2 By use of RPE (P2, APF 10): 0.2	

*Based on MMAD of 1.5 um, if exposures are to particles with a MMAD of ≥30 um, the equivalent DNEL is estimated as ≥6.4 mg Ni/m^3.

**When handling powders of particle diameter below 10 µm, exposures (8h TWA) to these powders should be kept under 0.01 mg Ni/m^3 and when exposure are solely to metallic and oxidic nickel dusts (without exposure to soluble nickel or sulfidic nickel) and the particle size of the aerosol is greater than 10 µm diameter (≤ 10% of aerosol in respirable fraction), inhalable exposure levels up to 0.2 mg Ni/m^3 could be reasonably assumed to be safe (see Appendix C3).

GES 9.2. Powder metallurgy, pressing of powders into shapes/articles

	Unit	DNEL	Exposure concentrat	RCR	Methods for calculation of

			ion		exposure
Dermal					
Acute systemic	mgNi/kg/day	-	NR		
Acute local	mgNi/cm^2/day	-	NR		
Long-term systemic	mgNi/kg/day	-	NR		
Long-term local	mgNi/cm^2/day	0.015 (Sensitisation)	0.009	0.6	
Inhalation					
Acute systemic	mgNi/m^3	816	0.03	0.00004	Estimate assumes automated and contained processes. LEV should be used for operations giving rise to airborne dust, e.g. charging of powder. In addition RPE is required when handling nickel powder (<5µm)
Acute local	mgNi/m^3	1.6*	0.03	0.019	
Long-term systemic	mgNi/m^3	0.05**	0.01	0.2	
Long-term local	mgNi/m^3	0.05**	0.01	0.2	

* Based on MMAD of 1.5 um, if exposures are to particles with a MMAD of ≥30 um, the equivalent DNEL is estimated as ≥6.4 mg Ni/m^3.

**When handling powders of particle diameter below 10 µm, exposures (8h TWA) to these powders should be kept under 0.01 mg Ni/m3 (see Appendix C3). and "When exposure are solely to metallic and oxidic nickel dusts (without exposure to soluble nickel or sulfidic nickel) and the particle size of the aerosol is greater than 10 µm diameter (≤ 10% of aerosol in respirable fraction), inhalable exposure levels up to 0.2 mg Ni/m^3 could be reasonably assumed to be safe (see Appendix C3)..

GES 9.3. Powder metallurgy, Sintering

	Unit	DNEL	Exposure concentration	RCR	Methods for calculation of exposure
Dermal					
Acute systemic	mgNi/kg/day	-	NR		
Acute local	mgNi/cm^2/day	-	NR		
Long-term systemic	mgNi/kg/day	-	NR		
Long-term local	mgNi/cm^2/day	0.015	0.009	0.6	
Inhalation					
Acute systemic	mgNi/m^3	816	0.03	0.00004	Estimate assumes automated and
Acute local	mgNi/m^3	1.6*	0.03	0.019	

Long-term systemic	mgNi/m³	0.05**	0.01	0.2	contained processes. LEV should be used for operations giving rise to airborne dust, e.g. charging of powder. In addition RPE is required when handling nickel powder (<5µm)
Long-term local	mgNi/m³	0.05**	0.01	0.2	

* Based on MMAD of 1.5 um, if exposures are to particles with a MMAD of ≥30 um, the equivalent DNEL is estimated as ≥6.4 mg Ni/m^3.

**When handling powders of particle diameter below 10 µm, exposures (8h TWA) to these powders should be kept under 0.01 mg Ni/m3 (see Appendix C3). and "When exposure are solely to metallic and oxidic nickel dusts (without exposure to soluble nickel or sulfidic nickel) and the particle size of the aerosol is greater than 10 µm diameter (≤ 10% of aerosol in respirable fraction), inhalable exposure levels up to 0.2 mg Ni/m^3 could be reasonably assumed to be safe (see Appendix C3).

GES 9.4. Powder metallurgy, Powder injection moulding

	Unit	DNEL	Exposure concentration	RCR	Methods for calculation of exposure
Dermal					
Acute systemic	mgNi/kg/day	-	NR		
Acute local	mgNi/cm²/day	-	NR		
Long-term systemic	mgNi/kg/day	-	NR		
Long-term local	mgNi/cm²/day	0.015	0.009	0.6	
Inhalation					
Acute systemic	mgNi/m³	816	0.25	0.0003	Estimate assumes automated and contained processes. LEV should be used for operations giving rise to airborne dust, e.g. charging of powder. RPE is required when handling nickel powder
Acute local	mgNi/m³	1.6*	0.25	0.15	
Long-term systemic	mgNi/m³	0.05**	0.05	1 By use of RPE (P2, APF=10): 0.1	
Long-term local	mgNi/m³	0.05**	0.05	1 By use of RPE (P2, APF=10): 0.1	

* Based on MMAD of 1.5 um, if exposures are to particles with a MMAD of ≥30 um, the equivalent DNEL is estimated as ≥6.4 mg Ni/m^3.

**When handling powders of particle diameter below 10 µm, exposures (8h TWA) to these powders should be kept under 0.01 mg Ni/m3 (see Appendix C3). and "When exposure are solely to metallic and oxidic nickel dusts (without exposure to soluble nickel or sulfidic nickel) and the particle size of the aerosol is

greater than 10 µm diameter (≤ 10% of aerosol in respirable fraction), inhalable exposure levels up to 0.2 mg Ni/m^3 could be reasonably assumed to be safe (see Appendix C3).

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GES 9.5. Powder metallurgy, Post sintering operations

	Unit	DNEL	Exposure concentration	RCR	Methods for calculation of exposure
Dermal					
Acute systemic	mgNi/kg/day	-	NR		
Acute local	mgNi/cm^2/day	-	NR		
Long-term systemic	mgNi/kg/day	-	NR		
Long-term local	mgNi/cm^2/day	0.015	0.009	0.6	
Inhalation					
Acute systemic	mgNi/m^3	816	0.1	0.0001	Estimates assumes full automation and containment of the processes. In addition RPE is required when handling fine nickel powder
Acute local	mgNi/m^3	1.6*	0.1	0.063	
Long-term systemic	mgNi/m^3	0.05**	0.01	0.2	
Long-term local	mgNi/m^3	0.05**	0.01	0.2	

* Based on MMAD of 1.5 um, if exposures are to particles with a MMAD of ≥30 um, the equivalent DNEL is estimated as ≥6.4 mg Ni/m^3.

**When handling powders of particle diameter below 5 µm, exposures (8h TWA) to these powders should be kept under 0.01 mg Ni/m3 (see Appendix C3). and "When exposure are solely to metallic and oxidic nickel dusts (without exposure to soluble nickel or sulfidic nickel) and the particle size of the aerosol is greater than 10 µm diameter (≤ 10% of aerosol in respirable fraction), inhalable exposure levels up to 0.2 mg Ni/m^3 could be reasonably assumed to be safe (see Appendix C3).

GES 9.6. Powder metallurgy, Cleaning and maintenance

	Unit	DNEL	Exposure concentration	RCR	Methods for calculation of exposure
Dermal					
Acute systemic	mgNi/kg/day	-	NR		
Acute local	mgNi/cm^2/day	-	NR		
Long-term systemic	mgNi/kg/day	-	NR		
Long-term local	mgNi/cm^2/day	0.015	0.009	0.6	

Inhalation					
Acute systemic	mgNi/m³	816	1.4	0.002	RPE (P3 or P2) is required to ensure safe conditions during maintenance and cleaning operations. RPE is required where airborne nickel dust may occur
Acute local	mgNi/m³	1.6*	1.4	0.875	
Long-term systemic	mgNi/m³	0.05**	0.05	1 By use of RPE (P2, APF 10): 0.1	
Long-term local	mgNi/m³	0.05**	0.05	1 By use of RPE (P2, APF 10): 0.1	

* Based on MMAD of 1.5 um, if exposures are to particles with a MMAD of ≥30 um, the equivalent DNEL is estimated as ≥6.4 mg Ni/m^3.

**When handling powders of particle diameter below 10 µm, exposures (8h TWA) to these powders should be kept under 0.01 mg Ni/m3 (see Appendix C3). and "When exposure are solely to metallic and oxidic nickel dusts (without exposure to soluble nickel or sulfidic nickel) and the particle size of the aerosol is greater than 10 µm diameter (≤ 10% of aerosol in respirable fraction), inhalable exposure levels up to 0.2 mg Ni/m^3 could be reasonably assumed to be safe (see Appendix C3)

4. Guidance to DU to evaluate whether he works inside the boundaries set by the ES

Environment

Scaling tool: Metals EUSES IT tool (free download: http://www.arche-consulting.be/Metal-CSA-toolbox/du-scaling-tool)

Scaling of the release to air and water environment includes:
Refining of the release factor to air and waste water and/or and the efficiency of the air filter and wastewater treatment facility.

Scaling of the PNEC for aquatic environment by using a tiered approach for correction for bioavailability and background concentration (C_{local} approach). See Appendix D1

Scaling of the PNEC for soil compartment by using a tiered approach for correction for bioavailability and background concentration (C_{local} approach). See Appendix D1

Workers

Scaling considering duration and frequency of use

Collect process monitoring data. Use aerosol particle size information, when available, to confirm the appropriate use of an inhalable DNEL. Chemical speciation data showing that only Ni metal and/or Ni oxides are present in the workplace air can be used to indicate RCR <1 at exposure levels between 0.05 and 0.2 mg Ni/m3. See Appendix C3