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SECOND CYCLE DEGREE IN CHEMICAL AND PROCESS ENGINEERING

MASTER'S THESIS IN CHEMICAL AND PROCESS ENGIEERING

WET ELECTROSTATIC PRECIPITATOR: INSTALLATION, COMMISSIONING AND OPTIMIZATION OF A DUST AND AMMONIA ABATEMENT SYSTEM

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ABSTRACT

Emissions of polluting substances into the atmosphere are at the origin of some of the most important and urgent environmental problems to be addressed.

Human-caused emissions are due to industrial activities, energy production, transport as well as the consumption and lifestyle of individuals.

The aim of this thesis "Wet Electrostatic Precipitator: installation, commissioning and optimization of a dust and ammonia abatement system" is to describe and analyse the expected performance of an air emission treatment unit on the prilling tower, installed at the YARA site in Ravenna (RA), and any process optimisation. In particular, the main purpose is to reduce the emissions of dust and ammonia from the prilling tower into the atmosphere by introducing a modification to the existing NAS (Stamicarbon Ammonium Nitrate) plant.

Summary

INTRODUCTION

Emissions of polluting substances into the atmosphere are at the origin of some of the most important and urgent environmental problems to be addressed.
The 1979 Geneva Convention on Transboundary Air Pollution in Article 1 defines air pollution as "the introduction into the atmosphere by man, directly or indirectly, of substances or energy which have harmful effects which may endanger human health, damage biological resources and ecosystems, deteriorate material assets and harm recreational values and other legitimate uses of the environment, the expression 'air pollutants' must be understood in the same sense".
The 1999 Gothenburg Protocol defines emission as "the release into the atmosphere of substances produced from point or diffuse sources".
Human-caused emissions are due to industrial activities, energy production, transport as well as the consumption and lifestyle of individuals.
The effects of anthropogenic emissions that alter the normal balance of the atmosphere can occur on very different spatial and temporal scales. In fact, if, for example, emissions of pollutants due to traffic or particular industrial activities make their effects felt quickly and in "limited" territorial areas the emissions of greenhouse gases or gases that cause the destruction of the ozone layer produce effects on a global scale whose times are so long that it is necessary to take them into account in current choices so as not to compromise the quality of life of future generations.
For the emission of polluting substances into the atmosphere there are emission limit values: the emission factor, the concentration, the percentage or the mass flow of polluting substances in the emissions which must not be exceeded.
The atmospheric emission limit values expressed as a concentration are established with reference to the operation of the system in the most demanding operating conditions and, unless otherwise provided for by the emissions authorization, are considered established as an hourly average.
Current legislation requires that emissions analyses, relative values and limit values be kept track of in specific registers.
The authorization procedure for emissions into the ordinary atmosphere is included pursuant to Presidential Decree 59/2013 in the Single Environmental Authorization (AUA) procedure. For companies subject to the Integrated Environmental Authorization (AIA), this authorization replaces that relating to emissions pursuant to art. 269 and art. 272 of the Legislative Decree. 152/2006.
In terms of emissions, the Country, in compliance with European regulations (e.g. DIR/2010/75/EU) which provides for the limitation of emissions into the atmosphere of certain pollutants emitted by particular processes (for example activities that use organic solvents, large combustion plants) and

the national reference standards (in particular part five of Legislative Decree 152/2006), issues directives and guidelines aimed at simplifying and homogenizing authorization procedures, such as the criteria and methods for requesting authorizations for emissions into the atmosphere and of a general nature for particular types of systems defined by the same national standard.

In general, it is expected that the global requirement to reduce emissions will be higher in coming decades, the highest concentration of dust, high air flows and visual plumes in particular. As a result, Yara is investigating new technologies for ammonium nitrate dust removal.

The aim of this thesis “Wet Electrostatic Precipitator: installation, commissioning and optimization of a dust and ammonia abatement system” is to describe and analyse the expected performance of an air emission treatment unit on the prilling tower, installed at the YARA site in Ravenna (RA), and any process optimisation. In particular, the main purpose is to reduce the emissions of dust and ammonia from the prilling tower into the atmosphere by introducing a modification to the existing NAS (Stamicarbon Ammonium Nitrate) plant.

The modification pertains to the installation of a Wet ElectroStatic Precipitator (WESP), consisting of two absorption trays at the bottom to capture ammonia and an electrostatic wet precipitator at the top to capture the remaining dust and droplets. This is to comply with the new limits <10 mg/Nm^3 (dust) and <10 mg/Nm^3 (ammonia), to decrease the current emission limits of dust of 35 mg/Nm^3 and ammonia of 10 mg/Nm^3, as indicated in the prescriptions of D.M.181 of 11/05/2022 (AIA).

CHAPTER 1: NAS PRODUCTION PLANT

1.1 CHARACTERISTICS OF AMMONIUM NITRATE

Ammonium nitrate (AN) is the ammonium salt of nitric acid, formula NH_4NO_3 and it is a chemical compound that is used as fertilizer. Its main properties are summarized in the Table 1.

PROPERTY	VALUE	UNIT
N content	35	%w
Density	1725	Kg/m^3
Solubility in water	1920	g/L
pH	4.5	

Table 1: Properties of Ammonium Nitrate

When there is free moisture, AN crystal structure can change (phase transition), via a liquid phase, as shown in Figure 1.
The AN tends to absorb moisture (hygroscopic) so, the spheres of fertilizer would become soft.
During the crystal structure changes, the density and the dimension vary which is causing a mechanical stress on the particle.
AN can take different forms depending on the temperature:

1. 169.6 ÷ 125.2 °C cubic shape
2. 125.2 ÷ 84.2 °C tetragonal shape
3. 84.2 ÷ 32.2 °C orthorhombic shape
4. 32.2 ÷ -16.9 °C orthorhombic shape
5. < -16.9 °C tetragonal shape

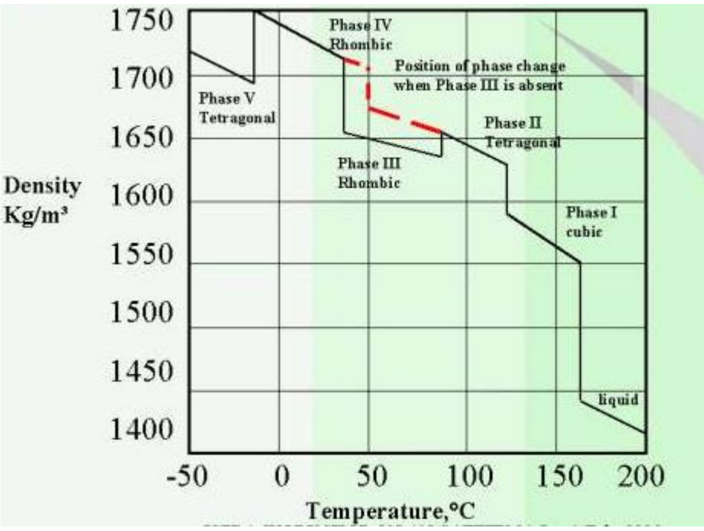

Figure 1: AN phase transition

The first two transformations take place in the prilling tower. The temperature then drops in the fluid bed leading to a reduction in volume.
Negative impact on physical and safety features consists in:

- Reduction of the density
- Lowering of strength and the granule breaks down

After production, AN is coated with anti-caking agent by spraying and micronized limestone.

1.2 DESCRIPTION OF THE PRODUCTION PLANT

The NAS production plant allows to produce the Ammonium Nitrate with different N content operating a Stamicarbon process (original equipment manufacturer).
Among the various types of products, the main ones are CAN and AN [1]:

- CAN: its denomination can be used for fertilizers that in addition to AN contain only calcium carbonate and/or magnesium carbonate and calcium carbonate. The minimum carbonates content has to be 20% and their degree of purity not lower than 90%
- AN: it is characterized by a nitrogen content higher that 28%, with the addition of additives, and does not contain stabilising materials

1.2.1 CAN production

The plant has a production capacity of 1600 t/d of ammonium nitrate 26% N; the steps on which the production process is based are [2]:

1. Ammonia evaporation
2. Ammonium nitrate reaction after evaporation of ammonia
3. Concentration of the ammonium nitrate solution
4. Mixing with ground limestone, gypsum and dolomite
5. Granulation, transport, cooling and anti- caking agent
6. Energy recovery
7. Effluent treatment

The usage time of the NAS system is normally equal to 24 h/d for 350 days/year; in the remaining days the stop is made for routine maintenance.

<u>AMMONIA EVAPORATION</u>

The liquid ammonia is evaporated partly in the radiators E402A/B exploiting the heat of the atmospheric air intended for the cooler E401 of the fertilizer produced plant (fluidized bed cooler) and partly in an exchanger with "U" tubes E210 using the heat of the cooling water.
Passing through the radiator, the atmospheric air causes the boiling of the liquid ammonia inside the radiator resulting in a circulation by natural convection of the liquid ammonia; the two-phase mixture, liquid plus steam, reaches the tank (V217A o V217B) where the gas is separated from the liquid. The liquid part takes part to the feed of the radiator while the gaseous part joins to the analogous currents produced respectively by the unit of evaporation to air, by the evaporator with "U" tubes E210 and from the distiller E405.
The liquid ammonia, containing water, is conveyed into the distiller E405, supplied with low-pressure steam (2.5 barg or 4.5 barg according to the needs); the ammonia is removed as a gas from the head of the distiller to be recovered in the reactor R201, after being preheated in E220, while the water, in the form of an ammoniacal solution with a 70% water content, is periodically sent to the NPK plant for recovery.
Ammonia gas from evaporator E210 and from distiller E405 is then preheated with low-pressure steam (2.5 barg) and sent to the reactor R201.

<u>AMMONIUM NITRATE REACTION AFTER EVAPORATION OF AMMONIA</u>

The neutralization reactor R201 is fed with gaseous ammonia, nitric acid and condensates produced in the same plant; in particular, nitric acid, pumped at 10-12 bar, is divided into two streams called primary acid and finisher acid.

Through the DCS, an appropriate ratio between the amount of gaseous ammonia and the primary nitric acid introduced into the reactor is maintained. Two pH meters (one in operation and one in stand-by) operate on the valve of the finisher nitric acid to obtain the desired pH (4.8-5.2). The neutralization reaction between gaseous ammonia and nitric acid in aqueous solution is as follows:

$$NH_3 + HNO_3 \rightarrow NH_4NO_3$$

The reaction is carried out in the neutralization reactor at a pressure of 3 bar, producing an aqueous solution of 75% ammonium nitrate (AN); the heat of the reaction causes the evaporation of a part of water entering in the reactor, in quantities such as to bring the enthalpic balance into equilibrium, with the production of steam at 3 bar, slightly polluted with ammonia and AN.
The reaction temperature is constantly monitored to avoid the AN decomposition (maintained at around 172-180 °C by introducing into the process condensate reactor through two independent systems and/or reduction of ammonia and nitric acid to the reactor).

CONCENTRATION OF THE AMMONIUM NITRATE SOLUTION

The 75% AN solution coming out of the neutralization reactor is concentrated up to 95-96% in the first concentrator E201-V202, operating at 0.3 bara and 130 °C. the under-pressure in maintained using the vacuum pump P205.
The first concentrator consists of a vertical tube-shaped exchanger E201, fed with the polluted steam produced in the reactor; this conveys the AN solution into the tank V202 where the vapour part is separated from the solution.
The solution coming out of the separator V202 is discharged into an atmospheric tank V203. Using pumps with a prevalence of 12 bar, before being sent to the second concentrator, the 95% AN, with the addition of an aqueous solution of additive (excluding the high AN production cases), is preheated to 150 °C into the exchanger E207.
The second concentrator E301 operates at 0.07-0.12 bar and 172 °C; consists of a vertical tube-shaped exchanger E301 supplied with saturated steam at a pressure lower than 13 bar, which conveys the AN solution into a tank V301 where the vapour part is separated from the solution.
The solution with a concentration of 99.4% and a temperature of 170 °C is discharged into the tank V302.
The vapours produced in the first concentration go to the scrubber C203 and then to the condenser E205. The vapours produced in the second concentration go to the condenser E206.

MIXING WITH GROUND LIMESTONE, GYPSUM AND DOLOMITE

The AN discharged from V301 is introduced into the atmospheric tank V302 where the ground diluent is added (limestone and dolomite coming from the grinding plant and/or gypsum coming from silos S505 - 506); higher the percentage of diluent, lower will be the nitrogen content in the fertilizer.
The presence of limestone significantly increases the pH of the mixture; the main problem in this operation is caused by the reactivity of the limestone with AN with the formation of calcium nitrate according to the following reaction:

$$2NH_4NO_3 + CaCO_3 \rightarrow Ca(NO_3)_2 + 2NH_3 + CO_2 + H_2O$$

The phenomenon is coupled with the production of carbon dioxide and ammonia, collected by the fan K310 and sent to the abatement column C30 before going into the atmosphere.
Against this high reactivity are used diluents richer in dolomite and/or gypsum, avoiding very fine grains of ground limestone that would accentuate this issue.

GRANULATION AND ANTI- CAKING AGENT

From the tank V302 the mixture is fed to the prilling basket; it is a metal cone with about 4500 holes, placed in rotation on its axis inside the prilling tower and from which the mixture comes out in the form of droplets. During the falling inside the tower, the fertiliser droplets meet a counter-current airflow, moved by four large fans K302A/B/C/D, causing the cooling and the solidification of the droplets.

The product leaves the prilling tower at a temperature of around 110 °C (with the exception of particular products). Before the WESP installation, the air was vented into the atmosphere, now it is sent to the WESP for treatment.

The solid product is transported in the different sections of the plant through a system of belt conveyors.

The salt coming out of the prilling tower must be cooled below 32 °C (allotropic transformation temperature of AN crystals) to avoid quality problems (fertilizer packing); the operation is carried out in the cooler E401 where the refrigerant fluid consists of cold ambient air (in hot weather the air is cooled by evaporating part of the ammonia introduced into the plant), after a slight heating (about +3 °C) to reduce relative humidity in order to avoid water absorption by the fertilizer (quality problem of the finished product).

The specified product is coated by means of a rotary drum ME405 in which the anti-packing substance is sprayed.

Through a system of belt conveyors, the product is then sent to the warehouse where it is stored in bulk before being bagged in the bagging unit.

ENERGY RECOVERY

The polluted steam produced in the reactor R201 is used in the same plant in heat exchangers for energy recovery in the following equipment:

- First concentrator E201
- Reboiler of the ammonia distillation column E208
- Recovery boiler E218 (produces steam at 2.5 barg)
- E202 tube-shape exchanger, which has the task of eliminate any polluted steam produced in excess and not recovered from the boiler E218
- Steam-tracing lines and equipment

EFFLUENT TREATMENT

The condensate obtained in the exchangers, feed with polluted steam from the reactor R201, is fed through the V207 into the distillation column C202 operating at atmospheric pressure; from the top of the column, a 20% ammoniacal solution in NH_3 is obtained and is totally recycled to the reactor R201. From the bottom of column, a condensate containing traces of ammonia comes out and is partly recovered in the reactor R201 and partly sent, together with the condensate obtained from the steam produced by the scrubber C203, to the nitric acid plants, complex fertilizers and liquid fertilisers; this last stream is called process water.

The steam of first concentration is added to the scrubber C203 where circulates a washing solution acidified with nitric acid (pH=1.5) for the reduction of ammonia and consequent formation of ammonium nitrate; part of this solution, containing about 15% AN, is sent to the reactor R201.

The refilling of water to the scrubber C203 is guaranteed by recovering the vapour condensate of second concentration.

The heat released from the condensing steam in the exchanger E205 to the cooling water is used to evaporate the ammonia in the main evaporator E210. The thermal content of the condensates coming from the bottom part of the distillation column C202 is used for heating nitric acid adduced to the reactor R201.

1.2.2 High-grade AN production

The plant has a lower production capacity for AN fertilizer as nitrogen higher than 28%, e.g. for AN 34,2% the maximum production capacity is 1200 t/d.
This production is practically the same as the previous one, except for the lack of diluent and the anti-caking agent. Therefore, during this type of production, the following sections are excluded from the production cycle:

- Transport system and diluent dosing
- Anti-caking agent dosing

Typically, an additive solution is used to guarantee the reduction of the crystallization temperature which allows the prilling basket to be at lower temperatures. The result is a reduction in the surface tension of the product and consequently in gaseous emissions from the prilling tower.
In addition, during the production of high grade AN, the fertilizer bypasses the drum ME405 to be conveyed, without coating, directly to the packaging plant (Coter) forming part of the logistics section, where it is packed on pallets in sacks of 25, 40 or 50 kg or in bags of 600 kg, 750 kg or 1200 kg.
The following block diagram is referred to the CAN 26 production that is the most characteristic.

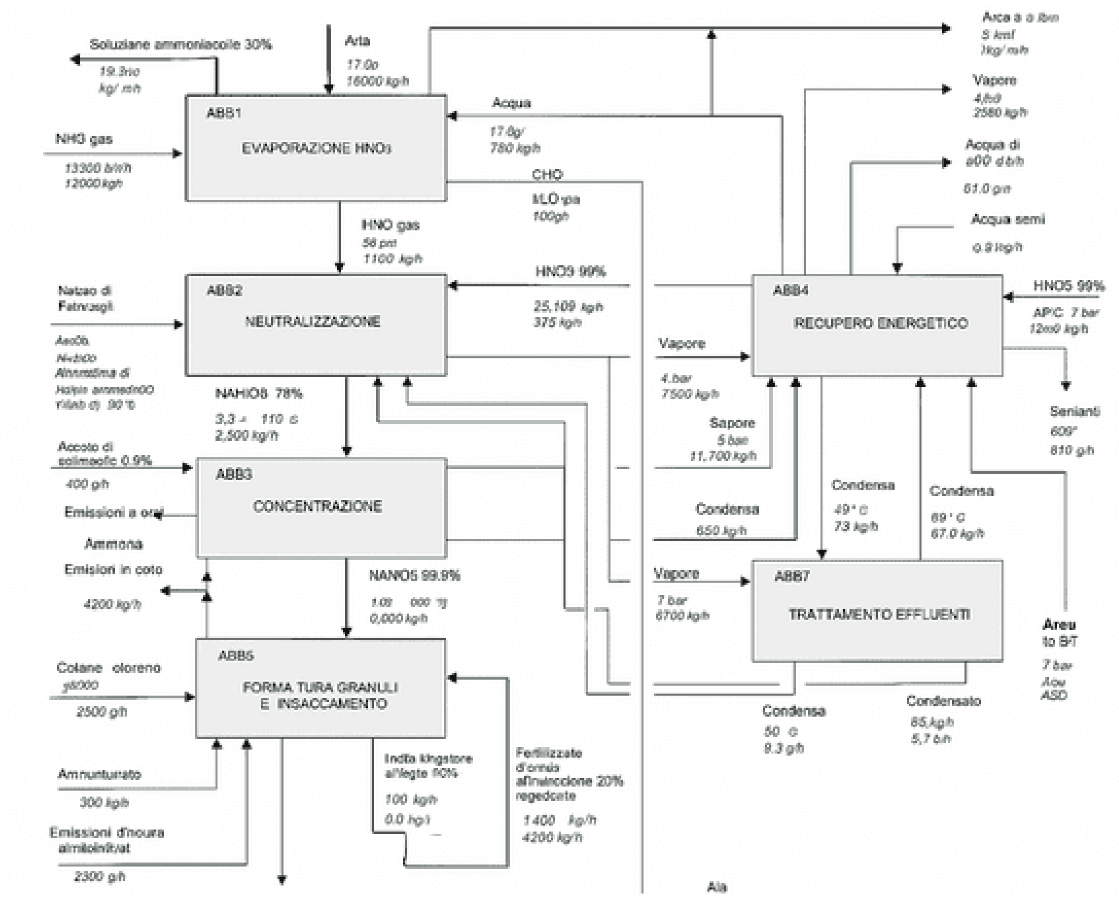

Figure 2: block diagram of CAN 26 production

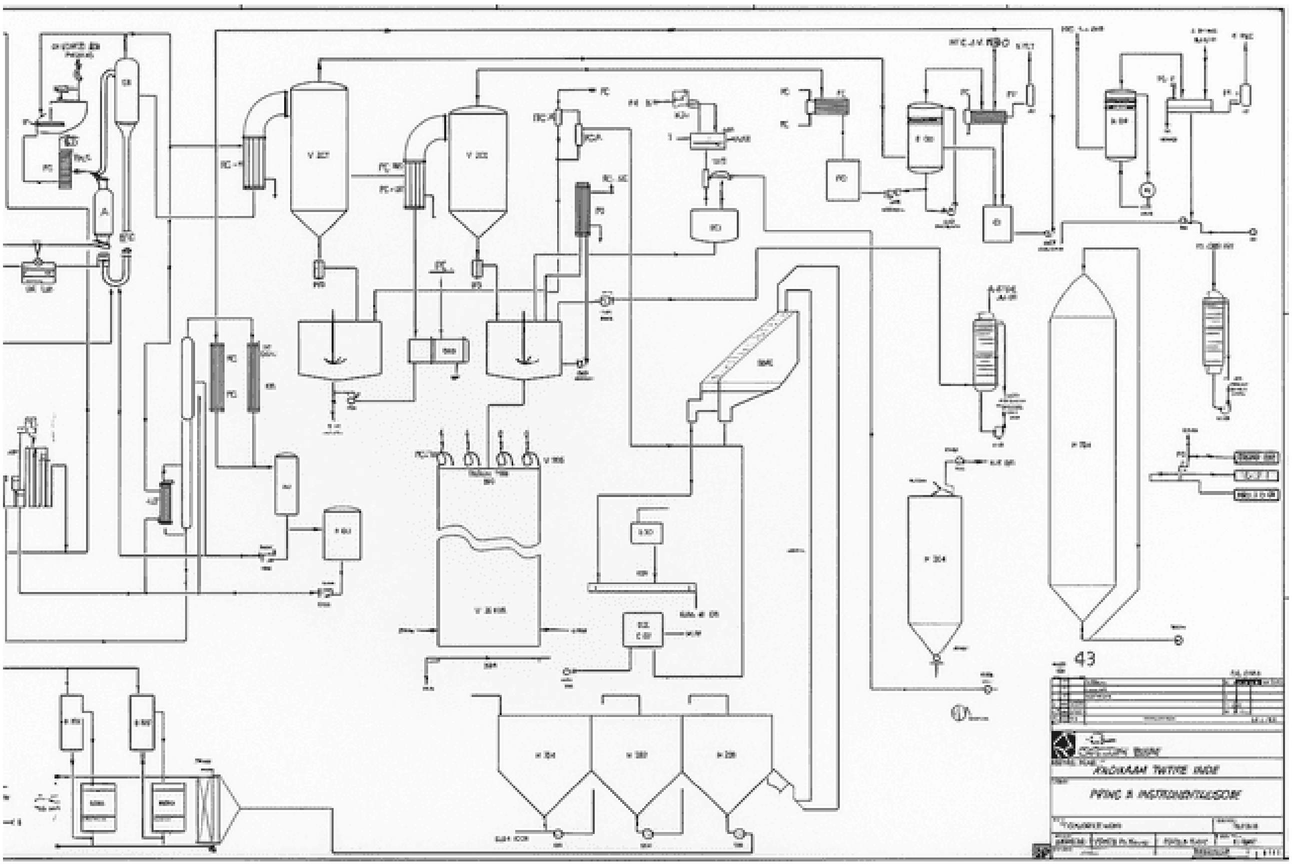

Figure 3: P&I of NAS plant

PRODUCTS

Product	Total nitrogen [%]
CAN 21%	21.0
CAN 24/15 SO_3	24.0
CAN 26%	26.0
CAN 27% prilled	27.0
AN 33,5%	33.5
AN 34.2%	34.2
AN 33.2%	33.2

Table 2

1.3 MANAGEMENT OF THE ENVIRONMENTAL ASPECT "ATMOSPHERIC EMISSIONS"

The Commission's Group AIA-IPPC [3] justifies its prescriptive choices based on the opportunity to correlate the exercise of the installation with the evolution of technological progress, in a way that ensures the highest levels of environmental protection in relation to the application of the best available technologies, with a view to continuous improvement.
Point emissions from localized sources are those from chimneys and vented conveyed of the plants.
In particular, focusing on the prilling tower, the AIA currently in force authorises emission points relating to prilling tower until June 2025 as listed in the table below

Prilling Tower Chimney	Characteristics (h/section)	SME[1]	Flow MCP[2] (Nm^3/h)	Pollutant	VLE AIA (mg/Nm^3)
A	50 m 3.14 m^2 (for each inlet)	No	145000	Dust	35
				Ammonia	10
B			145000	Dust	35
				Ammonia	10
C			145000	Dust	35
				Ammonia	10
D			145000	Dust	35
				Ammonia	10

Table 3

The Best Available Techniques (BAT) that are applied or intended to be applied, as described in the relevant BATConclusions reference documents (BATC) and Bref, for the purpose of adjusting the authorisation pursuant to art. 29-octies, comma 2, of D.Lgs. 152/2006.
For what concern the atmospheric emissions, an example of BATC, applied in August 2007 (BREF "Large volume inorganic chemicals" – 9.4.1 Optimisation of the neutralisation section), is:

- The heat produced in the neutralization section is used to: concentrate the solution
- Produce low pressure steam used in the plant itself and as integration into other plants (nitric acid and NPK) and activities (heating of rooms and equipment)
- The neutralization is carried out under pressure (3 bar). The temperature is regulated by recycling in the reactor condensates polluted with NH_3 and/or ammonium nitrate. Do not recycle solid material from any source
- Periodic analyses of chlorides, organic matter, nitrites and metals (in particular Cu) shall be carried out on the raw materials
- The Stamicarbon plant has nitric acid heating equipment
- The alternative of double-stage neutralization is equivalent to pressure conduction

[1] SME = monitoring in continuous of atmospheric emissions
[2] MCP = maximum production capacity

1.4 MONITORING AND MEASUREMENT OF EMISSIONS TO AIR

Following the ARPA guidelines [4], in order to have a representative small sample of taken fluid of the entire quantity emitted from the chimney, this fluid must have:

- In space: physical characteristics and homogeneous composition throughout the duct section where the sampling is located
- Over time: steady-state flow (physical characteristics and composition constant over time)

The current standard UNI 10169:2001[3] indicates that in order to carry out a sampling of acceptable accuracy, it is essential that the flow of gas inside the duct is sufficiently stationary and homogeneous. To achieve this, it is necessary that the section of duct being measured meets certain requirements.
Sampling points shall be located in straight sections of a regular section (circular or rectangular) pipe, preferably vertical, away from obstacles, curves or any discontinuities which may affect the flow of the effluent. In order to ensure the stationary condition necessary for carrying out measurements and sampling, the location of the sampling point must comply with the conditions imposed by the technical reference standards (UNI 10169:2001, UNI EN 13284-1:2003, UNI EN 15259:2008) or at least five hydraulic diameters downstream and at least two hydraulic diameters upstream of any discontinuity.
Each emission shall be numbered and uniquely identified by indelible marking of the emission number and chimney diameter on the relevant article near the sampling point.
Each sampling point must be equipped with an internal diameter 3” nozzle internally threaded and must protrude for about 50 mm from the wall.
Depending on the size of the duct, one or more sampling points must be provided. The number of sampling points is determined on the basis of the following table:

<table>
<tr><th colspan="2">CIRCULAR DUCT</th><th colspan="3">RECTANGULAR DUCT</th></tr>
<tr><th>Diameter (m)</th><th>N° sampling points</th><th>Shorter side (m)</th><th colspan="2">N° sampling points</th></tr>
<tr><td>Until 1 m</td><td>1</td><td>Until 0.5 m</td><td colspan="2">1 at the centre of the edge</td></tr>
<tr><td>From 1 to 2 m</td><td>2 (located at 90°)</td><td>From 0.5 to 1 m</td><td>2</td><td rowspan="2">At the centre of the equal segments into which the side is subdivided</td></tr>
<tr><td>Higher than 2 m</td><td>3 (located at 60°)</td><td>Higher than 1 m</td><td>3</td></tr>
</table>

Table 4

In the NAS plant are present 4 circular ducts with a diameter higher than 2 m (2.30 m), each equipped with 3 nozzles for sampling. Due to the fact that when the plant was built the specification regarded the dimension and position of nozzles was not specified, it is performed a fluidymanic study in the chimney to determine which nozzle is more representative to use for the future samplings.

The measurements of the emissions to air from the chimneys of the prilling tower have to be carried out each semester with manual sampling and laboratory analysis.
The checks should be carried out in batch.
Analytical determinations in the laboratory must be carried out using official nationally and/or internationally recognized methods of analysis and good laboratory and quality practice or CEN, UNI, ISO, US EPA, APAT/IRSA-CNR, ISS, etc.

[3] Standard UNI 10169:2001 "Emission measurements - Determination of the velocity and flow rate of gaseous streams conveyed by means of the Pitot tube", second edition May 2001

Laboratories for sampling and analysis of pollutants shall use methods accredited at least for the following types:

- The pollutants identified in the BATconclusions
- The pollutants relevant to the production process (relevant are those pollutants that have been declared by the operator in the application for AIA, evaluated as part of the investigation procedure and prescribed with Competent Emission Limit Values)

In the case of discontinuous measurements (carried out by means of continuous or field sampling and subsequent laboratory analysis), emissions are considered to comply with the limit values if, during a measurement, the concentration, calculated as the average of the analytical values of at least three consecutive samples taken according to the sampling methods and representative of at least 90 minutes of operation of the installation, does not exceed the emission limit value. Where the sampling methods identified in the authorisation provide for a minimum sampling period of more than or equal to 6 hours for specific substances, a single sample may be used for the purpose of assessing compliance of emissions with limit values.
For the analysis of air emissions, the following table shows analytical methods recognised at European level as reference methods for parameters to be controlled.

Parameter	Method	Principle of the method
Dust	UNI EN 1384-1:2017	Gravimetric determination after isokinetic gas sampling
	UNI EN 1384-2:2017	The standard specifies requirements for calibration, validation, continuous quality control during operation and annual monitoring test of automatic dust monitoring systems described in EN 13284-1
Ammonia	EPA CTM 027/97	Determination by ion chromatography of the ammonium ion
	UNI EN ISO 21877:2020	The standard specifies a method for sampling and determination of gaseous ammonia in gaseous effluents from stationary emission sources

Table 5

By 30th of April of each year, Yara Ravenna is required to transmit to the Competent Authority (now Ministry of the Environment and Protection of the Territory and the Sea - Directorate for Environmental Protection), to the Control Unit (now ISPRA), to the Region, to the Province, to the municipality concerned and the competent territorial ARPA, an annual report describing the operation of the plant in the previous year.

1.5 NEW AUTHORIZATION LIMITS

In order to frame and then define the requirements for the operation aimed at regulating emissions into the atmosphere, Yara Ravenna must comply within June 2025 with the emission limit values given in the following table, such as:

- Daily average, for parameters subject to continuous measurements (in such cases none of the hourly averages shall exceed the VLE by a factor greater than 1.25)
- Average of the sampling period (mean value of three consecutive measurements of at least 30 minutes each) for parameters subject to periodic measurements

It refers to dry fumes under normal conditions (273.15 K and 101.3 kPa). The reference oxygen content is to be understood as such for all emission points.
To respect these limits, the Wet ElecroStatic Precipitator technology is built.

Prilling Tower Chimney	Characteristics (h/section)	SME[4]	Flow MCP[5] (Nm^3/h)	Pollutant	VLE AIA ex DM 220/2021 (mg/Nm^3)	VLE AIA (mg/Nm^3)
A	50 m 3.14 m^2 (for each inlet)	No	145000	Dust	35	10 (until June 2025)
				Ammonia	10	10
B			145000	Dust	35	10 (until June 2025)
				Ammonia	10	10
C			145000	Dust	35	10 (until June 2025)
				Ammonia	10	10
D			145000	Dust	35	10 (until June 2025)
				Ammonia	10	10

Table 6

[4] SME = monitoring in continuous of atmospheric emissions
[5] MCP = maximum production capacity

CHAPTER 2: AIR EMISSION ABATEMENT PLANT (WESP)

2.1 WET ELECROSTATIC PRECIPITATOR TECHNOLOGY

A Wet Electrostatic Precipitator, known as WESP, is an equipment designed to remove liquid and solid particles from a gas flow. It offers efficient control of sub-micron particulate emissions, heavy metals, acid fogs, oil fogs.
In the case of WESP, the inlet flow is saturated or the liquid is sprayed so, the droplets and particles collected on the plates flow down as a liquid phase.
The wet electrostatic precipitator has no moving parts, unlike a high energy scrubber, it has an exceptionally low-pressure drop.
Typically, the pressure drop does not exceed 15 mm circa in the collecting section and the total pressure drop of the WESP is between 15-200 mm circa, implying lower operating and energy costs.
Depending on the process characteristics, a WESP could be constructed using various materials and it can be built either as a single unit or with multiple components to be assembled on-site.

The main sections are:

- Inlet section and distribution of gas: the inlet section is the section where gas enters the WESP. The inlet section can be either in the upper part, in the case of flow from top to bottom, or in the lower part, in the case of flow from bottom to top. Within the input section we can have one or more layers of Rod deck or perforated plates. Rod deck and perforated plates have the task of evenly distributing the gas within the WESP before passing inside the tube bundle

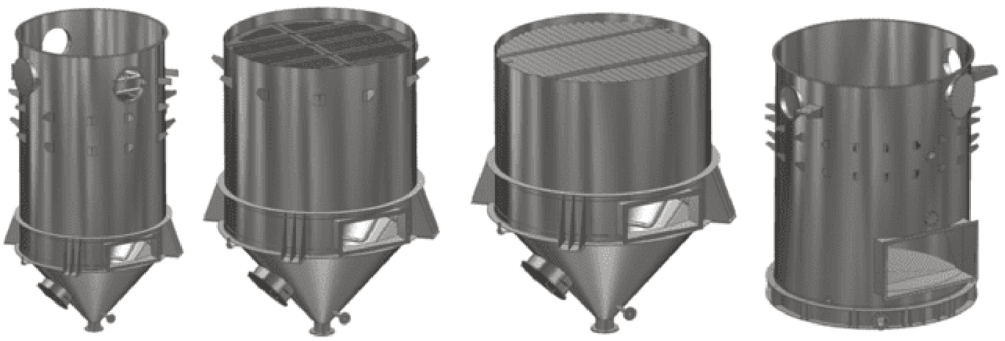

Figure 4: inlet section and distribution of gas

- Tube bundle: the tube beam is the central part of the WESP and consists of a set of cylindrical or hexagonal tubes in the centre of which an electrode is installed. All the liquid and solid particles which are removed from the gaseous stream are deposited on the walls of the tubes and, once deposited, by gravity, fall to the bottom of the WESP. Where present, the intermittent washing system washes the walls of the tube beam by removing accumulated deposit

Figure 5: tube bundle

- Gas outlet section: the outlet section is the section where the gas leaves the WESP. The output section can be placed either at the bottom, in the case of top-down flow, or at the top, in the case of bottom-up flow

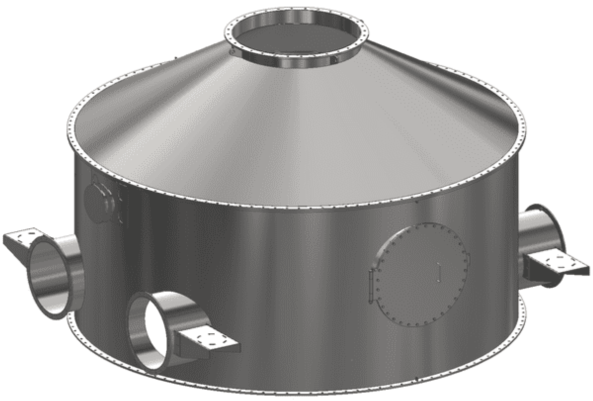

Figure 6: gas outlet section

- Insulating sectors and ceramic insulators: the insulator sections are used to contain the ceramic isolators which have the task of electrically isolating the WESP body from the electrodes and their supporting structure. The isolating compartments can be installed above the pipe bundle or either above or below the pipe bundle

Figure 7: insulating sectors and ceramic insulators

- Electrodes and support structure: electrodes are the main component of WESP. They are “special tubes”, placed inside the tube bundle and supported by a structure connected to ceramic insulators

Figure 8: electrodes and support structure

- Transformer and grounding: the transformer, also in this document called rectifier, is a component capable of generating a potential difference of thousands of volts between the electrodes and the WESP body. This difference in potential results in the removal of liquid and solid particles from the gaseous stream. Grounding is a safety device that ensures the “earthing” of the transformer, locking it in a safe position making possible maintenance operations. Grounding is usually mounted under the transformer and in some cases integrated inside the transformer

Figure 9: transformer and grounding

- Connection system: the transformer needs to be connected to the electrodes and their support structure. The connection can be made with:
  - Bus duct
  - High voltage cable

  The connection with Bus duct consists of a rigid connection, carried out with a metal bar placed inside a small conduit called Bus duct. The high voltage cable connection is made with a special cable protected by a metal sheath

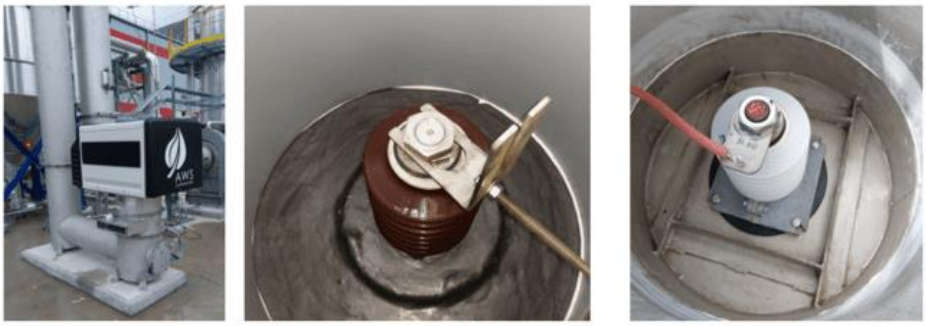

Figure 10: connection system

- Flushing system: the flushing system continuously injects ambient air into the insulating compartments to keep ceramic insulators clean and prevent dust, dirt or moisture from depositing on their surface. The flushing system can be realized with a dedicated fan for each isolator compartment or with a single fan connected to all isolating compartments. In the case of a single fan, an electric resistor may be installed which heats the air before injecting it into the insulating compartments

Figure 11: flushing system

- Heating system: in some cases, the WESP is equipped with a heating system that ensures a constant temperature of the tube bundle walls and prevents the solidification of deposits. If present, the heating system is typically installed around the tube bundle and around the bottom tank. The heating system is controlled by a dedicated small skid

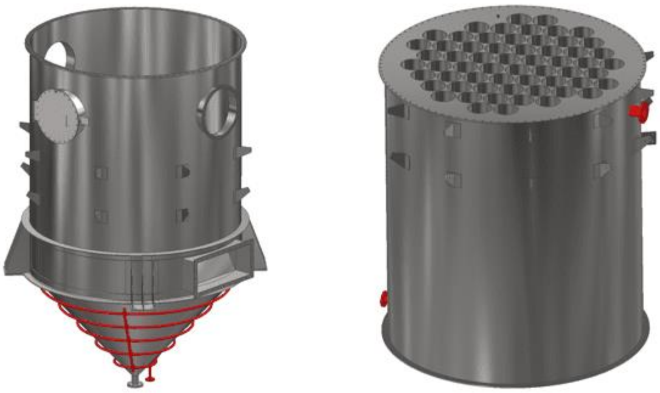

Figure 12: heating system

The WESP functioning principle is based on the corona effect and the movement of charged particles within an electric field.
The electrodes, connected to the transformer, are brought to a voltage exceeding 15 kV, while the body of the WESP is grounded. Thanks to the high voltage, the electrodes ionize the gas passing through the tubes, charging the liquid and solid particles present in the gas.
Due to the potential difference between the electrodes and the body of the WESP, the charged particles are removed from the gas flow and attracted to the walls of the WESP. The accumulated particles are thus removed either by gravity or by the washing system.

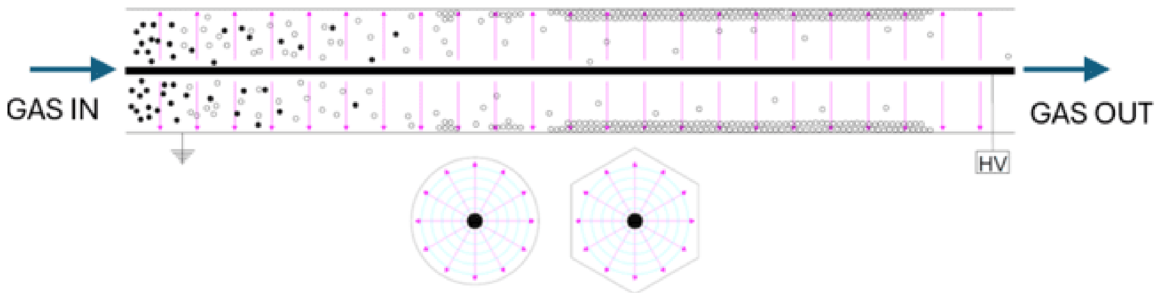

Figure 13: working principle

2.1.1 Test on a pilot system

Before the construction of the WESP plant in Ravenna were made test on a pilot system in another Yara plant. In fact, in all Yara ammonium nitrate plants there are no other WESPs and the one that will be installed in Ravenna is the first, for this reason it was useful to carry out a test in a pilot plant.
The pilot unit contains out of two skids, one skid with a fan and transformer and the second skid has the WESP and scrubber. The pilot unit contains internal washing possibilities in case there will be fouling of the product to the wall.
The P&ID of the WESP pilot unit consist out of three units. The gas stream is fed from the bottom left side; this gas enters a saturation vessel. The vapors flow to the second vessel where typically ammonia is captured. The third vessel is the WESP unit. The gas stream leaves the WESP via the fan before is goes into the atmosphere.

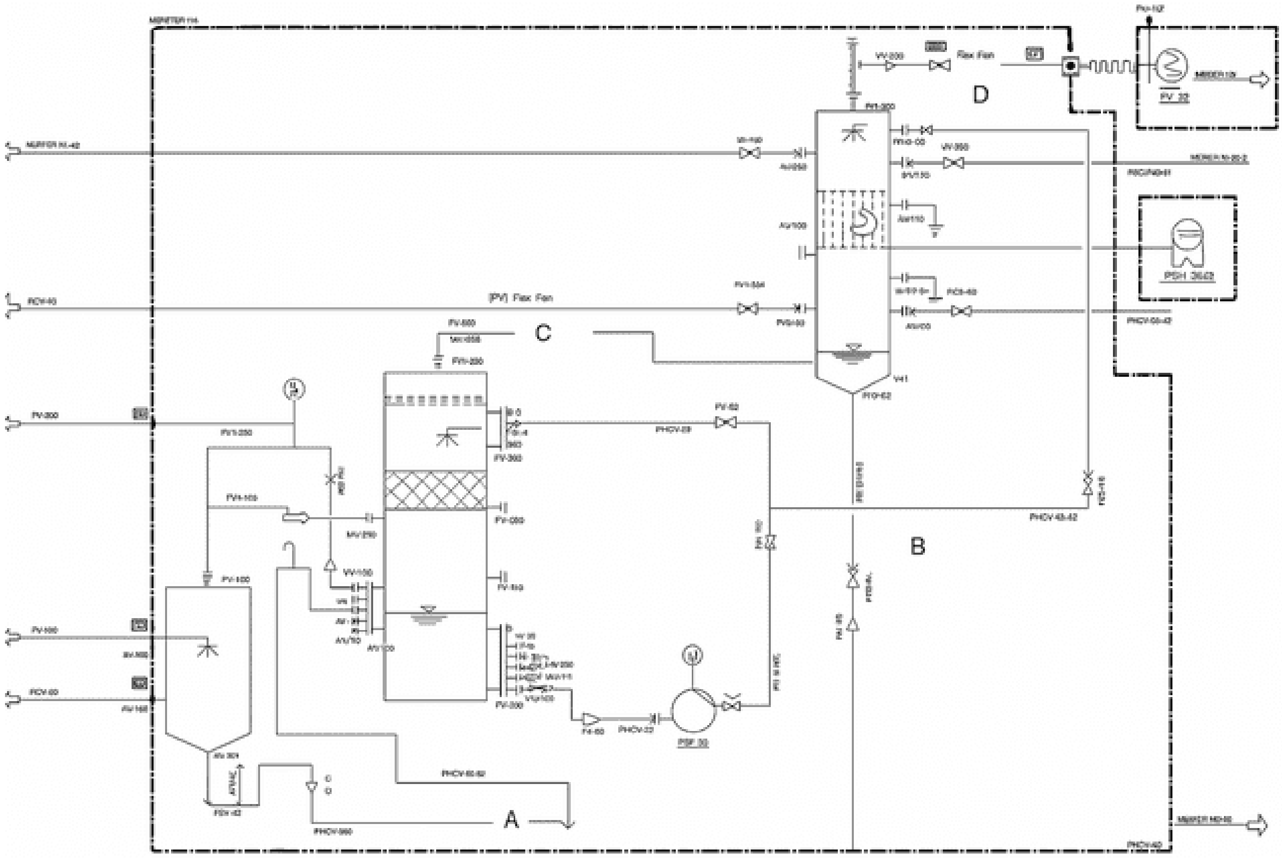

Figure 14: A condensate bleed. B WESP bleed. C WESP inlet sample point. D WESP outlet sample point

The flush air is required to keep insulator blocks clean so to preserve the insulation function so that the High Voltage can be maintained. Typically, on industrial units this flush air flow is negligible compared to the main flow of gas to be treated. On the pilot unit it is not the case so results will need to be corrected for dilution.
The WESP is operated by setting a given % of the max voltage of the transformer (70 kV) and reading the achieved current through the WESP display. The higher the voltage the higher the current. In theory the higher the current and voltage to higher the collection efficiency.
At some point when voltage driving force is high (too high), there will be formation of electrical arcs/sparks. This will result in a temporary drop of voltage and intensity and subsequently efficiency. So, the optimal setting to be found is a compromise between the highest voltage and current without excessive sparking.
The first run with process gas also gave visual evidence that the WESP was taking out a significant amount of dust/droplets as the stack opacity changed drastically when the WESP was in operation.
Five weeks of emission measurements resulted in good and stable AN dust scrubbing efficiency. In average AN dust was scrubbed to about 5 -15 ppm. The small differences in efficiencies cannot be linked to product grade or to dust inlet levels. The differences in efficiency are probably linked to the normal sampling/analysing standard deviations.

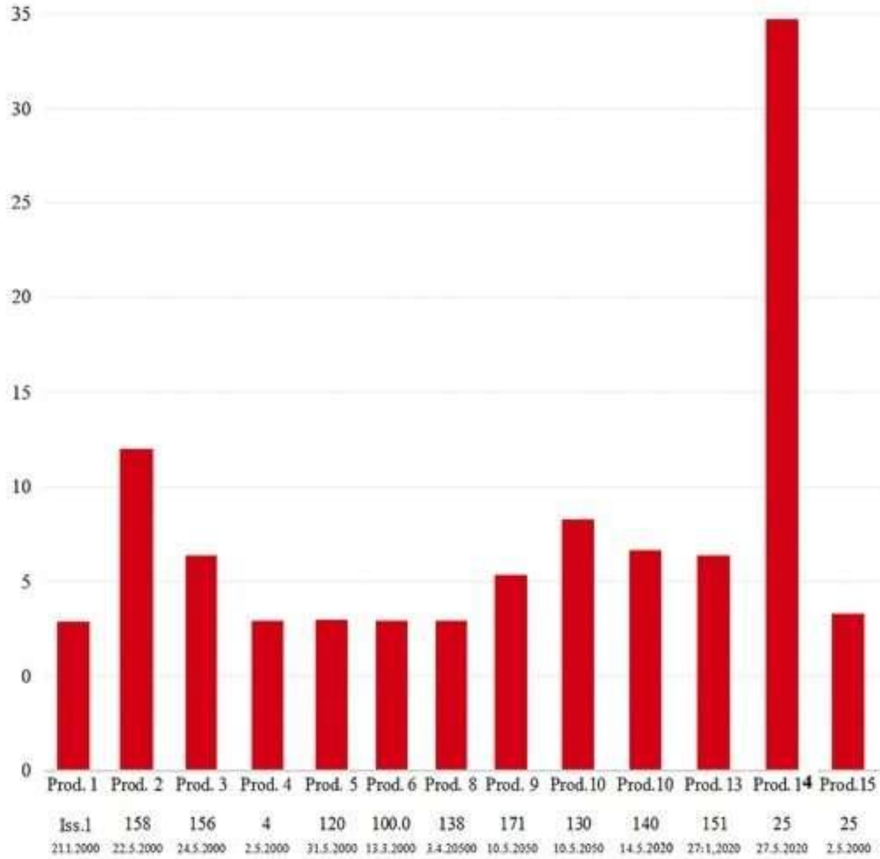

Figure 15: AN dust emissions outlet WESP

The NH_3 emissions were also measured but no noticeable reduction has been found.

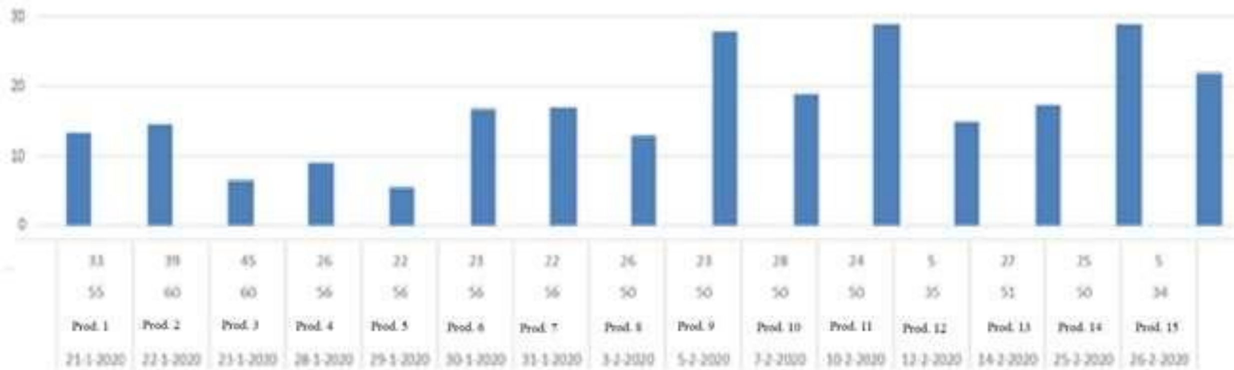

Figure 16: NH_3 emissions outlet WESP

The WESP was inspected in the beginning and at the end of the run. There was no significant fouling and scaling visual and measurable.

Figure 17: fouling and scaling

When the system was washed with water, there was no noticeable difference measured on the current. This was tried several times. This is an indication that the system keeps itself clean. This is probably due to the fact that the AN concentration is low and the air stream is fully saturated. The AN does therefore not stick to the walls.

Varying the transformer settings (kV-mA) did not give different emission results, however this was generally expected (within the range of testing). However, at a given voltage setting, the resulting current (mA) was different for different products.

All in all, the test period did not reveal any operational or reliability issues. The pilot unit was stable and did not require particular attention. The abatement efficiency of the WESP was satisfactory in all the tests carried out, managing to reduce consistently the outlet AN emission from 35-70 mg/Nm^3 to 5-10 mg/Nm^3 according to the samples made.

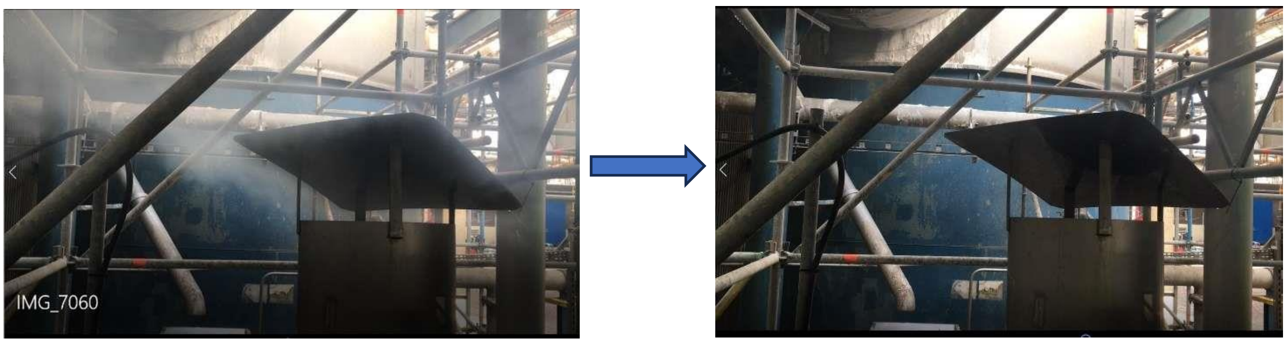

Figure 18: visual impact of the start-up of the pilot plant

2.2 YARA RAVENNA WESP PROJECT

2.2.1 Yara Ravenna WESP description

The aim of the new plant is to reduce dust and ammonia emissions from the prilling tower into the atmosphere.
The unit is designed to treat 580 000 Nm^3/h of dry air, containing a dust content of 70 mg/Nm^3 and an ammonia content of 20 mg/Nm^3, in order to achieve a maximum dust content of 5 mg/Nm^3 and ammonia content of 5 mg/Nm^3 [5].
The abatement of dust and ammonia design is higher of the AIA authorization limits, <10 mg/Nm^3 for dust and <10 mg/Nm^3 for ammonia, until June 2025 to manage possible set-up and avoid to stop the granulation section.
The selected treatment steps are:

1. Trays at the bottom of the WESP, for absorption of ammonia by a continuous washing system
2. High voltage section for the removal of remaining dust and liquid particles

The emission to the chimney, according to AIA, shall contain at most:

- 10 mg/Nm^3 (dry air) for NH_3
- 10 mg/Nm^3 (dry air) for dust

The treatment system produces a solution which, properly treated by filtration and preheated, is recovered and reintroduced in the same production process before the second concentration section. The solid resulting from the filtration, mainly limestone, dolomite and calcium sulphate, will be sent and recovered in the NPK plant.

Modifications of the plant

The modifications consist of:

- Installation of n. 1 wet electrofilter (WESP- Wet Electro Static Precipitator) for the abatement of fumes coming from the existing prilling tower
- Construction of a collector into which confluent n. 4 currents from the existing chimneys of the prilling tower (A/B/C/D). This stream, through a fan, will be sent to the new WESP wet electrofilter
- Installation of a new chimney (E42-11) above the washing unit for the release of effluents into the atmosphere at the correct elevation
- Installation of a section dedicated to the liquid stream leaving the WESP; this is a current consisting of a 12% AN solution
- Installation buffer tank to collect the 12% AN solution
- Installation of a filter on the tank V601 for the elimination of suspended solids
- Installation of heat exchanger to preheat the stream before it is recycled to tank V203
- Construction of a new electric cabin dedicated to some users of the new dust abatement system. The cabin will be equipped with a fire detection system with warning and alarm in the existing control room of the NAS system. Characteristics of the cab:
    - Transformer cabin 6-0.4 kV
    - Equipped with a fiberglass transformer
    - Installed power 2000 kVA
    - Absorbed power 1100 kW
- Extension/update of the DCS and the SIS already in operation for the control, command and locking of the NAS installation

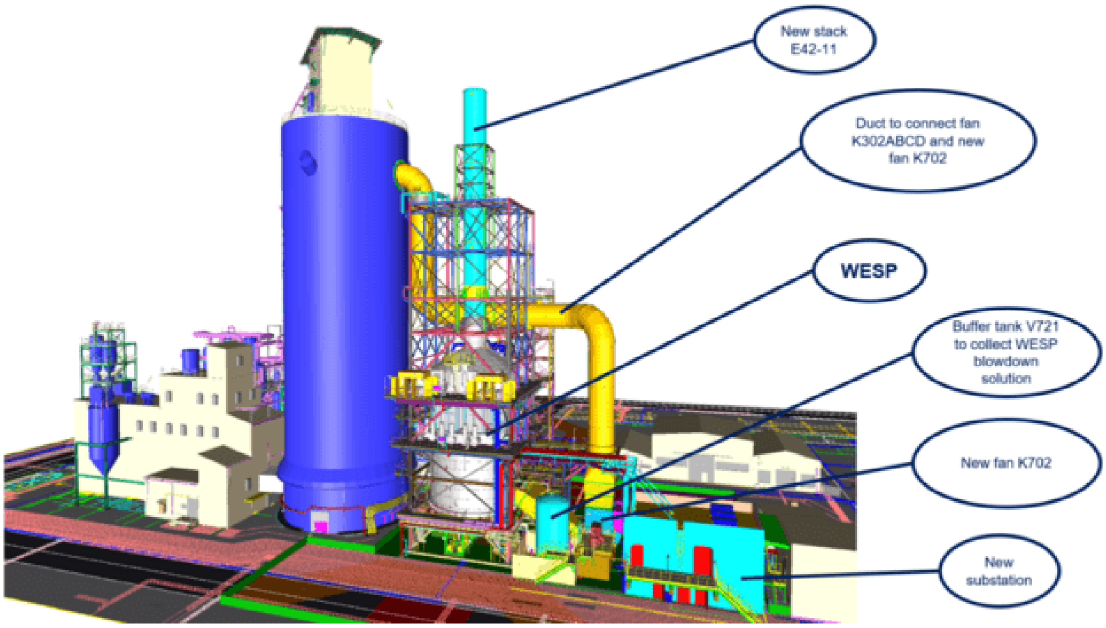

Figure 19: 3D model of WESP

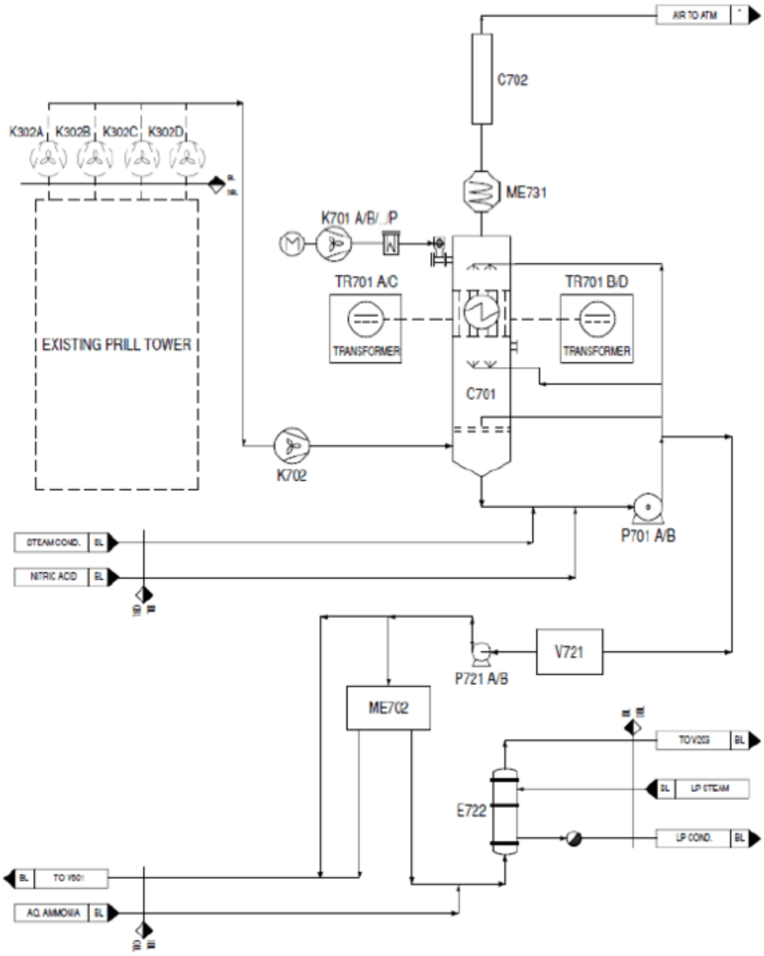

Figure 20: schematization of WESP plant

The operating data are:

ITEM	DATA	UNITS
Flowrate of gas to be treated	580000	Nm^3/h (dry base)
Operating temperature	26-42	°C
Operating pressure	25	mbarg
Flowrate of recirculation	450	m^3/h
Flowrate of purge	0.53	m^3/h
Flowrate of nitric acid	0.05	m^3/h
Flowrate of condensates	5.26	m^3/h
Temperature of solution in V203	95	°C

Table 7

The Ravenna WESP consists of the following main sections, from bottom to top, following the gas flow [6]:

- Gas inlet to be treated: this section is dedicated to conveying and distributing the gas in the WESP. Normally it is a rectangular opening where the speed of gas does not exceed 10 m/s, protected at the top by a shelter to prevent water droplets, falling from the washing sprayers inside the WESP, are pushed out of the nozzle itself
- Absorption plates section: the gas is guided through two layers of absorption trays fed with an acid solution (pH=3). In this phase the removal of larger dust and absorption of ammonia takes place. The water is recirculated continuously by means of two pumps, one in operation and the other in stand-by. For the removal of ammonia, a certain amount of nitric acid is injected into the recirculated feed water in order to set the correct pH for the reaction between ammonia and nitric acid, obtaining mainly ammonium nitrate salts dissolved in water. The injection is controlled by a pH meter and a control valve
- Perforated plate section: after the absorption section, the gas meets a redistribution section designed to create uniform distribution over the whole section of the tank (12 m in diameter) before reaching the high voltage stage. This section is made up of a layer of perforated sheet metal with a degree of vacuum of about 30%
- Collection section: The collector section contains the grounded round collector tubes, each with a negatively charged ionizing rod (electrode). Scrubbed gas that contains ultra fine particulate is charged by the gaseous ions generated by corona discharge. These negatively charged particles are collected on positively charged walls of the collecting tubes. The electrodes also act as a mist eliminator. The tubes provide the best possible use of surface area while maintaining the ideal electrical field characteristics. The access door is intended for inspecting during routine maintenance and for access to the upper high voltage support frame for assembly and inspection. The access door is furnished with key interlocks to prevent unauthorized entry while the unit is in operation
- Purge system and insulators: the internal beams and electrodes are mechanically supported by a series of ceramic isolators, intended for both mechanical and electrical disconnection. The purge system provides clean, filtered ambient air to the insulation chambers to prevent the accumulation of dirt and moisture on the insulators. The system consists of four blowers equipped with high efficiency filter for dust removal. The purge system shall start at least one minute before the unit is started and shall always be maintained in operation during normal operation

- Transformer/Rectifier section: the high voltage system consists of 4 rectifiers (one for each section of the tube bundle) placed at a height of about 20 m. They are places on two shelters, each one containing two rectifiers. The rectifiers contain 80 kg of dielectric oil each and are equipped with a containment tank to prevent oil leakage in case of leakage. They are also equipped with PSV that protects the oil bath from overpressure and are equipped with high temperature detection/alarm/lock
- Cyclonic demister: the cyclonic demister is a static mechanical equipment mounted on top of the WESP. The cyclonic demister is a low pressure drop separator, anti-clogging and high efficiency. The droplets are removed by the centrifugal force transferred to the gas stream from the static impeller installed inside the cyclonic demister casing
- Treated gas outlet: this section is dedicated to channel the clean gas leaving the WESP directly into the stack, installed above the cyclone demister and disconnected by an anti-vibration joint

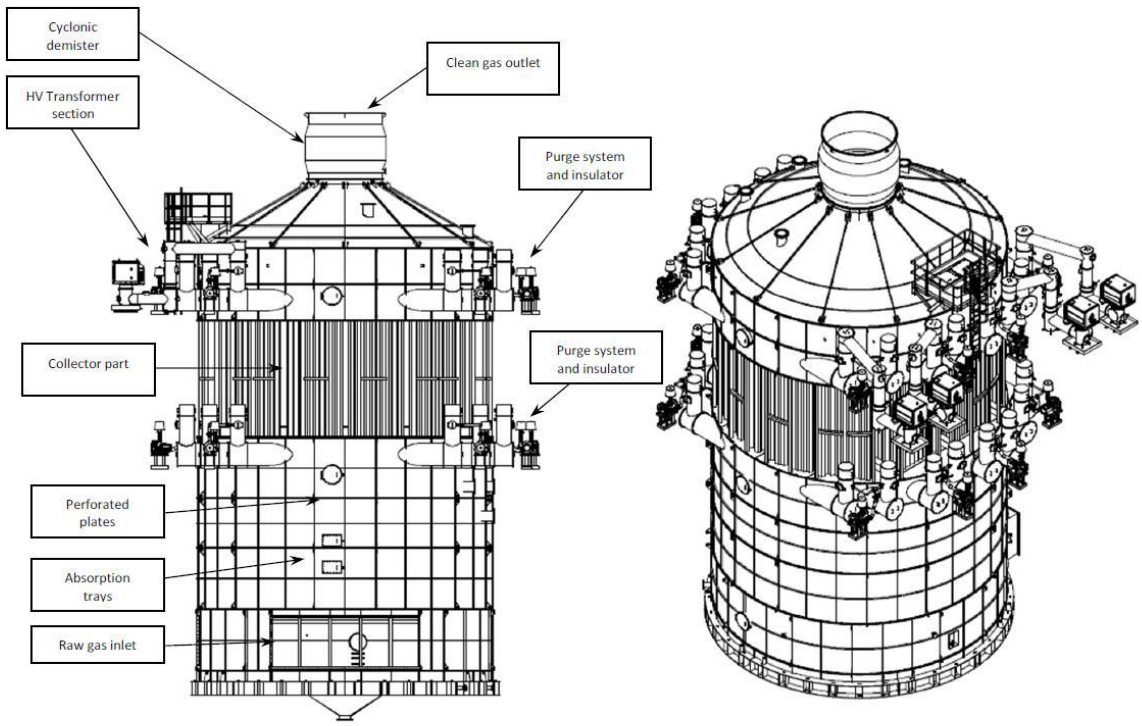

Figure 21: Sketch of the WESP system

2.2.2 Blowdown solution treatment

The blowdown solution is:

- Filtered by special self-cleaning filter ME702
- Corrected in pH by regulation of rich condensates
- Heated to a temperature of about 95 °C, using 2.5 barg steam
- Sent to the tank V203. Expected flow rate about 0.5 m^3/h

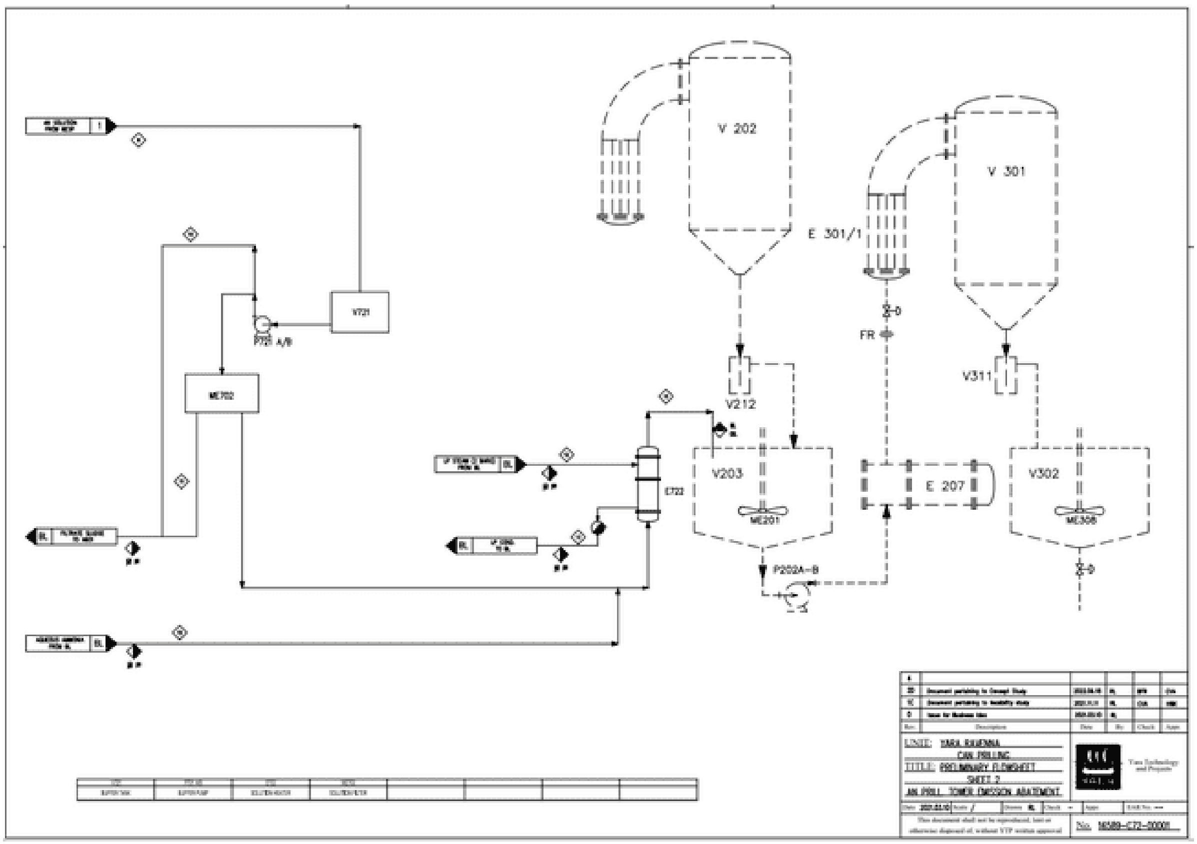

Figure 22: P&I diagram

2.2.3 Main sections and equipment

The main sections and equipment are:

- Connection between the output from fans K302A/B/C/D and the fan K702
- Fan K702
- Piping skids
- Transformer
- Pump P721A/B
- Filter ME702
- Heat exchanger E722

Connection between the output from fans K302A/B/C/D and the fan K702

To send gas from the K302A/BC/D fan outputs to the WESP, a collection system was designed and built that forms a toroidal duct on the fourth floor of the prilling tower. The duct consists of a first toroidal part that collects and joins the outputs of the K302A/B/C/D fans and an external part that comes down from the hole of the K302A and connects to the intake of the K702.

Going into detail, the toroidal part is made up of 3 sections:

- The first one goes from K302C to K302B and is an 80” conduit. A special piece has been set up at the K302B which is capable of combining the delivery of the two fans (it starts with two 80” couplings and ends with a 100” output)
- A 100” duct starts from the special piece and will be inserted into the special piece A
- To join the delivery of the K302D to the special piece A there is another 80” duct

Special piece A combines the outputs of all the fans and has a 130” output (it was necessary to widen the hole of the K302A fan as it was not large enough to pass the tube). Each of the 3 sections is

equipped with manholes to carry out cleaning of the ducts, a drain to drain the washing water and internal nets to prevent falling inside the tower. On the special piece A, there is an additional manhole for cleaning.
The outer duct consists of:

- A descending first part on which there is a manhole for the cleaning of the vertical section
- A horizontal stretch on which there are two manholes to clean
- A final descending part that will split into the two aspirations of K702.

Once the geometry of the duct had been defined, a fluid dynamic study was carried out to understand the type of flow inside the duct and to calculate the pressure drops.

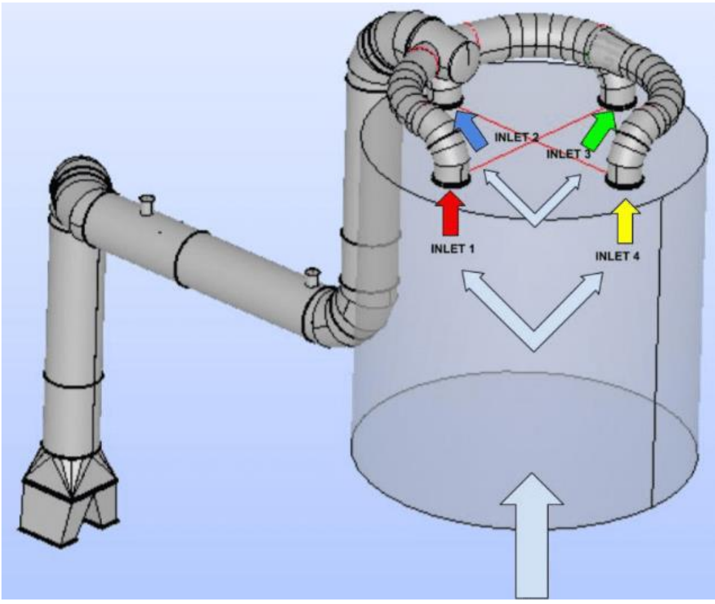

Figure 23: Scheme of the second analysis performed with the inlet plenum upstream the four inlet fans

<u>Air treatment</u>
The air to be treated comes from the existing prilling tower and, through the existing fans K302A/B/C/D enters the collecting duct. From here, the new fan acts as a booster, to provide the extra pressure drop generated by the downstream system. The exhaust of the fan K702 is directed to the new scrubber C701.
The air to be treated enters the new scrubber from below and exits from above.
In the scrubber, ammonia in the air is captured by the washing solution circulated by the scrubber pumps P701A/B at the bottom of the scrubber. Dust is captured by the wet electrostatic precipitator operated by high-voltage transformers TR701A/B/C/D. Negatively charged dust particles are collected on the positively charged WESP tube wall and then fall.
The WESP is also equipped with an air purge system to keep the insulation rooms clean. Clean air is injected from the fans K701A/B/… /P.
To keep the WESP pipes clean, intermittent washing is provided: the washing solution is pumped P701 A/B and sprayed into the pipes. During the wash cycle, both pumps operate in parallel to ensure sufficient wash flow. The WESP C701 is divided into four tube sections (one transformer per section). Only one section can be washed at a time. When the washing cycle is activated, the corresponding transformer section automatically stops.
The clean air then passes through a droplet separator ME701 to remove any droplets in the air, which are generated mainly during the pipe washing process, and then the air is discharged into the atmosphere via the chimney C702.

Fan K702

The gas coming out of the prilling tower does not have sufficient pressure to pass through the WESP so, requires a booster blower.

The gas reaches the impeller from two sides; this requires two suction nozzles and a push nozzle. The shaft support is lubricated with a circulation of oil.

The stop brake is set to prevent rotation of the rotor when the fan is not active; it is permitted to use the brake only when the fan is already stopped. The brake is needed to ensure that the impeller does not move when, for instance, it is needed to enter the case for inspection or maintenance activities.

The water injection is used to clean the impeller and prevents solid substances from settling on the impeller. Water is sprayed through nozzles on the parts of the impeller affected by deposits. The centrifugal force on the moving impeller causes the water to be deflected outwards; the drain in the lower part of the housing must remain open.

Figure 24: fan K702

Piping skids

The electrostatic precipitation plant is equipped with three Skids that allow its operation:

- WESP Recirculation pump skid (P701A/B): The liquid collected in the integrated tank at the bottom of WESP is recirculated by means of a pump skid, on which two centrifugal Stainless-Steel pumps are installed. Pumps operate with the logic one-out-of-two (one in operation and one in standby), so that plant do not need to be stopped in case of malfunction on one of the two pumps. Both pumps will be in operation only during the automatic washing of WESP. Double Trip and Bleed philosophy has been followed in order to allow easy and safe maintenance on the two pumps whenever required. WESP recirculation skid is also equipped with a small by-pass line through which density and pH of the recirculation liquid is constantly measured and monitored. A magnetic flowmeter for the recirculation flowrate and a bleed line complete with control valve and flowmeter, complete the WESP Recirculation Pumps skid

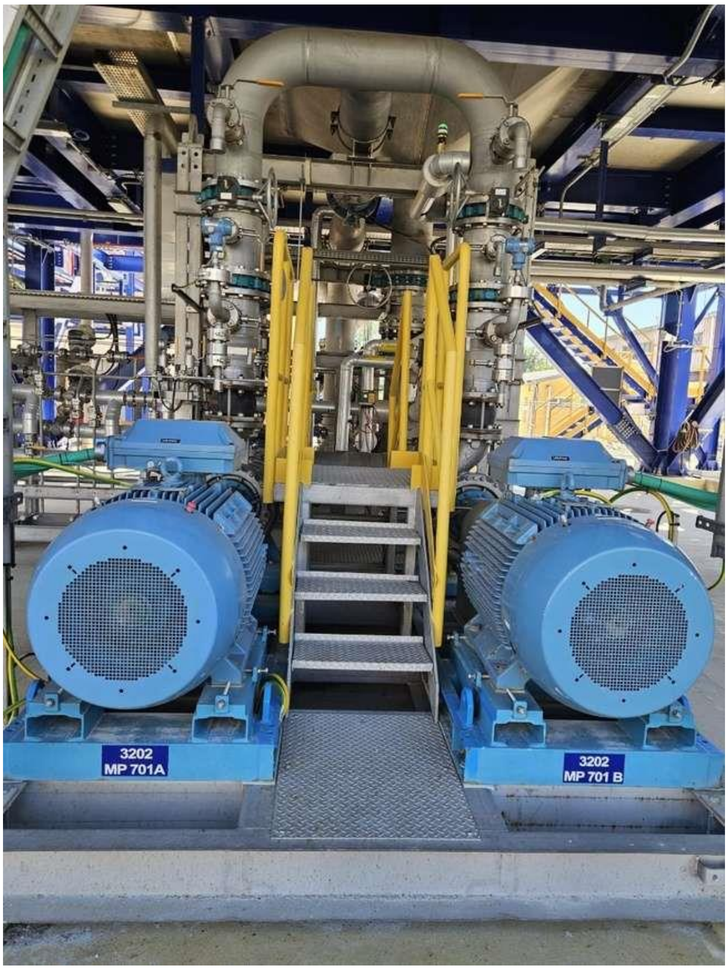

Figure 25: pumps P701A/B

- WESP Distribution Lines: Recirculation pumps skid outlet nozzle is directly connected to WESP Distribution Line Skid. This Skid is used to distribute the recirculation liquid pressurized in the Recirculation pumps Skid between the various liquid inlets at WESP casing. In particular, liquid is distributed to the following locations:
  - WESP Absorption section: liquid is constantly fed to WESP Absorption trays
  - WESP Top / Bottom Washing section: during washing, liquid is sprayed above and below WESP electrodes. Each line of WESP Distribution Line Skid deals with one single field of WESP, both for the top and bottom washing.

  Each line can be isolated and closed individually

Figure 26: distribution skid

- Utilities Rack: WESP Distribution Line Skid includes all the regulation devices for connecting utilities to Electrostatic Precipitation Plant. Three lines are installed:
    - Instrument Air Line, with isolation valve and Pressure transmitter
    - Process Condensate Make Up Line, with Control Valve
    - Nitric Acid Line, with Flowrate and Pressure control valves

Figure 27: utility skid

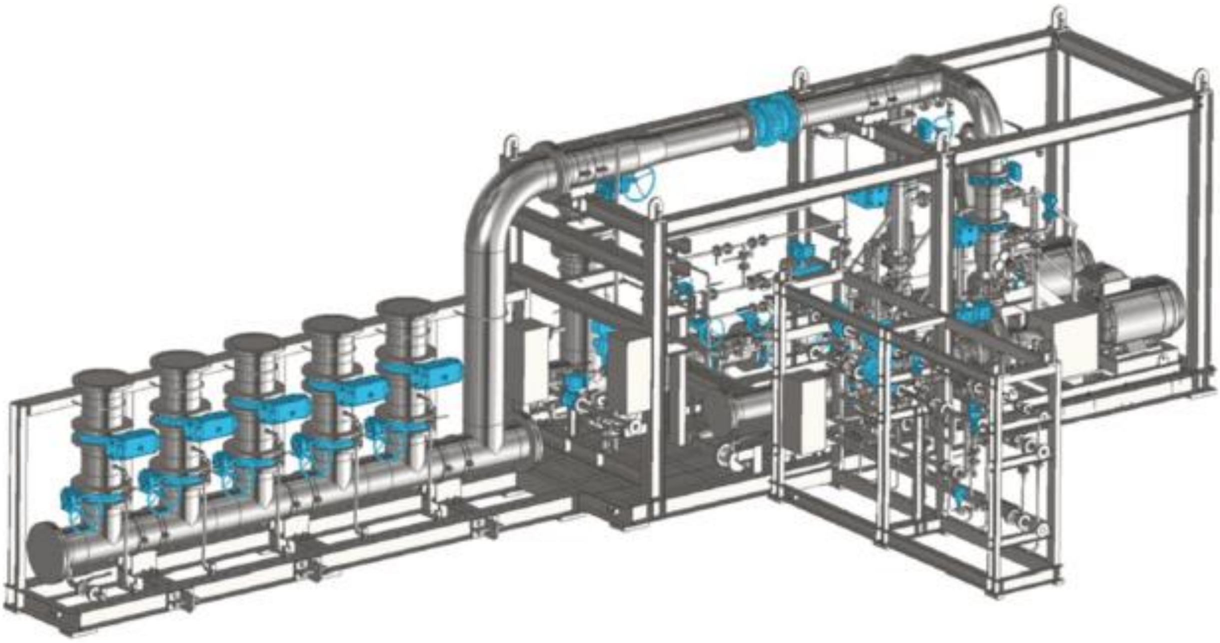

Figure 28: piping skids

Transformer

The bus bar and its duct are intended for providing a high voltage connection between the high voltage transformer rectifier set and the electrodes.

The High Voltage System provides voltage transformation from the Customer's input voltage to a 50,000 VDC average, input and output monitoring, performance optimization, spark control and short circuits protection. The high voltage system consists of a high voltage transformer rectifier set with internal current limiting reactor, and an automatic voltage controller.

The automatic voltage controller consists of the microprocessor, switching and monitoring apparatus, phase angle control type solid state controller, relays and interlocks. The micro-processor-based system optimizes the average kilovolt output that the transformer rectifier set delivers to the precipitator. The microprocessor has its operating program stored in solid state memory. Control parameters changes can be entered through the communication protocol Modbus TCP-IP. Any changes to the control parameters must be saved through the control panel.

The automatic voltage control offers a comprehensive set of operational and reporting functions. Among them are:

- Spark and arc detection
- Comprehensive alarm provision, including four user defined auxiliary alarms
- High voltage control
- Current and voltage limiting
- Automatic ramp rate adjustment for non - sparking conditions

Figure 29: transformer

In the high voltage system, the sharp points along the rod are obtained by laser cutting metal plates, thus increasing the ionizing electric field.

The backbone of the ionizing rod is a stiff tubular element, so there is no risk of breakage or bending.

Figure 30: high voltage system

Special rods have the following advantages over standard wire rod electrodes:

- The upper and lower support prevent misalignment and oscillation during normal operation
- Avoid variations in the electric field
- No variation on the secondary electric field

Given the geometry of an electrostatic precipitator, one of the most important mechanical design criteria is the alignment system of the rods.
The distance between the ionizing rod and the collecting rod directly affects the operating voltage of the precipitator so, if the distance is reduced due to misalignment, the voltage decreases and consequently the average current.
Therefore, the worse the alignment, the worse the removal efficiency of the precipitator.
In addition, the misalignment of a single ionizing bar affects the operating voltage of all remaining ionizing bars. This means that if only one rod would become misaligned during normal operation, this could lead to an unexpected shutdown of the plant in order to recover the previous removal efficiency of the precipitator.
The ionising bars are then fixed at two points, up and down, with solid hooks which ensure easy alignment and avoid any risk of misalignment during operation.
Large diameter collection tubes prevent excessive accumulation of collected particles.
The collecting tubes are welded to upper and lower tube plates, made of metal or composite material.
In the composite design, the pipe plates are made of carbon fibre composite material instead of graphite powder to ensure high surface conductivity and no risk of sparks.
In electrostatic precipitators the high-voltage is supplied using the Switch Mode power supply. This electronic power rectifier has several advantages over traditional 60 Hz transformers widely used today.
The required high voltage will be generated by 4 rectifiers placed at a height of about 20 m and at the four corners of the structure with a distance between them of about 10 meters.
The rectifiers contain 80 kg of dielectric oil each and will be equipped with a containment basin in order to avoid spillage of oil in case of leakage.
The grinders have a PSV that protects the oil-soaked part from overpressure and are equipped with high temperature detection/alarm/lock.
The Switch Mode Rectifiers are significantly smaller and lighter than traditional transformers. The insulating oil tank is smaller than that of traditional transformers and all components are in the grinder cabinet. Their operation is high frequency (25 kHz) and the waveform of the output voltage can be adjusted by an almost pure DC current (low ripple) also have a very high-power factor that provides

more power in the precipitator while consuming less input kVA than conventional transformer systems.

Pump P721A/B

The slurry accumulated in tank V721 is sucked by pumps P721A/B (one operating + one spare in normal operation) and partly constantly recirculated to ensure a continuous mixing inside the tank not stirred, partly sent to filter ME702.
Pump seals are continuously fluxed with process condensates.

Figure 31: pump P721A/B

Filter ME702

The filter consists of a lamellar filter for fluid or pasty materials with a viscosity up to 500 Pas, which can be cleaned without interrupting its operation.
The suspension flows into the filter element from outside to inside. The particles settle outside in the filter element.
The deposition of particles on the coil or slit tube leads to an increase in the pressure difference between the dirty and clean side of the filter element. If this differential pressure exceeds the limit value, a cleaning is activated. The filter element is rotated. The scraper removes the filtration residue from the filter element.

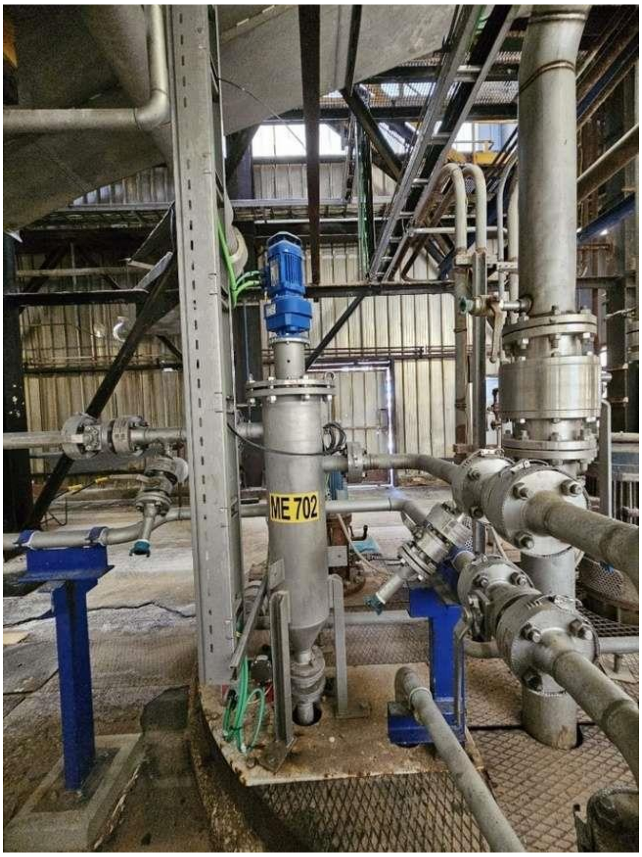

Figure 32: filter ME702

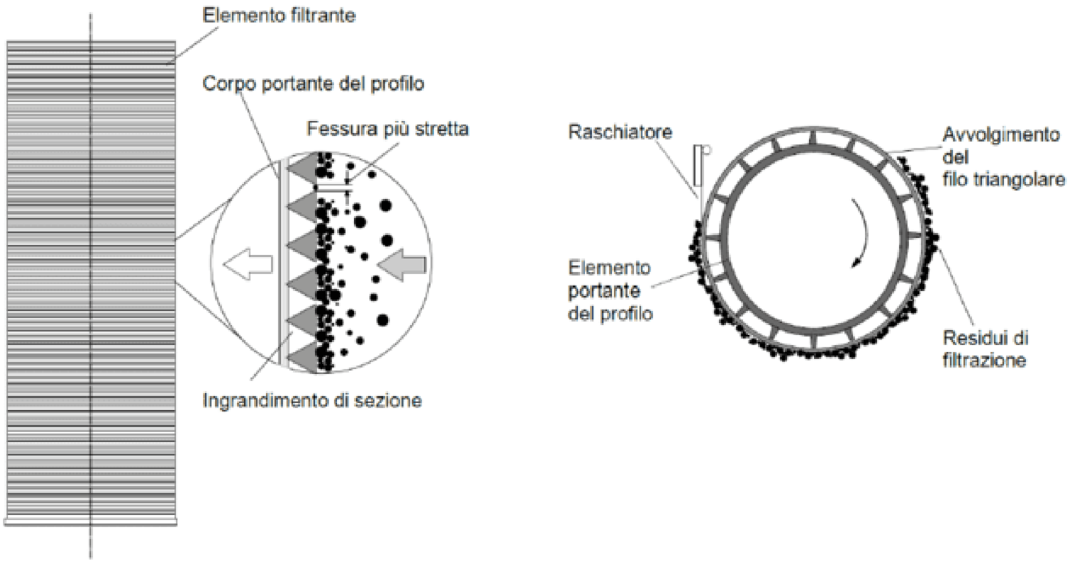

Figure 33: filter

At the outlet of the filter ME702, the filtrate, consisting of ammonium nitrate 12% w/w, is sent to the exchanger E722, while the purge, consisting of an aqueous fraction and a solid fraction of gypsum and additive, is sent to the existing tank V601 of the ammonium nitrate plant (NAS) and then transferred to the NPK plant, where it is recycled in reaction.
When the cartridges run out, this is indicated by the local differential pressure indicator and the local control panel (LCP).
The filter can be bypassed manually by opening the pre-arranged valve.

Heat exchanger E722

The heat exchanger E722 is installed near the tank V203. It is a tube beam exchanger which has the function of heating the filtered solution sent to the tank V203 so, as not to burden too much on the evaporation process downstream.

The heating fluid is low-pressure steam, the flow rate of which is regulated by temperature control on the solution outlet line.

Figure 34: heat exchanger E722

2.2.4 Description of auxiliary systems

The plant is served by the following services derived from existing distribution systems:

- Steam 2.5 barg: the steam is used as a heating fluid for the heat exchanger E722
- Instrument air: the instrument air is used for the control of the pneumatic components of automatic ON/OFF and control valves (CV). The air sent to the WESP users is first filtered through a pair of filters; the air for the effluent treatment users is taken directly from the outlets already available in the NAS system
- Service air: the service air is used only as a fluid for maintenance operations. There are in fact n. 6 US that allow to serve the whole structure of the WESP
- Nitrogen: nitrogen is used only as a maintenance fluid. There are in fact n. 6 US that allow to serve the whole structure of the WESP
- Drinking water: the existing drinking water supply network supplies n. 2 safety eye washes in the WESP area
- Fire water: fire water is only used for manual work. There are in fact n. 8 US which allow to serve the whole structure of the WESP
- Demineralized water: demi water is used as a cleaning fluid during the maintenance of ducts and lines. There are in fact n. 6 US that allow to serve the whole structure of the WESP

Effluent treatment
The effluent from the scrubber C701 is discharged into the reused storage tank V721.
The purge flow rate can be controlled by a fixed flow setpoint or by the recirculation density.
From the storage tank V721, the purge is normally filtered ME702 and recycled in the process into the 95% tank V203: the pH of the solution can be adjusted by adding 15% ammoniacal water, then the flow is heated E722 before being sent to the existing tank V203.
The filter ME702 is installed above the sump V601, so that the sludge produced falls directly from the filter to the sump V601. The discharge sequence of the filter sludge in solution ME702 is adjusted according to the quantity of solids generated and the evolution of the pressure drop inside the filter.
Alternatively, however, the filter ME702 can be bypassed manually and the entire purge is sent directly to the sump V601.

Liquid flow out of the WESP
At the outlet of the WESP abatement system there is a liquid current with a flow rate of 0.6 m^3/h, containing 12 %w/w of ammonium nitrate. This current is sent via pumps P701A/B to the tank V721, which acts as a buffer tank (storage tank).
The pumps P721 A/B send this solution to the filter ME702 (brush filter), where the solid part of the solution is separated. At the filter outlet there are two currents, in particular:

1. The filtrate (sludge current with a volumetric flow rate of 0.024 m^3/h), formed by a solid fraction and an aqueous fraction. The solid fraction consists of gypsum and additive. This current is sent to the existing tank V601 of the Ammonium Nitrate (NAS) plant, and then transferred to the NPK plant
2. A 12 % w/w current of 0.54 m^3/h of diluted ammonium nitrate, which is sent to the heat exchanger E722 (tube bundle, heated with 2 bar steam), go from 25 °C to 95 °C. This current is finally recycled in the tank V203 (existing) of the Ammonium Nitrate (NAS) plant

2.2.5 Safety of the plant
The control logic of the gas treatment system is managed by the plant Distributed Control System (DCS), which will exchange signal with the field. Alarms, in some cases, have to be acknowledged and reset through the DCS [7].
There will be three kinds of “alarm”:

- Critical Alarms divided in two sub categories:
    - Critical Alarm (CA): will shut down the plant immediately and directly (according to the shutting down sequence). Needs to be acknowledged and reset by operator before start up again the plant
    - Emergency stop (ES): will shut down the plant immediately and directly (not according to the shutting down sequence). Needs to be acknowledged and reset by operator before start up again the plant
- Warning: just a report to be displayed on HMI/DCS, but as well important to be noticed by the operator. Warnings don’t need to be acknowledged and reset by operator. The reset is automatic once the warning is no more active.

All timing parameters have to be set/modified by operator through control logic software.

Securing the WESP is a task to be performed whenever the WESP is turned off. This activity serves to ensure safety during maintenance activities.
Securing consists of the following:

- Shutdown of all utilities connected to the WESP
- Safety of the utilities connected to the WESP with the LOTO procedure of the plant
- Transformer safety procedure with interlock
- Flushing the WESP with ambient air to remove any residual gases

Procedure for interlocking

In addition to the Yara's internal procedures for de-energizing and securing, there is a procedure for interlocking. An interlock is a protective response initiated on the detection of a process hazard.
The interlock system consists of the measurement devices, logic solvers, and final control elements that recognize the hazard and initiate the appropriate response. Most interlocks consist of one or more logic conditions that detect out-of-limit process conditions and respond by driving the final control element to the safe state.
Interlocks can be broadly classified as follows:

- Safety Interlocks: these are designed to protect the plant personnel and possibly the plant equipment from process hazards
- Process Interlocks: these are designed to prevent the process conditions that would unduly stress equipment, lead to off-specification product and so on. Basically, the process interlocks address hazards whose consequences essentially lead to a monetary loss, possibly even a short plant shutdown

A permissive is a special type of interlock that controls a set of conditions that must be satisfied before an equipment can be started or stopped. A permissive interlock will not necessarily shut-down the equipment if one or more of its conditions are not met, but it will keep the equipment preventing from starting up or stopping.

The interlocking procedure serves to ensure additional security of the WESP. The activities that make up the interlocking procedure are:

- Switching off the transformer
- Sectioning of the transformer inside the electrical cabinet
- Locking in the switch position by means of interlock "A"
- Removal of the key "A" from the interlock "A" placed inside the electrical panel
- Insertion of the key "A" in the interlock "A" placed on the transformer grounding
- Rotation of the grounding lever and earthing of the transformer
- Locking in the ground lever position by means of the "B" interlock placed on the transformer grounding
- Removal of key "B" from interlock "B"
- Insertion of the key "B" into the exchange box
- Remove any key "C" from the interchange box to lock the key "B" in it
- Handing over key "C" to the shift manager

In this way the transformer is secured and cannot be energized. To energize the transformer and power on the WESP, it is necessary to perform the operations of the interlock procedure in reverse order.

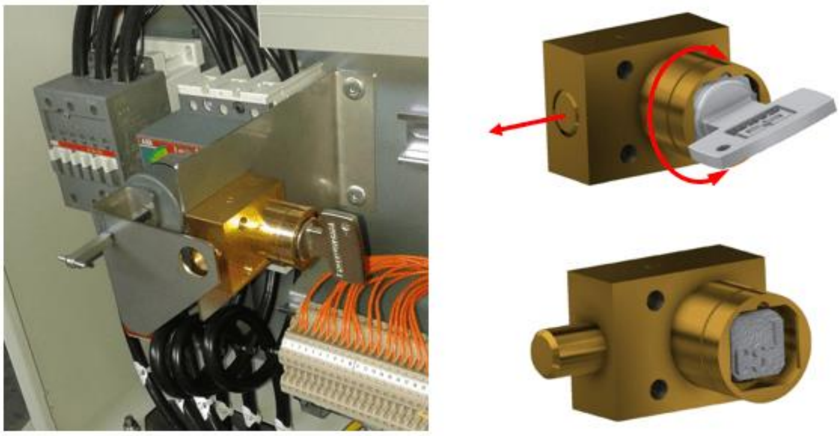

Figure 35: interlock

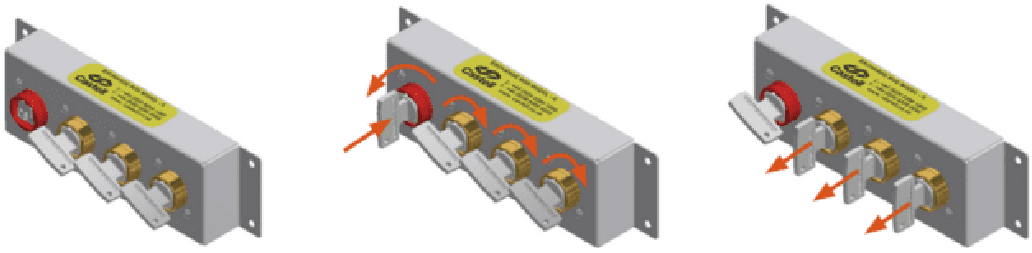

Figure 36: interlock procedure

2.3 ENVIRONMENTAL IMPACTS OF THE NEW WESP PLANT

The following currents are used for process purposes [3]:

- Nitric acid: this solution is necessary to acidify the current circulating in the WESP and ensure the abatement of ammonia present in it
- 15% ammonia solution: this solution is necessary to neutralize the current input to the stirred tank V203, in order to be recycled within the production cycle

SUBSTANCE	DENSITY [kg/m^3]	FLOW RATE [kg/h]	CONCENTRATION [%w/w]
Nitric acid	1330.6	56	58
15% ammonia solution	-	<1 (about 0.5 kg/h)	15

Table 8

The quantities are negligible in comparison with what is already present and produced in the plant and do not lead to increases in production or to an increase in wastewater.

Water consumption

The only water resource used in the plant will be industrial water used only for annual washes and remediations.

This resource is available in the plant and does not aggravate the water balance since it is a negligible amount compared to the total consumption of the site.

Resource and energy consumption

These energy resources are available in the plant and do not aggravate the energy balance since they are quantities not recorded in relation to the total consumption of the site.

Installed electrical power	1600	kW
Power consumption	1100	kW
Steam	2	bar
	43.7	m^3/h

Table 9

The environmental impacts of this change are summarised below:

Air	A new point of emission is planned, channelled with air from the new WESP abatement system with a flow rate of 580000 Nm^3/h and a maximum dust content of 10 mg/Nm^3 and ammonia content of 10 mg/Nm^3. The issue will be continuous. The new emission point will replace prilling tower emission A/B/C/D. and significantly reduce dust emissions. No significant impacts can be identified for diffuse, fugitive and odour emissions.
Water	The increase in water consumption does not aggravate the water balance, since it is a negligible amount compared to the total consumption of the site
Soil and subsoil	The installation methods are designed to protect the soil and subsoil from accidental pollution.

	The surface occupied by the plant will be paved and any washing or remediation water from the equipment will be channelled into the existing process sewer. The land resulting from the construction of foundations will be managed in accordance with current regulations.
Wastes	No increase in waste generation is expected during the operational phase. The waste generated during construction will be of types already present in the plant and managed on the basis of the procedure already in place.
Noise	No significant increases in noise levels are expected
Vehicle traffic	No increase in vehicle traffic is expected
Energy consumption	The increase in energy consumption does not aggravate the energy balance. To optimize the energy consumption all the fans and main pumps are feed by VFD (variable frequency drive)
Raw materials	No new raw materials are to be introduced
Visual impact	No impact on the environment and landscape is expected due to its location in an industrial area overlain by similar and significantly higher structures
Hazardous substances	The quantities are negligible in comparison with what is already present and produced in the plant and do not lead to increases in production or to an increase in wastewater
Electromagnetic fields	The equipment installed shall comply with the following directives: • DIRECTIVE 2014/30/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 26 February 2014 on the harmonisation of the laws of the Member States relating to electromagnetic compatibility (recast) • DIRECTIVE 2013/35/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 26 June 2013 on minimum safety and health requirements relating to the exposure of workers to the risks arising from physical agents (electromagnetic fields) • IEC standard EN 50499 "Procedure for the assessment of exposure of workers to electromagnetic fields"

Table 10

2.4 IMPROVEMENT OF THE EMISSION VALUES

The implementation of the project will allow the elimination of the four prilling tower emission points, which will be replaced by a single emission point from WESP plant fulfilling what is indicated in the prescription n° 9 of chapter 9 of the D.M.181 of 11/05/2022 "Review with renewal of the decree of the Minister for the Environment and Protection of the Territory and the Sea N.220 of 12 December 2012 of integrated environmental authorization (AIA) and ss. mm. ii., for the operation of the installation of YARA ITALIA Spa located in the Municipality of Ravenna. Procedure ID 89/10475" [3].

The new emission point will replace prilling tower emission A/B/C/D and will have the following characteristics:

- Maximum expected flow rate 580000 Nm^3/h
- Maximum expected dust content 10 mg/Nm^3
- Maximum expected ammonia content 10 mg/Nm^3
- Duration of issue (continuous)

The new emission point will not be monitored through the use of an SME[6], but will be subject to discontinuous monitoring.

According with the ARPA guidelines [4], the current standard UNI 10169:2001 indicates how to carry out an acceptable sampling. In the WESP plant are present circular duct with a diameter higher than 2 m (3.30 m), equipped with four nozzles.

[6] SME = monitoring in continuous of atmospheric emissions

CHAPTER 3: INSTALLATION AND COMMISSIONING OF THE WESP PLANT

3.1 PRE-COMMISSIONING

Yara (Company) has appointed EPCm (Contractor) as its contractor in relation to the engineering, procurement management and construction management of the Project [8]. The EPCm Contractor shall co-ordinate, provide superintendence, administration and project management and monitor the performance of the works.

EPCm shall be responsible for all activities related to Construction completion and Pre-Commissioning [9].

During the detailed engineering period EPCm shall prepare and submit to Yara for review the procedures, documentation and set up of software.

Yara's approach to Plant systemization is its subdivision into Systems and Commissioning Packages (refer to figure below). Each Commissioning Package (CP) is further subdivided into related disciplines, i.e. into Mechanical Completion Packages (MC), and its components, i.e. Mechanical Completion Tags.

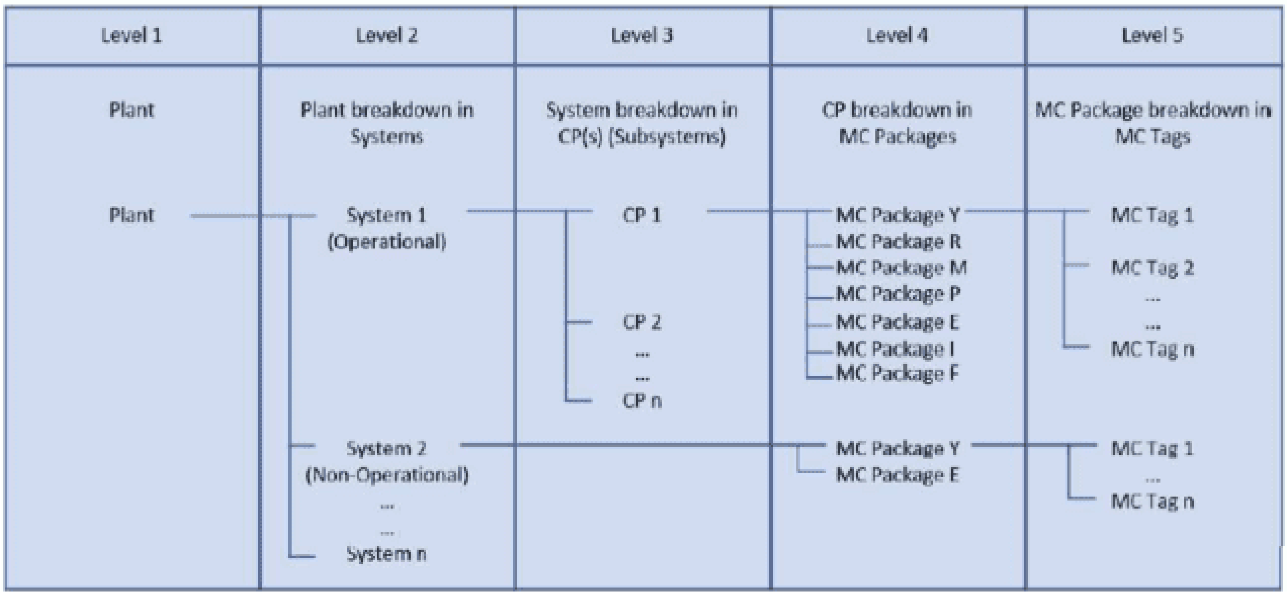

Figure 37: scheme of pre-commissioning

Furthermore, Yara's approach to Systems classification is to distinguish between Operational Systems and Non-Operational Systems:

- An Operational System includes utility Systems or process Systems, for example ammonia systems, cooling water system, process gas system, atmospheric vent system, HVAC, etc.
- A Non-Operational System includes, for example, piling, foundations, elevated structures, steel structures, sewer and drainage systems, fireproofing, underground earthing, buildings structures and architecture, markings and signs, cable and tubing trays, surface protection, insulation, telecom, etc.

EPCm shall prepare the Plant systemization during the detailed engineering period of the project.

Mechanical Completion (MC) of an installation means that the installation is built and verified in accordance with applicable drawings, specifications, instructions, Statutory Requirements and Ready

for Commissioning (RFC) to take place in a safe manner and in compliance with requirements in the Contract.
Mechanical Completion is achieved when all installation and Pre-Commissioning work related to each MC Package is completed, verified, documented and the relevant certificate is issued.
To achieve the status of Mechanical Completion the following two phases have to be completed:

- Construction
- Pre-Commissioning

Construction
Construction is the phase during which the activities associated with the prefabrication, fabrication, assembly, erection and installation take place.
Typical Construction completion verification activities include:

- Visual inspection for complete and correct installation
- Internal inspection of tanks and vessels and cleaning
- Conduct all non-operating field pressure tests or field leak tests
- Witness stress-free pump connection to the extent desired
- Verify that installed systems conform strictly with P&IDs, other drawings, specifications and documents
- Make grounding system tests
- Verify instrument installation in accordance with hook-up drawings

Construction of a MC Package is completed when it has been verified and documented by EPCm that all prefabrication, fabrication, assembly, erection and installation activities of this MC Package have been done in accordance with the applicable drawings, specifications, instructions and Statutory Requirements.
The documentation of the above is done by means of completion of Construction Acceptance Check Records by EPCm. When Construction of a MC Package has been completed and the other prerequisites are satisfied, the Construction Acceptance Certificate of this MC Package can, upon EPCm’s request, be issued by Yara.

Pre-commissioning
Pre-Commissioning is the phase during which a group of non-operating adjustments and cold alignment checks, flushing, blowing, chemical/mechanical cleaning activities and reinstatement take place and which can be conducted by temporarily energizing said parts and without introducing the final medium (gas, liquid or solid) and / or test media.
Typical Pre-Commissioning activities include:

- Energization of motor feeders, etc.
- Flushing / draining / blowing / drying of piping and equipment
- Chemical cleaning
- Cold alignment and preparation for running in of rotating equipment
- Rotation check and running test for all drivers
- Execution of all de-energized tests
- SAS (Safety and Automation Systems) energization, open loop checks, communication tests and setting up the systems ready for functional testing
- Reinstatements

Pre-Commissioning of an MC Package is completed when it has been verified and documented by EPCm that this MC Package has been installed and pre-commissioned in accordance with the applicable drawings, specifications, instructions and Statutory Requirements. The documentation of the above is done by means of completion of the Mechanical Completion Check Records by EPCm. When Pre-Commissioning of a MC Package has been completed and the other prerequisites are satisfied, the Mechanical Acceptance Certificate of this MC Package can, upon EPCm's request, be issued by Yara.

The figure below shows an example of Plant systemization as well as a schematic representation of the phases and milestones towards MC.

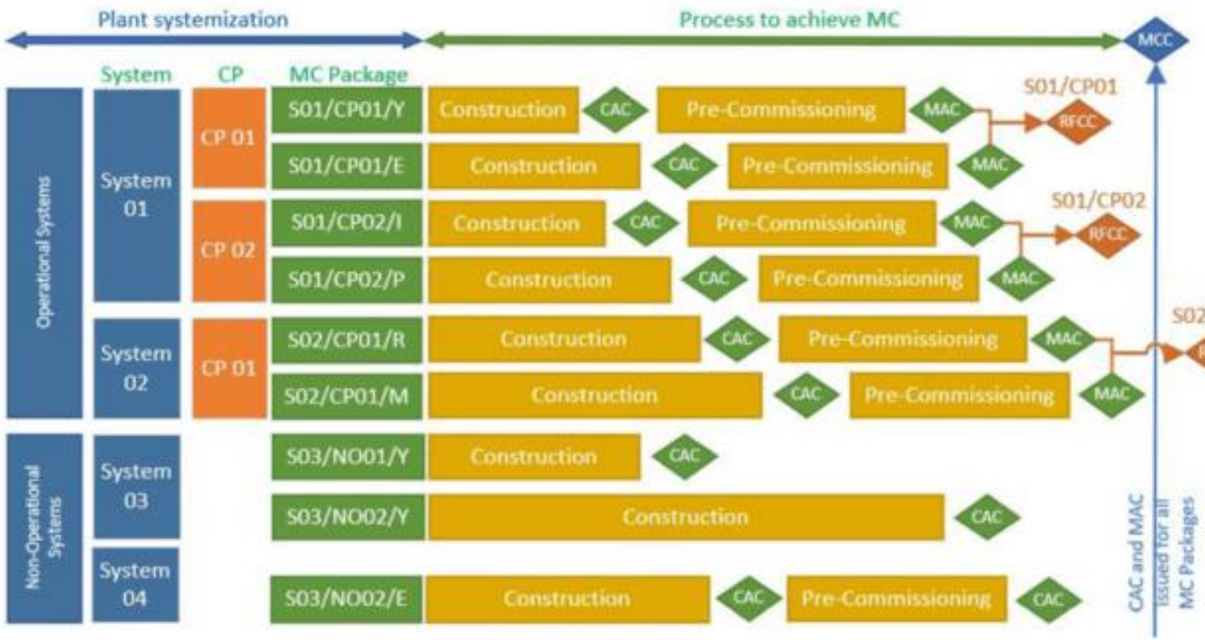

Figure 38: plant systemization and process to achieve MC

Mechanical completion and ready for commissioning

The following sections describe in more detail the requirements to achieve MC and CPs' RFC, in particular [9]:

- Construction completion and Construction Acceptance: Construction of an MC Package is completed when it has been verified and documented that prefabrication, fabrication, assembly, erection and installation have been completed in accordance with the applicable drawings, specifications, instructions and Statutory Requirements. Construction Acceptance of a Mechanical Completion Package occurs when, upon EPCm's request, Yara issues the Construction Acceptance Certificate (CAC)
- Pre-Commissioning and Mechanical Acceptance: Pre-Commissioning of an MC Package is completed when it has been verified and documented that this MC Package has been installed and pre-commissioned in accordance with the applicable drawings, specifications, instructions and Statutory Requirements. Pre-Commissioning activities are only allowed to start for a MC Package for which a CAC has been issued and provided that all other MC Packages that constitute a precedence or a safety constraint to start the Pre-Commissioning activities have achieved CAC. The Construction Execution Plan (CEP) is a strategy document

which explains how all the construction activities shall be handled through Mechanical Acceptance of the plant, including construction completion and Pre-commissioning [11].
The scope of this document is to provide to the project team and to Yara Technology & Projects Management a single source of information on how the construction activities shall be executed and how the various interfaces with other disciplines and external parties shall be handled

- Ready for Commissioning: A Ready for Commissioning Certificate indicates the transfer of a Commissioning Package to the Commissioning phase. RFC of a Commissioning Package occurs when, upon EPCm's request, Yara issues the Ready for Commissioning Certificate (RFCC)
- Mechanical Completion: Mechanical Completion of the Plant occurs when, upon EPCm's request, Yara issues the Mechanical Completion Certificate (MCC)

The figure below shows a schematic representation of the Punch Item categorization related to the MC activities and Commissioning activities.

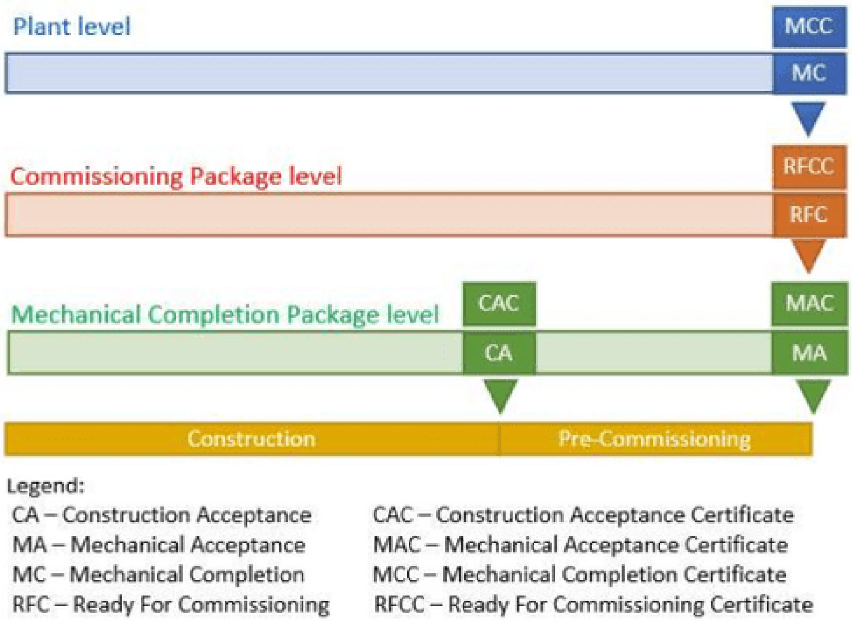

Figure 39: milestones and certificates process

3.1.1 Testing and inspections

Inspection Test Plan (ITP) identifies the types of intervention points, the reference documents and the acceptability criteria, attributing a dedicated ITR for each required check.
Inspection Test Report (ITR) means a list of the checks carried out, the results of the inspection, the measurements carried out, any detected pending activities.
Before the inspection execution it is necessary to verify that:

- All Construction completion and Pre-commissioning activities and corresponding documents to check them per items have been identified
- Pre-commissioning activities on the single item can start when Construction is over
- Nature and sequence of the above said activities are connected to the progress of Construction. For example, the sequence of flushing on pipeline depends on the sequence of hydrotests and on Construction schedule

All necessary documents shall be available in the required quality and formats, i.e.:

- PFD/P&ID
- Single line/wiring diagrams
- Layouts/general arrangements
- Equipment data sheets
- Instruments data sheets
- Operating data (including manuals)
- Process variables
- Control system description
- Others as necessary

The necessary utilities shall be guaranteed on site, i.e.

- Compressed air
- Electrical power
- Utility water

The necessary test equipment shall be guaranteed at site:

- Mechanical (comparators, torque wrench, greasing pumps, etc)
- Electrical (relays testing units, injection sets, hi-pot test equipment etc)
- Instrumental (multimeters, calibrators, etc)
- Commissioning spare parts as per dedicated Material requisition/parts confirmed and supplied by vendor
- Special tools (as per Vendor installation manual)
- Consumables
- Lube oil/greases

3.2 COMMISSIONING

Yara shall be responsible for all activities related to Commissioning, Start-Up and Performance Test [9].

The Commissioning phase follows after completion of the Pre-Commissioning activities and the issuance of the Ready for Commissioning Certificate. Commissioning means the functional and operational testing of a Commissioning Package, or System when practical, and is primarily a group of energized and dynamic activities and tests that constitute verification that each Commissioning Package, or System, is ready for Plant Start-Up.

The Commissioning phase is subdivided in two sub-phases:

- Cold Commissioning
- Hot Commissioning

Cold commissioning

Cold Commissioning is the phase during which a group of energized and dynamic activities and tests of a Commissioning Package, or System when practical, without using the final medium (gas, liquid or solid) take place. In this phase test media or inert substances can be used.

Typical Cold Commissioning activities include:

- Closed loop (i.e. functional loop) tests
- Interlock, sequence and complex loop checking
- Emergency, sequential and alarm interlock checks
- System purging and inerting with nitrogen
- Tightness test

Cold Commissioning of a CP is completed when it has been verified and documented by Yara that the group of energized and dynamic activities and tests of this CP, without using the final medium (gas, liquid or solid), have taken place as per the Commissioning procedure.

The documentation of the above is done by means of completion of the Commissioning Preparatory Check Lists and the issuance of the Cold Commissioning Check Sheet by Yara.

When Cold Commissioning of a Commissioning Package has been completed and the other prerequisites are satisfied, the Ready for Fluid-In Certificate (RFFIC) can, upon completion of the related EPCm's Project Works, be issued by Yara. Consequently, this Commissioning Package can be hot commissioned.

Hot commissioning

Hot Commissioning is the phase during which a group of energized and dynamic activities and tests of a Commissioning Package, or System when practical, using the final medium (gas, liquid or solid) take place with the intention to prepare all Systems for Plant Start-Up.

Typical Hot Commissioning activities include:

- Permanent energization of the electrical substations
- Introduction of the final medium (gas, liquid or solid)
- Dry-out systems, refractories and linings when this drying operation is to be accomplished by means of permanently installed equipment
- Adjustments and tuning of controls
- Pre-heat up of boilers and furnaces according to vendors heating up and first start-up procedures;

- When possible, circulation without reaction at the operating conditions or as close as possible to them for verification of the whole plant, i.e. rotating equipment, instrumentation, safety systems, etc., prior to the introduction of the feedstock and the start of reaction

Hot Commissioning of a CP is completed when it has been verified and documented by Yara that all activities and tests of this CP have taken place as per the Commissioning procedure. The documentation of the above is done by means of completion of the Hot Commissioning Check Sheet by Yara.

When Hot Commissioning of a CP has been completed and the other prerequisites are satisfied, the Technical Acceptance Certificate can, upon completion of the related EPCm's Project Works, be issued by Yara.

When all the Commissioning Packages of the Plant have obtained the Technical Acceptance Certificate and the other prerequisites are satisfied, the Ready for Start-Up (RFSU) Certificate can be issued by Yara.

Start-up

Start-Up encompasses all activities starting with the introduction of the feedstock, as the case might be, and establishing the process conditions needed to make products in a safe manner and in compliance with the requirements of the Contract.

Ready For Normal Operation represents the transfer of the Plant and certain documentation to operation. In particular, the prerequisites for ensuring a proper transfer include:

- Construction and Pre-Commissioning completed and Mechanical Completion achieved
- Commissioning and Start-Up completed
- All documentation as per section 11 below submitted by EPCm and accepted by Yara
- Two years operation spare parts delivered to Yara's operation
- Capital spares and special tools delivered to Yara's operation raining to Yara's operation and maintenance personnel completed

The activities to be performed by EPCm as part of the Services are divided in two categories [12]:

- Preparation activities for Commissioning and Start-Up
- Assistance activities for Commissioning and Start-Up

Project completion system (pcs) preparation

EPCm shall be responsible for PCS preparation [13].

All the documents in this section shall be prepared by Rose EPCm tti with input from Yara, during the detailed engineering period of the Contract and reviewed for acceptance/comments by Yara before being taken into use.

A Commissioning procedure is a detailed step by step description of the necessary Commissioning preparatory checks, Cold Commissioning activities, Hot Commissioning activities and equipment run tests, which shall be carried out and documented during the Commissioning of the Plant.

A Commissioning procedure shall be developed for each CP, or System when practical.

Commissioning procedures shall include Marked Up Drawings (MUD) showing the temporary blinds required for isolation, temporary inserts and other elements that shall be connected during the execution of the Commissioning activities. The MUDs shall also show permanent parts (e.g. control valves, PSV, tubing, etc.) that shall be temporarily disconnected, if any, during the execution of the Commissioning activities.

A proper register of temporary blinds, gaskets, inserts and disconnected permanent parts shall be prepared and included in the Commissioning procedures and managed in accordance with the blinds

management procedure. The register shall include a proper control of installation and removal of the temporary elements.
The Commissioning procedures shall describe the CPCL preparatory checks required prior to start the Commissioning activities and include Commissioning Check Sheets used to document the completion of Commissioning activities.
The Commissioning procedures shall also include the values, with range of acceptance, of the standard parameters to be verified during Commissioning and Start-Up and define the Running Logs to be used to record the equipment run tests and include the parameters values to be verified.

Commissioning and start-up
The Commissioning activities start with the Commissioning preparatory checks, followed by Cold Commissioning and Hot Commissioning phases, to achieve the status of RFSU.
The following sections describe the detailed requirements to achieve RFSU, in particular:

- Cold Commissioning and Ready for Fluid-In: prior to starting any Commissioning activities the Commissioning preparatory checks will be performed. Cold Commissioning of a CP is completed when it has been verified and documented that the group of energized and dynamic activities and tests of a CP, without using the final medium (gas, liquid or solid), have been completed as for the Commissioning procedure. Ready For Fluid-In of a Commissioning Package occurs when, upon completion of the related EPCm's Project Works, Yara issues the RFFIC
- Hot Commissioning and Technical Acceptance: Hot Commissioning of a CP is completed when it has been verified and documented that all activities and tests of a CP have been completed as per the Commissioning procedure. Hot Commissioning of a CP is completed when it has been verified and documented that all activities and tests of a CP have been completed as per the Commissioning procedure

Ready For Start-Up of the Plant occurs when, upon completion of the related EPCm's Project Works, Yara issues the RFSU Certificate.
The RFSU Certificate will be issued after review by Yara that the following prerequisites are satisfied:

- A RFFIC has been issued for every CP
- A TAC has been issued for every CP
- All pre-Start-Up safety review and any other HES action are completed and documented by EPCm and reviewed by Yara

Start-Up encompasses all activities starting with the introduction of the feedstock and establishing the process conditions needed to make products in a safe manner and in compliance with the requirements of the Plant operating manual. This phase starts with the issuance of RFSU Certificate and ends when the Plant achieves Ready for Normal Operation.

3.2.1 Definition of commissioning procedures

The Ravenna WESP plant is divided into 12 systems and for each a commissioning procedure has been redact.
Each procedure consists in:

- System description
- Test duration and manpower

- Safety precautions
- Preparation works
- Commissioning procedure

The systems are reported in the table below and the procedures are attached at the end of the report (Attachment 1-12).

OTP-C1-01	AN solution
OTP-C1-02	AN solution bleed to filter and heater, LP steam and steam condensates
OTP-C1-03	WESP skid and package
OTP-C1-04	Process condensates
OTP-C1-05	Nitric acid
OTP-C1-06	Aqueous ammonia 15%
OTP-C1-07	Instrument air
OTP-C1-08	Potable water
OTP-C1-09	Service air
OTP-C1-10	Service nitrogen
OTP-C1-11	Demi water
OTP-C1-12	Air to treatment

Table 11

OTP-C1-01 and OTP-C1-02

<u>SYSTEM DESCRIPTION</u>

For the sake of simplicity, the AN solution system is divided into two procedures.

The scrubber C701 blowdown effluent is discharged to the reused buffer tank V721. Blowdown flowrate can be controlled based on fixed flowrate setpoint or based on recirculation density. From the reused buffer tank, the blowdown can be sent to two locations:

- The blowdown can be sent directly to the sump V601, by using the buffer pump P721A/B. in this case, the unfiltered solution is sent directly to the sump V601, without passing through the filter ME702. This is not normal operation, but an alternative solution in case operator want to bypass the filter ME702
- The blowdown can be sent recycled into the process into the 95% tank V203, filtered in the solution filter ME702 which can also be bypassed. When filtered, the produced sludge is directly to the sump V601. The pH of the solution can be adjusted via the addition of a 15% aqueous ammonia steam. It is then heated in the solution heater E722 before being sent to the existing tank V203

In order to avoid sludges handling, the solution filter ME702 will be installed on top of the sump V601 so that sludges will fall down directly from the filter to the sump V601. The solution filter ME702 sludge discharge sequence will be adjusted on site based on the amount of generated solids and pressure drop evolution inside the filter. As

As the reused buffer tank V721 is not equipped with an agitator, the buffer pump P721A/B is designed to keep a continuous recirculation from and to the buffer tank V721. This will ensure a minimum mixing effect in the bottom tank to avoid solids deposition.

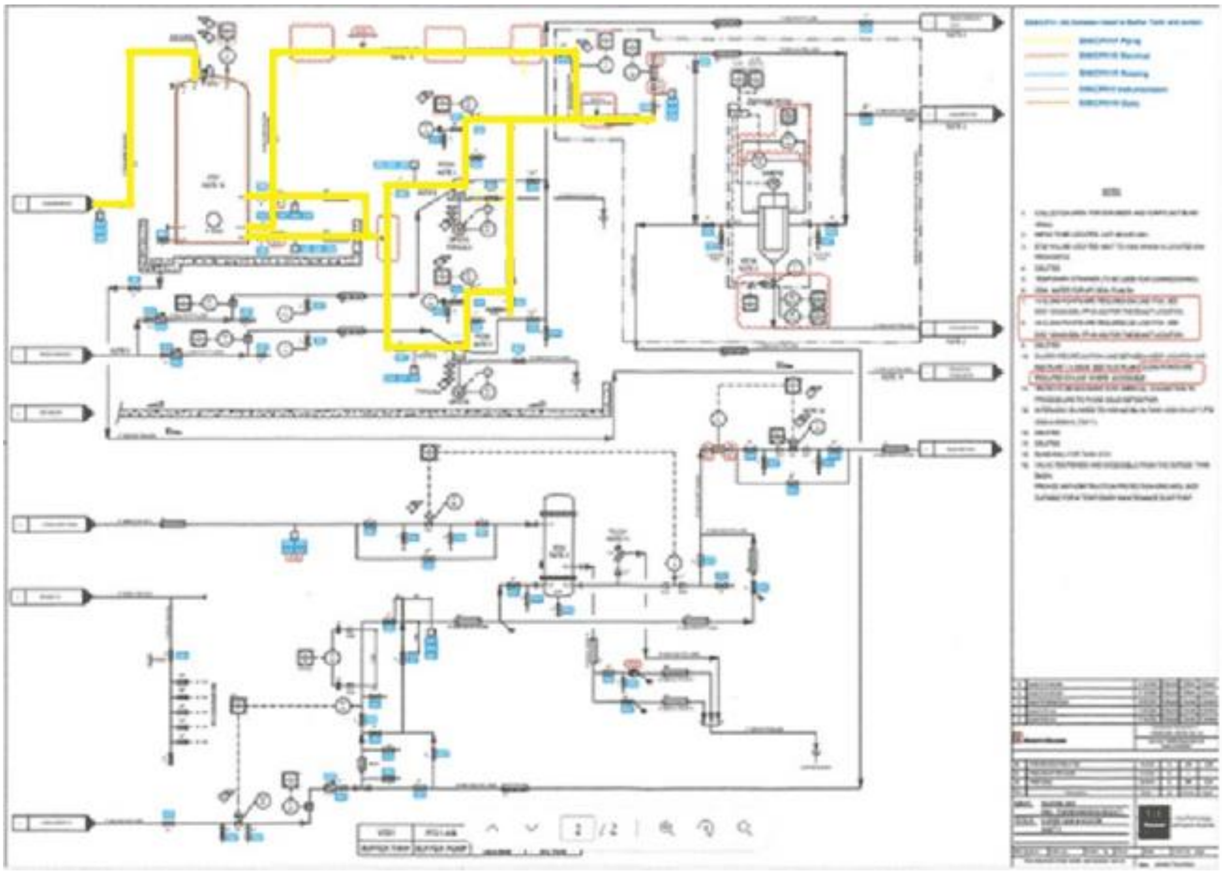

Figure 40: P&I diagram of AN solution system OTP-C1-01

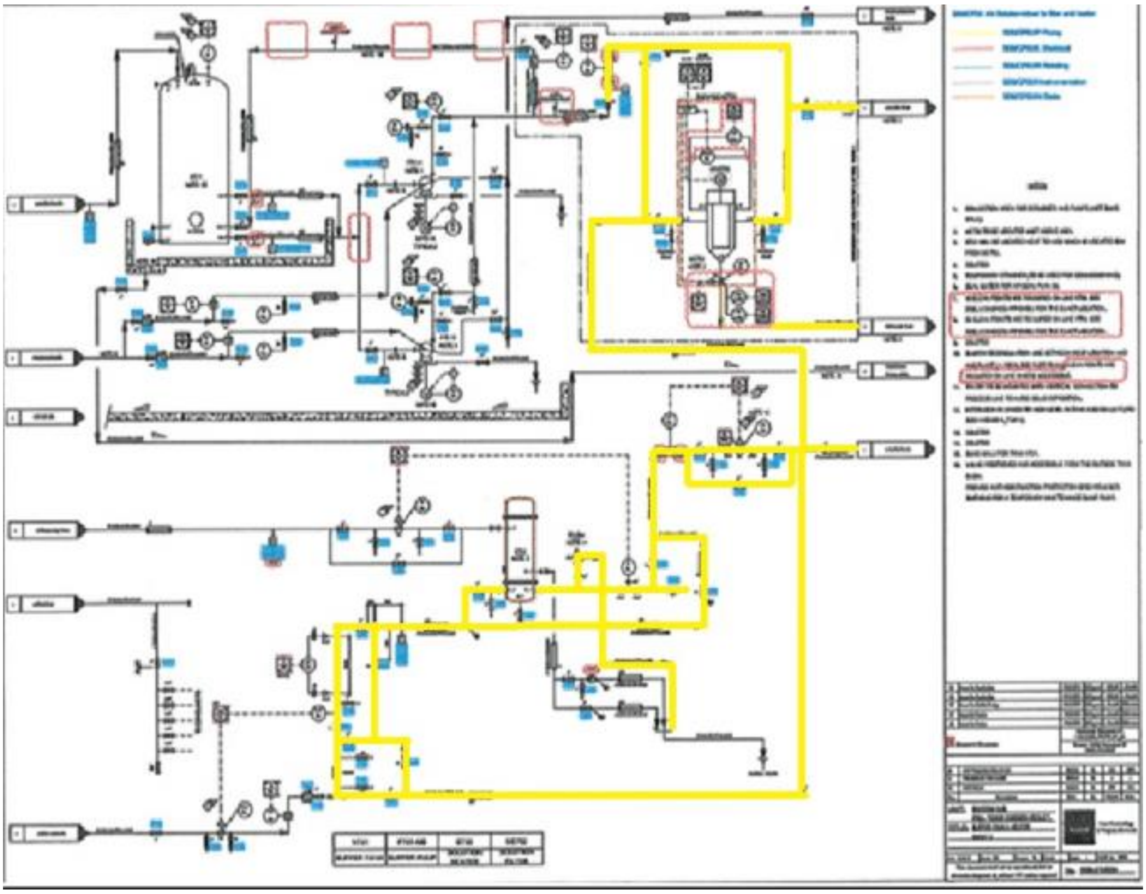

Figure 41: P&I diagram of AN solution system OTP-C1-02

<u>TEST DURATION AND MANPOWER</u>

Expected duration for performing the activities is 5 days.

The personal involved is:

- Electrical, mechanical and instrument commissioning personnel
- Control room operator

OTP-C1-03

SYSTEM DESCRIPTION

Wet gasses from the prilling tower enter into the WESP up-flow, from the bottom to the top. Gases are driven through two layers of absorption trays fed with an acidic solution. In this stage the removal of biggest dust and the complete absorption of ammonia take place. Water is recirculated continuously by two pumps: one is operation and the other one spare in line. Pumps are swapped according to time T_{swap} settable by operators. Pump's sealing is flushed with a barrier water, according to API PLAN 32 scheme.

For the ammonia removal, a certain amount of nitric acid is injected into the recirculated feeding water in order to set up the proper pH for the reaction between ammonia and nitric acid to obtain mainly ammonium nitrate salts dissolved in water. The injection is regulated by a pH-meter installed on the recirculation line and regulation valve.

After the absorption trays section, the gasses encounter a re-distribution section, designed to create a homogeneous distribution across the entire area of the vessel (12 m diameter), before reaching the high voltage stage. The gas is ready to enter into the high voltage section, needed to remove all the remaining dust. The high voltage section is called tube bundle and it is composed by a set of hexagonal pipes installed in vertical, creating a honeycomb structure shape. The high voltage section is divided into four portions, each independent from the others.

The power for the electrostatic precipitator is given by four high voltage electrostatic transformers/rectifiers working independently each other. The transformers are connected to the WESP ionizing rods through four bus bars, protected mechanically by a stainless-steel duct, called bus ducts. Electrical separation between the casing of the WESP (connected to ground) and the rods and their support structure (under voltage) is given by ceramic insulators specific for high voltage. High voltage transformers are operated by DCS via hard wired connection but at the same time the main operating parameters can be written/read via PROFINET protocol.

Insulator compartments are continuously flushed with ambient air in order to avoid accumulation of mist and dust on ceramic insulators' surface. Air is pushed by a set of side lateral channels blowers.

On the upper and lower part of the tube bundle there is a set of sprayers, needed for cleaning the collection section below. A set of on/off valves allows to use flushing water for washing the WESP section from the top and from the bottom. Switching times for washing procedure can be set by the operator on software, according to the effective needs, to be defined during the commissioning by AWS. During the washing cycle both pumps have to be put in operation in order to achieve the required flow rate to grant the complete cleaning of each portion of tube bundle, one by one.

The level of water inside the WESP is regulated through two level transmitters operating co-currently. From the supervision software the programmer could choose to display the average value or all single value. A regulation valve installed on the condensate water inlet line to rinse the water evaporated and blow down. When one level transmitter is on fault condition the software keeps into account only the other measurement from the second instrument. A certain amount of recirculating water is sent to the tank V721.

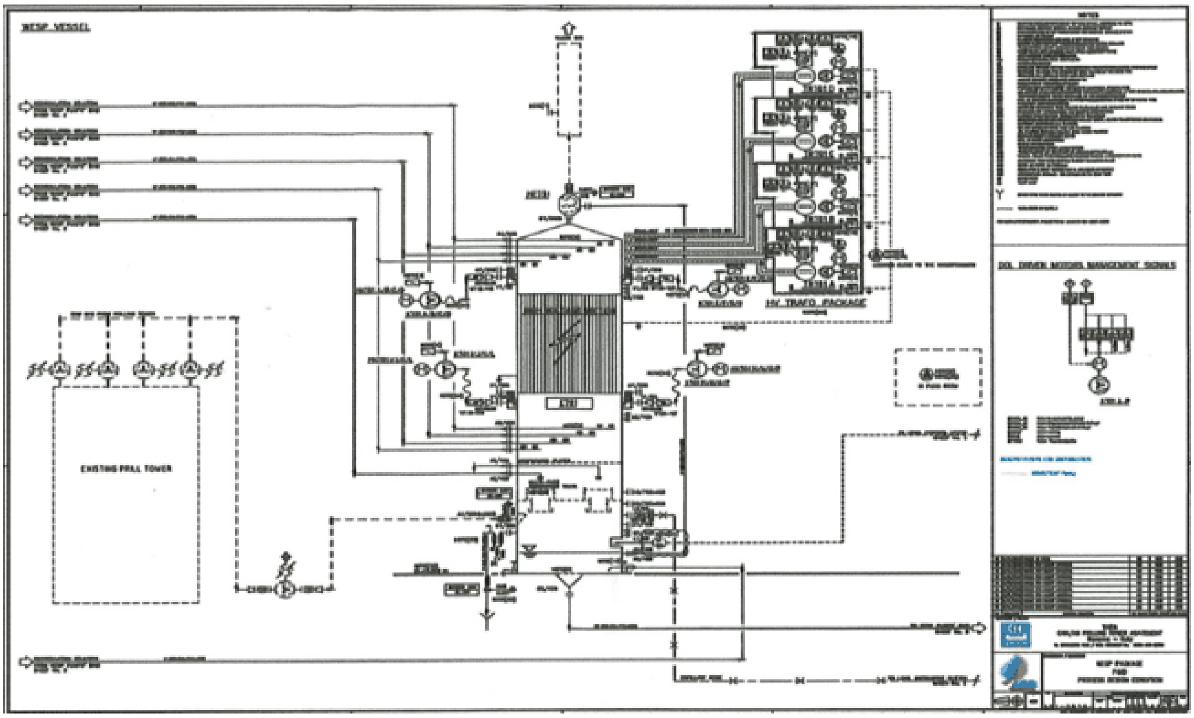

Figure 42: P&I diagram of WESP skid and package system OTP-C1-03

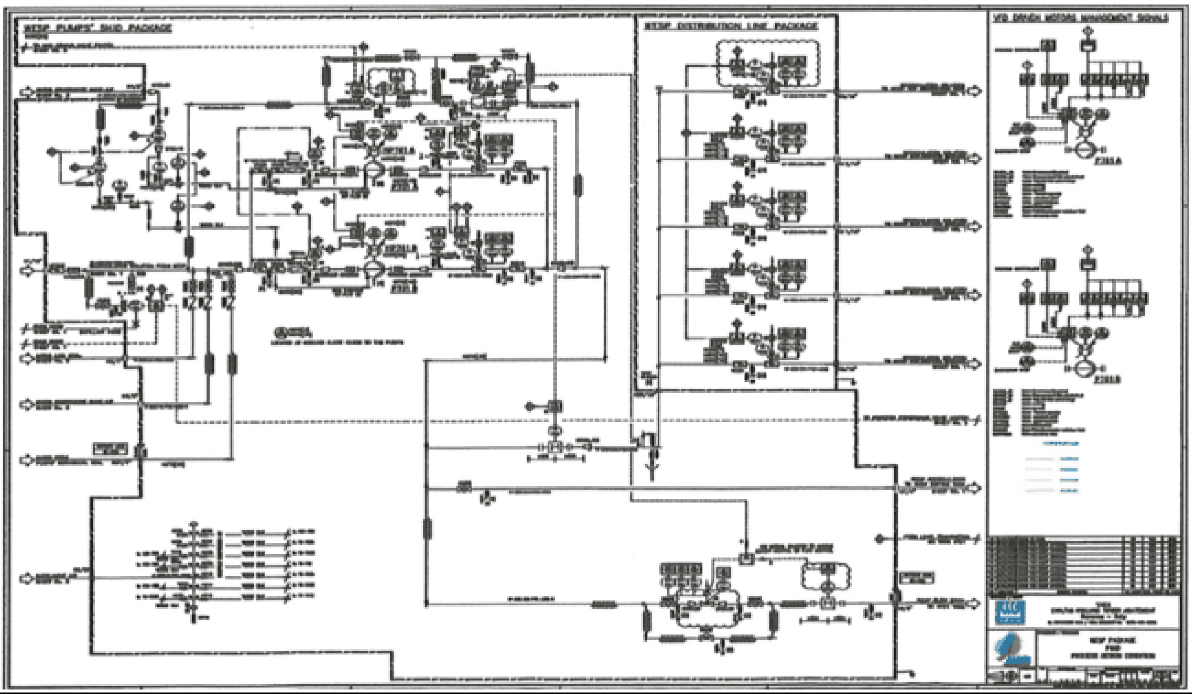

Figure 43: P&I diagram of WESP skid and package system OTP-C1-03

TEST DURATION AND MANPOWER

Expected duration for performing the activities is 12 days.
The personal involved is:

- Electrical, mechanical and instrumental commissioning personnel
- Control room operator
- Supplier personnel (AWS)

OTP-C1-04

<u>SYSTEM DESCRIPTION</u>

Form Tie-in 05 the process condensates can go to:

- Buffer tank pumps P721A/B
- WESP for water make up (a regulation valve installed on the condensate water inlet line to rinse the water evaporated and blow down)
- Pumps P701A/B (pumps' sealing is flushed with a barrier water)
- Exhaust fan K702

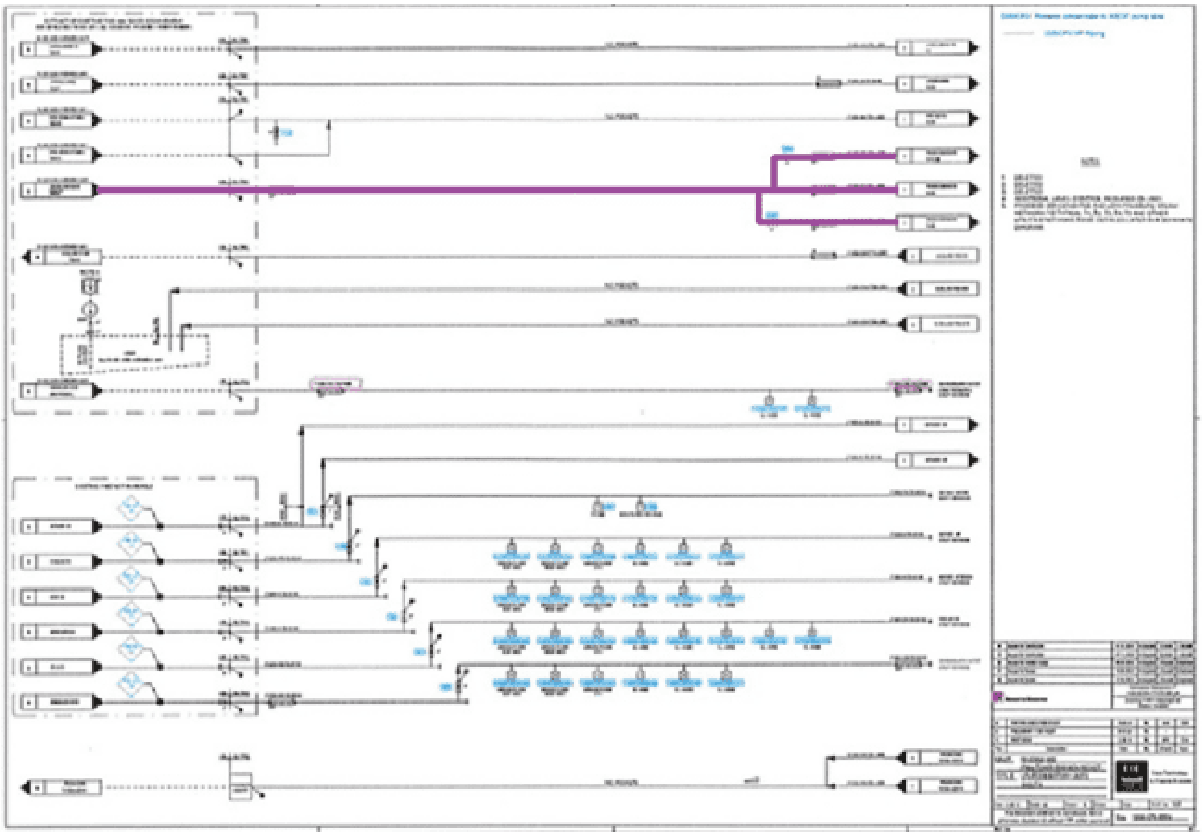

Figure 44: P&I diagram of process condensates system OTP-C1-04

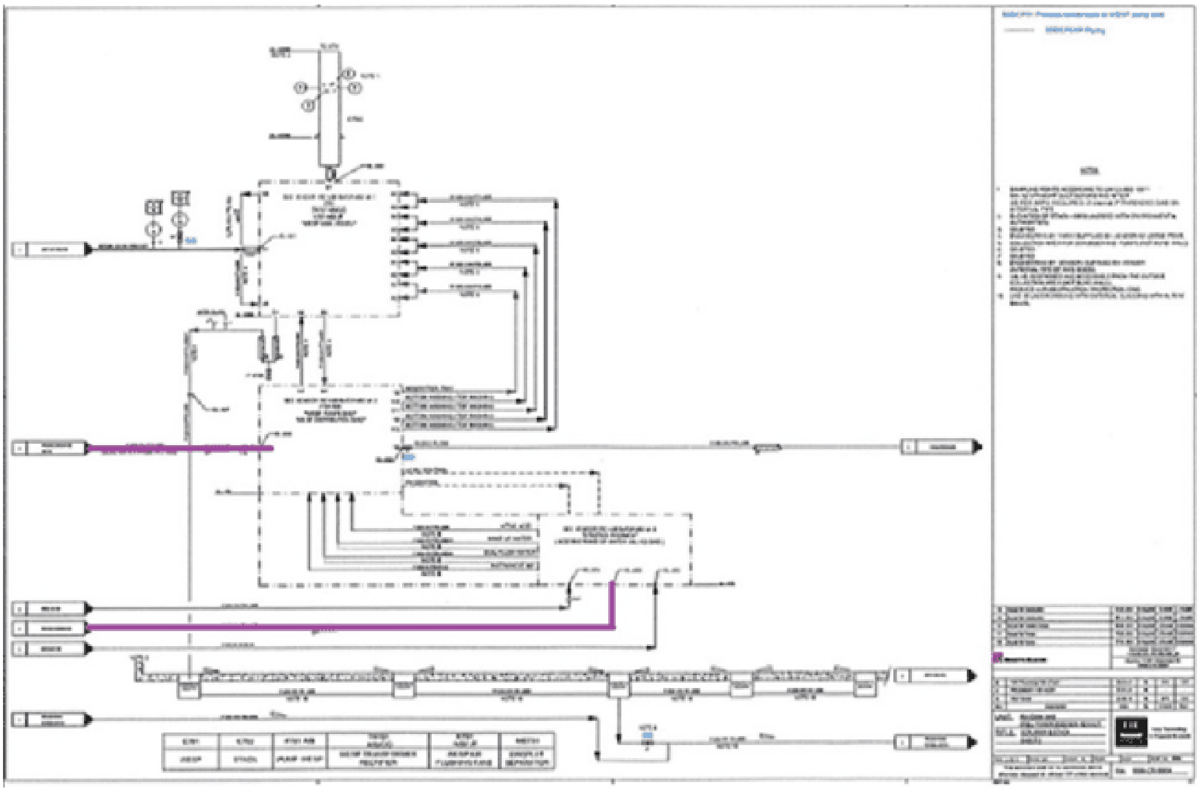

Figure 45: P&I diagram of process condensates system OTP-C1-04

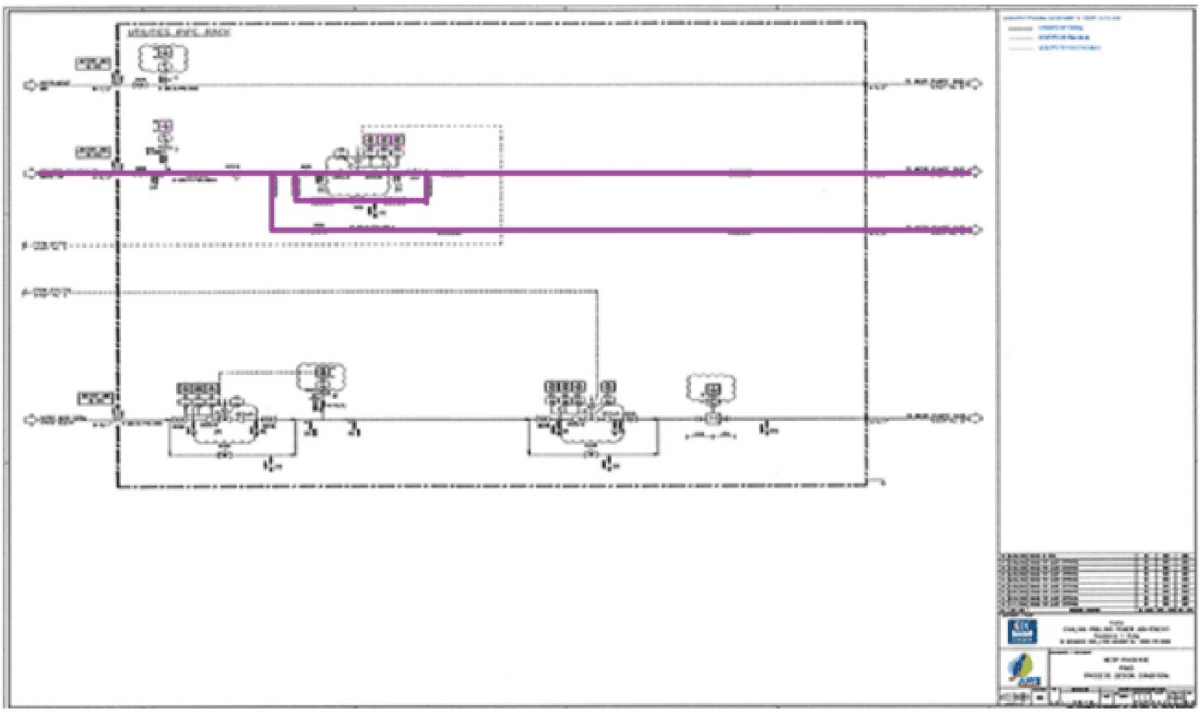

Figure 46: P&I diagram of process condensates system OTP-C1-04

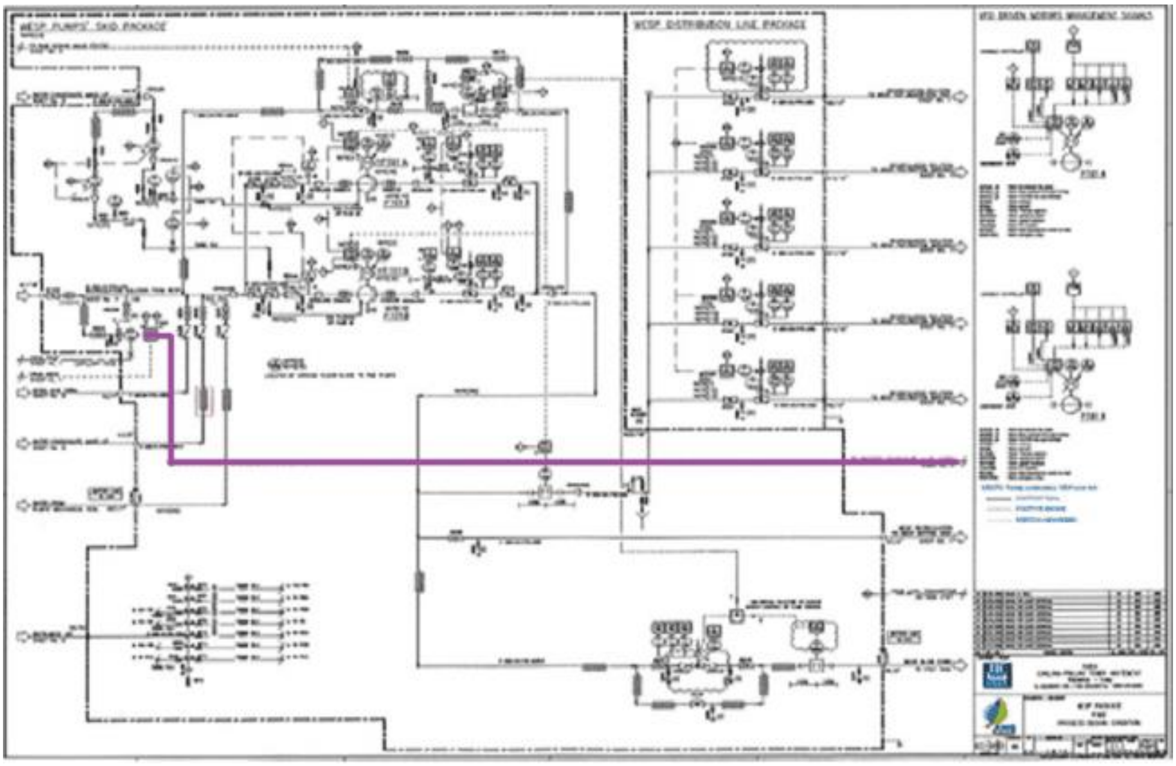

Figure 47: P&I diagram of process condensates system OTP-C1-04

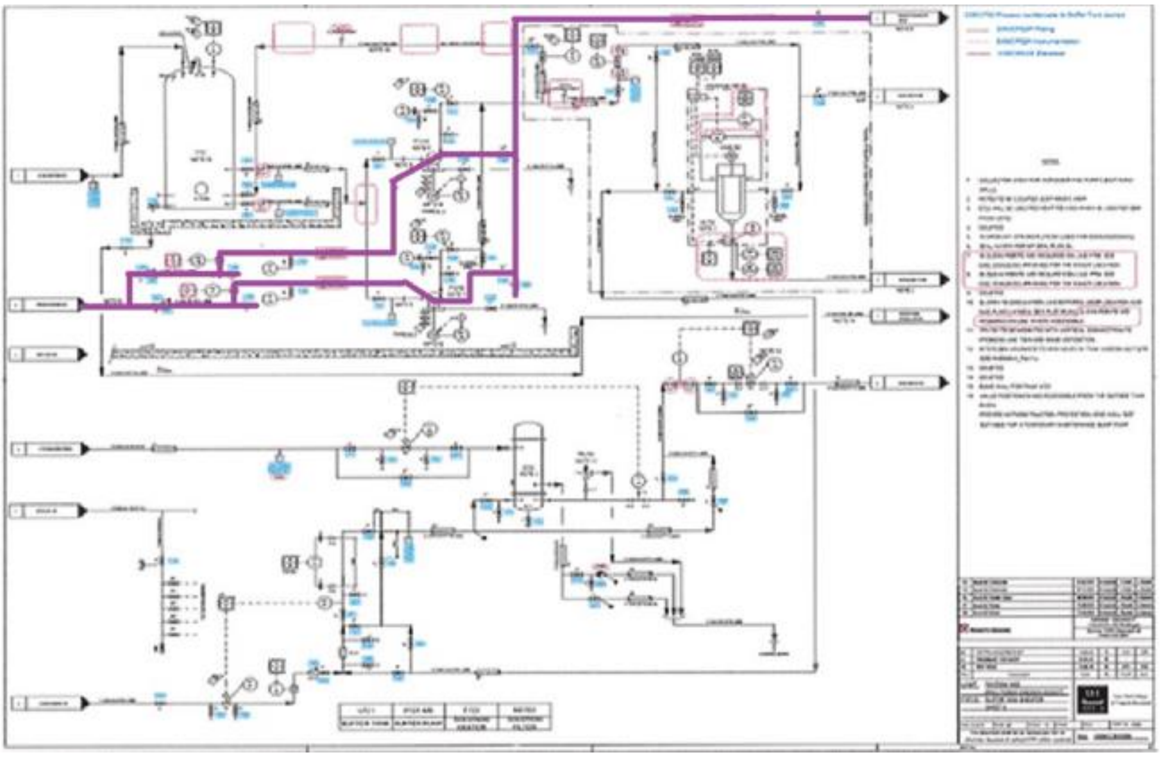

Figure 48: P&I diagram of process condensates system OTP-C1-04

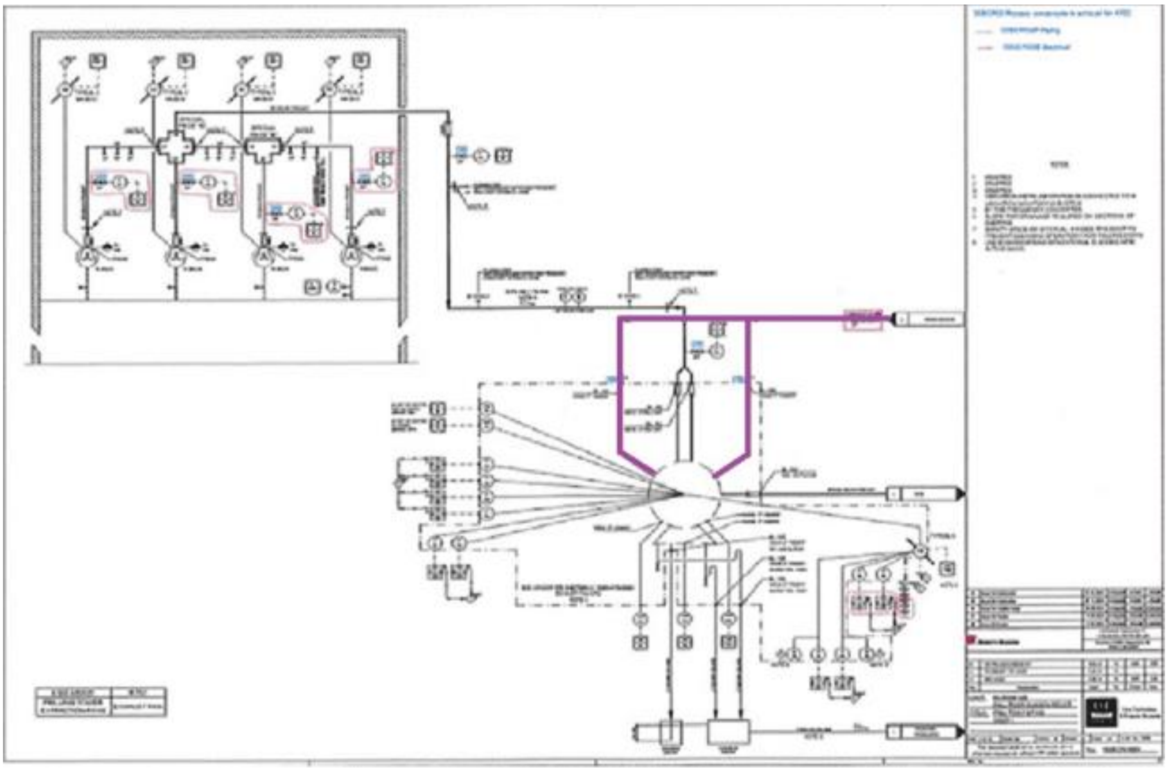

Figure 49: P&I diagram of process condensates system OTP-C1-04

TEST DURATION AND MANPOWER

Expected duration for performing the activities is 4 days.

The personal involved is:

- Electrical, mechanical and instrumental commissioning personnel
- Control room operator

OTP-C1-05

SYSTEM DESCRIPTION

For the ammonia removal, a certain amount of nitric acid is injected into the recirculated feeding water in order to set up the proper pH for the reaction between ammonia and nitric acid to obtain mainly ammonium nitrate salts dissolved in water. The injection is regulated by a pH-meter installed on the recirculation line and regulation valve.

From the Tie-in 01A and 01B the nitric acid goes to the WESP utilities pipe rack where during operation the pH of the recirculating water is regulated by the injection of a solution 58%w of HNO_3. In line it is installed the pH transmitter and through a PID regulation function it is set the operating of the dosing regulation valve in order to keep the “pHWESP” set point value imposed by the operator at the DCS.

Since the nitric acid amount is very limited a pressure reduction is mandatory. A pressure transmitter, through a PID regulation function, can regulate the nitric acid feeding pressure through the control valve; using a PID regulation function it is set the operating of the dosing regulation valve in order to keep the “$P_{nitricacid}$” set point value imposed by the operator by DCS.

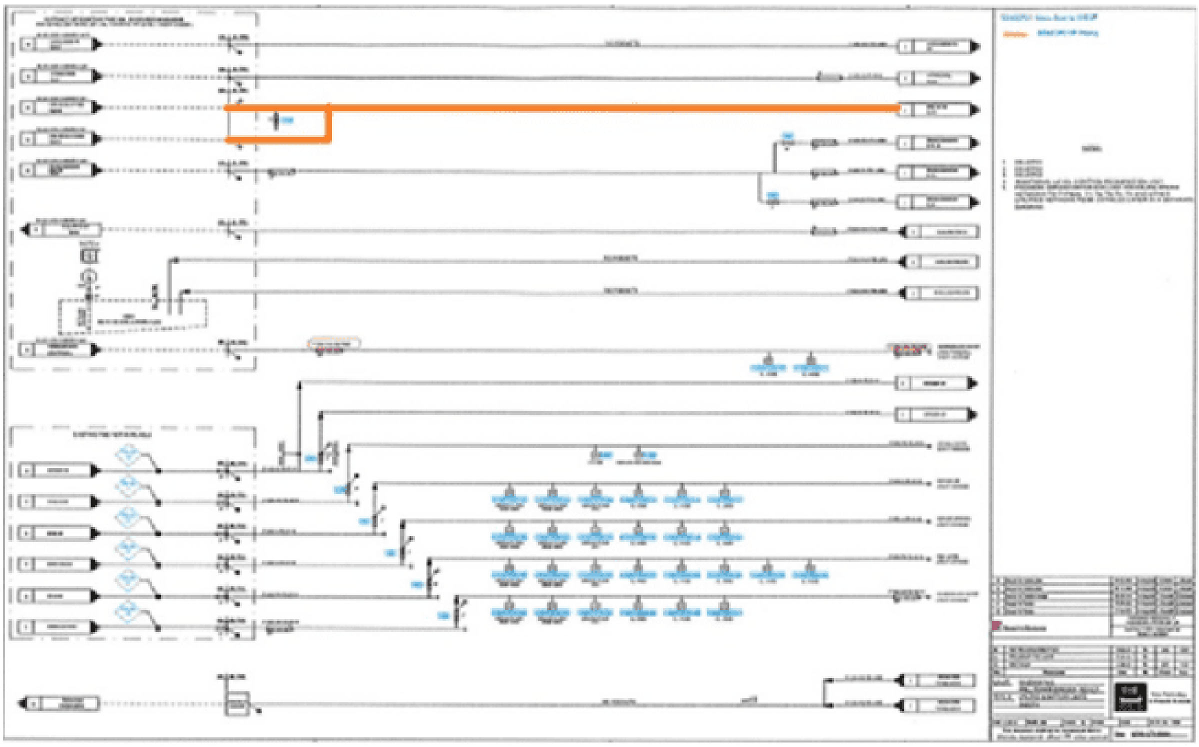

Figure 50: P&I diagram of nitric acid system OTP-C1-05

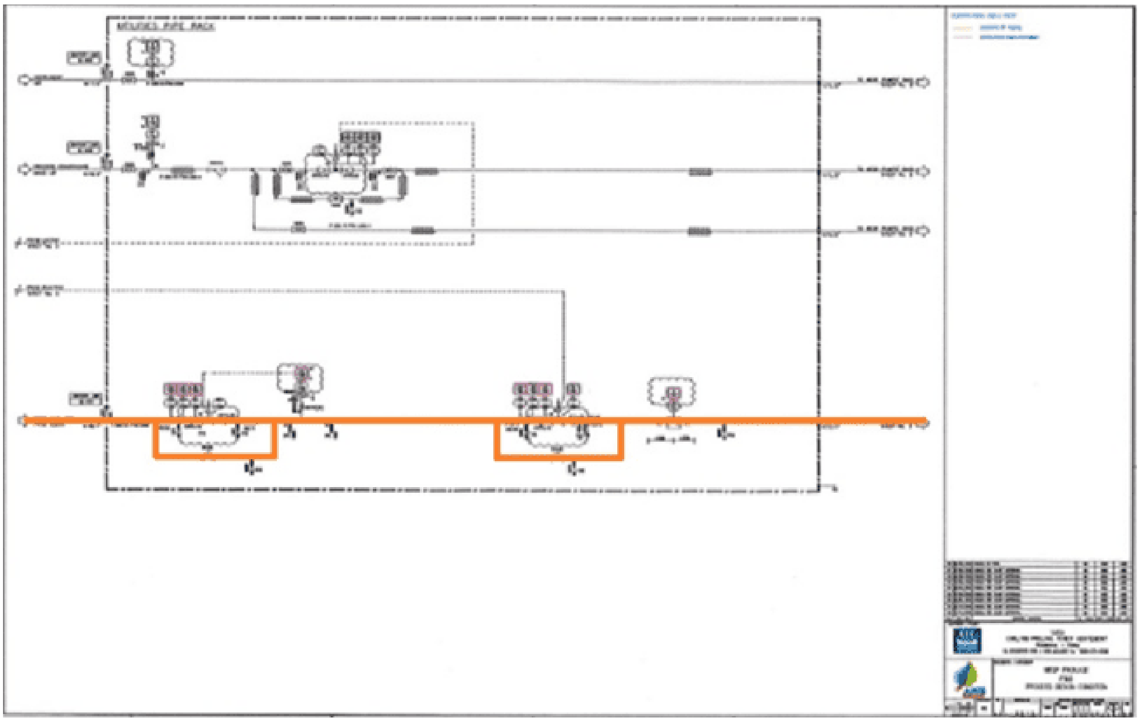

Figure 51:P&I diagram of nitric acid system OTP-C1-05

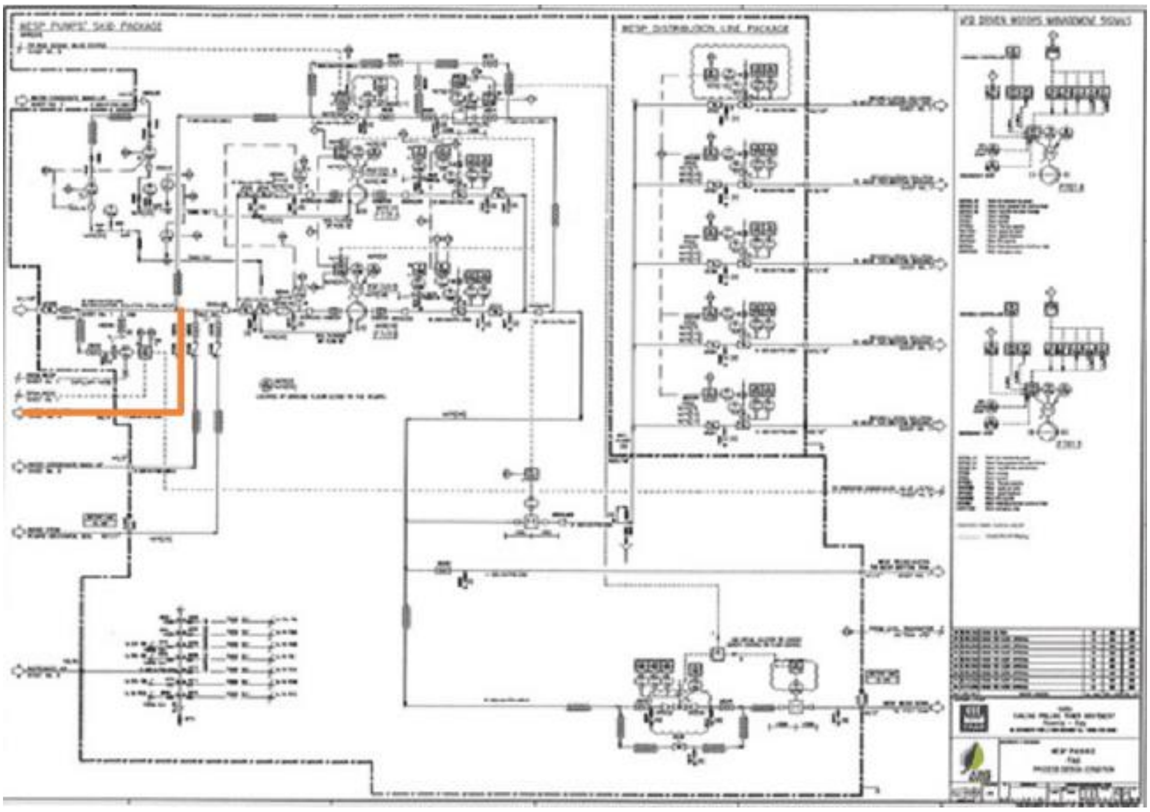

Figure 52: P&I diagram of nitric acid system OTP-C1-05

TEST DURATION AND MANPOWER

Expected duration for performing the activities is 4 days.

The personal involved is:

- Electrical, mechanical and instrumental commissioning personnel
- Control room operator

OTP-C1-06

<u>SYSTEM DESCRIPTION</u>

Since the WESP blowdown has an acidic pH, it has to be corrected to be neutral before being sent to the AN solution tank V203. To do so, a pH correction step is foreseen in the Bleed treatment process. The filtered solution pH is corrected by injecting aqueous ammonia 15%. The pH-meter can automatically adjust the aqueous ammonia injection.

From Tie-in 06 the aqueous ammonia goes to the filtered solution where during operation the pH of the solution is regulated by the injection of the aqueous ammonia. In the line it is installed the pH transmitter and through a PID regulation function it is set the operating of the dosing regulation valve in order to keep the pH set point value imposed by the operator at the DCS.

In the line is also present the flow transmitter which send the signal of flow measurement of the ammonia water to DCS generating alarms H and L.

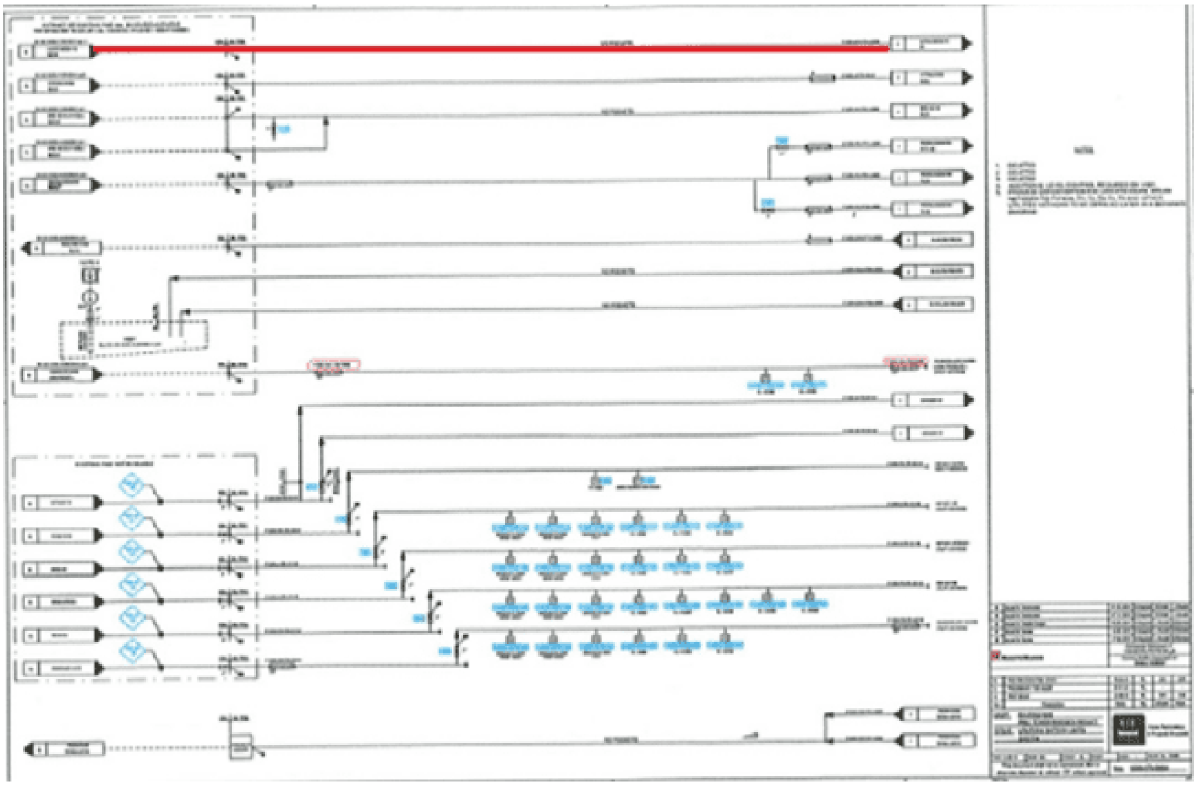

Figure 53: P&I diagram of aqueous ammonia 15% system OTP-C1-06

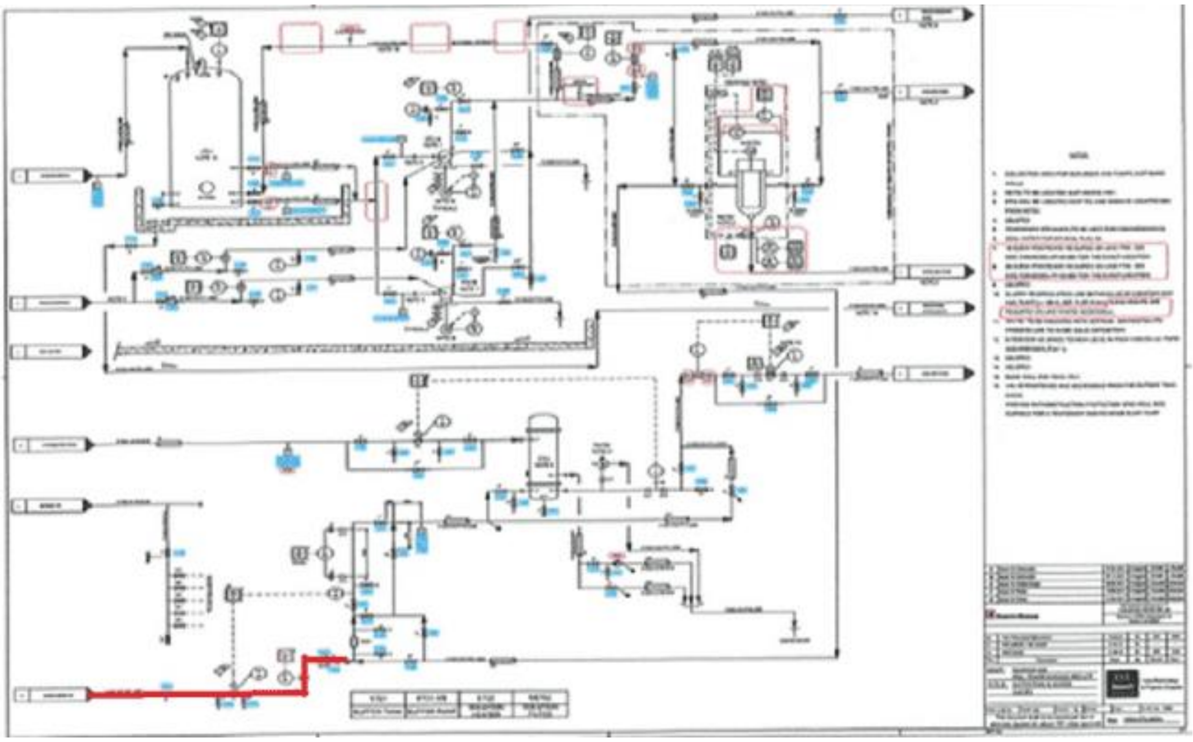

Figure 54: P&I diagram of aqueous ammonia 15% system OTP-C1-06

<u>TEST DURATION AND MANPOWER</u>

Expected duration for performing the activities is 4 days.

The personal involved is:

- Electrical, mechanical and instrumental commissioning personnel
- Control room operator

OTP-C1-07

SYSTEM DESCRIPTION

From Tie-in 10 the instrument air goes, with separate lines, to the WESP utilities pipe rack and to the buffer tank-filter-heater utilities. On the WESP utilities pipe rack it is installed the pressure transmitter which send the signal of pressure of the instrument air to DCS generating alarms HH and LL.

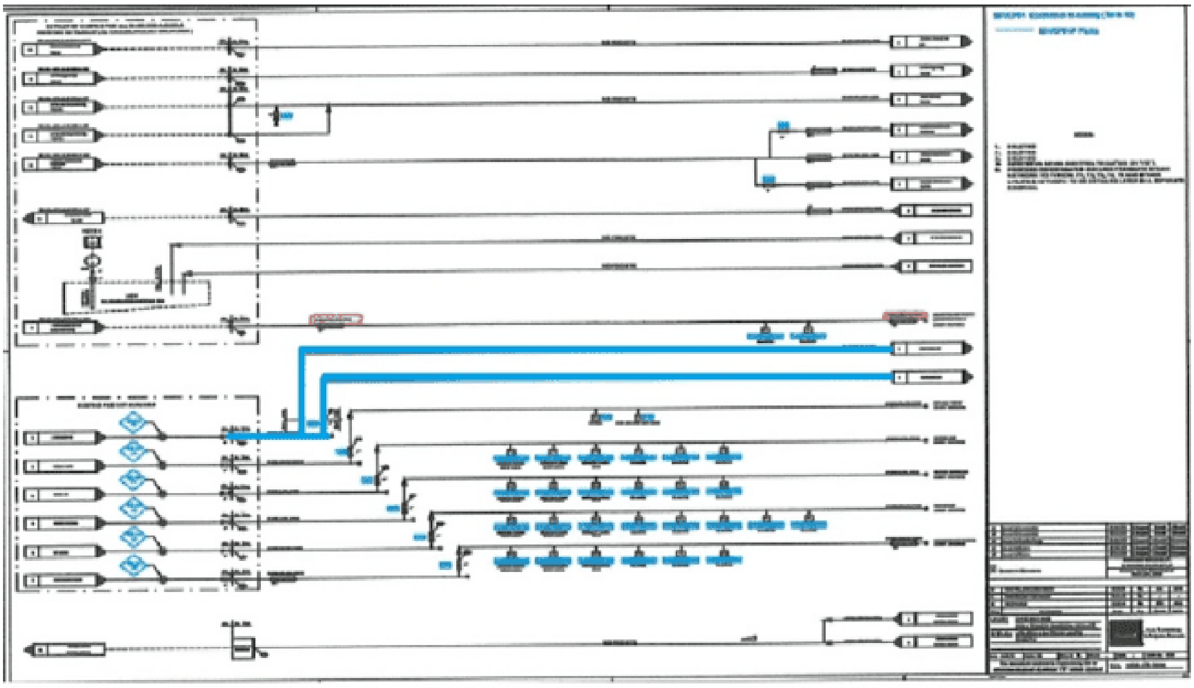

Figure 55: P&I diagram of instrument air system OTP-C1-07

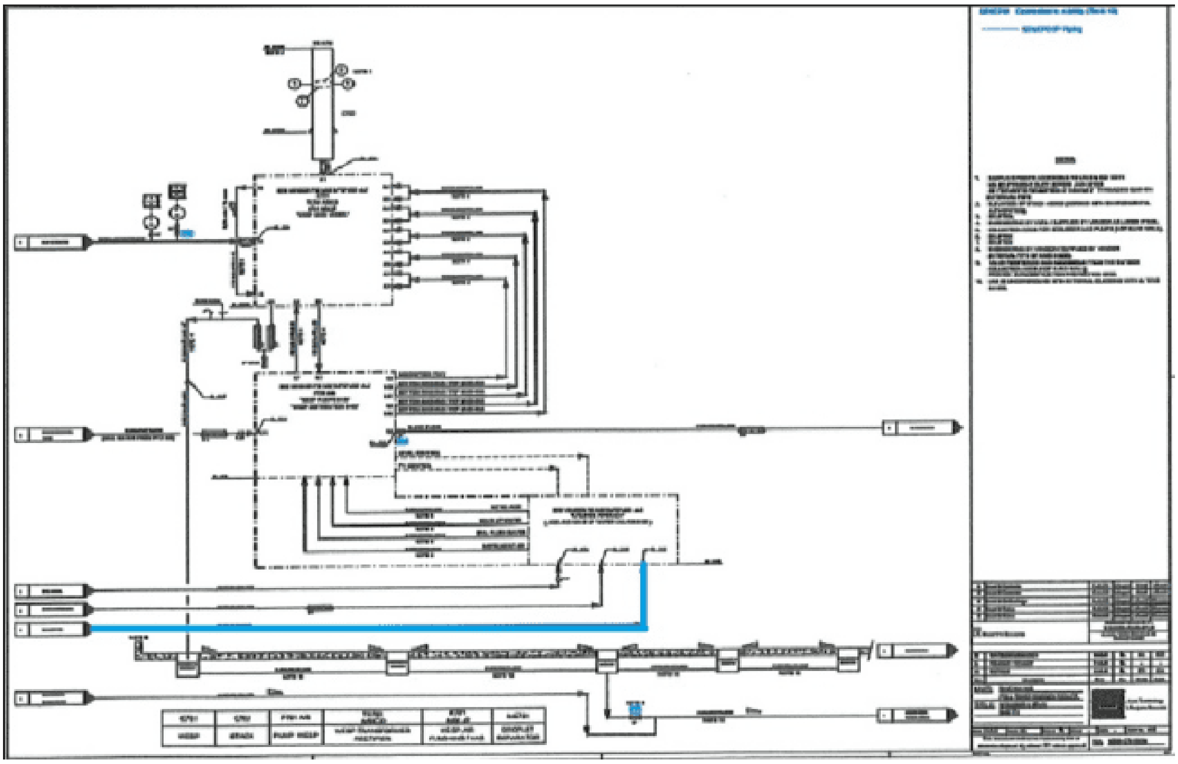

Figure 56: P&I diagram of instrument air system OTP-C1-07

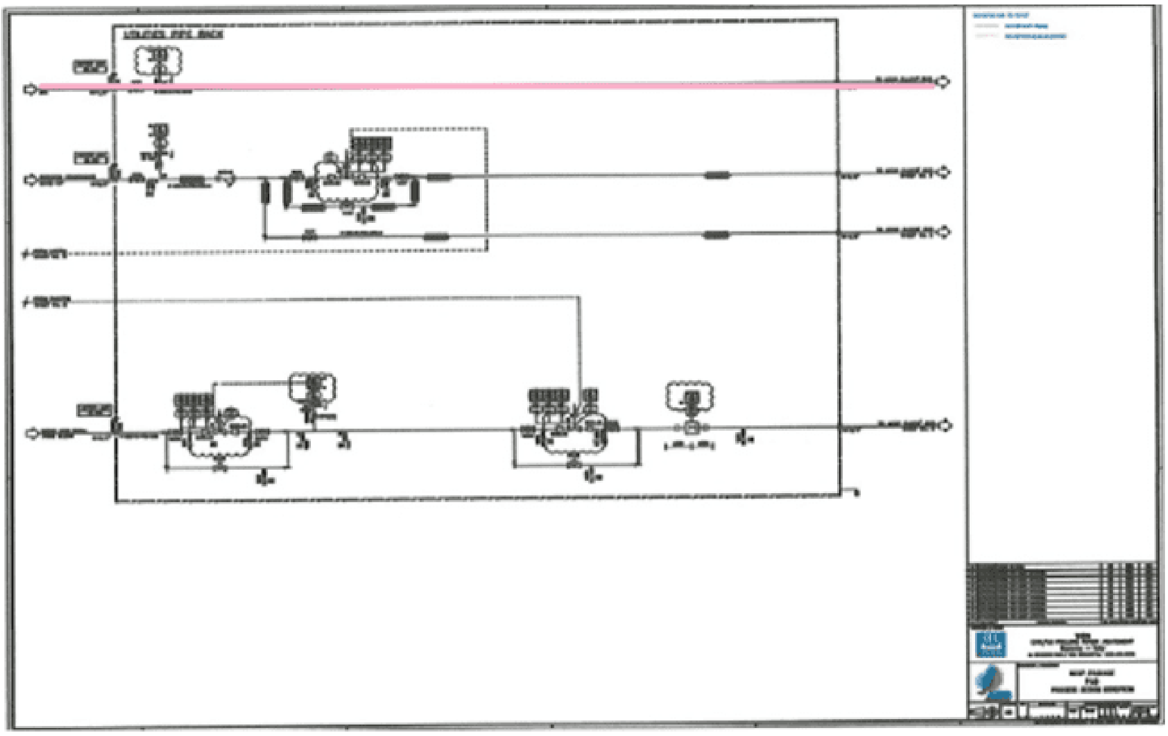

Figure 57: P&I diagram of instrument air system OTP-C1-07

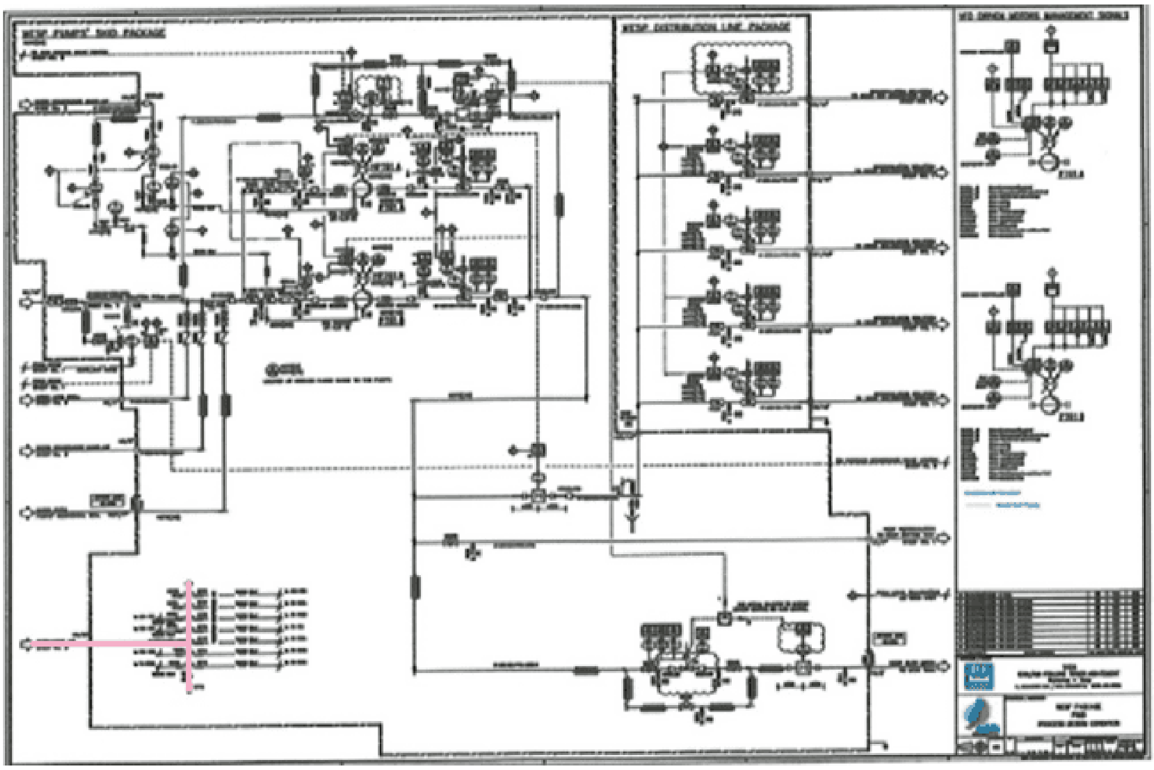

Figure 58: P&I diagram of instrument air system OTP-C1-07

TEST DURATION AND MANPOWER

Expected duration for performing the activities is 4 days.

The personal involved is:

- Electrical, mechanical and instrumental commissioning personnel
- Control room operator

OTP-C1-08

SYSTEM DESCRIPTION

From Tie-in 21 the potable water goes to the two safety showers. The safety showers are positioned near the buffer tank pumps and near the WESP utilities rack.

The connection from the header is according the typical T9 on the P&ID.

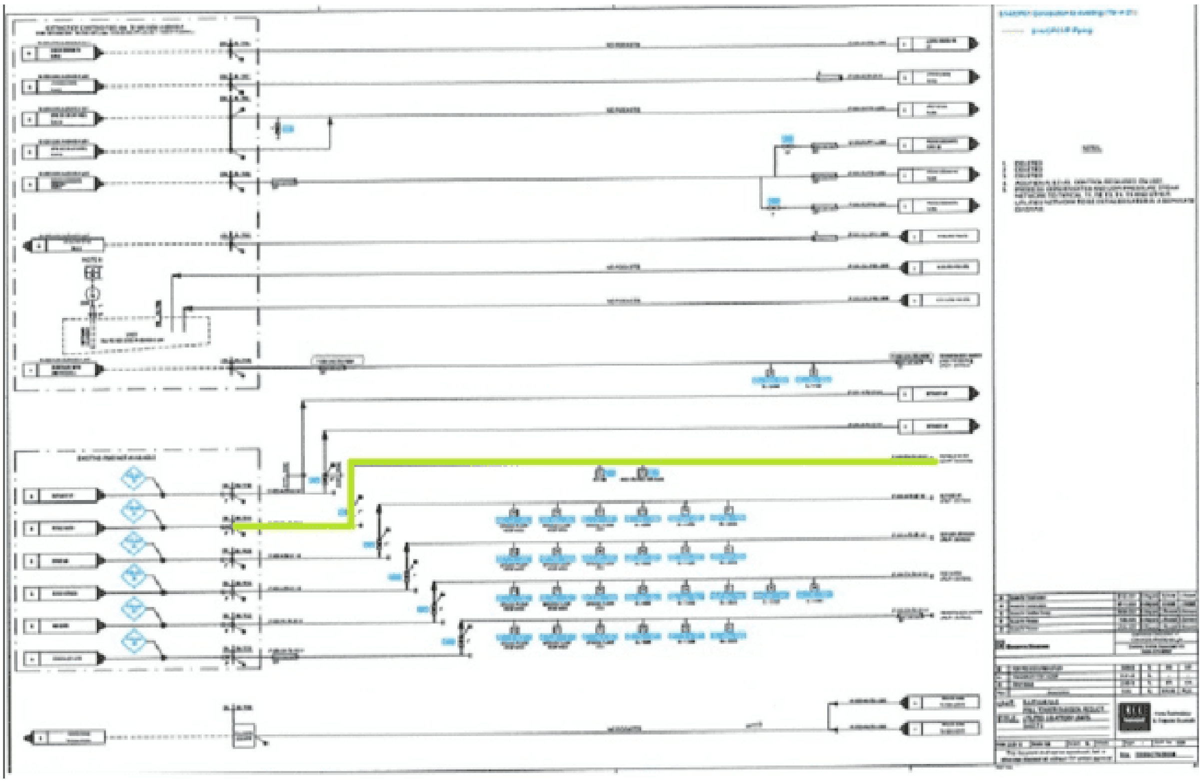

Figure 59: P&I diagram of potable water system OTP-C1-08

OTP-C1-09

SYSTEM DESCRIPTION

From Tie-in 23 the service air goes to the utility stations. The utility stations are located at ground floor in WESP area and in buffer tank area and at elevation +5000, +14200 and +20540.

The connection from the header to each utility station is according the typical T8 on the P&ID.

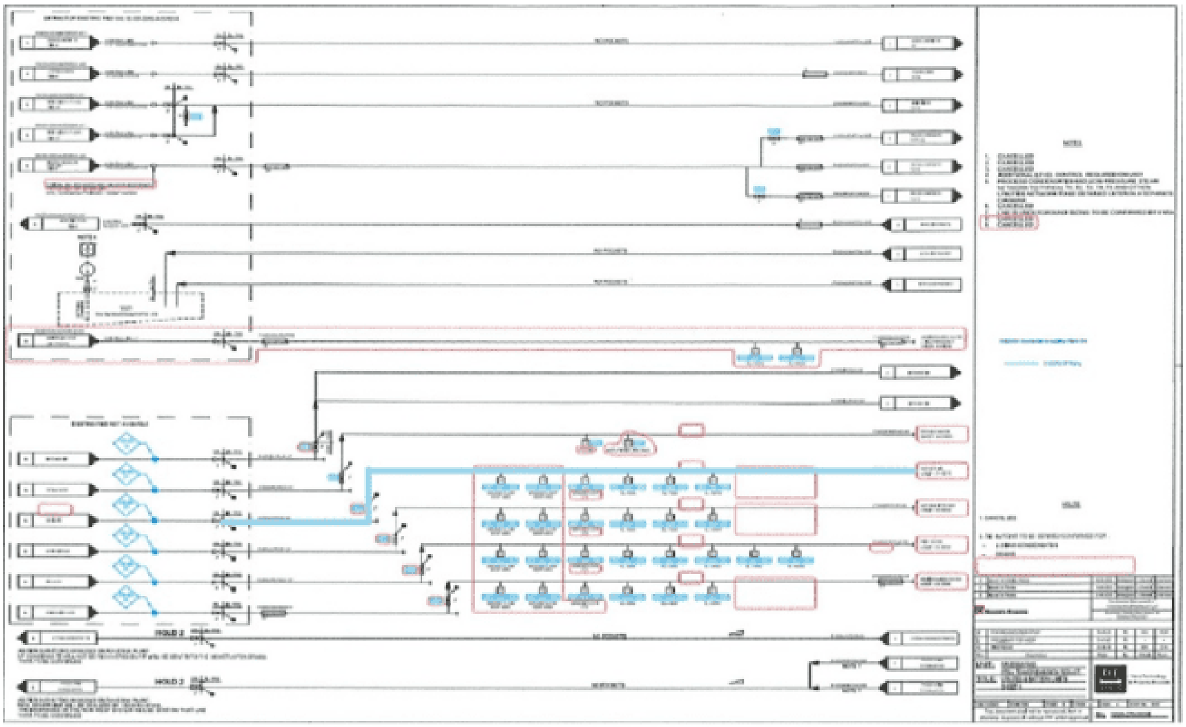

Figure 60: P&I diagram of service air system OTP-C1-09

TEST DURATION AND MANPOWER

Expected duration for performing the activities is 3 days.

The personal involved is mechanical commissioning personnel.

OTP-C1-10

SYSTEM DESCRIPTION

From Tie-in 24 the service nitrogen goes to the utility stations. The utility stations are located at ground floor in WESP area and in buffer tank area and at elevation +5000, +14200 and +20540. The connection from the header to each utility stations is according the typical T8 on the P&ID.

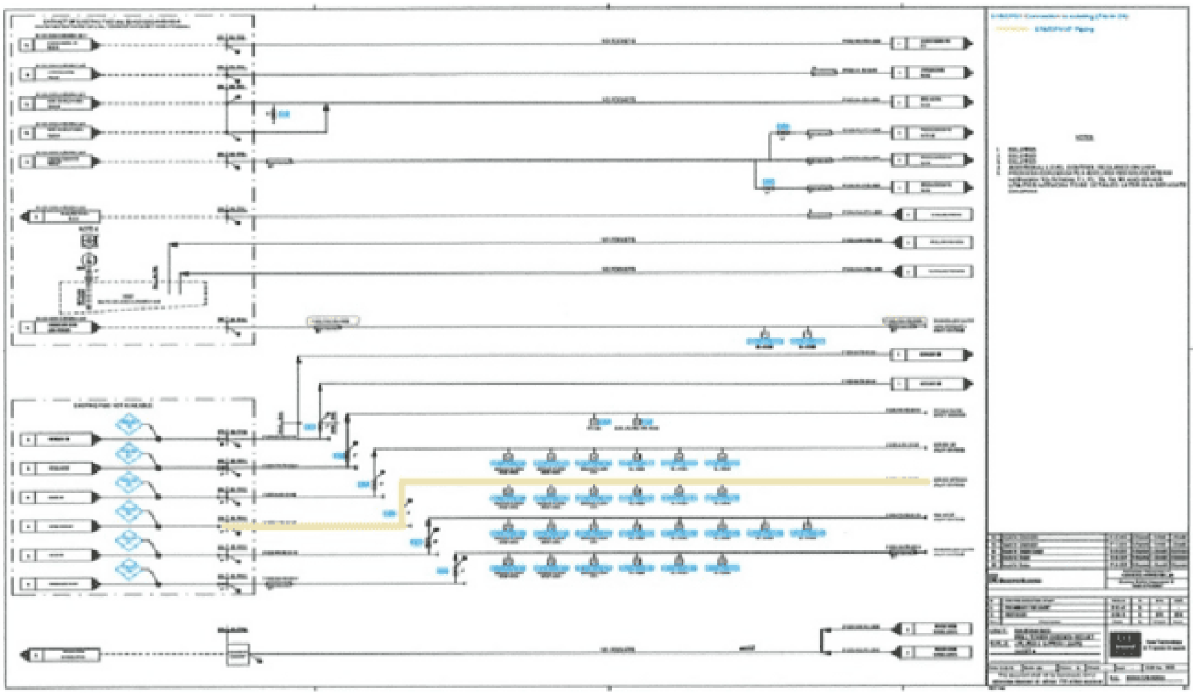

Figure 61: P&I diagram of service nitrogen system OTP-C1-10

TEST DURATION AND MANPOWER

Expected duration for performing the activities is 3 days.

The personal involved is mechanical commissioning personnel.

OTP-C1-11

SYSTEM DESCRIPTION

From Tie-in 25 the demi water goes to the utility stations. The utility stations are located at ground floor in WESP area and in buffer tank area and at elevation +5000, +14200 and +20540.

The connection from the header to each utility stations is according the typical T8 on the P&ID.

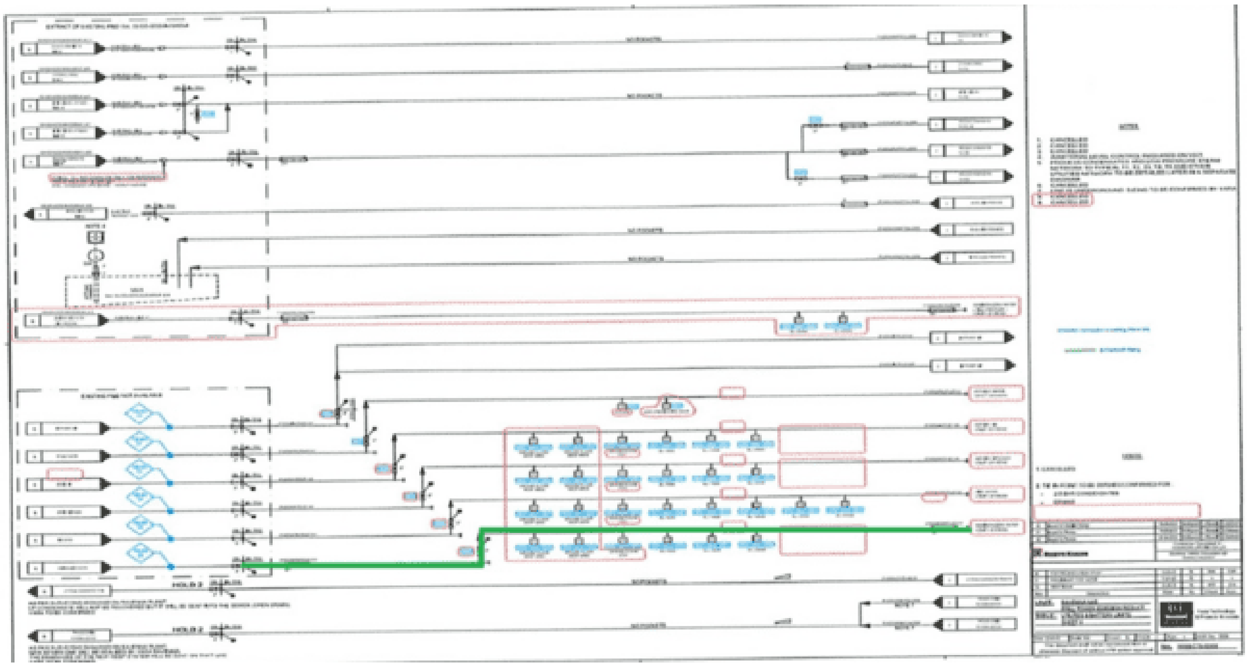

Figure 62: P&I diagram of demi water system OTP-C1-11

TEST DURATION AND MANPOWER

Expected duration for performing the activities is 3 days.

The personal involved is mechanical commissioning personnel.

OTP-C1-12

SYSTEM DESCRIPTION

The dirty air that is coming from the upstream existing prilling tower. It is then sucked by the existing prilling tower extraction fans which are provided with four new VFD[7]. A new duct header will collect the dirty air from four fans and then send it to new exhaust fan.

The new exhaust fan will act as a booster, to provide the extra pressure drop generated by the downstream system. The discharge of the exhaust fan is directed to the new scrubber.

Dirty gas enters the new scrubber from the bottom and exits from the top.

In the line are also present pressure transmitters and temperature transmitter which send the signal of measurements to DCS generating alarms H and L.

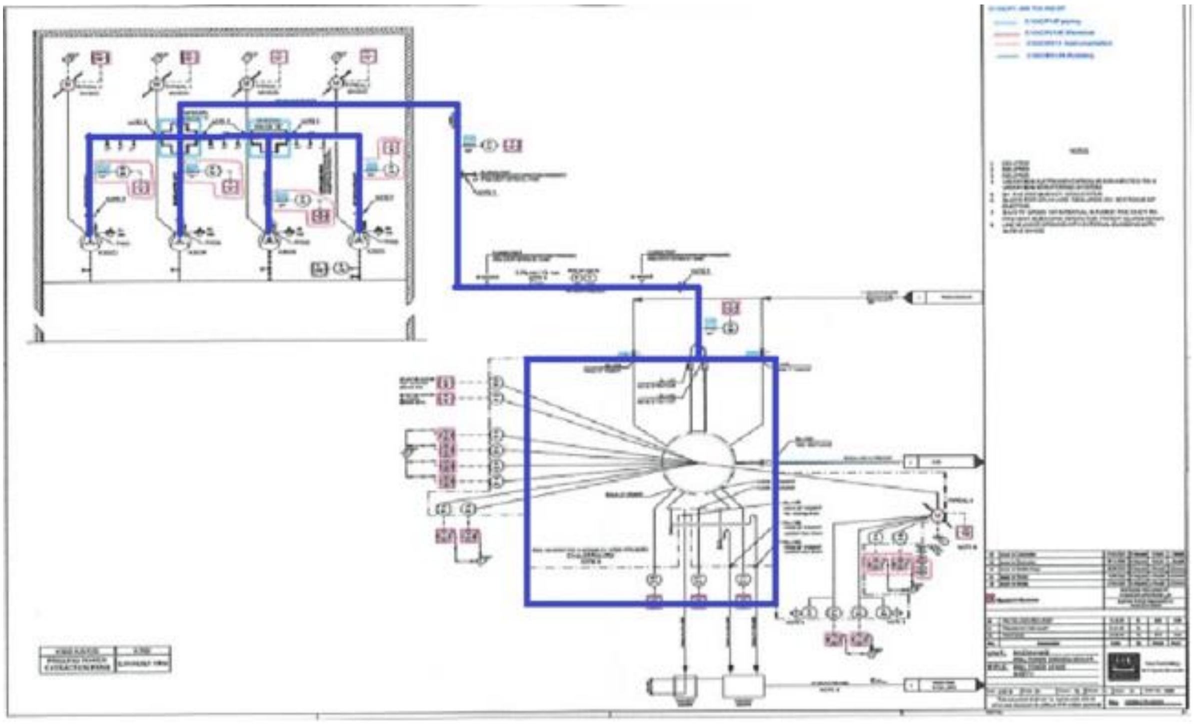

Figure 63: P&I diagram of air to treatment system OTP-C1-12

[7] VFD=variable frequency drive

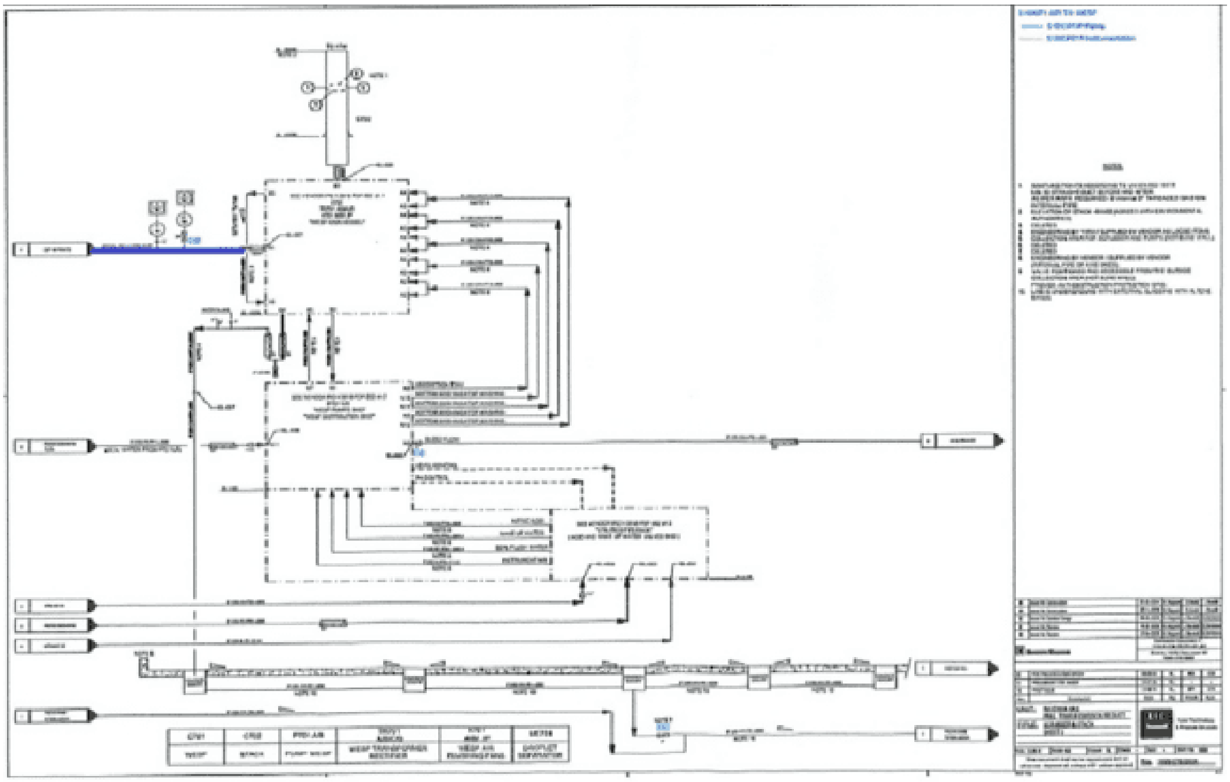

Figure 64: P&I diagram of air to treatment system OTP-C1-12

<u>TEST DURATION AND MANPOWER</u>

Expected duration for performing the activities is 4 days.

The personal involved is:

- Electrical, mechanical and instrumental commissioning personnel
- Control room operator
- Vendor personnel

3.2.2 Analysis of results

The commissioning is verified when all the steps of the checklists are checked and if they are not verified, the steps have to be repeated.

Below are reported the checklists of each procedure with the respective notes and the procedures are attached at the end of the report (Attachment 1-12).

OTP-C1-01

PREPARATION WORKS		
STEP	TASK DESCRIPTION	STATUS
1	TBD by commissioning team: prepare a list of temporary items to able to perform the commissioning	-
2	If WESP skid is not available (not commissioned), connect with temporary flexible hose the demi water with buffer tank	Ok
3	If WESP skid is not available (not commissioned), connect temporary V098 with buffer tank and close valve V095	No WESP skid available
4	Install the temporary commissioning strainer on pumps suction	Ok
5	Application of LOTO to valve V031	Ok

COMMISSIONING PROCEDURE		
STEP	TASK DESCRIPTION	STATUS
Electric power supply		
1	From power centre energize the local control panels for MP721A/B	Ok
2	From marshalling cabinet energize instruments of the system	Ok
Buffer tank		
1	The tank should be already clean after mechanical completion checks	Ok
2	If WESP bleed already commissioned and available, fill buffer tank from WESP bleed by opening FCV705 and ignore following steps 5 and 6	NA
3	If WESP bleed not available, fill with demi water from N7 using a temporary connection. Quantity of water about 60 m^3	Ok
4	Check that the tank is isolated from WESP bleed (VB246 and VV248 closed)	Ok
5	Check correct communication between LT701 and DCS (signals from level transmitter)	Ok
6	Fill until LT701 level is 50%	Ok
7	Open valve V014	Ok
8	Open valve V011	Ok
Process condensates		
1	Process condensate system already commissioned and connected to Tie-in 05 (to use final media)	Ok

Pump MP712A		
1	Check if lubricant is present (see quantity and type in pumps' manual)	Ok
2	Open valve V093 (seal flushing)	Ok
3	Open valve V027	Ok
4	Close valve V043	Ok
5	Close valve V029	Ok
6	Check correct communication between valve V027 and DCS (signals from valve). Check if can be done before	Ok
7	Check that all pipe drains are closed	Ok
8	Open valve V014	Ok
9	Open valve V011	Ok
10	Open valve V040	Ok
11	Close valve V031 to isolate filter and heater	Ok
12	Open valve V028 (PI704)	Ok
13	Check correct communication between MP721A and DCS (signals from electric motor)	Ok
14	Install the temporary commissioning strainer	Ok
15	Start pump MP721A	Ok
16	Gradually open valve V043 until pressure indicated by PI701 is 5 bar	Ok
17	Test start/stop pump from DCS	Ok
18	Test pump emergency stop	Ok
19	Restart pump MP721A	Ok
20	Check correct communication between FT712 and DCS (signal from flowmeter)	Ok
21	Test interlock I-06 (FT721): pump shall stop if recirculation is below 7 m^3/h	Ok
22	Test interlock I-07 (V027/ZSL701): pump MP721A shall stop if discharge valve is closed; pump MP721B shall stop if ZAL701 is in open position	Ok
23	Test interlock I-04 (LT701): P721A shall stop if LALL-701 is active (set point 2300 mm); P721A can start if LALL-701 is not active	Ok
24	Stop pump MP721A	Ok
25	Check if commissioning strainer is dirty	Ok
Pump MP721B		
1	Check if lubricant is present (see quantity and type in pumps' manual)	Ok
2	Open valve V091	Ok
3	Open valve V029	Ok
4	Close valve V043	Ok
5	Close valve V027	Ok
6	Check correct communication between valve V029 and DCS (signals from valve)	Ok
7	Check all pipe drains are closed	Ok

8	Open valve V014	Ok
9	Open valve V012	Ok
10	Open valve V040	Ok
11	Close valve V031 to isolate filter and heater	Ok
12	Open valve V030 (PI705)	Ok
13	Check correct communication between MP721B and DCS (signals from electric motor)	Ok
14	Install the temporary commissioning strainer	Ok
15	Start pump MP721B	Ok
16	Gradually open valve V043 until pressure indicated by PI705 is 5 bar	Ok
17	Test start/stop pump from DCS	Ok
18	Test pump emergency stop	Ok
19	Restart pump MP721B	Ok
20	Check correct communication between FT721 and DCS (signal from flowmeter)	Ok
21	Test interlock I-06 (FT721): pump shall stop if recirculation is below $7m^3/h$	Ok
22	Test interlock I-07 (V029/ZSL702): pump MP721B shall stop if discharge valve is close; pump MP721A shall stop if ZAL702 is in open position	Ok
23	Test interlock I-04 (LT701): MP721B shall stop if LALL-701 is active (set point 2300 mm); MP721B can start is LALL-701 is not active	Ok
24	Stop pump MP721B	Ok
25	Check if commissioning strainer is dirty	Ok

The notes reported are:

- Demi water temporary used
- Abnormal noise when the pumps start

OTP-C1-02

PREPARATION WORKS		
STEP	TASK DESCRIPTION	STATUS
1	TBD by commissioning team: prepare a list of temporary items to be able to perform the commissioning	-
2	Remove LOTO to valve V031	Ok
3	Aqueous ammonia system already commissioned and temporary connected with demi water	Ok
4	Check availability of V601 to receive water from filter ME702	Ok
5	Check availability of V203 to receive water from heater E722	Ok
6	Install a manometer on LP steam line after valve V080	NA

PREPARATION WORKS		
STEP	TASK DESCRIPTION	STATUS
Electric power supply		
1	Energize the control cabinet of filter ME702	Ok
2	Energize instruments of the system	Ok
Filter package ME702		
1	Commissioning package S06/CP01 (AN solution bleed to buffer tank and pumps) in operation	Ok
2	Check that all pipe drains are closed	Ok
3	Close valve V032 (bypass filter ME702)	Ok
4	Close valve V039	Ok
5	Open gradually valve V031	Ok
6	Check correct communication between FT703 and DCS	Ok
7	Close valve V038 and V050 (flushing points)	Ok
8	Close valve V046	Ok
9	Close valve V047	Ok
10	Close valve V052	Ok
11	Close valve V053	Ok
12	Close valve V059	Ok
13	Close valve V061	Ok
14	Close valve V062	Ok
15	Open valve V069 (bypass FV702)	Ok
16	Open valve V060 (bypass heater E722)	Ok
17	Open valve V048	Ok
18	Open valve V045 (bypass mixer)	Ok
19	Open valve V044	Ok
20	Supply compressed air to the drain valve	Ok
21	Switch on the control panel	Ok
22	Open gradually valve V033	Ok
23	Vent the filter	Ok
24	Starting a manual cleaning cycle and check the opening and closing of the drain valve HV701	Ok

25	Check correct communication between drain valve HV701 and DCS (signals from valve)	Ok
26	Check correct communication between PDT706A and DCS (signals from DP transmitter)	Ok
27	Select automatic mode of cleaning: test start of cleaning by setting time and DP. This is the interlock I-03: XV701 open if pressure drop on filter ME702 is very high (PDAHH-706 active)	Ok
28	Adjust the set differential pressure to the setpoint	Ok
29	Check correct communication between FT702 and DCS (signals from flow transmitter)	Ok
Aqueous ammonia injection		
1	Aqueous ammonia system already commissioned and temporary connected with demi water	Ok
2	Close valve V055, V049 and V028 (flushing points)	Ok
3	Open valve V046	Ok
4	Open valve V045	Ok
5	Open valve V051	Ok
6	Open valve V052	Ok
7	Open valve V048	Ok
8	If necessary, regulate the valve V043 to have 5 bar in the line to mixer	Ok
9	Open valve V003	Ok
10	Check correct communication between PHT701 and DCS (signals from PH transmitter)	Ok
11	Test the functional loop PHT701-PHV701 by simulating the process variable of PHT701 from field or DCS. If the filtered solution pH exceeds the pH set point (5), the control valve PHV701 must close; if the filtered solution PH drops below the pH set point (5), the control valve PHV701 must open accordingly	Ok
12	Test the interlock I-02: PHV701 shall close when filter solution flowrate is very low (FALL702 active). PHV701 can open if FALL702 alarm is not active	Ok
LP steam line, heater E722 and LP condensates		
1	Check correct communication between DT707 and DCS (signals from density transmitter)	Ok
2	Check correct communication between TT704 and DCS (signals from temperature transmitter)	Ok
3	Check correct communication between TV704 and DCS (signals from control valve)	Ok
4	Test the functional loop TT704-TV704 by simulating the process variable of TT704 from field or DCS. If the filtered solution temperature exceeds the set point (95 °C), the control valve TV704 must close; if the filtered solution temperature decreases below the set point (95 °C), the control valve TV704 must open accordingly	Ok

5	Test the interlock I-02: TV704 shall close when filter solution flowrate is very low (FALL702 active). TV704 can open if FALL702 alarm is not active	Ok
6	Close valve V054 and V063 (flushing points)	Ok
7	Close valve V041	Ok
8	Open gradually valve V053	Ok
9	Close valve V060	Ok
10	Open valve V059	Ok
11	Open valve V073	Ok
12	Close valve V079	Ok
13	Close valve V085	Ok
14	Gradually open the Tie-in valve of LP steam	Ok
15	Open T7 on LP steam pipe to discharge steam condensate	Ok
16	Gradually open V085. At half of the opening pressure, check absence of deformations, damages of leakages of heater E722 and connections	Ok
17	Gradually open V085 until operating pressure and check absence of deformations, damages or leakages of heater E722 and connections	Ok
18	Open gradually valve V079	Ok
19	Close valve V085	Ok
20	Check if steam condensate is discharged (and so if the steam trap SC-001 is working properly)	Ok
21	Close valve V064 and V065 (flushing points)	Ok
22	Open valve V061	Ok
23	Close valve V069	Ok
24	Close valve V062	Ok
25	Check correct communication between FV702 and DCS (signals from control valve)	Ok
26	Test the functional loop FT702-FV702 by simulating the process variable of FT702 from field or DCS. If the filtered solution flowrate exceeds the set point (0,5 m^3/h), the control valve FV702 must close; if the filtered solution flowrate drops below the set point (0,5 m^3/h), the control valve FV702 must open accordingly	Ok
27	Test the interlock I-05: FV702 shall close when HH level is detected in V203 (LALL217 active)	Ok
Shut-down the system		
1	Switch off the main switch on the filter ME702 control cabinet	Ok
2	Disconnect the compressed air supply to the filter drain valve	Ok
3	Close valve V079	Ok
4	Close valve V003	Ok
5	Stop pump P721A/B	Ok
6	Drain the system (buffer tank, equipment, piping)	Ok

OTP-C1-03

PREPARATION WORKS		
STEP	TASK DESCRIPTION	STATUS
1	TBD by commissioning team: prepare a list of temporary items to be able to perform the commissioning	-
2	Application of LOTO to valve V187: close valve V187 (at BL-005 bleed flow from WESP)	Ok
3	Verify that mechanical interlocks are installed correctly	Ok
4	Check that keys A1-B1-C1-D1 available and installed on transformers main circuit breakers	Ok
5	Close valve VF212 and VF220	Ok
6	Connect nozzle Z1 of WESP vessel with demi water unis temporary flexible nose	Ok
7	Fill WESP bottom with demi water until hydraulic seal, about 100 m^3 need to fill in	Ok
8	Instrument air system already commissioned and in operation	Ok
9	Process condensate system already commissioned in operation with demi water	Ok
10	Nitric acid system already commissioned and in operation with demi water	Ok

COMMISSIONING PROCEDURE		
STEP	TASK DESCRIPTION	STATUS
Electric power supply		
1	Energize the systems equipment from power center	Ok
2	Energize instruments of the systems	Ok
3	Test emergency buttons ES701B (located at ground floor close to the pump) and ES701C (located neat electric substation and exhaust fan): push the button and check if the contact gives the signal to the DCS/SIS and verify that all trip interlock of all equipment is activated	Ok
Purge system		
1	Check that purge air flow orifice is installed on purge air inlet flange on each insulator compartment	-
2	Test the start/stop blowers from DCS	Ok
3	Open valve VF112 and VF127	Ok
4	Run the blowers and check there are no unusual vibrations, no unusual noise, measure the motor absorption and check compliance with the rated value	Ok
Transformers		
1	High voltage transformer start-up protocol completed successfully	Ok
2	V-I curve taken in blank conditions	(1)
3	Check communication with DCS via hardwire: remote ON	Ok

4	Check communication with DCS via hardwire: remote OFF	Ok
5	Check communication with DCS via hardwire: alarm feedback	Ok
6	Check communication with DCS via hardwire: mA feedback	Ok
7	Check communication with DCS via hardwire: kV feedback	Ok
8	Check communication with DCS via TCP/IP protocol	Ok
9	Ensure kV and mA limits have been implemented according to AWS indications	Ok
WESP tank and skids		
1	Check correct communication between LIT704 and DCS (signals from level transmitter)	Ok
2	Check correct communication between DLIT704 and DCS (signals from level transmitter)	(2)
3	Test the functional loop LIT704 and DLIT704-LCV704 (WESP water level control) by simulating the process variable of LIT704 and DLIT704 from field of DCS. If LIT704 and DLIT704 > set point, the control valve LCV704 increases closure; if LIT704 and DLIT704 < set point, the control valve LCV704 decreases closure	Ok
4	Check interlock I-60: if both LIT704 and DLIT704 LL or fault, trip pumps P701A and P701B	Ok
5	Check interlock I-61: if LIT704HH and DLIT704HH, close valve LCV704	Ok
6	Check interlock I-66: if LSL703A is activated, trip pumps P701A	Ok
7	Check interlock I-67: if LSL703B is activated, trip pumps P701B	Ok
8	Check interlock I-68: if LSL703A and LSL703B are activated, trip pumps P701A and P701B	Ok
9	Open valve VB709 (instrument air to YV701X)	Ok
10	Check correct communication between YV701X and DCS (signals from valve, from DCS open/close valve and check its correct operation, check that limit switches feedback is received from DCS correctly)	Ok
11	Check interlock I-57: if YV701X dose not open anymore at the end of the washing cycle, trip immediately pumps	Ok
12	Open valve VB705 (instrument air to YV701D)	Ok
13	Check communication between YV701D and DCS (signals from valve, from DCS open/close valve and check its correct operation, check that limit switches feedback is received from DCS correctly)	Ok
14	Check interlock I-56: if YV701D open, interlock transformer TR701D	Ok
15	Open valve VB712 (instrument air to YV701C)	Ok

16	Check correct communication between YV701C and DCS (signals from valve, from DCS open/close valve and check its correct operation, check that limit switches feedback is received from DCS correctly)	Ok
17	Check interlock I-55: if YV701C open, interlock transformer TR701C	Ok
18	Open valve VB711 (instrument air to YV701B)	Ok
19	Check communication between YV701B and DCS (signals from valve, from DCS open/Close valve and check its correct operation, check that limit switches feedback is receives from DCS correctly)	Ok
20	Check interlock I-54: if YV701B open, interlock transformer TR701B	Ok
21	Open valve VB710 (instrument air to YV701A)	Ok
22	Check correct communication between YV701A and DCS (signals from valve, from DCS open/close valve and check its correct operation, check that limit switches feedback is received from DCS correctly)	Ok
23	Check interlock I-53: if YV701A open, interlock transformer TR701A	Ok
24	Check interlock I-58: if YV701X and YV701A/B/C/D close at the same time, trip immediately pumps	Ok
25	Open valve VB706 (instrument air to FCV705)	Ok
26	Check correct communication between FCV705 and DCS (signals from valve, from DCS set valve opening to 0%, 25%, 75%, 100% and check its correct operation, check that positioner and limit switches feedback is received from DCS correctly)	Ok
27	Check interlock I-52: if V721HH level, close valve FCV705	Ok
28	Check correct communication between FIT705A and DCS (signals from flow transmitter, simulate the 0%, 25%, 50%, 75% and 100% value and verify that DCS reads it correctly)	Ok
29	Test the functional loop FCV705-FIT705A > set point (0,5 m^3/h), the control valve FCV increases closure; if FIT705A < set point (0,5 m^3/h), the control valve	Ok
30	Check correct communication between MP701A and DCS (signals from pump motor)	Ok
31	Check correct communication between MP701B and DCS (signals from pump motor)	Ok
32	Check interlock I-77: if P701A VFD703 fault/not running, trip pump P701A and swap the pump to P701B	Ok
33	Check interlock I-78: if P701B VDF703 fault/not running, trip pump P701B and swap the pump to P701A	Ok
34	Check interlock I-79: if P701A/B, VFD703A/B, fault/not running or both in MAN and stopped, interlock blow	Ok

	down system, close valve FCV705 and make up system close valve LCV704, interlock nitric acid dosing system, close valve FCV702 and PCV709. Interlock flushing valves YY705A/B and valves YY701X, YV701A/B/C/D, YV706A/B to close. Same interlock if PTC signals TSH703A/B same interlock if signals from HS703A/B. same interlock if main fan K702 fault/not running or in MAN and stopped	
35	Check interlock I-59: if WESP plant under shutting down-sequence due to CA or ES activated, interlock the main fan	NA
36	Check correct communication between PT708A and DCS (signals/alarms from pressure transmitter, simulate the 0%, 25%, 50%, 75% and 100% value and verify that DCS reads it correctly)	Ok
37	Check correct communication between PT708B and DCS (signals/alarms from pressure transmitter, simulate the 0%, 25%, 50%, 75% and 100% value and verify that DCS reads it correctly)	Ok
38	Open valve VB707 (instrument air to YV706A)	Ok
39	Check correct communication between YV706A and DCS (signals from valve, from DCS open/close valve and check its correctly operation, check that limit switches feedback is received from DCS correctly)	Ok
40	Open calve VB708 (instrument air to YV706B)	Ok
41	Check correct communication between YV706B and DCS (signals from valve, from DCS open/close valve and check its correctly operation, check that limit switches feedback is received from DCS correctly)	Ok
42	Check interlock I-72: YV706A not open when P701A in operation trip immediately pump P701A	Ok
43	Check interlock I-76: YV706A not close when P701A stopped trip immediately pump A and B	Ok
44	Check interlock I-73: YV706B not open when P701B in operation trip immediately pump P701B	Ok
45	Check interlock I-75: YV706B not close when P701B stopped trip immediately pump A and B	Ok
46	Check interlock I-74: YV706A and YV706B close at the same time trip immediately pump	Ok
47	Check correct communication between FIT/DIT705B and DCS (signals from pH/temperature transmitter, simulate the 0%, 25%, 50%, 75% and 100% value and verify that DCS reads it correctly)	Ok
48	Check interlock I-70: if FIT705BLL, interlock the nitric acid dosing system. Force valve FCV702 and PCV709 to close	Ok

49	Check interlock I-71: if DIT705BHH, open valve FCV705	Ok
50	Check correct communication between PHIT/TIT702 and DCS (signals from pH/temperature transmitter, simulate the 0%, 25%, 50%, 75% and 100% value and verify that DCS reads it correctly)	(4)
51	Test the functional loop PHIT702-FCV702 (HNO_3 dosing flow control) by simulating the process variable of PHIT702 from field or DCS. If PHIT702 > set point (6), the control valve FCV702 increases opening; if PHIT702 < set point (6), the control valve FCV702 decreases opening	Ok
52	Check interlock I-69: if PHIT702 fault, interlock the nitric acid dosing system. Close valve FCV702 and PCV709	Ok
53	Check correct communication between FIT704 and DCS (signals from flow transmitter, simulate the 0%, 25%, 50%, 75% and 100% value and verify that DCS reads it correctly)	Ok
54	Test the functional loop VFD701A/B-FIT704 (WESP pump control) by simulating the process variable of FIT704 from field or DCS. If FIT704 > set point (450 m^3/h), VFD701A/B rate decreases; if FIT704 < set point (450 m^3/h), VFD701A/B rate increases	Ok
55	Check interlock I-51: if FIT704LL, trip immediately pumps	Ok
56	Check interlock I-65: if YY705A/B close at the same time, trip immediately pumps	Ok
57	Check interlock I-63: if YY705A close when pump P701A is running, trip immediately pump P701A and swap the pump P701B	Ok
58	Check interlock I-62: if FIS705ALL, pump P701A forced to stop. Trip pump P701A and swap the pump to P701B	Ok
59	Check interlock I-64: if YY750BLL, pump P701B is running, trip immediately pump P701B and swap the pump P701A	Ok
60	Check interlock I-80: if FIS750BLL, pump P701B forced to stop. Trip pump P701B and swap the pump to P701A	Ok
61	Check interlock I-81: if FIS750A/BLL at the same time, pumps P701A/B forced to stop	Ok
62	Open valve VF212 and VF220	Ok
63	Check liquid is present in pump suction lines (LSL703A and LSL703B not activated)	Ok
64	Check that all blind flanges have been removed and routing towards absorption trays is free and open	Ok
65	Check that temporary strainers installed on pump suction lines	Ok

66	Check that splash guards are installed	Ok
67	Open valve VB388 (recirculation to WESP bottom)	Ok
68	Close valve VB345 and VV248	Ok
69	Open valve VF250 (recirculation to WESP top)	Ok
70	Check that valve YV701X is open (recirculation to WESP top)	Ok
71	Close valve VF252, VF266, VF264 and VF251 (washing lines)	Ok
72	Open valve VF240	Ok
73	Open valve YV706YA	Ok
74	Open valve VF226	Ok
75	Open valve VB271	Ok
76	Open valve VB281	Ok
77	Close valve VB270	Ok
78	Close valve VB283	Ok
79	Open valve VB288	Ok
80	Open valve VV229	Ok
81	Close valve VB282	Ok
82	Open valve YV705A (seal flushing)	Ok
83	Check pumps are filled with lubricant oil	Ok
84	Start in manual (MAN mode) pump MP701A and check FIT704 flowrate (set point 450 m^3/h). test start/stop pump from DCS	(3)
85	Verify that pump is operating correctly in LOC mode, using the VFD	Ok
86	Verify that flowrate and pressure of pump are within operating curve diagram	(3)
87	Verify that no abnormal vibrations or noise is present	(3)
88	Stop pump MP701A	Ok
89	Open valve YV705B (seal flushing)	Ok
90	Open valve VF242	Ok
91	Open valve YV706B	Ok
92	Open valve VF214	Ok
93	Close valve YV706A	Ok
94	Start in manual (MAN mode) pump MP701B and check FIT704 flowrate (set point 450 m^3/h). test start/stop pump from DCS	(3)
95	Verify that pump is operating correctly in LOC mode, using the VFD	Ok
96	Verify that flowrate and pressure of pump are within operating curve diagram	(3)
97	Verify that no abnormal vibrations or noise is present	(3)
98	Put all items in AUTO	Ok
99	Simulate the signal of exhaust fan ready to start/run K702	Ok
100	Check all permissive for starting	Ok
101	Verify that start up sequence proceeds correctly	Ok

102	Verify that start up sequence automatically stops when a critical alarm occurs during start up	Ok
103	Verify that pump swap sequence proceeds correctly	Ok
104	Verify that washing sequence proceeds correctly	Ok
105	Operate the system in normal mode for 2 hours as test run, with no malfunctions or unexpected alarms and check the temporary strainers if there is some dirtiness	Ok
Shut-down		
1	Verify that shut down sequence proceeds correctly	Ok
2	Verify that critical instant alarms bring the system to shut down procedure	Ok

The notes reported are:

1. To be provided by AWS after the start up
2. Check the value at DCS
3. Supply valve to increase the pressure and decrease vibrations
4. Alarn on local display

OTP-C1-04

PREPARATION WORKS		
STEP	TASK DESCRIPTION	STATUS
1	TBD by commissioning team: prepare a list of temporary items to be able to perform the commissioning	-
2	Close valve V087	Ok
3	Close valve V090	Ok
4	Close valve VB302	Ok
5	Instrument air system already commissioned and in operation	Ok
6	Open Tie-in 05	Ok
7	Application of LOTO to block in close position the Tie-in valve after commissioning tests	Ok

COMMISSIONING PROCEDURE		
STEP	TASK DESCRIPTION	STATUS
Electric power supply		
1	Energize the systems equipment from power center	Ok
2	Energize instruments of the systems	Ok
Process condensates to buffer tank pumps		
1	Check correct communication between FSL710 and DCS (signals from flow transmitter)	Ok
2	Check correct communication between FSL711 and DCS (signals from flow transmitter)	Ok
3	Close valve VB298	Ok
4	Open valve V098	Ok
5	Open valve V096	Ok

6	Open valve V097	Ok
7	Open valve V093	Ok
8	Open valve V091	Ok
9	Open valve V090	Ok
10	Check FDL710 and PI715	Ok
11	Check FSL711 and PI716	Ok
12	Close valve V098	Ok
Process condensates to WESP skids		
1	Check correct communication between PI710 and DCS (signals from pressure transmitter)	Ok
2	Open valve VB702 (instrument air to LCV704)	Ok
3	Check correct communication between LCV704 and DCS (signals from valve from DCS set valve opening to 0%, 25%, 50%, 75%, 100% and check its correct operation, check that positioner and limit switches feedback is received from DCS correctly)	Ok
4	Close valve VB205	Ok
5	Close valve VV333	Ok
6	Open valve VB306	Ok
7	Open valve VB307	Ok
8	Check open/close valve YY705A from DCS	Ok
9	Check open/close valve YY705B from DCS	Ok
10	Open valve VB390	Ok
11	Open valve VB302	Ok
12	Check pressure value of PI750A	Ok
13	Check pressure value of PI750B	Ok
14	Open drain point of pump P701A and test FIS750A	Ok
15	Open drain point of pump P701B and test FIS750B	Ok
16	Close valve YY705A	Ok
17	Close valve YY705B	Ok
Process condensate to exhaust fan K702		
1	Close valve V088 and V089	Ok
2	Open valve V087	Ok
3	Open valve V088and V089 and test arrive of process condensates to fan K702	Ok
4	Close valve V088 and V089	Ok
5	Drain the fan casing	Ok

Note: it was also carried out the leak test.

OTP-C1-05

PREPARATION WORKS		
STEP	TASK DESCRIPTION	STATUS
1	List of temporary items to be able to perform the commissioning: flexible hose ¾” 5 m long and flexible hose ¾” 20 m long	-
2	Application of LOTO to block in close position the Tie-in valve 01A and 01B	Ok
3	Application of LOTO to block in close position valve VB204	(1)
4	Connect the flexible hose to NAS pump for demi water	Ok
5	With a flexible hose connect the VB349 to the sewer	Ok
6	Connect a flexible hose to service nitrogen Tie-in	(2)
7	Instrument air system already commissioned and in operation	Ok
8	Remove the flange guards	Ok

COMMISSIONING RPOCEDURE		
STEP	TASK DESCRIPTION	STATUS
Electric power supply		
1	Energize the system equipment from power center	Ok
2	Energize instrument of the systems	Ok
Nitric acid to WESP		
1	Open valve VB704 (instrument air to PCV709)	Ok
2	Check correct communication between PCV709 and DCS (signals from valve, from DCS set valve opening to 0%, 25%, 75%, 100% and check its correct operation, check that positioner and limit switches feedback is received from DCS correctly)	Ok
3	Check correct communication between PIT709 and DCS (signals from pressure transmitter)	Ok
4	Test the functional loop PIT709 and PCV709 (nitric acid pressure control) by simulating the process variable of PIT709 from field or DCS. If PIT709 > set point, the control valve PCV709 increases closure; if PIT709 < set point, the control valve PCV709 decreases closure	Ok
5	Open valve VB703 (instrument air to FCV702)	Ok
6	Check correct communication between FCV702 and DCS (signals from valve, from DCS set valve opening to 0%, 25%, 75%, 100% and check its correct operation, check that positioner and limit switches feedback is received from DCS correctly)	Ok
7	Check correct communication between FIT702 and DCS (signals from magnetic flow transmitter)	Ok
8	The functional loop PHIT702 and FCV702 is tested in commissioning procedure of WESP OTP-C1-03	Ok
9	Open valves (manual and pneumatic) on the line	Ok

10	Open all drains on the line	(3)
11	Fill the demi water from valve V179	Ok
12	Close the drains during the filling and leave open only the VB349	Ok
13	Flush the line until the water is clean (visual check)	Ok
14	Close the valve VB349	Ok
15	Check the pressure from PIT709 and fill until about 3 bar	Ok
16	Close valve V179	(2)
17	Disconnect the V179 from demi water and connect the flexible hose of service nitrogen	(2)
18	Pressurize the line with nitrogen to 6 bar	(2)
19	Wait the pressure is stable (leave the V179 open)	Ok
20	Visual check of any leak	Ok
21	Close the V179 and check the pressure from PIT709 for 30 min without pressure drops	Ok
22	Drain the line by opening the VB349	(4)
23	Open V179 (connect with nitrogen)	(2)
24	Open all drains and leave the V179 open until no water is coming out from drains	(4)
25	Close the drain caps and reinstall the flange guards	Ok
26	Close the bypasses	Ok
27	Close valve V179	Ok
28	Disconnect the flexible hose	Ok
29	Close the cap of valve V179	Ok

The notes reported are:

1. It was decided to send demi water to the suction line of pump P701A/B so the valve have to be maneuverable
2. It was decided to use demi water to unavailability of nitrogen due to the stop of NAS plant
3. It was decided to maintain close drains due to current antiacid treatment
4. It was decided to leave the line depressurize but with the water inside
5. All the seals had been changed in the AN line because the once installed by AWS were of Teflon. They were substituted with seals of KWO by Yara

OTP-C1-06

PREPARATION WORKS		
STEP	TASK DESCRIPTION	STATUS
1	List temporary items to be able to perform the commissioning: two flexible hose ¾” 20 m long and a manometer 0-10 bar ½”	-
2	Application of LOTO to block in close position the Tie-in valve 06	Ok
3	Application of LOTO to block in close position valve V003	Ok
4	Connect the flexible hoses to nearest service nitrogen Tie-in	Ok
5	Connect the flexible hoses for service nitrogen to the V006	Ok
6	Install the manometer at V005	Ok
7	Instrument air system already commissioned and in operation	Ok
8	Remove the flange guards	Ok

COMMISSIONING PROCEDURE		
STEP	TASK DESCRIPTION	STATUS
Electric power supply		
1	Energize the system equipment from power center	Ok
2	Energize instruments of the systems	Ok
Aqueous ammonia 15% to heater E722		
1	Open valve of instrument air to PHV701	Ok
2	Check correct communication between PHV701 and DCS (signals from valve, from DCS set valve opening to 0%, 25%, 75%, 100% and check its correct operation, check that positioner and limit switches feedback is received from DCS correctly)	Ok
3	Check correct communication between FT701 and DCS (signals from flow transmitter)	Ok
4	The functional loop PHT701 and PHV701 is tested in commissioning procedure of WESP OTP-C1-02	Ok
5	The interlock I-02 between FT702 and PHV701 is tested in commissioning procedure of WESP OTP-C1-02	Ok
6	Open valve V002	Ok
7	Fill the line with nitrogen from V006	Ok
8	Read the pressure on the manometer and stop the filling to 6 bar	Ok
9	Perform a check of any leak with soapy water	Ok
10	Close the V006	Ok
11	Check the pressure from manometer for 30 min without pressure drops	Ok
12	Depressurize the hose from vent which is present in the service Tie-in	Ok

13	Disconnect the hose from V006	Ok
14	Depressurize the aqueous ammonia line by operating the V006	Ok
15	Close cap of V006	Ok
16	Remove the manometer	Ok
17	Close cap of V005	Ok

OTP-C1-07

PREPARATION WORKS		
STEP	TASK DESCRIPTION	STATUS
1	List of temporary items to be able to perform the commissioning	Ok
2	To install the manometer on a spare utility available on the manifold after V178	NA
COMMISSIONING PROCEDURE		
STEP	TASK DESCRIPTION	STATUS
Electric power supply		
1	Energize the PIT711	Ok
Instrument air to buffer tank, filter and heater		
1	Close the valve V072	NA
2	Open the valve V178	NA
3	Close all the utilities on the manifold	NA
4	Open the discharge valve of manifold	NA
5	Open a little the Tie-in 10	Ok
6	Check that air which exit from the manifold discharge is without humidity ad solid particles	NA
7	Close the discharge valve of manifold	NA
8	Read the pressure on the manometer until it arrives to the net pressure (about 5 bar)	NA
9	Open completely the Tie-in 10	Ok
10	Check if there is some leak on the line with soapy water	NA
11	Open one by one the utilities on manifold and check that no leaking on tubing	NA
12	Leave the line pressurized and the manometer installed	NA
Instrument air to WESP		
1	Check correct communication between PIT711 and DCS (signals from pressure transmitter)	Ok
2	Open the valve VB300	Ok
3	Open the valve VB301 (isolation valve of PIT711)	Ok
4	Close all the utilities on the manifold	Ok
5	Open the discharge valve of manifold	Ok
6	Open a little the valve V072	Ok
7	Check that air which exit from the manifold discharge is without humidity ad solid particles	Ok
8	Close the discharge valve in manifold	Ok

9	Read the pressure on the manometer PIT711 until arrives to the net pressure (about 5 bar)	Ok
10	Open completely the valve V072	Ok
11	Check if there is some leak on the line with soapy water	Ok
12	Open one by one the utilities on manifold and check that no leaking on tubing	Ok
13	Leave the line pressurized	Ok

OTP-C1-08

COMMISSIONING PROCEDURE		
STEP	TASK DESCRIPTION	STATUS
Potable water to safety showers		
1	Open the gate valve up-steam the safety shower (V099 and V193)	Ok
2	Leave the eye wash and shower open	(1)
3	Open the valve V100 completely	Ok
4	Open Tie-in 21	Ok
5	Check if the water coming out from the safety showers is clean	Ok
6	Close the eye wash and shower	(1)
7	Visual check of possibility leaks	Ok
8	Leave the line pressurized	Ok

The notes reported are:

1. Safety showers not yet installed. The safety showers remain to be tested

OTP-C1-09

PREPARATION WORKS		
STEP	TASK DESCRIPTION	STATUS
1	Check that all the utility stations are closed	Ok

COMMISSIONING PROCEDURE		
STEP	TASK DESCRIPTION	STATUS
Service air to utility stations		
1	Open the valve (V155) up-steam the utility station at higher level (+20540)	Ok
2	Open a little the valve V001	Ok
3	Open the Tie-in 23	Ok
4	Check if the air coming put from the utility station is clean without dirt	Ok
5	Close the utility station at elevation +20540	Ok
6	Open completely the valve V001	Ok
7	Check if any leaks with soapy water	Ok
8	Open one by one the other utility station from higher elevation to lower elevation and check the air is coming out	Ok

9	Close the utility station after test	Ok
10	Leave the line pressurized	(1)

The notes reported are:

1. The line is left depressurized and the Tie-in was closed with a mechanical LOTO

OTP-C1-10

PREPARATION WORKS		
STEP	TASK DESCRIPTION	STATUS
1	Check that all the utility stations are closed	Ok

COMMISIONING PROCEDURE		
STEP	TASK DESCRIPTION	STATUS
Service nitrogen to utility stations		
1	Open the gate valve (V133) up-steam the utility station at higher level (+20540)	Ok
2	Open a little the valve V086	Ok
3	Open Tie-in 24	Ok
4	Check if nitrogen coming out from the utility station is clean without dirt	Ok
5	Close the utility station at elevation +20540	Ok
6	Open completely the valve V086	Ok
7	Check if any leaks with soapy water	Ok
8	Open one by one the ither utility station from higher elevation to lower elevation and check the nitrogen is coming out	Ok
9	Close the utility station after test	Ok
10	Leave the line pressurized	(1)

The notes reported are:

1. The line is left depressurized and the Tie-in was closed with a mechanical LOTO

OTP-C1-11

PREPARATION WORKS		
STEP	TASK DESCRIPTION	STATUS
1	Material to prepare: hose ¾" for connection with utility station (max elevation +20540) to ground floor	Ok
2	Check all the utility stations are closed	Ok
3	To connect a hose from the utility station to test which are in elevation (the utility stations will be testes one by one) to ground floor	Ok

COMMISSIONING PROCEDURE		
STEP	TASK DESCRIPTION	STATUS
1	Open the gate valve (V169) up-steam the utility station at higher level (+20540)	Ok

2	Open a little the valve V070	Ok
3	Open The Tie-in 25	Ok
4	Check if demi water coming out from the utility station is clean without dirt (the hose should be already connected from the utility station to ground floor. After the test of this utility station, connect the hose to the utility station at the elevation below)	Ok
5	Close the utility station at elevation +20540	Ok
6	Open completely the valve V070	Ok
7	Visual check if any leaks	Ok
8	Open one by one the other utility station from higher elevation to lower elevation and check the demi water is coming out clean	Ok
9	Close the utility station after test	Ok
10	Leave the line pressurized	Ok

The notes reported are:

- Safety tags on utility stations installed
- Connectors for hose installed on utility stations (provided by Yara)

OTP-C1-12

PREPARATION WORKS		
STEP	TASK DESCRIPTION	STATUS
1	List temporary items to be able to perform the commissioning: temporary grid 130" and hose from nearest demi water utility station to VB106	Ok
2	Install of the grid on the duct at the opening of the EB005 (the EB005 is not yet installed)	Ok
3	Application of LOTO to open the electric feeding of the exhaust fan K702	Ok
4	Application of LOTO to open electric feeding of the fan MK302A/B/C/D	Ok
5	Connect the hose from demi water filling point to VB106	Ok
6	WESP vessel mechanical completed (including stack)	Ok
7	Instrument air system already commissioned and in operation	Ok

COMMISSIONING PROCEDURE		
STEP	TASK DESCRITPION	STATUS
Part I		
1	Energize instruments of the systems	Ok
2	Check correct communication between PT701 and DCS (signals from pressure transmitter)	(1)
3	Check correct communication between PT702 and DCS (signals from pressure transmitter)	Ok

4	Check correct communication between PT703 and DCS (signals from pressure transmitter)	Ok
5	Check correct communication between TT703 and DCS (signals from temperature transmitter)	Ok
6	Check correct communication between K702 instruments and DCS (signals from temperature/vibration transmitters): ZAL781, ZAH782, TT781, TT782, TT783, TT784, VT781, VT782, LT781A/B/C, TE793, TT794, TT785, TE786, VT783, VT784	Ok
7	Check correct communication between MK702 and DCS (signals from exhaust fan motor)	Ok
8	Check with simulator trip T-01: HH vibration velocity motor drive side bearing (VAHH783 active) or HH vibration velocity motor non drive side bearing (VAHH784 active)	Ok
9	Check with simulator trip T-05: HH vibration velocity motor drive side bearing (VAHH782 active) or HH vibration velocity motor non drive side bearing (VAHH781 active)	Ok
10	Check with simulator trip T-08: HH temperature fan drive side bearing (TAHH781/TAHH782 active) or HH temperature motor non drive side bearing (TAHH783/TAHH784 active)	Ok
11	Check with simulator trip T-09: HH temperature fan drive side bearing (TAHH785/TAHH786 active) or HH temperature motor non drive side bearing (TAHH793/TAHH794 active)	Ok
12	Check with simulator trip T-10: HH motor winding temperature (TAHH787/788/789/790/791/792)	Ok
13	Check that all manholes on WESP vessel are closed	Ok
14	Check that all manholes on the duct are closed	Ok
15	Check that the exhaust fan casing and impeller is clean (absence of foreign material)	Ok
16	Close inspection doors of exhaust fan	Ok
17	Check that lubricant of exhaust fan is present	Ok
18	If in the WESP bottom there is no water, close the valve VF200 and VB288 and all the drains	Ok
19	From valve VB106 fill the demi water until water is coming out from drain	Ok
20	Close valve YV701X/A/B/C/D	Ok
21	Close the valve of blowers V112…V127	Ok
22	Energize the systems equipment (remove the LOTO for exhaust fan K702)	Ok
23	Remove LOTO to supply electricity to exhaust fan	Ok
24	Start the fan with minimum speed	Ok
25	Check the pressure from pressure transmitters	Ok
26	Increase speed until max value of pressure in the duct	(2)

27	Check vibration and temperature	Ok
28	Check eventual leaks on EB007	-
29	Stop the fan after 1 hour running	Ok
Part II		
1	Check correct communication between PT707 and DCS (signals from pressure transmitter)	(2)
2	Check correct communication between PT704 and DCS (signals from pressure transmitter)	(3)
3	Check correct communication between PT705 and DCS (signals from pressure transmitter)	(3)
4	Check correct communication between PT706 and DCS (signals from pressure transmitter)	(3)
5	Check correct communication between MK302A and DCS (signals from fan motor)	Ok
6	Check correct communication between MK302B and DCS (signals from fan motor)	Ok
7	Check correct communication between MK302C and DCS (signals from fan motor)	Ok
8	Check correct communication between MK302D and DCS (signals from fan motor)	Ok
9	Check interlock I-01 between K302A/B/C/D and K702: fan K302A/B/C/D shall stop if fan K702 stops (motor status CIPK702 not active) and fan K302A/B/C/D can start if K702 is confirmed running (motor status CIPK702 active)	Ok
10	Check that all manholes on the duct are closed	Ok
11	Check no persons are present in the bottom of prilling tower	Ok
12	Check door in the bottom of prilling tower is closed	Ok
13	Remove LOTO to supply electricity to fan MK302A/B/C/D	Ok
14	Start exhaust fan K702	(4)
15	Start one by one MK302A/B/C/D	Ok
16	check the pressure from pressure transmitters	(5)
17	Test variation of speed of MK302A/B/C/D	Ok
18	Check, if possible, eventual leaks on EB005	-
19	Stop fan MK302A/B/C/D and exhaust fan K702 after 1 hour running	Ok

The notes reported are:

1. No communication with DCS that has been solved
2. 600 rpm
3. Negative value when the fan goes
4. Maximum speed 670 rpm

5. DP and water flowrate do not correspond to the design values (320 mmH_2O as WESP input while the design value is 200 mmH_2O while the flowrate is 420000 m^3/h instead of the design value 560000 m^3/h)

Thanks to the positive results of the commissioning, it has been possible to proceed with the start-p of the plant.

CHAPTER 4: PLANT OPERATION, RESULTS AND POST-START-UP OPTIMIZATION

4.1 PLANT OPERATION

A Wet Electrostatic Precipitator, known as WESP is an equipment designed to remove liquid and solid particles from a gas flow.
Depending on the process characteristics, a WESP could be constructed using various materials and it can be built either as a single unit or with multiple components to be assembled on-site.
All WESPs are made of:

- Inlet and distribution section
- Tube bundle
- Outlet section
- Insulator compartment and ceramic insulators
- Ionizing rods and their supports (upper/lower)
- HV transformer and grounding
- Connection system WESP – HV TR
- Purge air system

In some WESPs, the following options could also be installed:

- Washing system (continuous or intermittent)
- Heating system
- Instruments

4.1.1 Normal operation

During normal operation, the WESP does not require any special adjustments but it is advisable to monitor the progress of some operating parameters.
The parameters to be monitored are:

- Secondary voltage
- Secondary current
- Electrical discharges per minute

A stable trend of the secondary voltage and current values is a symptom of a good functioning of the WESP. The voltage and secondary current values can and should be selected according to the process type and operating conditions.
To ensure stable operation of the WESP, the number of electrical discharges per minute should be as low as possible, ideally between 0 and 10. If the number of electrical discharges per minute is more than 15 or 20 it means that you need to adjust the transformer parameters or work on some parts of the WESP.
The secondary voltage indicates the voltage at which the electrodes are located and the secondary current indicates the amount of current flowing through them. Both affect removal efficiency.
A secondary voltage which is too low does not achieve the desired efficiency but a secondary voltage which is too high can lead to an excessive number of electrical discharges per minute which could damage the WESP and transformer.
The secondary voltage can and must be adjusted according to the characteristics of the process.
The value of the secondary current generally depends on the value of the secondary voltage.
Electrical discharges or arcs occur when an electric arc is generated between the electrode and the surface of the tube beam generating a momentary short circuit.

Each time an electrical discharge or arc occurs, the voltage passes from the working voltage to zero and then returns back to the working voltage. This means that the secondary voltage trend is not stable over time and consequently reduces efficiency.
Excessive electrical discharge per minute could damage the WESP and transformer.

Design parameters

The following parameters can be modified by the operators if necessary.

PARAMETER	DESCRIPTION	RANGE	DEFAULT VALUE
T_{start} count down	Operator confirms the start-up of plant between status Partially ready and Ready	0-300 s	60 s
T_{step}	-	0-300 s	1 s
T_{wash}	WESP washing interval	0-2880 min	1440 min
T_{hwash}	WESP washing duration	0-300 min	4 min
T_{drip}	Dripping time after washing	0-300 s	240 s
T_{purge}	Purging duration	0-600 s	60 s
T_{cool}	Cooling duration	0-600 s	30 s
T_{wait}	Waiting step for malfunction at the start-up	0-600 min	25 min
T_{swap}	Swapping the pumps	0-10000 min	10000 min

Table 12

Other parameters

The following parameters can be modified by the operators if necessary.

PARAMETER	DESCRIPTION	RANGE	DEFAULT VALUE
$VFD_{speed\ FIT\ fault}$	WESP recirculation flowrate in fault – speed of the pumps P701A/B	0-1490 rpm	1200 rpm
FIT704 set point	WESP recirculation flowrate set point	0-1200 m^3/h	480 m^3/h
$VFD_{speed\ washing}$	WESP recirculation flowrate during washing – speed of the pumps P701A/B	0-1490 rpm	1200 rpm
FIT704 set point	WESP recirculation flowrate set point during washing	0-1200 m^3/h	700 m^3/h
$\%_{bleed\ fault}$	WESP bleed flowrate in fault – opening the bleed valve FCV705	0-100%	10%
$\%_{PIT\ fault}$	Nitric acid pressure transmitter in fault – opening the valve PCV709	0-100%	5%
FIT705 set point	WESP bleed flowrate set point	0-10 m^3/h	0.5 m^3/h
DIT705B set point	WESP bleed density set point	1000-1300 kg/m^3	1070 kg/m^3
PHIT702 set point	WESP recirculation pH set point	0-14	3
LIT704 & DLIT704 set point	WESP level tank set point	0-750 mm	400 mm

$P_{nitric\ acid}$	Pressure on nitric acid feeding line	0-10 bar(g)	1.5 bar(g)

Table 13

Washing system

The washing system may be continuous or intermittent and, in some cases, both systems can be installed. It is used to clean the bundle tube that contain the electrodes to maximize the efficiency of abatement in the high voltage section.

The continuous washing system is located in the inlet section and has the task of cooling the incoming gas to the WESP. In our case, we have the absorption section where the gas becomes saturated., the temperature drops and NH_3 is knocked down.

The intermittent washing system is used to clean the bundle tube that contain the electrodes to maximize the efficiency of abatement in the high voltage section. It is located near the electrode support structure and is intended to clean the interior of the WESP. The frequency and duration of washing can and must be adjusted.

The continuous washing system does not need to be adjusted.

The intermittent washing system is managed by the plant logic and its duration and frequency must be adjusted according to the characteristics of the process.

High washing frequency and duration ensure a better internal cleaning of the WESP but increase the water consumption of the plant.

Insufficient frequency and duration of washing encourage the accumulation of deposits on the walls of the tube beam and on the electrodes, increasing the number of electrical discharges per minute and favoring fouling.

In normal operation the system operates a timed wash of the WESP; the time interval between two wash cycles (T_{wash}) and can be set by the operator between 0 and 48 hours. The washing is carried out by recirculating the solution present in the bottom of the WESP and is regulated using the YV-701A/B/C/D ON/OFF automatic valves.

The wash sequence is [7]:

1. When T_{wash} timer = set point
2. Voltage stops on transformer TR701 A, valve opening YV-706 A and YY-705 A and pump start P701 A (if pump P701 B was already running or vice versa), valve opening YV-701 A; pump motor speed should work at set point $VFD_{speedwashing}$
3. Waiting for T_{step} and stopping T_{wash} timer with reset and restart
4. Closing flush valve YV-701 X
5. Wait T_{hwash}
6. Transformer stop TR701 B, wash valve opening YV-701 B
7. Waiting T_{step}
8. Closing wash valve YV-701 A, waiting T_{drip} and restarting transformer TR701 A
9. Wait T_{hwash}
10. Transformer stops TR701 C, wash valve opening YV-701 C
11. Waiting T_{step}
12. Closing wash valve YV-701 B, waiting T_{drip} and restarting transformer TR701 B
13. Wait T_{hwash}
14. Transformer stops TR701 D, wash valve opening YV-701 D
15. Waiting T_{step}
16. Closure of YV-701 C wash valve, T_{drip} standby and TR701 C transformer restart

17. Wait T_{hwash}
18. Flushing valve opening YV-701 X
19. Waiting T_{step}
20. Closing wash valve YV-701 D, waiting T_{drip} and restarting transformer TR701 D
21. Valve closure YV-706 A, YY-705 A and pump stop P701 A (if pump P701 B was already running before the wash cycle or vice versa); restoration of normal regulation of the pump still running
22. The wash sequence ends; HV ON gear resumption

From the tests on the pilot system, the WESP was inspected in the beginning and at the end of the run. There was no significant fouling and scaling visual and measurable. When the system was washed with water, there was no noticeable difference measured on the current. This was tried several times. This is an indication that the system keeps itself clean. This is probably due to the fact that the AN concentration is low and the air stream is fully saturated. The AN does therefore not stick to the walls. So, the gas that passes through the tube bundle has a self-cleaning function on the walls of the tube bundle itself (an action more evident in winter).

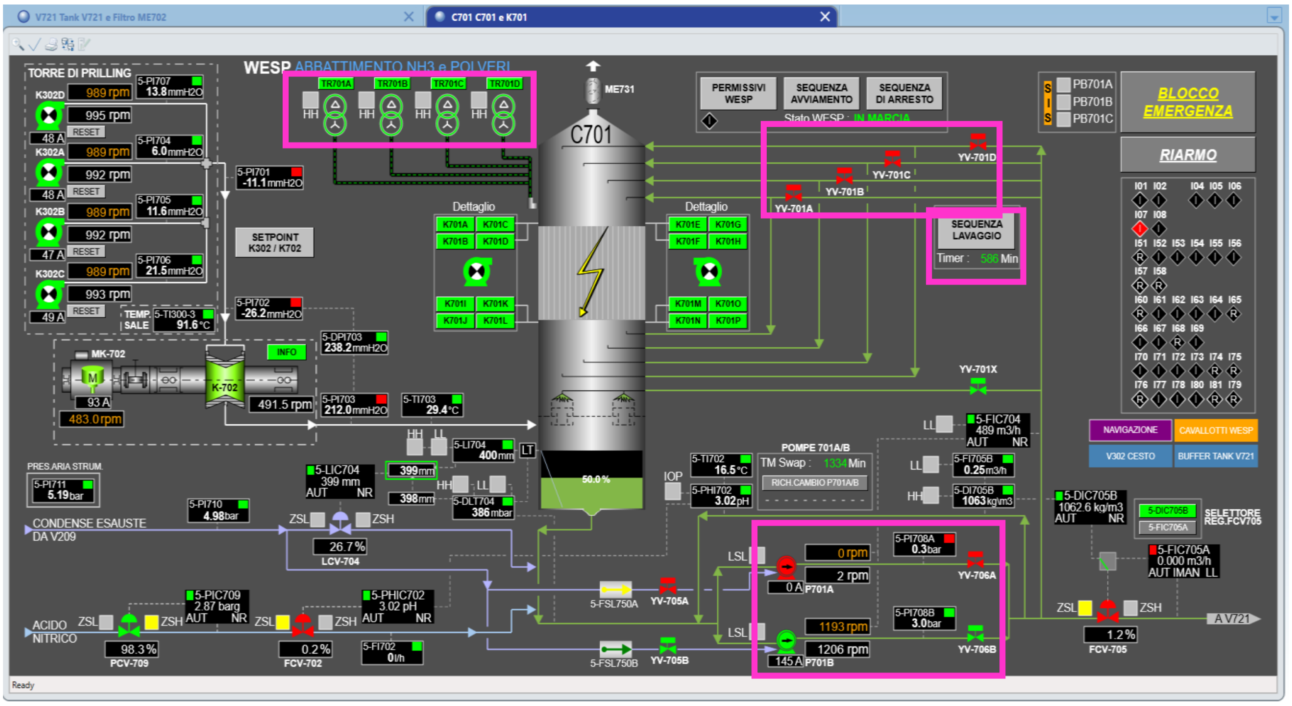

Figure 65: graphical page of DCS in which is underline the washing system. In pink are underline the main items involved in the washing system

4.1.2 Start-up

The following operations are required to start WESP:

- Check that there are no foreign objects inside the electro-filter such as tools, instruments or equipment
- Check that the ceramic insulators are intact, not broken and clean
- Check that all the sockets are closed
- Check that all ground connections are in good condition
- Follow the procedure of interlocking in reverse order to energize the transformer
- Switch on the flushing system
- Turn on the main fan

- Turn on the transformer

and, in particular, the permissive are [7]:

- Emergency stop (ES701 A, ES701 C) not active
- K702 fan ready to start
- No automatic ON/OFF or control valves in MAN or error (FCV-705, YV-701 X, YV-701 A, YV-701 B, YV-701 C, YV-701 D, FCV-702, PCV-709, LCV-704, YY-705 A, YY-705 B, YV-706 A, YV-706 B)
- Both pumps P701 A/B (or related VFD703 A/B, HS703 A/B, TSH703 A/B) in MAN/LOC or in error
- No active alarm that can interlock P701 A/B pumps
- No critical service in MAN/LOC or in error
- Valve YV-701 X open
- No WESP background level transmitter in LL or in error (at least one transmitter must be in operation)
- Level in the bottom of the WESP greater than the minimum (LIT704 and DLIT704 > L)

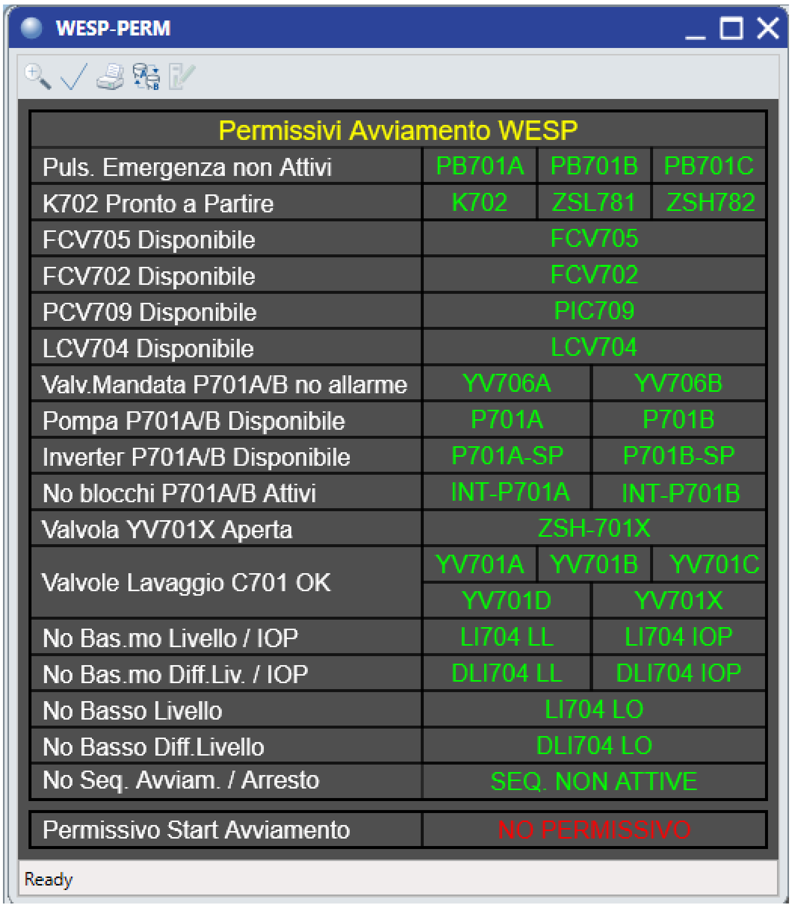

Figure 66: graphical page of DCS for permissive

The start of the system is given by the operator via DCS, acting on the "START PLANT" button. The plant goes from state Ready or Partially ready to the start-up sequence.
If the implant is ready, after pressing the start button, the implant performs a check. If there are no non-critical users in MAN/LOC mode, the implant will start immediately.

If there is at least one non-critical user in MAN/LOC mode or at least one alarm not included among the permissive or only one alarm on critical equipment, the system will be partially read. The plant will not yet be started until confirmed on DCS/HMI by the operator. Operator confirmation must be performed within a defined T_{start} countdown. Otherwise, the system returns to state Ready.

The start-up procedure is [7]:

1. Waiting for signal LIT704 and DLIT704 to be ≥ L; if level < L opens valve LCV-704 until L level is reached; if not, wait until Twait at most and then stop the start sequence
2. Waiting T_{step}
3. T_{purge} timer start
4. Starting fans K701 A/B/C/D/E/F/G/H/I/J/K/L
5. Waiting until T_{purge} = setpoint
6. Opens valve YV-706 A, YY-705 A OR YV-706 B, YY-705 B and starts respective pump P701 A OR P701 B
7. Activation of HNO_3 to WESP dosage control sequence
8. WESP exhaust control sequence activation
9. WESP make-up water control sequence activation
10. T_{purge} stops and resets
11. Starting T_{swap} timer
12. Waiting T_{step}
13. Starting K702 fan and waiting for feedback
14. Waiting T_{step}
15. Starting TR701 A/B/C/D transformers
16. Starting T_{wash} timer

Figure 67: graphical page of DCS for the start-up

Figure 68: visual impact of the start-up of the plant Starting TR701 A/B/C/D transformers

4.1.3 Shut down

To switch off the WESP follow these steps:

- Switch off the transformer
- Main fan K702 shut off
- The flushing system is switched off

If the shutdown is linked to a long-term installation or maintenance, the WESP must be secured. The shut down procedure is [7]:

1. Transformers stop
2. Waiting T_{step}
    a. Waiting for operator confirmation
3. Fan stop K702
4. Waiting T_{step}
5. Stop blow down sequence
6. Waiting T_{step}
7. Stop make-up sequence
8. Waiting T_{step}
9. pH adjustment sequence stops
10. Waiting T_{step}
11. P701 A/B pump stop and resting positioning of automatic valves
12. Waiting T_{cool}
13. Blowers stop K701 A-P
14. Waiting T_{step}
15. WESP unit stop

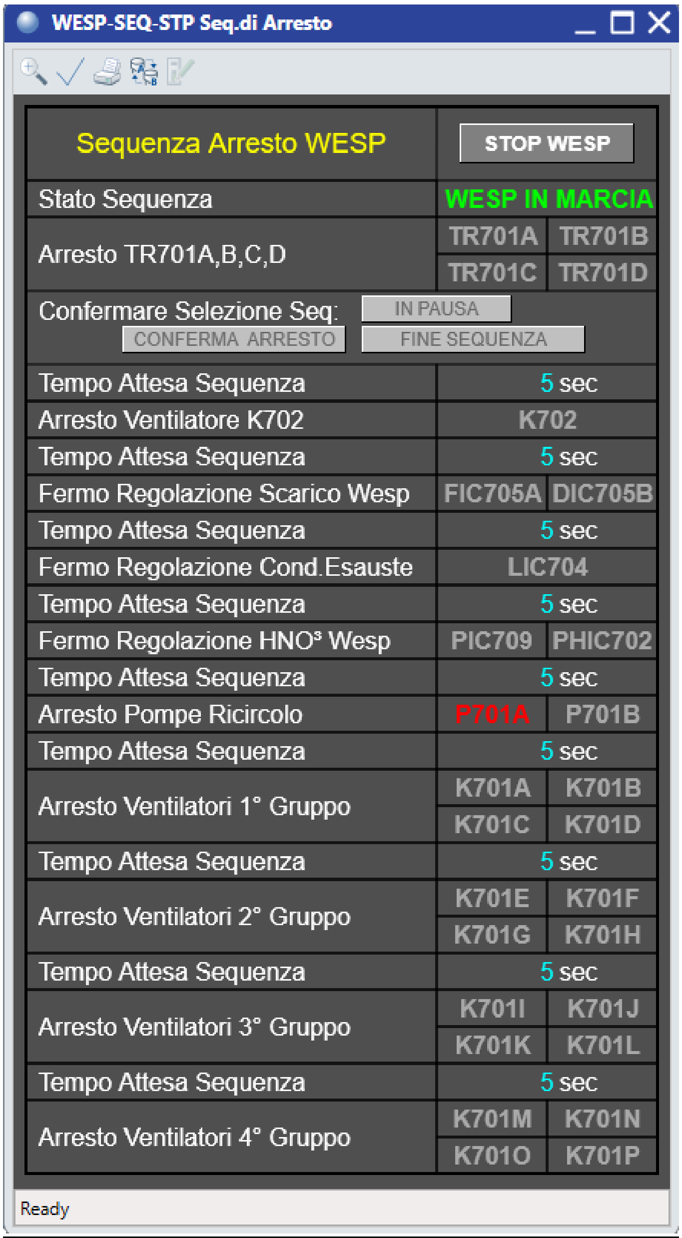

Figure 69: graphical page of DCS for the shut down

Short-term scheduled stop

A short-term stop presupposes leaving the plant ready for resumption of service.
Stopping the gas flow (fan stop K302A/B/C/D or K702) implies stopping the entire WESP.
Only P721A/B pumps can stay in recirculation mode to avoid sedimentation of solids within the V721, while downstream TIC-204, FIC-702 and PHIC-701 loops must be deactivated.
For the scheduled short-term stop, the following procedure will be observed:

- Stop fans K302 A/B/C/D
- Shutdown sequence until the end
- Disable FIC-702, TIC-204, PHIC-701 loops
- Make sure the ME702 filter is not by-passed, otherwise close manual by-pass valve

Long-term scheduled stop

In the shut down for a long period, or in the case of an internal maintenance of the equipment, after stopping the system following the shutdown procedure, the P721A/B pumps must also be stopped and the system must be emptied.

To recover the solution as much as possible, the drainage of the WESP and the V721 tank can be carried out mostly via the relevant circulation pumps (P701A/B and P721A/B), so that the solution is sent from WESP to V721 and from this to V203.

In order to drain almost all the liquid through the circulation pumps, these must be managed locally with manual operation, thus disinhibiting the relevant trips and, in particular, the trip for very low suction levels.

Following the reported procedure:

- Align the circuits for drainage operations by closing/opening the appropriate manual shut-off valves
- Open vents
- Start-up of a circulation pump (P701 A or B and P721 A or B), with the delivery valve only partially open so as to have a flow rate lower than the maximum flow rate of the pump
- Carefully follow the lowering of levels within the WESP and within the V721 tank
- As soon as there is no knocker on the pump suction, stop it to avoid cavitation
- Complete emptying of appliances and lines

If maintenance work needs to be done inside the equipment, it must, after drainage, be flushed first with water and then with air before opening the manholes.

Emergency shut down

Besides what has already been described, the causes that generate an emergency situation are [7]:

- Lack of instrument air: the following valves in the system assume the closed position:
  - YV-706 A/B in P701 A/B pump delivery
  - YV-701A/B/C/D on WESP washing lines
  - FCV-705 for WESP blow down
  - LCV-704 for WESP make-up
  - PCV-709 and FCV-702 for nitric acid entry
  - FV-702 for Filtered Solution Output
  - TV-204 for steam input to heater E722
  - PHV-701 for the addition of AW to the filtered solution

  In this case, YV-701 X on recirculation line is assumed in the opening position.

  The lack of instruments air, therefore, causes the WESP to trip and it is necessary to stop the K302A/B/C/D and K702 fans.

  In these conditions the system is completely stopped and the operator will, however, have to check that no anomalous situations arise and, if necessary, intervene adequately, acting, if necessary, on the manual valves
- Lack of electricity: the lack causes all machines (fans, WESP, pumps) to stop and does not, however, cause the valves to close.

  In these conditions the system is completely stopped and the operator will, however, have to check that no anomalous situations arise and, if necessary, intervene adequately, acting, if necessary, on the manual valves

- External causes: refer to YARA emergency procedures; it is important to decide as soon as possible whether to proceed with a total or partial stop in the affected area. In any case, it is advisable to proceed immediately with the suspension of operations

4.2 VERIFICATION OF EQUIPMENT AND PERFORMANCE

4.2.1 Analysis of results of emission in air

The samplings are made in particular with three specific productions:

- AN 33.2%: stabilized by the contract because AWS does not guarantee the performances of the adsorption trays. It is necessary to specify that for reasons related to production and thermal load in the prilling tower, only two out of four extraction fans were used before the WESP installation. This is because the grains are too small so, the product will get very cold, giving quality problems. For this reason, the load will be lowered. After the WESP installation the same result will be achieved lowering down the speed of the K302A/B/C/D fans, all of them in operation
- AN 34: stabilized by the contract and because is the critical production for the development of dust
- CAN 24/15 SO_3: is the critical production for the development of ammonia

SAMPLING BEFORE WESP					
PARAMETER	VALUE				UNIT
AN 33.2%					
Chimney	A	B	C	D	
Average T in pipeline	/	41 ± 1	/	47 ± 1	°C
Average smoke speed	/	14.1 ± 0.6	/	13.4 ± 0.5	m/s
Average normalized wet flowrate	/	138166 ± 6867	/	130254 ± 6474	Nm^3/h
Average normalized dry flowrate	/	128166 ± 6987	/	128652 ± 6520	Nm^3/h
Dust	/	**25.8 ± 4.0**	/	**23.4 ± 3.6**	mg/Nm^3
NH_3	/	**1.4 ± 0.1**	/	**2.28 ± 0.16**	mg/Nm^3
AN 34					
Chimney	A	B	C	D	
Average T in pipeline	38.7 ± 0.46	40.1 ± 0.46	39.4 ± 0.46	45.8 ± 0.49	°C
Average smoke speed	13.25 ± 0.31	13.34 ± 0.31	13.42 ± 0.31	14.53 ± 0.34	m/s
Average normalized wet flowrate	132478 ± 3801	132747 ± 3809	133863 ± 3841	142151 ± 4079	Nm^3/h
Average normalized dry flowrate	130583 ± 3823	131114 ± 3837	132217 ± 3869	140403 ± 4108	Nm^3/h
Dust	**23.7 ± 2.4**	**18.0 ± 1.8**	**18.4 ± 1.9**	**22.9 ± 2.2**	mg/Nm^3
NH_3	**1.1 ± 0.2**	**6.9 ± 0.5**	**6.74 ± 0.42**	**1.22 ± 0.18**	mg/Nm^3

CAN 24/15 SO_3					
Chimney	A	B	C	D	
Average T in pipeline	22.5 ± 0.4	17.1 ± 0.4	16.5 ± 0.4	22.8 ± 0.4	°C
Average smoke speed	12.5 ± 0.6	13.1 ± 0.6	13.1 ± 0.6	13.2 ± 0.5	m/s
Average normalized wet flowrate	130806 ± 3754	138600 ± 3977	138771 ± 3982	137967 ± 3959	Nm^3/h
Average normalized dry flowrate	128452 ± 3765	136382 ± 3885	136689 ± 4003	136689 ± 3991	Nm^3/h
Dust	**12.0 ± 1.2**	**12.3 ± 1.2**	**11.1 ± 1.1**	**12.2 ± 1.2**	mg/Nm^3
NH_3	**8.9 ± 0.7**	**9.1 ± 0.7**	**7.1 ± 0.6**	**6.4 ± 0.5**	mg/Nm^3

SAMPLING AFTER WESP		
PARAMETER	VALUE	UNIT
AN 33.2%		
Average T in pipeline	21.00 ± 0.38	°C
Average smoke speed	16.74 ± 0.39	m/s
Average normalized wet flowrate	395306 ± 11343	Nm^3/h
Average normalized dry flowrate	387136 ± 11358	Nm^3/h
Dust	**0.16 ± 0.02**	mg/Nm^3
NH_3	**0.41 ± 0.08**	mg/Nm^3
AN 34		
Average T in pipeline	16.00 ± 0.36	°C
Average smoke speed	24.20 ± 0.57	m/s
Average normalized wet flowrate	585952 ± 16813	Nm^3/h
Average normalized dry flowrate	572475 ± 16808	Nm^3/h
Dust	**0.68 ± 0.03**	mg/Nm^3
NH_3	**0.99 ± 0.18**	mg/Nm^3
CAN 24/15 SO_3		
Average T in pipeline	15.0 ± 0.35	°C
Average smoke speed	23.92 ± 0.59	m/s
Average normalized wet flowrate	578883 ± 16611	Nm^3/h
Average normalized dry flowrate	567691 ± 16648	Nm^3/h
Dust	**0.66 ± 0.16**	mg/Nm^3
NH_3	**2.79 ± 0.51**	mg/Nm^3

4.2.2 Detected issues

Oscillation of the recirculation flow rate value

In the start-up phase, the measured recirculation flow rate had many oscillations with peaks of up to 0. The problem is that there is a plant trip due to the low flow rate of the recirculation solution to protect the pumps. When the flow rate was below the threshold it trips the WESP, therefore an excessive series of trips occurred over 2 hours of testing. This occurs especially with the production of CAN 24/15 SO3 and CAN26. The trip has no delay and the magnetic flow meter has been installed in the highest part of the skid so if there is bubble formation they accumulate near the instrument and it trips immediately. To make sure that the oscillations are not real, we rely on other tags: the speed of the pump P701A/B is fixed, the motor amperage is constant, the pressure in the discharge is constant, the flow rate of the solution that goes to the pH-meter, which is in the discharge of the pumps, is constant so, there is no reason why the recirculation solution flow oscillates that much.
The oscillations were therefore due to the formation of bubbles due to the reaction between nitric acid and the diluent coming from the NAS, a reaction that occurred directly in line. Since nitric acid is dosed according to the suction of the pumps and since the meter is right on the delivery, bubbles accumulate on the flow meter. To solve the problem, it is therefore decided to work with excess acid (pH=3) to ensure that the reaction occurs in the WESP and that the bubbles are released there. In any case, a trip delay has been added so the WESP goes into trip if you go below the threshold for more than 30s.

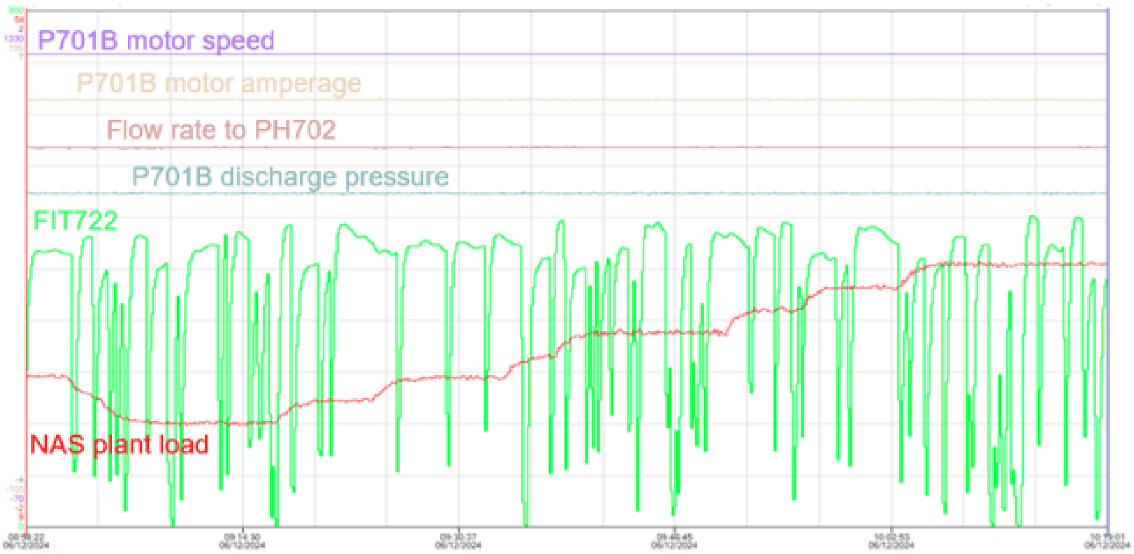

Figure 70: oscillation in recirculation solution flow rate

Fouling inside the prilling tower

After some' time, fouling of the interior walls of the prilling tower occurred. The air in the prilling tower is sucked in by the four K302A/B/C/D fans and the K702, therefore by varying the number of revolutions of the K702 fan the air entering the tower is varied. Initially there was a fixed number of revolutions of the K702, however due to the nature of the fan if the temperature of the aspirated gas changes, the aspirated flow rate also changes, with the same number of revolutions. Over time the external temperature increased so the quantity of air sucked into the tower decreased and part of the drops that fell from the basket reached the walls and bottom which were not yet perfectly solidified. This led to the dirt. To solve the problem, the philosophy of the system had to be changed: the aspirated flow rate must therefore be fixed instead of the number of revolutions. Since there is no gas flow meter, an automatic engine speed controller (PIC703) based on the delivery pressure of the K702

(PI703) fan has been introduced, as the flow rate is linked to pressure drops. Checking the PI703 makes strong approximations:

- The pressure drops in the WESP never increase when washing once a day and assuming the dishes don't plug
- No consideration is given to the dependence of pressure drops on temperature

The value of the PI703 (210 mmH_2O) was decided starting from an attempt value (according to the design) and samples were made to see if the flow rate value corresponded to the expected one (580000 Nm^3/h). It should be kept in mind that with the variation in temperature and production the value of the PI703 may change.

Figure 71: fouling inside the prilling tower

4.2.3 Performance and optimization test

Performance test

Performance testing was carried out for two grades, AN 33.2% and AN 34.
For each grade the period between two WESP washing cycles was chosen as reference period.
WESP washing is carried out every 24 hours at around 2:00 AM-3.00AM as agreed after startup for the period until performance test completion.
Flowrate and emission measurement were performed by external certified contractor.
For the 100% air flowrate (AN 34 grade), the stack emission shall contain maximum:

- 5 mg/Nm^3 (dry air) for NH3
- 5 mg/Nm^3 (dry air) for dust

For the 50% air flowrate (AN 33.2% grade), the stack emission shall contain maximum:

- 10 mg/Nm^3 (dry air) for NH_3
- 5 mg/Nm^3 (dry air) for dust

The guaranteed pressure drop is 21 mbar over the complete package, including the cyclonic demister, in clean conditions (initial operation) at nominal flow conditions.
During the performance test, some alternative parameters/measurements have also been used when direct measurements were not practically possible.
It was not possible to rely on the fan K702 curves to confirm the measured flowrate due to so far unexplainable discrepancy between actual behaviour and predicted curves.

The acceptable flowrates are:

- 387136 $Nm^3/h \pm$ 11358 dry basis for AN 33.2%
- 572475 $Nm^3/h \pm$ 16808 dry basis for AN 34

The maximum water content of the washing solution is 90%. This parameter indirectly assessed through the online measurement of the density DIT705. A measured density of 1060 kg/m^3 or above ensures that there will be less than 90% water in the washing solution.
The accepted washing solution densities are:

- 1069.1 $\pm$ 2.2 kg/m^3 for AN 33.2%
- 1069.0 $\pm$ 2.6 kg/m^3 for AN 34

Overall pressure drop is guaranteed from inlet flange of WESP C701 (A1) to outlet flange of the cyclonic demister (A2).
Due to lack of accessibility, it was not possible to have a measurement point after the cyclonic demister.
So, a direct measured value is not available. The agreed alternative is to consider the pressure at the inlet of the WESP to which an estimated value for the stack will be deducted (B2).

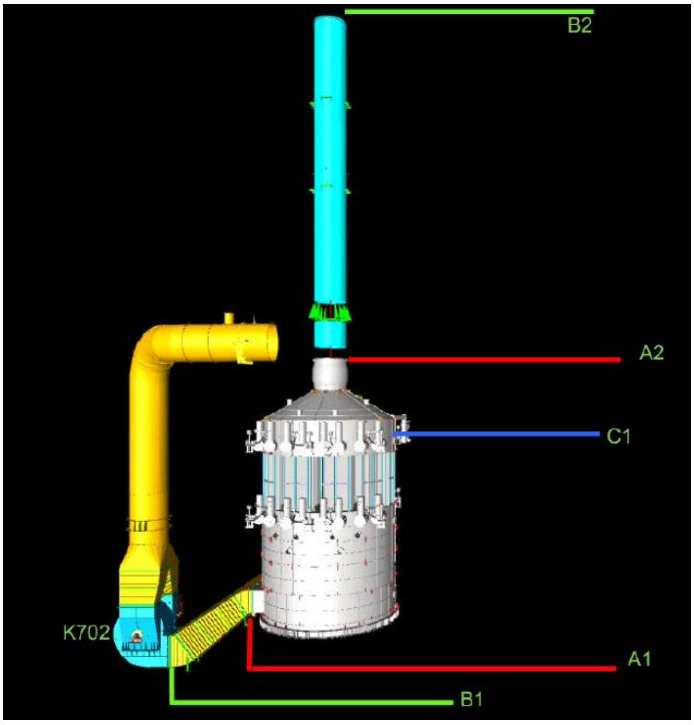

Figure 72: B1 – location of pressure transmitter PI703
C1 – local measurement points downstream of the WESP tubes and upstream of the outlet cone and cyclonic separator

The performance guarantee for pressure drop corresponds to the pressure drop between point A1 and A2.
Pressure drops between point B1 and A1 was assessed by installing temporary tubing from a nozzle at point A1 to the manifold of PI703. Switching between these source points at flow conditions similar (same speed on fan K702) to the ones during the reference periods showed that the pressure drops between B1 and A1 was typically very low and always less than 1 mbar.
Pressure at A2 could not be measure due to inaccessibility.
Measurements performed at point C1 showed that pressure drop of the stack (between point A2 and B2) was not negligible. Indeed, values at C1 were measured in the range of 6-7 mbar.

The pressure drops between point C1 and point A2 corresponding to the contribution of the outlet cone of WESP and the cyclonic separator is taken to be 2.6 mbar (1.5 mbar for the cyclonic separator and 1.1 mbar for the outlet cone). The pressure drop of the stack would be considered to be at least 3 mbar.
So, for the purpose of the verification of the performance guarantees with regards to pressure, the pressure drop of the stack (between point A2 and B2) will conservatively take to be 1.5 mbar.
The performance guarantee reference values will thus be the value recorded at B1 (PI703) minus the pressure drop of the stack (1.5 mbar).
The acceptable of pressure drops are:

- 13 ± 0.8 mbar for AN 33.2% with reference value of 11.5 ± 0.8 mbar
- 20.4 ± 0.8 mbar for AN 33.2% with reference value of 18.9 ± 0.8 mbar

For both grades these values are below the guaranteed value of 21 mbar.
The acceptable emissions to air are:

- For AN 33.2%
    - 0.16 mg $NH_3/Nm^3 \pm 0.02$
    - 0.41 mg dust/$Nm^3 \pm 0.08$
- For AN 34
    - 0.68 mg $NH_3/Nm^3 \pm 0.03$
    - 0.99 mg dust/$Nm^3 \pm 0.18$

In conclusion, for both grades, Emissions to air as well as pressure drop over the system were compliant with the guaranteed figures.

Optimization test

The purpose of the test is to evaluate the performance of the WESP to understand optimization margin, first turning off one rectifier and then two, verifying compliance with the emissive limits of ammonia and dust concentrations at the chimney. The test will be carried out both during CAN 24/15 SO_3 production and during pure ammonium nitrate (AN 34) production.
Regarding ammonia, CAN 24/15 SO_3 is the most critical production.
For dust, AN 34 is the most critical, as it generates a greater amount of fine dust, in the form of aerosols, which cannot be captured by the absorption plates and which, for this reason, challenge more the high-voltage section. So, we decided to test only with 1 transformer turned off and not with two, to avoid few margins respect to the limits.
The test consists of testing the performance of the WESP in the following configurations:

- CAN 24/15 SO3:
    - All 4 rectifiers on
    - 1 rectifier off and 3 on
    - 2 rectifiers off and 2 on
- AN 34:
    - All 4 rectifiers on
    - 1 rectifier off and 3 on

As indicated in the previous paragraph, the tube beam is divided into 4 parts, each fed by a dedicated rectifier. In order to define which rectifier to switch off in the second and third tests, it must be borne in mind that the four parts are not equal; in particular, the central sections (B and C), although approximately equal, are larger than the lateral sections (A and D), they are also about equal to each other. To consider, even indirectly, all possible cases, it was decided to switch off the rectifier

TR701A or TR701D for the second test and, in addition to one of these, the TR701B for the third test (the latter is characterized by a higher current value than TR701C).
The load of the plant must be maximum in all 3 settings and the most critical productions from the point of view of emissions must be selected.
For each set-up of each production, the chimney gas will be sampled by a certified external laboratory technician and then analysed by their certified laboratory. The sampling and analysis shall be in accordance with the official ones that are normally carried out, i.e. mean value of three successive 30-minute samples, as indicated in AIA.

Below are reported the main results.

PRODUCTION	TEST	DRY FLOW RATE [Nm^3/h]	T_{gas} [°C]	P_{gas} [mg/Nm^3]	DUST [mg/Nm^3]	NH_3 [mg/Nm^3]
CAN 24/15 SO_3	1	567691	15	101600	0.66	2.79
	2 (TR701D off)	558349	16.7	101500	2.39	5.29
	3 (TR701B/D off)	559765	16.1	101500	1.97	7.7
AN 34	1	572475	16	102100	0.68	0.99
	2 (TR701A off)	572194	16	102100	9.9	1.87

Table 14

As can be seen from the table, in the case of CAN 24/15 SO_3, the concentration values for dust and ammonia were below the emission limits for all three systems. So, it turns out that, going to turn off one or two transformers, is possible to march respecting the limits.
When the results are analyzed, the effect of the rectifiers is clearly visible, especially on NH_3. In the high-voltage section, not only the solid particles passing through the tube beam are separated from the gas, but also the liquid ones. Probably, going to turn off the rectifiers, the ammonia dissolved in the liquid particles or the one present in the solid particles is not retained and reaches the chimney. The effect more evident as more rectifiers are turn off; in fact, comparing the different settings, it is observed that the concentration of ammonia in the third test is higher than the one of the second test which is higher than the one of the first test.
The same trend should have been observed for dust. It can be seen that the dust concentration in the second test is higher than in the first one, but there is no big difference between the second and the third tests, in fact, it’s slightly lower in third one.
In any case, it is clear that the dust concentration also increases when the rectifiers are switched off. Probably the increase is not so evident, since absorption plates are already able to retain most of the dust, demonstrating that for this type of production it is less fine, i.e. the formation of aerosols is limited.
Another obvious aspect concerns the visibility of the plume. In the images below it is shown for each of the 3 arrays.
It is observed that in the first test, it is practically invisible, increases in the second one and further increases in the third one.

1° test

2° test

3°test

In the case of the AN 34 the results in the second test have been obtained with the shutdown of the TR701A, the rectifier that feeds one of the two smaller parts of the tube beam. An even higher concentration would be obtained by switching off the TR701B or the TR701C which carry the high voltage to the two larger parts.

In this case, the effect of the rectifiers being turned off on dust concentrations is well noted; when all the rectifiers are switched on, the concentration is 0,68 mg/Nm^3; contrary, the dusts do not appear to be partially captured by the absorption plates, which proves that during the production of AN 34 the dusts are fine, in the form of aerosols.

The concentration of ammonia also increases as the rectifiers are switched off. The same reasoning applies to CAN 24/15 SO_3. However, the values in this case are lower than those obtained with CAN 24/15 SO_3 and also the differences between the various arrangements are smaller. There are two main reasons:

- During the production of AN 34, less ammonia is generated than the one generated during the production of CAN 24/15 SO_3
- During the production of AN 34, the pH of the recirculating solution of the WESP, with which the absorption plates are fed, was equal to 3, while during the production of CAN 24/15 SO_3, it was still equal to 5 (the value was then increased to 3 for all productions for other process reasons). The abatement of ammonia in plates was, therefore, higher in the case of AN 34, compared to the CAN 24/15 SO_3 case

Also, for the test with the AN 34, it is evident the difference in visibility of the plume in the 2 settings. Exactly what was observed for the CAN 24/15 SO_3 test is observed: with the first test the plume is practically invisible, it increases in the second test and increases even more in the third one.

1° test

2° test

In conclusion, tests have shown that, in the case of CAN 24/15 SO_3 production, the concentrations of dust and ammonia are below the emission limits even when only two out of four rectifiers are on.
In the case of AN 34 production at maximum production load, however, it has to be always kept all four rectifiers on to march with due margins.
However, in both cases, it has been observed that by turning off even just one rectifier the visibility of the plume increases a lot and turning off two is even more obvious, in the case of CAN 24/15 SO_3.
The optimization tests were performed with different formulations but always at maximum production capacity also to verify the behavior of the plant in cases of anomalies/disservices to grinding machines. The outcome of the optimization tests leads to highlighting that with the production of AN 34 in the event of a rectifier malfunction it is still advisable to reduce the production load in order to have a greater margin compared to the authorized limit.

4.2.4 Future improvements

The plant is already functioning and working well, has no issues, is stable and does not require particular attention and has been effectively assimilated by the production department which must manage it through adequate training and information. However, there are still several things to fix in terms of logic or small implant improvements. Below are reported some of the most important future improvements:

- A test will need to be done to understand what the operating window is in terms of secondary voltage with all four transformers turned on. The test will consist of carrying out various sampling at the WESP, lowering the secondary voltage value from one sampling to another. This lowering will not be abrupt, as it is necessary to always remain within the emission limits. The values obtained from the sampling carried out so far have shown that we are well below the emission limits and that therefore there could actually be a margin to lower the voltage. This would also lead to economic savings
- As was also seen from the pilot plant, it would not be necessary to carry out the washes once a day as they are carried out now. The plan is to stay as we are now until the stop. At the stop we inspect the WESP, monitoring the degree of cleanliness/fouling. Upon restart, we will only set the washes during production changes. Furthermore, over the course of the sequence, one transformer is turned off at a time (in some phases you even have two turned off at the same

time) and the abatement efficiency, therefore, drops. During the washes the test carried out certify that the emission level are well within the authorized limits. The need to predict washes or not is information that can also be useful for future WESP designs in other Yara plants. However, the secondary current values of the transformers will be monitored while driving to keep the degree of soiling of the tube bundle under control: if, under the same conditions, the current value tends to derive downwards, this is a sign of soiling and therefore of the need for washing. After a further year of marching with this configuration, you will access the WESP again to monitor the degree of fouling

CONCLUSIONS

Air pollution represents one of the most pressing environmental challenges, with significant consequences for human health, ecosystems, and future generations. Regulations at international, European, and national levels have progressively tightened emission limits, requiring industries to adopt more efficient technologies to reduce atmospheric pollutants.

At the Yara site in Ravenna, the reduction of dust and ammonia emissions from the prilling tower is a key objective. To achieve compliance with the new stricter limits, the installation of a Wet Electrostatic Precipitator (WESP), combined with absorption trays, has been identified as the most effective solution. This system is designed to capture both ammonia and fine dust particles, ensuring substantial improvement in air quality and alignment with legal requirements.

In conclusion, the project addresses the dual challenge of meeting environmental obligations while implementing technological innovation to minimize the impact of industrial processes on the atmosphere. The NAS production plant is designed to manufacture ammonium nitrate (AN) and calcium ammonium nitrate (CAN) fertilizers through the Stamicarbon process, with production capacities adapted to the nitrogen content required to feed the world and responsibly feed the planet. The process involves ammonia evaporation, neutralization with nitric acid, concentration, mixing with diluents, granulation, cooling, and application of anti-caking agents, as well as energy recovery and effluent treatment to optimize efficiency and sustainability.

The plant also produces high-grade AN without diluents, using additive to stabilize the product and improve handling properties. Environmental management is a key aspect: emissions, particularly from the prilling tower, are strictly monitored according to national and European regulations. Best Available Techniques (BAT) are applied to minimize dust and ammonia emissions, supported by periodic monitoring and reporting obligations.

To comply with new legal limits effective by June 2025, the plant has implemented Wet Electrostatic Precipitator (WESP) technology, ensuring significant reductions in dust and ammonia emissions. Overall, the plant combines high production capacity with environmental compliance, integrating advanced technological solutions to guarantee safe, efficient, and sustainable fertilizer production.

The introduction of the Wet Electrostatic Precipitator (WESP) at the Yara Ravenna plant represents a significant technological advancement in controlling atmospheric emissions from the prilling tower. Pilot tests confirmed the WESP's effectiveness in removing ammonium nitrate dust with stable efficiency and minimal maintenance needs, while ammonia abatement is achieved through additional absorption stages.

The full-scale WESP installation is designed to treat 580,000 Nm^3/h of process air, ensuring emission levels below 10 mg/Nm^3 for both dust and ammonia—well within the new authorization limits effective from June 2025. The system also integrates with existing process streams, recycling ammonium nitrate solutions and reducing waste generation.
From an environmental perspective, the WESP project consolidates four existing emission points into a single outlet, providing substantial improvements in emission quality without creating additional burdens in terms of water, energy, noise, waste, or raw material use. Its implementation aligns with Best Available Techniques (BAT), ensuring compliance with European and national regulatory frameworks while enhancing plant sustainability and safety.
Overall, the project delivers a modern, efficient, and environmentally responsible solution that guarantees long-term compliance and improved air quality performance.
The safety and risk assessment of the new WESP installation at the Yara Ravenna site demonstrates that the project ensures high levels of operational safety and compliance with regulatory requirements. The design includes advanced interlock systems, emergency shutdown procedures, and redundancy in critical equipment, minimizing the likelihood of accidents and ensuring safe maintenance conditions.
The analysis of potential hazards confirmed that risks to workers, the environment, and the community are low, provided that standard operating procedures and safety measures are properly followed. The system's integration into the existing Distributed Control System (DCS) and Safety Instrumented System (SIS) strengthens monitoring and control capabilities, ensuring rapid response to abnormal events.
Overall, the study concludes that the WESP plant introduces no significant additional risks compared to current operations, while contributing to substantial environmental benefits through reduced dust and ammonia emissions. The project thus supports both environmental protection and operational safety, aligning with best industrial practices and legal obligations.
The installation and testing of the Wet Electrostatic Precipitator (WESP) confirmed that the system works effectively in reducing both dust and ammonia emissions, keeping them well within the required environmental limits. During normal operation the equipment runs reliably, with automatic washing cycles and the natural self-cleaning action of the gas flow helping to prevent fouling. Performance tests carried out on different productions showed full compliance with emission and pressure-drop guarantees. Optimization trials revealed that, for CAN 24/15 SO_3 production, the WESP can operate even with fewer rectifiers while still meeting standards, whereas for AN 34 at maximum production load all four rectifiers must remain active to march with due margins. The outcome of the optimization tests leads to highlighting that with the production of AN 34 in the event

of a rectifier malfunction it is still advisable to reduce the production load in order to have a greater margin compared to the authorized limit.

Some operational issues, such as flow oscillations and fouling in the prilling tower, were identified but successfully solved through process adjustments. Looking ahead, further testing could help optimize voltage settings, which would not only maintain environmental performance but also reduce energy consumption and operating costs. Overall, the WESP installation proved to be reliable, efficient, and capable of further improvement.

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[8] Mechanical completion procedure
[9] Appendix E34: plant completion - mechanical completion, commissioning and start-up
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[11] Construction Execution Plan (CEP)
[12] Commissioning Execution Plant (ComEP)
[13] Appendix E35: commissioning and start-up requirements

ACKNOWLEDGMENTS

A voi che siete al mio fianco ad ogni passo
Siete scolpiti nel mio cuore
A me dico "Vivi bene, semplicemente vivi"

ATTACHMENTS

1. PFD WESP plant
2. Graphical pages DCS of WESP plant
3. OTP-C1-01
4. OTP-C1-02
5. OTP-C1-03
6. OTP-C1-04
7. OTP-C1-05
8. OTP-C1-06
9. OTP-C1-07
10. OTP-C1-08
11. OTP-C1-09
12. OTP-C1-10
13. OTP-C1-11
14. OTP-C1-12