KRIBHCO

250 MTPD Nitric Acid Plant
300 MTPD AN Solutions Plant

Technical Information Package

License, Basic Engineering Design, Post-Basic Engineering Design, Proprietary Equipment & Spare Parts Supply & Commissioning & Startup Support

August 2022

We Deliver.

PREFACE

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1 ABOUT KBR

We, at KBR, not only offer mono-pressure and dual-pressure nitric acid technology for grassroots, but also provide support for your existing plant-capacity upgrades, environment control and digitalization solutions.

Since 1954, KBR has licensed over 76 grassroot nitric acid plants globally and is the No. 1 technology in the demanding US market, with around 80% market share. This technology is selected due to its superior CAPEX, OPEX, energy efficiency, reliability and environmental performance, with very low technical risk:

- Pressure system @ 12 bar (HP) (= lower CAPEX)
- Smaller footprint/vertical design (= lower CAPEX)
- Tail gas heat recovery system/greater steam recovery (= lower OPEX)

KBR mono-pressure and dual-pressure technologies provide superior CAPEX, OPEX, energy efficiency, reliability and environmental performance through low capital cost, high energy efficiency and ammonia conversion at reduced catalyst and maintenance cost, and minimal site footprint requirements. The unique feature of tail gas heat recovery results in high energy efficiency. KBR's proven track record ranges between 20 and 1,000 MTPD of installed capacity, globally.

KBR's nitric acid technology process knowhow can help you optimize process parameters for energy-efficient operations and to identify de-bottlenecking solutions for increasing your existing plant capacity.

Our team of experts offers to leverage KBR's vast experience and operations knowledge base. Through process study and by undertaking basic engineering and design, we optimize ammonia consumption, improve nitric acid concentration – throughput and maximize waste heat recovery for steam export for your existing nitric acid facility.

For emission control, KBR offers the most advanced retrofit NO_x and N_2O abatement systems for existing nitric acid units. The N_2O abatement system is capable of 95% N_2O emission reductions guarantee with an expected value of 98% at temperatures up to 650 °C (1200 °F).

In addition, KBR provides advanced digital solutions to enhance your equipment performance, extend catalyst lifetime, and help reduce unplanned downtime via:

- Advanced process control
- Reliability-based maintenance
- Operations management
- Dynamic simulation/computational fluid dynamics/logistics

Besides, KBR recovers platinum deposits through non-destructive and destructive cleaning for nitric acid and caprolactam producers. We are committed to Zero Harm, zero environmental incidents and 100% successful performance.

KBR is a global provider of differentiated professional services and technologies across the asset and program lifecycle within the Government Solutions and Energy sectors. KBR employs approximately 37,250 people worldwide (including our joint ventures), with customers in more than 80 countries, and operations in 40 countries, across three synergistic global businesses:

- Government Solutions, serving government customers globally, including capabilities that cover the full lifecycle of defense, space, aviation and other government programs and missions from research and development, through systems engineering, test and evaluation, program management, to operations, maintenance, and field logistics
- Technology Solutions, including proprietary technology focused on the monetization of hydrocarbons (especially natural gas and natural gas liquids) in ethylene and petrochemicals; ammonia, nitric acid and fertilizers; oil refining and gasification
- Energy Solutions, including onshore oil and gas; LNG (liquefaction and regasification)/GTL; oil refining; petrochemicals; chemicals; fertilizers; differentiated EPC; maintenance services (Brown & Root Industrial Services); offshore oil and gas (shallow-water, deep-water, subsea); floating solutions (FPU, FPSO, FLNG & FSRU); program management and consulting services

KBR is proud to work with its customers across the globe to provide technology, value-added services, integrated EPC delivery and long term operations and maintenance services to ensure consistent delivery with predictable results. At KBR, We Deliver.

2 VALUE PROPOSITION of KBR TECHNOLOGY

This document provides an outline of the design of the plant for the manufacture of 250 MTPD (100% basis) of nitric acid, at a nominal concentration of 65 wt.%, and containing less than 0.01 wt.% of dissolved oxides of nitrogen and the manufacture of 300 MTPD of AN solution at a concentration of 88 wt%.

For nitric acid, KBR is capable of both mono-pressure technology and dual-pressure technology. Mono pressure technology is recommended for this size plant.

The expected performance shown is based on using a main air compressor set consisting of a Centrifugal Volute Multistage Air Compressor driven by a Hot Gas Expander and a steam turbine.

Principle features of the design of the nitric acid plant are as follows:

- High ammonia filtration efficiency provided by:
- High quality filtration of both air and ammonia feeds to the gauze.
- Intimate mixing of feeds in a static mixer.
- KBR's proven converter design.

Control of NOx and N2O emissions is obtained by utilizing KBR's proven extended absorption design coupled with a proven selective catalytic NOx reduction system and a tertiary N2O catalytic reduction system.

High efficiency heat recovery including:

- Generation of 4100 kPag steam superheated to 400 °C for export.
- Tail gas reheating for enhanced power recovery in the expander.
- Ammonia vaporization by waste heat from cooling water. Compact layout providing easy access for operation and maintenance.

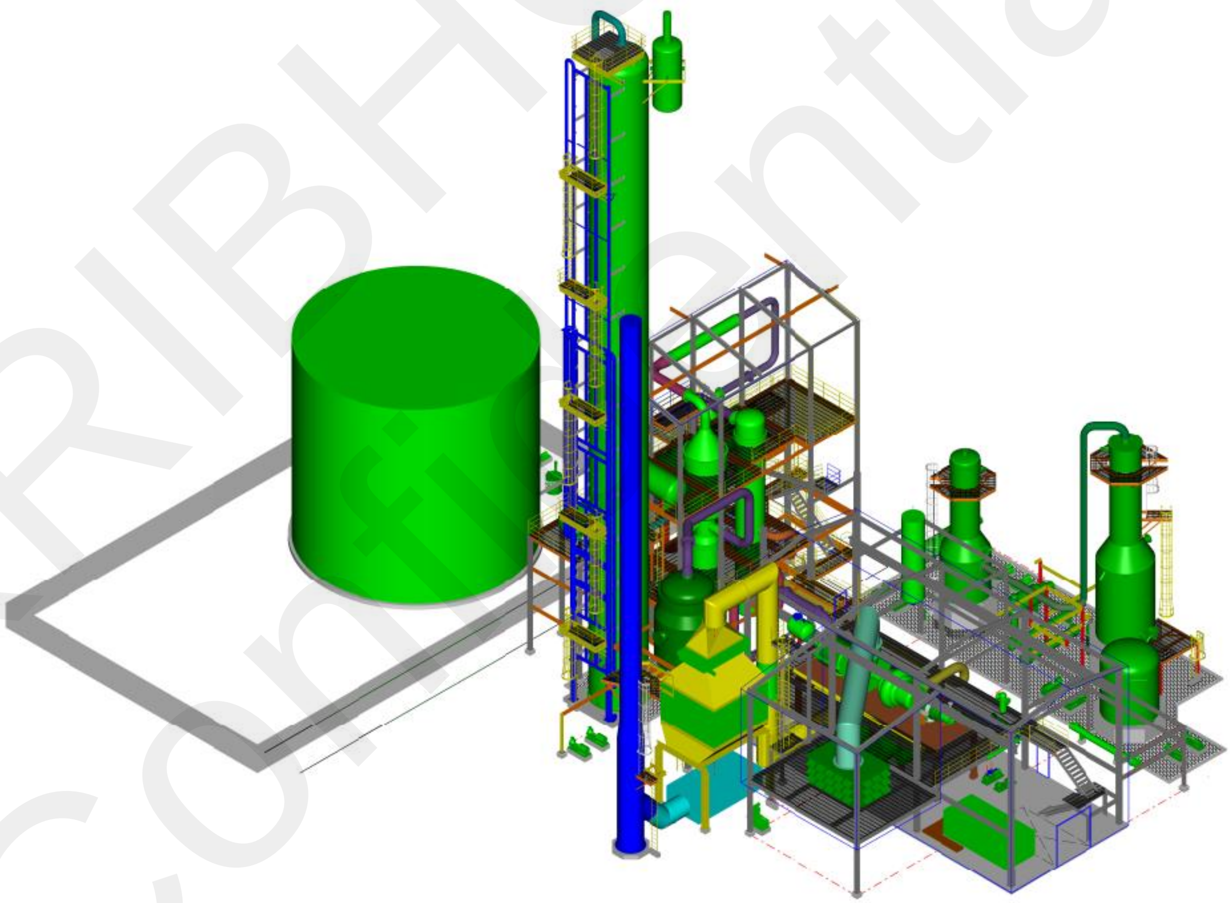
Principle features of the AN Solutions plant are as follows:

§ Proven design of the Neutralizer and AN Scrubber.
§ Limiting emissions by:
§ Precise pH control in the neutralizer
§ Packed sections in the AN Scrubber and Vent Scrubber operating in condensing mode.

3 EXECUTIVE SUMMARY

Kellogg Brown & Root LLC ("KBR") is pleased to offer this technical information package for a License, Basic Engineering Design ("BED"), Post-Basic Engineering Design ("Post-BED"), Proprietary Equipment ("PEQ") & Spare Parts Supply & Commissioning & Startup Support ("CSS") for a new 250 MTPD Nitric Acid Plant and a 300 MTPD AN Solutions plant.. The new plants are to be located at Kribhco's Saharanpur site in India.

KBR has a very strong track record in Nitric Acid, Ammonium Nitrate and UAN, with leading state of the art technology which results in lower capital costs, lower variable costs and higher plant reliability for its licensees than its competitors can provide. KBR's design experience in these technologies dates back to 1954, with 76Nitric Acid Licenses, 30 Ammonium Nitrate Solution and 12 UAN plants to date.



4 TECHNICAL OUTLINE

This document provides an outline of the design of the plant for the manufacture of 250 MTPD (100% basis) of nitric acid, at a nominal concentration of 60 wt.%, and containing less than 0.01 wt.% of dissolved oxides of nitrogen. The nitric acid will feed a 300 MTPD AN Solutions plant which is also outlined in this proposal.

The expected performance shown in Section 4.2.1 is based on using a main air compressor set consisting of a Centrifugal Volute Multistage Air Compressor driven by a Hot Gas Expander and a steam turbine.

Principle features of the design of the nitric acid plant are as follows:

- High ammonia filtration efficiency provided by:
- High quality filtration of both air and ammonia feeds to the gauze.
- Intimate mixing of feeds in a static mixer.
- KBR Weatherly's proven converter design.

Control of NOx and N2O emissions is obtained by utilizing Weatherly's proven extended absorption design coupled with a proven selective catalytic NOx reduction system and a tertiary N2O catalytic reduction system.

High efficiency heat recovery including:

- Generation of 4100 kPag steam superheated to 400 °C for export.
- Tail gas reheating for enhanced power recovery in the expander.
- Ammonia vaporization by waste heat from cooling water.
- Compact layout providing easy access for operation and maintenance. For a 250 MTPD plant the space required is 31 m x 42 m (refer to section 5.2 Plot Plans, for details)

4.1 PROCESS DESIGN

4.1.1 Process Description

NITRIC ACID – MONO PRESSURE TECHNOLOGY

(Refer to process flow diagram)

<u>NITRIC ACID PLANT</u>

The raw materials required for production of nitric acid are atmospheric air and ammonia. These raw materials are combined at elevated temperature and pressure and passed over a platinum catalyst where the ammonia reacts with the oxygen. The resultant process gas is passed through the heat exchanger train where the major portion of this reaction energy is recovered as heat. The process gas is cooled and oxidized further in the cooler condenser and absorber where nitric oxide, nitrogen dioxide, oxygen and water combine to form nitric acid. A portion of the reaction energy recovered in the heat exchanger train is used to reheat the tail gas to provide power for the air compressor by driving a hot gas expander.

Atmospheric air is filtered in a two-stage inlet air filter. The filtered air is then compressed by the air compressor. The air compressor is powered by a steam turbine and a hot gas expander. The hot gas expander supplies approximately 90% of the compressor power required.

Air from the compressor discharge enters the air/tail gas interchanger where it is cooled by heating the tail gas fed to the tail gas heater. A portion of the air is separated after the air/tail gas interchanger for use as bleach air and is routed under manual flow control to the bleacher section of the absorber. The main process air stream then flows to the air heater, which is part of the process gas heat exchanger train and is heated by process gas. It is then filtered in a high efficiency sintered metal filter, before entering the ammonia/air mixer.

Liquid ammonia feed to the plant is filtered in a cartridge type filter for removal of suspended solids before entering the ammonia vaporizer. The ammonia vaporizer utilizes waste heat from the cooling water to vaporize the majority of the ammonia for feed to the nitric acid plant.

Ammonia is then fed to the auxiliary ammonia vaporizer/superheater where the ammonia is superheated with 345 kPag steam to prevent any liquid carryover, which could damage the platinum catalyst. The resulting superheated ammonia vapor stream is filtered in a high efficiency sintered metal filter to remove possible contaminants and protect the platinum catalyst.

Catalyst temperature is controlled by direct adjustment of the ammonia flow to the ammonia air mixer. This control scheme has proven extremely effective in maintaining stable catalyst temperatures and has been used widely in Weatherly nitric acid plants.

The clean streams of air and ammonia are intimately mixed in the ammonia/air mixer and the mixture is evenly distributed over the catalyst where reaction occurs producing nitric oxide and water vapor. The resulting high temperature process gas then flows through the heat recovery system, which consists of the expander gas heater, waste heat boiler, steam superheater, an oxidation spool, the tail gas heater, the platinum filter and the air heater.

The heat recovered by the waste heat boiler is used to generate 4100 kPag steam, which is then superheated to 400 ºC in the steam superheater. The steam so generated is sufficient to supply a steam export after fulfilling all steam requirements for the air compressor set steam turbine driver. Additional energy is recovered by the tail gas heater to reheat tail gas which increases power recovery in the hot gas expander.

Process gas from the tail gas heater is fed to the platinum filter, which recovers platinum particles lost from the platinum gauze during the course of operations. The shell of the platinum filter provides volume for additional oxidation to enhance downstream heat recovery in the air heater where the process gas is further cooled by heating the process air feed to the ammonia/air mixer.

The process gas then enters the cooler condenser where it is cooled by cooling water. Water vapor is condensed and reacts with the nitrogen dioxide in the gas stream to form weak nitric acid. The weak acid and process gas are separated in the outlet channel of the cooler condenser. The gas flows into the absorber column in a separate line while the weak acid is fed to the weak acid sump in the absorber where it is then pumped to the appropriate absorber tray via weak acid pumps.

The absorber column is a sieve tray absorber, in which the bottom portion contains both a process gas conditioning zone and a product acid bleacher section. Absorber feedwater of suitable quality is fed to the top tray of the absorber.

The process gas from the cooler condenser is mixed with the bleach air stream leaving the bleacher section carrying the nitrogen oxides stripped from the product acid. This additional air supplies the oxygen requirements for the reoxidation of nitric oxide to nitrogen dioxide, which takes place continuously in the absorber column. The mixed gas stream enters the absorption column and passes through a gas conditioning zone before reaching the first absorption tray. The heat of the oxidation reaction in this zone is removed by passing the gas through trays which are equipped with cooling coils and on which a liquid level is maintained automatically by further continuous condensation of a small amount of weak acid from the process gas stream. This additional weak acid flows to weak acid sump in the absorber where it combines with the weak acid that has been condensed in the cooler condenser.

After leaving the gas conditioning zone, the process gas flows upward through absorption trays where it is contacted counter-currently with absorber feedwater and weak acid to produce nitric acid of the desired strength.

Product acid flows from the bottom absorption to the bleacher section. In the bleacher, the product acid contacts a counter-current flow of bleach air, which strips the remaining dissolved nitrogen oxides from the acid. The stream of clear, bleached acid is then allowed to flow under pressure to storage.

The heat produced in the oxidation and absorption reactions is removed by cooling water passing through coils on the trays in the column. The tail gas, which has been reduced in NOx content to approximately 250 ppm by volume, leaves the absorber and flows to the tail gas reheating system.

Tail gas first enters the steam tail gas preheater where 345 kPag steam is used to preheat the tail gas entering the shell side of the air-tail gas interchanger. Air from the compressor discharge is interchanged with tail gas to provide the final tail gas preheating step. The tail gas is then fed to the tail gas heater. The tail gas is preheated sufficiently to avoid process gas condensation in the tail gas heater.

In the tail gas heater, the tail gas is heated to approximately 339 °C. It then flows to the expander gas heater where it is further heated to 649 ºC. Tail gas from the expander gas heater is fed to the N2O Abator. The N2O Abator catalytically destructs nitrous oxide (N2O) by approximately 95% before being fed to the hot gas expander. Tail gas exit from the hot gas expander is mixed with a small stream of ammonia vapor and recycled tail gas in the ammonia/tail gas mixer before entering the NOx abator. In the NOx abator, the tail gas NOx concentration is reduced to less than 25 ppm by volume.

During start-up and controlled shutdowns, a start-up heater located upstream of the NOx abator is used to heat the tail gas and abator before gauze light-off. The start-up heater utilizes 4100 kPag steam imported from battery limits to heat the tail gas and abator to approximately 204°C. This insures that the NOx abator can operate during start-up and controlled shutdown to help achieve a near colorless tail gas stack.

The majority of the compression power required for the plant is extracted from the heated tail gas in the hot gas expander. The tail gas is discharged from the expander, flows through the NOx abator and into the economizer to preheat boiler feedwater. The tail gas then exhausts to the atmosphere through the stack.

AN SOLUTIONS PLANT

(Refer to process flow diagram)

Ammonium nitrate is produced by the reaction between ammonia and nitric acid.

The ammonia vapor is metered to a sparger in the neutralizer. Nitric acid is supplied from battery limits to the neutralizer. The major portion of the nitric acid (approximately 95 to 97%) is fed to a sparger in the neutralizer under ratio control with pH trim. The remaining nitric acid is fed to the scrubber to neutralize unreacted ammonia leaving the neutralizer. The ammonium nitrate product overflows from the neutralizer into the AN SURGE Tank.

The heat of reaction generated in the neutralizer boils off steam which passes overhead into the scrubber along with a small amount of unreacted ammonia. The scrubber is a packed bed which contacts these off-gases with dilute acidic ammonium nitrate. The dilute AN solution is cooled externally in the circulated AN cooler; and, upon recirculation to the scrubber packing, condenses water from the steam to provide concentration control of the ammonium nitrate in the scrubber and, consequently, the neutralizer. A portion of this dilute ammonium nitrate overflows back to the primary neutralizer.

The remaining off-gas and condensate from the vaporizer then passes into the condensing section which recovers process condensate for use as absorber feedwater in the nitric acid plant. The condensing section is comprised of the process condensate pumps, circulated condensate cooler and vent scrubber. Process condensate is cooled and circulated over a packed bed where it contacts the remaining process steam from the neutralizer and vaporizer. Condensate is totally condensed over the packed section and the residual inerts vent to atmosphere while the condensate flows into the process condensate tank. The process condensate is then utilized for absorber feedwater.

Operation of the ammonium nitrate plant with the system just described is a very effective approach to pollution control. By use of pH control, the neutralizer is run under ammonia-rich conditions (pH 4.2 - 5.5) to minimize ammonium nitrate volatilization while the scrubber is run under acid rich conditions (pH 2.0 - 2.5). Since both the nitrate concentration and the temperature in the scrubber are lower than in the neutralizer, ammonium nitrate smoke is minimized. Additionally, the scrubber operates under condensing conditions to remove particulates and ammonia. A final condensing step results in an off-gas which is well below allowable emission levels.

4.1.2 Process Design Features

NITRIC ACID – MONO PRESSURE

High Purity Air to Process

High purity air is essential for both high ammonia conversion efficiency and extended gauze runs.

The design features which ensure the required high purity air are:

- High efficiency air intake filtration.
- Corrosion resistant materials of construction in the air flow path between the inlet air filter and the gauze.
- A final discharge air filter before the ammonia/air mixer

a) Inlet Air Filter

Two stage filtering is employed for the air intake to the air compressor set. The filter unit contains multiple individual filtration cells, each containing one pair of rigid aluminum frame first and second stage filter elements. The first stage element removes the bulk of atmospheric contaminants. This washable element can be removed on the run for washing and/or replacement with a clean element, without disturbing either the second stage element or its seal to the filter housing frame. The second stage element is not washable and has an expected life of 1 year.

b) Materials of Construction

The ductwork from the inlet air filter to the air compressor, the discharge piping from the air compressor to the ammonia/air mixer are all stainless steel.

c) Discharge Air Filter

As final protection against casual contamination, the discharge air filter uses stainless steel sintered metal washable elements. These durable high efficiency elements are subjected to a two-stage washing and rinsing procedure as required and are returned to service with complete renewal of the original performance.

High Purity Ammonia

Clean ammonia is just as important as clean air in increasing gauze life and ammonia yields. KBR-Weatherly plants utilize a single liquid ammonia filter to remove most contaminants before the liquid ammonia enters the vaporizer system. This filter contains disposable cartridge type elements, which can be easily changed during the catalyst changes.

From this point to the gauze, including all piping, the ammonia vaporizer and the auxiliary ammonia vaporizer/superheater, only stainless steel materials are allowed to come in contact with the ammonia. Final vapor ammonia filtering is accomplished using high efficiency, washable sintered metal filter elements.

Ammonia/Air Mixing

Ammonia/air mixing takes place in a static mixing system. This motionless in line mixer uses a large number of small intersecting channels to divide and redivide the gas stream resulting in a homogenous gas mixture leaving the unit.

Converter Basket Design

Clean raw materials streams and homogeneous mixing produce long gauze life, but good overall ammonia conversion also requires a converter basket design which allows no bypassing around the periphery of the catalyst.

The KBR-Weatherly catalyst basket design, developed and proven over many years of plant experience, has been effective in demonstrating high ammonia conversion efficiencies. The basket design is capable of using all of the latest platinum recovery gauze systems.

Absorber Design

The current KBR-Weatherly standard nitric acid plant absorber design utilizes bubble cap trays. Bubble cap tray absorbers had been used as the standard for many years in KBR-Weatherly nitric acid plants smaller than 750 tpd. For plants larger than 750 tpd, sieve trays are more commonly used.

Compressor Selection

The compressor set is an all centrifugal design with carefully matched impellers. This feature greatly simplifies overall plant design, while eliminating the need for variable stator geometry often encountered in axial/centrifugal and axial/axial designs. Interstage blow-off during start-up and for anti-surge control is not required. This greatly simplifies the design of the anti-surge control system. Furthermore, the range of stability of this type of air compressor set allows turndown to be achieved via speed changes in the compressor set without having to resort to the complexity of variable stator geometry in the expander. This is all accomplished using minimum power because of intercooling coupled with special high efficiency impellers.

Corrosion Control

KBR-Weatherly uses process design as a tool in avoiding conditions that lead to corrosion problems in nitric acid plants. The temperature cut-off points for heat recovery in gas to gas exchangers in the tail gas and the air heaters have been selected specifically to avoid corrosion problems associated with condensing acid from process gas on the inside tube walls at the low temperature end of each unit. Acid condensation from process gas takes place only within the tubes of the cooler-condenser, which features zirconium tubes and zirconium-clad S.S. tubesheets for long life in this corrosive environment.

Plant Capacity

KBR-Weatherly nitric acid plants are designed to produce acid at the nominal design rate on a design summer day. Built into the design is the capability to turn down the production rate or run the plant at "over capacity", provided ambient conditions are favorable.

Plant turndown is achieved by plant air bypassing; for turndown, air must be bypassed around the converter and routed to the tail gas system to maintain mass flow through the expander, which sets the plant pressure. Nitric acid production efficiency in the absorber is a direct function of pressure, therefore, satisfactory NOx abatement for lower production rates is sustained when plant pressure is preserved at a high level.

Since the air compressor is a fixed volume machine, overcapacity can be achieved when cooler than summer design ambient temperatures are present. Cooler ambient temperatures furnish additional mass flow, therefore, additional air is available for acid production. Usually the limiting factor in overcapacity is the mechanical design pressure of the equipment in the process. Conversely to turndown, the plant pressure will increase with more mass flow through the expander.

In general, the KBR-Weatherly nitric acid plant is designed to operate continuously from 70% to 110% of design production capacity given the right ambient conditions.

On-Stream Time

The KBR-Weatherly nitric acid plant is designed to be on-stream 96% of the time. The converter design, including the mixed gas inlet stream, takes into account the need for minimum down-time and minimum labor for catalyst changes. Because of the relatively compact design of the converter and removable catalyst basket, total down-time from production is usually only six to eight hours with an experienced crew.

Personnel Requirements

Normal operation of the nitric acid plant will require one-fifth of a control room operator and one-fourth of a field operator. One control room operator and one field operator are required for startup and shutdown.

Turndown

Plant turndown is achieved by plant air bypassing; for turndown, air must be bypassed around the converter and routed to the tail gas system to maintain mass flow through the expander, which sets the plant pressure. Nitric acid production efficiency in the absorber is a direct function of pressure, therefore, satisfactory NOx abatement for lower production rates is sustained when plant pressure is preserved at a high level. Turndown to approximately 70% design production rate can be achieved.

Emergency power

Emergency power is recommended for the following items:

- Lube oil pump for air compressor B1004
- DCS

4.1.3 Energy Conservation Features for Nitric Acid

The KBR-Weatherly nitric acid plant design includes an integrated system of energy utilization which recovers process heat to minimize energy losses in cooling water and stack tail gas.

NITRIC ACID – MONO PRESSURE

Process Heat Recovery and Ammonia Vaporization with Waste Heat

Process heat, recovered from the air-NOx mixture as it is cooled in the expander gas heater, waste heat boiler, and tail gas heater.

This very high heat recovery is due in part to the use of high pressure process gas (about 11.7 barg at the gauze) which favors the rapid oxidation of NO to NO2, which goes to almost 90% completion at the exit of the heat recovery system. Much of the oxidation heat released would not be available at lower process gas pressures and would thus be lost to cooling water in the cooler condenser and absorber tower.

Final cooling of the process gas takes place in the cooler condenser. This energy is subsequently recovered by vaporization of ammonia.

Tail Gas Reheating and Power Recovery

Tail gas reheating is the primary use for recoverable process energy because the heat and pressure energy can be used in the expander, which is the most efficient producer of power available in a nitric acid plant. Using proven gas expander technology, the power recoverable in the expander is approximately 89 to 95% of the air compressor set requirement for the various plant options.

Steam System (mono pressure)

The high pressure steam system is designed to generate 4100 kPag/400 °C superheated steam to provide 100% of the steam required by the steam turbine in normal operation. The remaining high pressure steam is exported to the plant battery limits at 4100 kPag/400 °C. Low pressure steam at 345 kPag is imported for supply to steam tracing, auxiliary ammonia vaporizer/superheater, and steam tail gas preheater.

Ammonium nitrate plant design features

Principle features of the design of the AN Solutions plant are as follows:

- Proven design of the Neutralizer and AN Scrubber.
- Limiting emissions by:

  Precise control of pH in the neutralizer.

  Packed sections of the AN Scrubber and Vent Scrubber operated in condensing mode.

The vent scrubber is equipped with the AN Particulate Demister. The purpose of the AN Particulate Demister is to filter AN particulate from the vent stream that is going to the atmosphere. The AN Particulate Demister is a candle type filter. The filter media is a fiber bed, supported by a stainless steel cage. The demister will typically remove 99% of particles 3 micron and larger and remove 90% of particles 1 micron and larger. The collected AN particulate will be return to the process by gravity.

Generation of absorber feedwater that can be utilized in the nitric acid plant.

The scrubber overheads pass through the ammonia vaporizer where process steam is utilized to vaporize ammonia for the ammonium nitrate processes

4.1.4 Process Chemistry

NITRIC ACID PLANT

The raw materials required for the production of nitric acid are atmospheric air and ammonia. These raw materials are combined at elevated pressure and temperature, then passed through a platinum gauze catalyst where the ammonia vapor reacts with a large portion of the oxygen in the air to produce nitric oxide.

Reaction No. 1

$4NH_3$	+	$5O_2$	à	$4NO$	+	$6H_2O$
Ammonia		Oxygen		Nitric Oxide		Water

The heat generated by Reaction No. 1 is removed and recovered by passing the resultant process gas through a series of heat exchangers.

As the process gas is cooled by heat recovery, the nitric oxide combines with additional oxygen to produce nitrogen dioxide.

Reaction No. 2

$2NO$	+	O_2	à	$2NO_2$
Nitric Oxide		Oxygen		Nitrogen Dioxide

Large oxidation spools are included in the heat exchanger train to promote this reaction and allow recovery of the reaction heat in the heat exchangers.

As the process gas enters the cooler condenser, nitric acid is formed when nitrogen dioxide combines with the water produced in Reaction No. 1. The reaction continues in the absorber where additional water is added to produce nitric acid.

Reaction No. 3

$3NO_2$	+	H_2O	à	$2HNO_3$	+	NO
Nitrogen Dioxide		Water		Nitric Acid		Nitric Oxide

This reaction also generates heat, which is removed by cooling water in the absorber cooling coils and the cooler condenser shell. The nitric oxide formed in Reaction No. 3 reacts again in accordance with Reaction No. 2. Excess oxygen is supplied by the bleach air to promote conversion of nitric oxide to nitrogen dioxide. Reaction Nos. 3 and 2 keep recurring up through the absorber trays producing nitric acid until the quantity of nitrogen oxides in the gas is below required emissions standards. Chilled coolant is used in the upper absorber trays' cooling coils to improve the rates of the reactions and remove reaction heat.

The overall reaction of Reaction Nos. 1 through 3 is shown by the following:

NH_3	+	$2O_2$	à	HNO_3	+	H_2O
Ammonia		Oxygen		Nitric Acid		Water

AMMONIUM NITRATE PLANT

The raw materials for producing ammonium nitrate are ammonia and nitric acid. The materials are reacted in the neutralizer/scrubber (R2503) which then flows by gravity to the solution mix tank (T5201).

NH_3 + HNO_3 à NH_4NO_3

4.2 PERFORMANCE

4.2.1 Expected Unit Consumption of Raw Materials and Utilities

NITRIC ACID – MONO PRESSURE

When the plant is operated in strict accordance with the procedures recommended by KBR-Weatherly Inc., KBR-Weatherly expects that the plant will consume the following quantities of raw materials and utilities per metric ton of nitric acid (100% basis) produced.

	Amount Per Metric Ton Acid (100% Basis)
	250 MTPD
Ammonia (100% basis) m. ton	**0.2875**
Gross Platinum Catalyst g (Note 1)	**0.280**
1900 kPag Steam Export (superheated to 360 °C) m. ton	<0.645>
Low Pressure Steam Import m. ton	0.0475
Boiler Feedwater m. ton (Note 2)	1.07
Steam Condensate Export m. ton	<0.0475>
Cooling Water Cubic meters (Note 3)	132.7
Turbine Condensate Export m. ton	<0.0278>
Electric Power 400 v KWh (Note 4)	8.34

NOTES:

1. Based on using platinum recovery gauze and a platinum filter net burnoff is 0.085 gm/mt.
2. Makeup feedwater to be of suitable quality to permit 1% blowdown while generating 4100 kPag steam.
3. Based on a cooling water temperature rise of 9.2 °C.
4. Includes pumps, lighting, and instrumentation.

Ammonium Nitrate Solutions Plant

When the plant is operated in strict accordance with the procedures recommended by KBR Inc., KBR expects that the plant will consume the following quantities of raw materials and utilities per metric ton of AN Solution produced.

	Amount Per Metric Ton AN 300 MTPD
Ammonia (100% basis) m. ton	0.213
Nitric Acid (100% basis) m. ton	0.747
Electricity kWh (1)	6.0
Cooling Water Cubic meters (2)	15.0
345 kPag Steam Import m. ton	0.02
Steam Condensate Export m. ton	<0.02>
Process Condensate Export m. ton	0.284

NOTES:

1. Includes pumps, lighting, and instrumentation.
2. Based on a cooling water temperature rise of 10 °C.

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4.2.2 Design Requirements for Supply of Raw Materials and Utilities

The information contained in this section is provided to assist the Owner in the evaluation and design of the support facilities, including the supply of raw materials and utilities, yard piping, electric feeder system, etc. required for the operation of the plant at 250 MTPD nitric acid and 300 MTPD AN Solutions Plant.

Item: Ammonia
Conditions: Supplied at piperack elevation as liquid at 1725 kPag and at the temperature available at the site, with a maximum water content of 0.5 wt.%.

Item: High Pressure Steam Export
Conditions: Supplied at piperack elevation at 1900 kPag (superheated to 360°C).
Remarks: During start-up 27,000 kg/h of 40 bar 400 C steam needs to be imported.

Item: Turbine Condensate Export
Conditions: 200 kPag and 46 °C at piperack elevation.
Remarks: Start-up requirement 22,000 kg/h

Item: Boiler Feedwater
Conditions: 4970 kPag and 109°C at piperack elevation.
Remarks: Boiler feedwater to be of suitable quality to permit 1% blowdown when generating 4100 kPag steam.

Item: Demineralized Feedwater
Conditions: Piperack elevation at 250 kPag and the temperature available at the site
Remarks: Max 1 ppm chlorides

Item: Cooling Water System
Conditions: Supplied at grade from a circulated cooling water system treated for normal scaling and corrosion control at 250 kPag and 33°C. Water is returned from the plant at 175 kPag and 37.2 °C at grade.
Remarks: Max 100 ppm chlorides

Item: Steam Condensate Export
Conditions: Supplied at piperack elevation at 200 kPag at 134°C.
Remarks: Start-up requirement 2,000 kg/h

Item: Low Pressure Steam Import
Conditions: Supplied at piperack elevation at minimum 345 kPag pressure (saturated).

Item: Electricity 400 V, 3 Phase, 50 Hertz
Conditions: Supplied and connected.

Item: Instrument Air
Conditions: At a nominal 690 kPag and - 40°C dew point at piperack elevation.
Remarks: Not more than 85 Nm3/h.

Item:	Plant Air
Conditions:	Nominally 690 kPag.
Remarks:	Not required for normal plant operation. Required for intermittent usage at utility station(s).

Item:	Potable Water
Conditions:	Piperack elevation at 175 kPag and ambient temperature.
Remarks:	Not required for operation. Intermittent use for safety showers, eye-baths, etc.

Item:	Nitric Acid Product
Conditions:	At 200 kPag and 60°C.
Remarks:	

Item:	AN Solution Product
Conditions:	At 200 kPag and 138°C.
Remarks:	

4.2.3 Effluents

NOx abatement catalyst and N2O abatement catalyst will typically last 5-10 years. Vendor providing replacement catalyst to be responsible to remove the exhausted catalyst from the site and send it to a reclaiming facility.

The following items are the expected effluents from the nitric acid plant during normal design day operations.

Item: Boiler Blowdown
Conditions: Saturated liquid at atmospheric pressure and 100°C supplied to battery limits in underground drain.
Remarks: Normal flow is approximately 200-300 kg/h, but intermittently may be a maximum of 1200 kg/h.

Item: Gaseous Effluent Nitric Acid Plant
Conditions: Tail gas at 127°C and atmospheric pressure from stack.
Remarks: Containing less than 50 ppm NOx (by volume) and less than 20 ppm NH3 (by volume). The N2O content will be less than 100 ppm by volume.

Item: Gaseous Effluent AN Solutions Plant
Conditions: Tail gas at 127°C and atmospheric pressure from stack.
Remarks: Containing less than 50 ppm NOx (by volume) and less than 20 ppm NH3 (by volume). The N2O content will be less than 100 ppm by volume.

Item: Gaseous Effluent AN Solutions Plant
Conditions: @ 96°C and atmospheric pressure from stack.
Remarks: The vent gas contains less than 1 kg/h of AN particulate.

4.2.4 Consumables and Catalyst

1) Consumables

The following consumables will be required for operation of the nitric acid plant:

Item:	Lubricants
Description:	Lubrication of equipment as required per vendors' recommendations.
Item:	Hydrogen
Conditions:	Supplied in 10 m³ commercial cylinders by owner.
Remarks:	Not required for normal operation. During startup approximately one-third to one-half a cylinder is required to light the gauze catalyst using the hydrogen torch.

2) Catalyst

NITRIC ACID – MONO PRESSURE

The ammonia conversion catalyst used in the nitric acid plant is a pad consisting of multiple layers of knitted platinum gauze. When a "getter" gauze is utilized, additional sheets of gauze containing Pd or other noble metals are added. Pt and Rh are captured on these layers while additional Pd is preferentially lost.

Special proprietary gauze support packs may also be used. These special support packs may permit lower catalyst loadings to be used.

Life Of Catalyst Charge

The efficiency of the conversion of ammonia to nitric oxide declines gradually during the course of a production run, resulting in increasing operation costs. The length of run for a single charge of catalyst is sometimes extended to meet immediate demands for continued production.

A standard length run can be expected to be at least 70 to 90 days. During initial operations, the first catalyst charge may be exposed to contaminants from the newly constructed process system which will result in decreased life. As contaminants are gradually cleared from the system and the rate of catalyst poisoning decreases, the operating life of subsequent catalyst charges will increase.

Changing Catalyst

The catalyst is installed in a basket which is removable from the converter for ease of changing catalyst. The converter design, including the mixed gas inlet system, takes into account the need for quick catalyst changes. When using a second preloaded basket, the time to switch converter baskets is four to five hours with an experienced crew. The plant can be restarted with a total down time of only six to seven hours.

Catalyst Recovery Systems

The nitric acid plant is designed to allow for platinum recovery gauzes, sometimes referred to as "getters", can be employed directly beneath the platinum catalyst. These units typically capture approximately 60 - 70 % of the gross catalyst burn off. They are constructed primarily of palladium and lose approximately 0.45 grams of palladium for every gram of platinum recovered.

4.2.5 Product Specifications

When the plant is operated in accordance with the guidelines established by KBR the following product specifications shall be met:

Nitric Acid

§ Concentration:	Not less than 60 wt.% Nitric Acid
§ Dissolved oxides of nitrogen:	Not more than 0.01 wt.% expressed as HNO2
§ Chlorides	Not more than 20 ppm w
§ Sulphates as H2SO4	Not more than 20 ppm w
§ Residue on ignition	Not more than 250 ppm w

AN Solution

§ Concentration:	Not less than 88 wt.% Nitric Acid

4.3 PFD UFD (WNA & ANS)

NOTES:

1. N2O ABATOR IS OPTIONAL. IF APPLICABLE THEN N2O ABATOR & NOX ABATOR CAN BE COMBINED

NO.	DATE	REVISION DESCRIPTION	BY	CHK	APP
A		PRELIMINARY PFD FOR PROPOSAL	PA	CJO	DB

250 MTPD MONO PRESSURE NITRIC ACID PLANT

NORMAL OPERATION

PROCESS FLOW DIAGRAM

MXXX-PR-DWG-PFD-01	MXXX	PFS-01
DOCUMENT NUMBER	JOB NUMBER	DRAWING NUMBER

MXXX-PR-DWG-PFD-01.dwg 3/22/2022 11:24:43 AM

NO.	DATE	REVISION DESCRIPTION	BY	CHK	APP
A		PRELIMINARY PFD FOR PROPOSAL	PA	CJO	DB

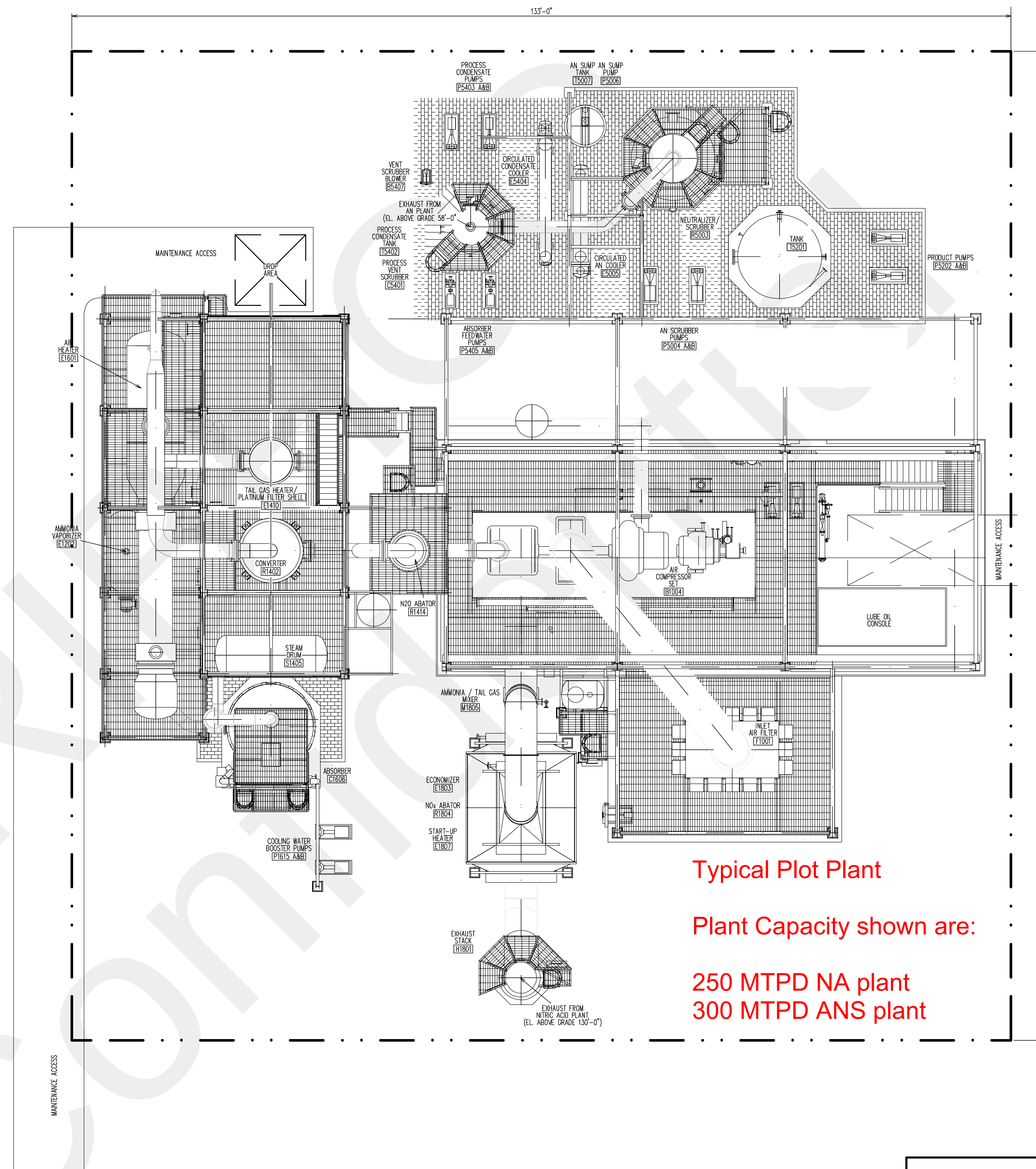
300 MTPD AMMONIUM NITRATE UNIT

PROCESS FLOW DIAGRAM

DOCUMENT NUMBER	JOB NUMBER	DRAWING NUMBER
MXXX–PR–DWG–PFD–02	MXXX	

MXXX–PR–DWG–PFD–02.dwg 3/22/2022 11:24:43 AM

4.4 Plot Plans (General Arrangement Drawings)



Typical Plot Plant

Plant Capacity shown are:

250 MTPD NA plant
300 MTPD ANS plant

Issue	Date	Description	Revised by	Check	Appr
P		PRELIMINARY ISSUE	JRP	WBL	BA

Appr	
Check	Scale 9"=1' 0"
Created by	Date
Dwg.No. 200	Issue P

PLOT PLAN

4.5 Typical Equipment List

- Weak Nitric Acid
- Ammonium Nitrate Plant

KBR Nitric Acid
Typical Equipment List

Since 1954, KBR Weatherly has licensed 76 grassroot nitric acid plants globally and is the No. 1 technology in the demanding US market, with around 80% market share. KBR mono-pressure and dual-pressure technologies provide superior energy efficiency, reliability and environmental performance through low capital cost, high energy efficiency and ammonia conversion at reduced catalyst and maintenance cost, and minimal site footprint requirements. The unique feature of tail gas heat recovery results in high energy efficiency.

Tag No	Equipment
F1001	Inlet Air Filter
B1004	Air Compressor Set (w/ Steam Turbine)
S1005	Interstage Vent Silencer (by compressor vendor)
S1006	Discharge Air Vent Silencer (by compressor vendor)
T1007	Lube Oil Rundown Tank
E1009	Surface Condenser
P1010 A&B	Condensate Pumps
S1011	Tail Gas Vent Silencer
L1040	Building Crane
P1050	Sump Pump
F1201	Liquid Ammonia Filter
E1202	Ammonia Vaporizer
E1203	Auxiliary Ammonia Vaporizer/Superheater
F1204	Ammonia Filter
P1205 A&B	Cooling Water Recirculation Pumps
V1206	Ammonia Blowdown Pot
M1401	Ammonia/Air Mixer
R1402*	Converter Cone
R1402.01*	Converter Basket
R1402.02*	Hydrogen Torch
R1402.03*	Hydrogen Torch Igniter assembly with pressure seal & exciter
E1403*	Expander Gas Heater
E1404*	Waste Heat Boiler
S1405*	Steam Drum
E1406	Blowdown Sample Cooler
S1407	Blowdown Drum
E1408*	Steam Superheater
S1409	Steam Superheater Separator
E1410*	Tail Gas Heater
F1411	Platinum Filter Element
E1412	Steam Tail Gas Preheater
E1413	Air/Tail Gas Interchanger
R1414*	N2O Abator
X1414*	N2O Abator Catalyst

X1420	Desuperheater
X1430	Converter Catalyst
E1415	Air/Air Interchanger
E1416	Air Cooler
E1417	Air Cooler Condenser
L1440	Converter Hoist
E1601	Air Heater
E1602*	Cooler Condenser
S1603	Mist Eliminator
P1605 A&B	Weak Acid Pumps
C1606*	Absorber
P1608	Sump Pump
T1609	Sump Tank
P1615 A&B	Cooling Water Booster Pumps
E1616	Bleach Air Cooler
L1640	Discharge Filter Hoist
H1801	Exhaust Stack
E1803	Economizer
R1804*	NOx Abator
X1804*	NOx Abator Catalyst
M1805	Ammonia/Tail Gas Mixer
M1806	Ammonia/Tail Gas Premixer
E1807	Start-Up Heater
B1812A/B	Abator Tail Gas Blower

* *KBR Proprietary Equipment*

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KBR Ammonium Nitrate Typical Equipment List

Since 1954, KBR Weatherly has licensed over 20 grassroot ammonium nitrate plants globally and is the No. 1 technology in the demanding US market. Distinctive yet simple, the ammonium nitrate (AN) process is designed for high energy recovery while maintaining low emission levels. KBR's Weatherly ammonium nitrate plants are available to produce solutions, high-density prills or granular product.

Production of ammonium nitrate solution occurs in a two-stage neutralization/scrubbing system. This results in low nitrogen losses - high efficiency and low-level effluent contamination.

Superior emission performance, Precise pH control in the neutralizer reduces ammonia losses, Packed sections of the AN scrubber and vent scrubber operate in condensing mode, minimizing AN mist from the scrubbers, Filters capture sub-micron ammonium nitrate mist, Small effluent volume- Process condensate can be utilized in the nitric acid plant. Lower risk- Proven AN technology with outstanding safety record & Low capital cost- Runs at atmospheric pressure, simple equipment.

Tag No	Equipment
T5001	Nitric Acid Feed Tank
P5002	A&B Nitric Acid Feed Pumps
R5003*	Neutralizer/Scrubber
P5004	A&B AN Scrubber Pumps
E5005	Circulated AN Cooler
P5006	AN Sump Pump
T5007	AN Sump Tank
E5010	Ammonia Vaporizer
E5211	AN Evaporator
P5212	A&B AN Transfer Pumps
E5213*	AN Concentrator
E5214	Concentrator Overheads Condenser
P5215	A&B AN Product Pumps
C5401*	Vent Scrubber
T5402	Process Condensate Tank
P5403	A&B Process Condensate Pumps
E5404	Circulated Condensate Cooler
P5405	A&B Absorber Feedwater Pumps
F5406*	AN Demister

* *KBR Proprietary Equipment*

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