CLEARING THE AIR

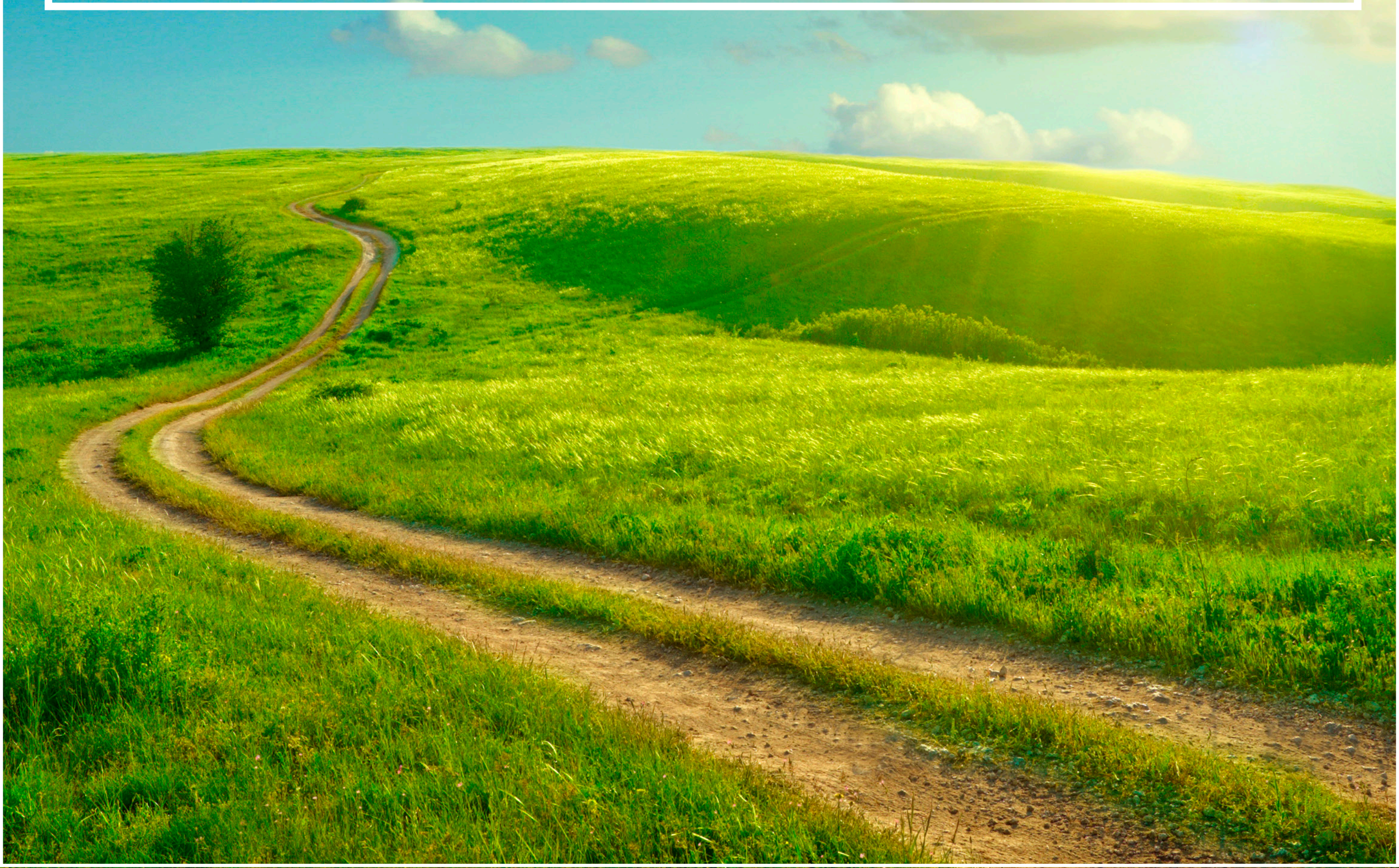
COREY SMITH AND JAMES KELLY MERRITT, JR, GRANNUS LLC, USA, DETAIL THE COMPANY'S LATEST EMISSIONS CONTROL TECHNOLOGIES THAT ARE HELPING A CALIFORNIA AMMONIA PLANT EFFICIENTLY PRODUCE AMMONIA AND MEET AIR QUALITY CONTROL STANDARDS.

The California Ammonia Co. (CALAMCO) imports 100% of its ammonia from outside the US. The company had been looking for years to build a regional-sized ammonia plant within the state so that it would have assured supply, lowered cost and a reduction in transportation related costs and risks. However, due to California's stringent air quality control standards no existing plant design could meet the less than 2 lb/day criteria pollutant threshold.

However, Grannus has developed a novel manufacturing process combining partial oxidation with cogeneration and emission control technologies that significantly reduces emissions while maintaining CAPEX and OPEX competitiveness on a per tonne basis with plants three times its size. The first plant to be built using the patented Grannus Process™ will be located in California's San Joaquin Valley and will supply 250 short tpd of ammonia – roughly 40% of California's agricultural usage. Commercial plant operation is slated for early 2019.

The innovation of the company's patented design is the incorporation of partial oxidation technology, which eliminates the need for a steam methane reformer. A steam methane, or auto-thermal reformer, requires the indirect heating of the endothermic catalyst bed resulting in significant emissions from the heat source. In Grannus' partial oxidation process, syngas is produced in a non-catalytic exothermic reaction, where 100% of the natural gas consumed by the plant is used as feedstock and converted into hydrogen.

There are many advantages to this new technology over existing methods, such as:



- Ultra-low emissions.
- High efficiency for reduced operating costs.
- Competitive cost.
- Modular design available at varying capacities.
- Proven technology from tier 1 suppliers.
- Accelerated environmental permitting.
- Best available control technology designation likely.
- Reduced water consumption.

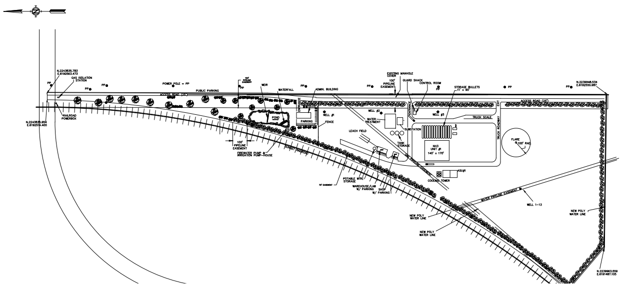


Figure 1. California Grannus ammonia plant site layout.

Figure 2. Lurgi GasPOX unit (courtesy of Air Liquide Global E&C Solutions).

Table 1. Waste fuel boiler

Component	Flow rate (lb/hr)
N_2	4823.38
O_2	1476.40
CO_2	188.37
CO	*0.075 (1.8 lb/day)*
H_2O	152.13
CH_4	0
Ar	85.23
NO_2	*0.075 (1.8 lb/day)*
PM2.5	*0.01 (0.045 μg/m³ per 24 hr)*
Total	6725.68

Ultra-low emissions

A significant portion of the air emissions associated with a traditional SMR-based ammonia plant arise from the combustion of fuel to heat the catalysts located in the reformer section of the SMR. The Grannus Process™ eliminates this waste by using pure oxygen and a non-catalysed exothermic partial oxidation system, where 100% of the natural gas entering the system is used as hydrogen producing feedstock. The system produces almost no nitrogen oxides (NO_X) and no sulfur oxides (SO_X) emissions because the system does not introduce nitrogen and requires no combustion of fuel for the generation of heat. Even the CO_2 produced by the plant is food grade and can be sold for beneficial use, and can create an additional revenue source for the plant.

Compared to a SMR-based ammonia plant, this new technology produces 20% less CO_2 per tonne of ammonia manufactured. Further enhancing the emissions profile of the California plant is the elimination of CO_2 emissions from long-transport via ocean vessel – reducing the total 'landed' CO_2 profile by 80%. The net effect of these innovations is a 250 short tpd ammonia plant that produces less than 2 lb/day of any criteria air pollutant.

High efficiency for reduced operating costs

Unlike an SMR-based plant, every stage of Grannus Process™ plants are exothermic. This creates an additional potential for cogeneration of power, which more than offsets the ancillary power demand for running an air separation unit (ASU). For the plant in California, this means a 250 short tpd plant has a total efficiency of less than 30 million Btu/short t (including all ancillary loads and power demand). This million Btu efficiency includes a 4 million Btu/short t 'surcharge' due to additional equipment necessary to achieve California's emissions requirements – an expense not incurred if constructed elsewhere. Further, as plant size increases, additional efficiency gains are realised by scaling efficiencies common to the industry (such as more efficient capture and utilisation of steam).

Competitive cost

SMRs represent a large portion of the overall CAPEX for nitrogen plants. Whereas, the PO_X burner and waste heat recovery systems included in a Grannus Process™ plant are less expensive at a wide variety of size classes. In particular, the PO_X system (e.g. the Lurgi GasPOX technology offered by Air Liquide Global E&C Solutions) has advantages at regional-sized plants where SMRs face scaling challenges. In addition, because the PO_X burner is non-catalytic, catalyst costs are eliminated and ongoing maintenance is reduced. Including the modular ASU in the CAPEX work-up, the California plant will have an installed cost per tonne at or below SMR plants three times its size.

Modular design available at varying capacities

The inherent CAPEX advantages of the Grannus Process™ design are being further leveraged through a focus on modular and scalable engineering designs that will allow for highly repeatable equipment fabrication at several standard plant sizes. Initial offerings will be at 250, 500 and 1000 short tpd, with larger plant sizes under development. The modular design coupled with standardised engineering and equipment packages will also reduce construction time and cost (including construction financing costs) when compared to traditional 'stick-built' construction.

Table 2. Ammonia vent (to Atm)

Component	Flow rate (lb/hr)
H_2	19.7
N_2	91.38
CH_4	2.55
NH_3	11.21
Ar	58.15
Total	183

Figure 3. Air separation unit (courtesy of Air Liquide Global E&C Solutions).

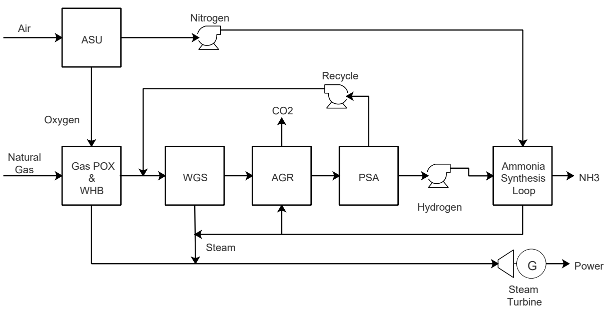


Figure 4. Grannus Process™ simplified process flow diagram.

Proven technology from tier 1 suppliers

All equipment contained in Grannus Process™ plants are proven technology and commercially available at scales from 250 short tpd to over 1000 short tpd. All equipment is provided by tier 1 vendors who have extensive experience in oxygen, hydrogen and ammonia production. For the California plant, Air Liquide is providing key equipment and engineering for the production of hydrogen and Haldor Topsoe is providing the same for the ammonia loop.

Accelerated environmental permitting

Since Grannus Process™ plants emit minimal levels of criteria air pollutants, project development risks associated with permitting are greatly reduced. Depending on the requirements of a customer's jurisdiction, the permitting process may be ministerial and can even make the permitting process non-applicable (i.e., no permit required).

Best available control technology

In the US, Grannus expects its design to become best available control technology (BACT) for all ammonia production facilities and, eventually, for all syngas derived products, thus eventually requiring new plants to meet Grannus' emissions profile.

Reduced water consumption

Water consumption is also a consideration for ammonia production, particularly during droughts and in arid locations. For comparison, a recent analysis estimated that 608 gal. of fresh water is consumed per short tonne of ammonia produced by an SMR based plant.[1] The Grannus Process™ uses 170 gal./short t produced. Of that total, two-thirds is used for making hydrogen. For the California plant, this represents a reduction of 117 acre/ft of water per year – or roughly 60 Olympic swimming pools. Further, due to the lower water usage, wastewater processing and remediation is less costly.

Simplified process flow

The Grannus Process™ uses basic building blocks that can be configured in a number of ways to make chemicals such as hydrogen, ammonia, methanol and associated byproducts.

As described in the preceding, partial oxidation is not full combustion; it is an exothermic reaction of the natural gas and pure oxygen gas mixing in a reduced atmosphere in the GasPOX reaction vessel, where heat is released and synthesis gas composed of carbon monoxide and hydrogen is produced. Heat is extracted from the hot syngas in a waste heat boiler (WHB) before it enters the water gas shift reaction (WGS) where additional hydrogen is released from water and carbon monoxide is converted to carbon dioxide by consuming the free oxygen. Hydrogen is then cleaned by the acid gas removal system (AGR) and pressure swing adsorption (PSA) systems. Recycled gas has a purge stream to remove inert gases below the US Environmental Protection Agency (EPA) limits. End-product food grade carbon dioxide can be sold or, if needed, released to the atmosphere. Clean hydrogen and nitrogen are sent to the ammonia loop. Steam created by heat recovery of the reaction is sent to the steam turbine generator to power the compressors and air separation unit.

Summary

In summary, the Grannus plant in California represents a significant step forward in the production of ammonia. With its highly efficient conversion of natural gas to ammonia, the plant is cost competitive with plants many times its size. Further, the plant may be the world's first LEEDS-Silver certified petrochemical plant – a major win for the environment and a major win for California farmers who will have a reliable, local supply of fertilizer for decades to come. **WF**

Notes

1. BROWN, T., 'The Water Intensity of Ammonia' AmmoniaIndustry.com (3 October 2016).