

Energy Analysis of Nitric Acid Process

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Abstract - Production on Nitric Acid is exothermic process. Ammonia oxidation releases tremendous heat which is recovered and used for the turbo compressor. As all heat energy cannot be converted to mechanical energy, there are some losses. In this paper production of Nitric acid is discussed along with its reactions. Simulation of process is carried out using ASPEN. Material and energy balance is carried out. Finally energy loss through cooling tower is calculated for estimation of energy efficiency.

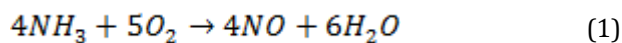
Key Words: Nitric acid, Energy efficiency, mono pressure, Energy balance

1. INTRODUCTION

There are some processes in inorganic chemical industries where raw material itself acts as a source of energy. Nitric acid production is that kind of process due to highly exothermic reactions involved in it. Irreversibility in the reaction is the major cause for the exergy loss. Using energy analysis, we can pinpoint true losses of available energy in this process. Commercial nitric acid plants are operated by two methods – mono pressure and dual pressure. In the present work an attempt has been made to carry out energy analysis of mono high pressure nitric acid process.

2. PRODUCTION OF NITRIC ACID

Ammonia is oxidized to form nitric oxide using air.



The heat generated by above reaction is removed and recovered by passing the resultant process gas through a series of heat exchangers. As process gas is cooled by heat recovery, the nitric oxide combines with additional oxygen to produce nitrogen dioxide.

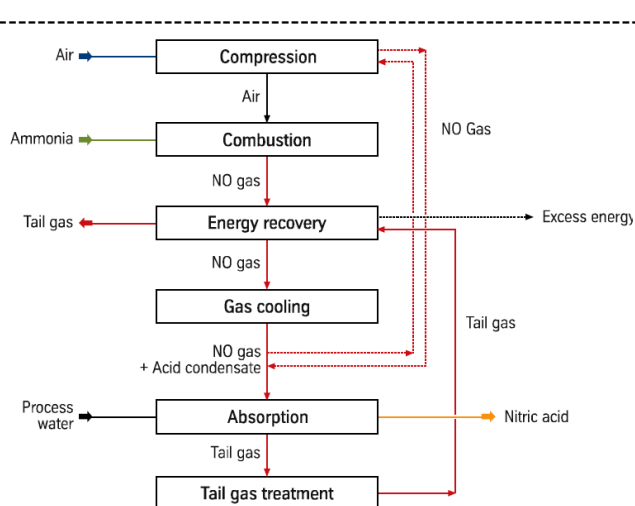
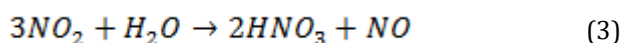


Fig -1: General scheme of nitric acid production

Large oxidation spools are included in the heat exchanger train to promote above reaction and allow recovery of the reaction heat in the heat exchanger. As process gas enters the cooler condenser, nitric acid is formed when nitrogen dioxide combines with water produced in reaction 1. The reaction continues in the absorber where additional water is added to produce nitric acid.



This reaction also generates heat which is removed by cooling water in the absorber cooling coils and the cooler condenser shell. The nitric acid formed in reaction 3 reacts again in accordance with reaction 2. Excess oxygen is supplied by the bleacher air to promote conversion of nitric oxide to nitrogen dioxide. Reaction number 2 and 3 recurring up through the absorber trays producing nitric acid until the quantity of nitrogen oxide in the gas is below required emission. Chilled coolant is used in the upper absorber trays cooling coils to improve the rates of reaction and remove heat of reaction. Overall reaction is

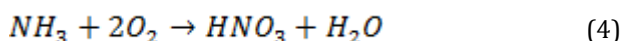


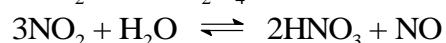
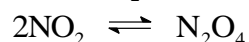
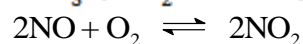
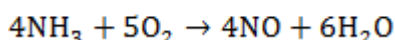
Figure 1 shows general scheme of nitric acid production.

2. CASE STUDY

A Plant having capacity of 300 metric tons of nitric acid (100%) per day is studied here. Raw material consumption is ammonia, air and process water. Heat generated during reactions is used to operate the plant. Air requirement is 2230.4 Kmol/hr, ammonia requirement is 206.7 Kmol/hr, water requirement is 207 Kmol/hr. Nitric acid produced is 198 Kmol/hr (100%).

Nitric acid production involves simultaneous physical and chemical processes. After oxidation of ammonia, process gas contains NO will travel to absorber through various heat exchangers to recover heat. During this period NO will react with available oxygen to form NO₂. All the reactions are taking place in gases phase except in cooler condenser. In cooler condenser nitric acid formed will be dissolved in water condensed to produce weak acid. AspenOne is used to simulate the whole plant. The main mixture property option used in the simulation is the ELECNRTL, which provides an accurate description of the aqueous nitric acid system. Nitric acid is a strong acid and thus it will be largely ionized in aqueous solutions. However, much of the plant operates at high temperature where liquid phases will not be present. For these sections NRTL-RK option is used. The NRTL-RK option has exactly the same description of the vapor phase (i.e., the Redlich-Kwong equation of state) as the ELECNRTL option. For pure water streams we use the STEAMNBS, which calls on the NBS/NRC equation of state for the properties steam and liquid water. As simultaneous heat transfer and chemical reaction occur in heat exchanger PFR model is used. For absorption RadFrac model is used. It is having provision of cooling coils incorporated in it. Fig 2 shows simulation of nitric acid plant in AspenOne. Table 2 shows details of model and property package used for simulation.

Reactions considered for simulation are



3. OVERALL ENERGY BALANCE

For the overall plant the input is air, ammonia and water while output is WNA and tail gas. Air is taken at atmospheric pressure and 35°C, water is at 40°C and ammonia is at -33°C. Tail gas is send to atmosphere through stack at 38°C. Weak acid is coming from absorber at 67°C. Around 90% of energy requirement of plant is available from heat of reaction. Ammonia oxidation contributes 50% of heat which is available at a stretch. Heat is mainly used to run compressor required to compress air at very high pressure

Table -1: Input material and energy to nitric acid plant

STREAM	FLOW (KMOL/HR)	TEMP (o C)	PRESSURE (KPAG, * KPA)	ENERGY (KW)
AIR IN	2230.40	35.00	100*	1952.76
NITROGEN	1678.70			
OXYGEN	446.20			
WATER	105.50			
AMMONIA IN	207.70	-33.00	1725.00	-315.42
AMMONIA	206.70			
WATER	1.00			
WATER IN	207.70	40.00	152.00	77.03
NITRIC ACID OUT	640.73	66.79	1112.00	793.32
NITRIC ACID	197.83			
WATER	442.90			
TAIL GAS OUT	1729.26	14.42	101*	312.72
NITROGEN	1682.81			
OXYGEN	43.42			
WATER	2.73			
NO	0.30			

Table -1: Energy balance of nitric acid plant

INPUT	KW	%
AIR	1952.76	7.41
WATER	77.03	0.29
PUMPS	160.50	0.61
HEAT OF NH3 OXIDATION	13217.71	50.15
HEAT GENERATED IN EQUIPMENTS	10682.95	40.53
HEAT GEN IN PIPE	264.00	1.00
TOTAL	26354.95	100.00
OUTPUT	KW	%
NITRIC ACID	793.32	3.01
WORK	6488.00	24.62
REFRIGERATION PKG	842.00	3.19
COOLING TOWER	17604.03	66.79
AMMONIA	315.42	1.20
TAIL GAS (STACK)	312.72	1.19
	26354.95	100.00

$$\text{Energy Efficiency} = \frac{\text{Energy input} - \text{Energy wasted}}{\text{Energy input}}$$

Energy efficiency = 68 %

Around 66% heat is lost through cooling tower. Cooling coils in absorber take out heat generated due to oxidation, mass transfer and heat of dilution. Surface condenser takes out heat before sending water to boiler. As inter-stage cooling is required in compressor to increase its efficiency, heat is given to cooling tower. The major candidate for heat loss is cooler condenser, where temperature is brought down from 191 °C to 54 °C.

3. CONCLUSION

Primary source of energy in the process is oxidation of ammonia. Steam produced from this heat is used to run compressor. Further oxidation of NO into NO₂ also produces considerable heat which is partly used but major portion is lost in cooling. Process energy efficiency is 68% and almost 25 % energy is lost in gas cooling, absorption and compressor cooling. Energy efficiency can be increased by recovering heat in cooler condenser and converting it into electricity by using ORC.

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