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INCREASED ENERGY RECOVERY IN A SULPHURIC ACID PLANT BY HEAT RECOVERY SYSTEM (HRS™) (a)

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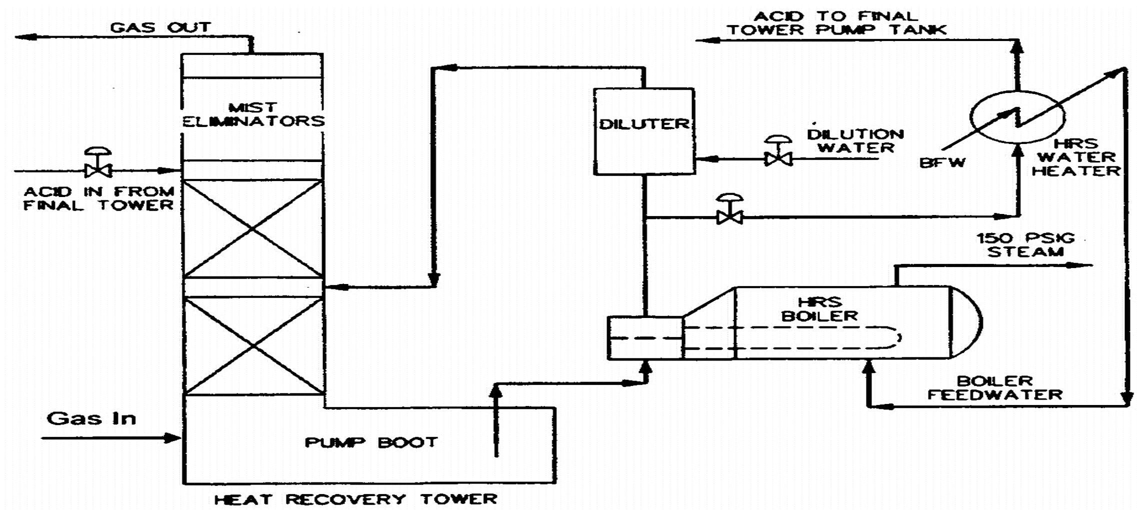
Sulphuric acid plant is a storehouse of energy. All the reactions in sulphuric acid manufacturing are exothermic. Generally most of exothermic heat available from gaseous phase oxidation of SO_2 to SO_3 is recovered as high-pressure steam. But exothermic heat of reaction evolved in liquid phase during formation of H_2SO_4 goes to waste and is discarded to cooling water. This is low-grade heat, which cannot be recovered economically. This heat was partly being recovered as hot water in a very limited way. Then came in the HRS ™ technology developed by Monsanto Enviro-Chem Systems Inc., USA, which recovers all this energy which otherwise goes to waste with the cooling water.

1. What is HRS™?

From the initial conception until now, the basic absorption process has not changed. A simplified flow scheme is shown below. The Heat Recovery System is basically an absorber that operates at 200° C. and uses a boiler to remove the absorption heat as steam (at up to 10 barg), instead of acid coolers (where heat is wasted). The hot gases leaving the first stage are then cooled in the second stage and the remainder of the $S0_3$ absorbed. Gases leaving the tower are essentially the same as gas leaving a conventional interpass tower.



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2. Process Description

The purpose of the two-stage Heat Recovery System (HRS) is to absorb SO3 from the gas stream and recover the heat from the absorption process as medium pressure steam. The first stage recovers the heat of formation of sulphuric acid. The second stage removes the residual SO3 and sulphuric acid vapor and recovers the remaining heat of formation, heat of condensation of sulphuric vapor and sensible heat from cooling process gas.

The HRS system consists of a two-stage packed heat recovery tower, horizontal steam boiler, HRS heater, diluter (in-line), acid circulating pump (in a pump boot), and acid drain pumps. Boiler feed water pumps are provided to supply the HRS boiler with deaerated water from deaerator.

The first stage of the heat recovery tower receives SO3 gas from an economizer upstream of the interpass tower. In this stage, SO3 is absorbed from the gas flowing upward through the packing into circulated sulphuric acid flowing downward through the packing. The process gas then passes through the second stage flowing upward through the packing, where essentially all the remaining SO3 is absorbed into circulated sulphuric acid flowing downward through the packing. The acid from the second stage drops directly onto the packing of the first stage. Acid from the first stage collects in the base of the tower and is circulated via a vertical submerged, centrifugal pump located in the pump boot.

Gas from the 2nd stage exits the tower through Monsanto ES mist eliminators installed in the top of the tower. The mist eliminator removes acid mist formed in the tower down to a level equal to that of a conventional interpass absorbing tower mist eliminator, to protect the downstream interpass heat exchanger.

Acid is pumped from the pump boot through the horizontal boiler and is then split into two streams. One stream flows through the diluter and is circulated over the first stage of HRS tower. The second acid stream flows through the HRS heater where heat is transferred to the HRS boiler feed water heater. From this acid flows through HRS Preheater which heats DM water going to deaerator. From the HRS preheater, the acid is sent to the drying tower or final tower pump tank, where it is mixed with acid from the other towers.

Cooled acid from the FAT acid cooler is received and supplied to the second stage of the HRS at required acid strength. Dilution water is continuously mixed with acid downstream of the HRS boiler to control acid strength. The acid is then circulated over the first stage. The addition of dilution water and the resulting absorption of SO3 raises the temperature of the circulated acid due to the heat of formation. As acid is circulated through the boiler, this heat is exchanged with boiling water. To provide a temperature driving force for heat exchange in the boiler, the acid is circulated at temperatures above the boiling point of the steaming water.

The material of construction of HRS components in contact with the acid with the exception of the ceramic tower packing is 310 stainless steel. These materials exhibit a low corrosion rate (<1 mil/year) with H2SO4 at the required operating temperatures as long as acid concentration is maintained. Corrosion rate monitors are provided at various points in the acid circulation system to sense corrosion rate and to actuate an alarm if the corrosion rate increases due to a loss of acid strength control.

Acid drain piping is constructed of stainless steel 310 and acid diluter is a 304 S.S. Teflon lined vessel.

Because of the importance of concentration control, the HRS and IPA analyzers utilize a toroidal shaped conductivity cell, which is mounted externally on the sample lines. This eliminates the problem of probe breakage and erroneous readings from inadequate sample flow. Four conductivity monitors are provided, one sampling the boiler inlet, two sampling the tower 1st stage inlet (after dilution), and one sampling the HRS product line.

A comprehensive system of interlocks (actuated by acid temperature, strength, corrosion rate and acid flow) is provided to ensure against continued operation with acid strength below the recommended minimum concentration.

3. Energy Recovery in Sulphur Burning Plants

In most sulphur burning sulphuric acid plants, the heat of combustion and SO_3 conversion are being recovered and utilized in power generation and supply of process heat. With a conventional acid plant, the fertilizer plants supply the whole fertilizer complex's electric power and steam needs. Table 1 first column shows that in a 2,000MTPD conventional double absorption plant, 8,200 kg/hr high pressure, high temperature steam (62 barg, 480^{o}C) can be generated. The steam generated has the potential to generate 28.1 MW for this size plant if no low-pressure steam was exported. Of course most fertilizer plants have other needs for the steam, thus part of this power potential is used meeting their other energy needs.

The energy recovery can be improved from 28.1 MW to 34.9 MW by replacing the interpass tower with Monsanto's HRS tower, which recovers most of the heat released in acid formation, condensation and dilution.

ENERGY RECOVERY POTENTIALS IN A 2,000MTPD SULPHUR BURNING PLANT

Form of Energy	Conventional with Interpass Tower	Conventional with HRS
Hp Steam, kg/h	220	195.5
IP Steam, kg/h		109.5
LP Steam, kg/h	- 8	-21.5
Total Heat Utilized M (Million) kcal/hr	73	98
Potential Power, MW	**28.1**	**34.9**

4. Energy recovery Potentials in Smelter Acid Plants

In smelter acid plants there is no heat released due to sulphur burning to SO_2. In fact, since the incoming gas is cold, it needs to be preheated to about 425°C for conversion. Therefore, in the conventional smelter sulphuric acid plants with about 8% SO_2, the heat released from the conversion is used to preheat the incoming gas and to reheat the gas after interpass tower. Therefore, there is not much conversion heat left for recovery.

In plants with 12% or more SO_2 concentration, Monsanto's heat recovery system can be employed to recover the available heat. For example in a 2,000MTPD smelter plant with 14% SO_2, 118 kg/h of 10 barg, 400 C steam can be recovered, including all the heat needed to preheat and deaerator BFW. This will give **11.5 MW** power generation potential (see next Table). In fact there is more heat that can be recovered to preheat BFW for smelter waste heat boilers.

ENERGY RECOVERY POTENTIALS IN A 2,000MTPD SMELTER ACID PLANT WITH 14% SO_2

Form of Energy	Conventional with HRS™	Wet Process with HRS (MONARCH™)
Hp Steam, kg/h	0	0
IP Steam, kg/h	118	160
LP Steam, kg/h	0	0
Total Heat Utilized M (Million) kcal/hr	40	55
Potential Power, MW	**11.5**	**15.5**

5. Economics For HRS™ In Small Capacity Plants

Generally HRS is very much suited for large size acid plants above 1000 MTPD capacity. However there are large numbers of small capacity acid plants in countries like India, which could also be candidates for HRS application. Based on Indian conditions a study done for small size plants indicated that it would be economical to have HRS in these plants provided the LP steam available could be utilised effectively. Generally the major part of HP steam is used to generate power. But a part of HP steam generated from gas section heat is downgraded to LP steam and used for melting of sulphur, deaeration of boiler feed water, etc. This HP steam could be saved to be used for power generation while using LP steam from HRS for sulphur melting, deaeration, phosphoric acid concentration, etc. This adds much more value to steam available from HRS and with rising cost of electricity and fuel, this becomes much more economical.

Based upon studies done for a 400 MTPD Sulphuric Acid Plant operating under Indian conditions the following financial analysis has emerged.

Technical Data

LP Steam from HRS	7.8	mt/hr
HP Steam available for power generation	7.8	mt/hr
Power generated	1.30	MW

Financial Data

Power Cost (US$/KWH)	0.08	Income Tax Rate (39.55)	40.0%
Operating hours per year	8000	Minimum Alternative Tax rate	7.5%
Interest Rate (Assuming present PLR at 12%)	15.0%	Cost of HRS (US$ K)	1800.0
Depreciation on Plant and Machinery	10.0%		
Depreciation under Income Tax Act	100.0%	Revenue (US$ K/year)	819.3
Spares/Operating cost (of Project Cost)	2.0%		
Insurance on Fixed Assets	0.5%	**IRR based on 10 years cash flow**	**27%**

6. Financial and other Details

1) Interest at 15%

2) Investment assumed to be by way of Term Loan for 5 years period

Moratorium: 1 year after project commencement

3) It is assumed that the project will be implemented over a period of one year.

Total Project Cost US$ K	
Plant and Machinery	1800.00
Interest Cost during construction	114.43
Total US$ K	**1914.43**

7. Cash Flow and Profit Projections (Figures in US$ K) for 10 Years Plant Life

Year	Gross Revenue	Spares/ operating cost	Insurance	Interest	Depreciation	Profit before Tax	Taxable Profit	Income Tax	Cash Flow
1st	819.3	38.3	9.6	287.2	1914.4	-1430.2	-1430.2	61.4	-1491.6
2nd	819.3	38.3	9.6	287.2	0	484.2	-945.9	61.4	422.8
3rd	819.3	38.3	9.6	229.7	0	541.7	-404.3	61.4	480.2
4th	819.3	38.3	9.6	172.3	0	599.1	194.8	77.9	521.2
5th	819.3	38.3	9.6	114.9	0	656.5	656.5	262.6	393.9
6th	819.3	38.3	9.6	57.5	0	714.0	714.0	285.6	428.4
7th	819.3	38.3	9.6	0	0	771.4	771.4	308.6	462.8
8th	819.3	38.3	9.6	0	0	771.4	771.4	308.6	462.8
9th	819.3	38.3	9.6	0	0	771.4	771.4	308.6	462.8
10th	819.3	38.3	9.6	0	0	771.4	771.4	308.6	462.8

Taxable profit is arrived at after taking into consideration 100% depreciation on investment of US$ 1914 K

In the calculations above, the income tax is considered treating the "Heat Recovery System" as a separate entity. However, the tax implication for the Company as a whole may be considered after taking into account 100% depreciation available for energy saving devices (Waste Heat Recovery Equipment)

IRR for this case works out to be a good 27% for a 400 MTPD capacity plant. Another benefit of the HRS system is the reduction in cooling water requirements due to the elimination of the acid cooler in the Interpass Tower acid circuit. Reduction in Cooling Water flow for 10^oC rise in temperature is 400 M^3/hr for a 400 MTPD plant.

8. Conclusion

HRS ™ has been implemented successfully in more than 20 plants worldwide in plants of various sizes; plants based on sulphur burning as well as metallurgical gas feed. These installations have been implemented in new plants and existing plants as well have been retrofitted with HRS. Numerous process enhancements like steam injection, high efficiency HRS (with and without deaerator) and condensing economizer/boiler make this process available for retrofitting of existing plants and new smaller capacity plants, and these should encourage customers to make the capital investment for adding the Heat Recovery Systems to their plants. Today, HRS™ systems operate reliably; generating steady income from the steam and electrical power it can produce.

9. References

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