1. Basic descriptions of two processes

1) via "Sulphuric Acid Vacuum concentration"

- **Typical Process:** Concentrating waste acid from 20% ~ 60% or even lower to 70% ~ 75% by pre-vacuum concentration process; concentrating acid from 70% to 85% by intermediate vacuum concentration; concentrating acid from 85% to 96% ~ 97% by high concentration process.

  Concentration：w（H_2SO_4）20% →→w（H_2SO_4）70%→→w（H_2SO_4）85% →→ w（H_2SO_4）95%

Phase Ⅰ pretreatment：

It can be operated at atmospheric pressure or in vacuum. Different materials and types of heaters can be used according to the concentration of waste acid and impurity characters. Multi-effect (or multi-stages) vacuum concentration will undoubtedly save energy, but because multi-effect vacuum concentration will increase the investment cost of equipment, generally it is not recommended to use more than three-effect pre-concentration processes.

Phase Ⅱ Intermediate vacuum concentration of sulphuric acid：w（H_2SO_4）20% →→→w（H_2SO_4）85%

Generally, it operates under the absolute pressure of 8 ~ 10Kpa and the operating temperature is 150~180℃. For the devices with high processing capacity, it can be divided into two or more stages to reach the final required product concentrations.

PhaseⅢ Highly concentrated： w（H_2SO_4）85%→→→w（H_2SO_4）95%

The main equipment is metal tantalum, which is expensive. Steam consumption is huge during this process.

- **About our task:**
  For the feed w (H_2SO_4) 45%, theoretically, it is possible to be concentrated to various concentrations of acid in the range of 45% ~ 95%.

2) via "Spent sulphuric acid regeneration (SAR) process"

- **Process:** thermal decomposition(Fuel must be added)→→gas clealing→→ dring&absorbtion→→converte

  Concentration： w（H_2SO_4）60% →→→w（H_2SO_4）98%

Generally, the feed concentration should be w (H_2SO_4) > 60%, because a large amount of water and air are brought into the combustion process. If the feed concentration is low, the heat balance of the conversion process will be affected. At the same time, if the water content is too high, the water balance in the dry suction section will be unbalanced.

- **About our task:**
  The feed with 45% concentration of (H2SO4) appears to be low in concentration by the above mentioned SAR method and may be necessary to be concentrated first. Then use SAR process for further concentration and purification.

w（H_2SO_4）45% →→w（H_2SO_4）65% →→w（H_2SO_4）75%【w（H_2SO_4）85%、w（H_2SO_4）95%】

Tab.1 Comparison of two processes：

comparative content	two processes	
	Sulphuric Acid vacuum Concentration	**SAR**
Impurity content in waste acid	It is more suitable for waste acid with low impurity content. It is suggested that it is suitable for small amount of acid and low impurity content.	Using calciner to incinerate and electrostatic precipitation to remove burning dust, no matter how much impurity content in waste acid, the process can be used to treat the acid to reach high quality acid and it can be used in a wide range.
Final product	Only sulphuric acid with a concentration of less than 98% can be produced, because 98% of the sulphuric acid is mixed with water during concentration, and only 98% can be achieved regardless of any measures taken. When the waste acid is concentrated, the solid impurities cannot be removed, but the water and volatile organic compounds are evaporated. The concentrated waste acid can only be reused by this product. Due to the recycling of concentrated waste acid, the pipeline is easy to be blocked after a long time, and acid sludge is easy to deposit at the bottom of the acid storage tank.	Different concentrations of waste acid can be produced. Similar to sulphur burning sulphuric acid, the quality of sulphuric acid produced could reach the national standard.
equipment investment	The use of tantalum material in the acid evaporating tower, with enamel glass lining in the washing tower, and the investment of the two equipment are relatively high.	The processes from calciner to transformation，and dust removal is gas flow. The equipment volume and pipe size are large, the occupied area (or footprint) is large, and the equipment investment is large.

operational cost	**Daily maintenance of equipment**	Vacuum concentration of waste acid is easy to leak under the condition of unstable temperature control and sharp change of temperature due to the use of some glass equipment pipes.	
	industrial wastes management	It mainly deals with acidic wastewater produced by condensation and acidic wastewater from vacuum pump.	Control the content of sulfur dioxide in waste gas, treat or use acid wastewater, and waste residue from electrostatic precipitator.
	Site environment and staffing	Depending on the size of the device, several full-time staff members are required.	The installation site is neat and clean, and the labor intensity of workers is not heavy.
	Consumption of waste acid treatment	Steam or heat transfer oil is needed to vaporize water under vacuum condition.	A large amount of natural gas is needed. The calciner temperature is controlled at about 1000 ℃, and the water in the waste acid is vaporized.
	Other consumption	Waste acid, low pressure steam, electricity, by-product medium pressure steam, water, deoxidizing water, circulating water, analysis costs, maintenance costs, equipment depreciation, personnel wages, management costs	

2. investigation of industrial waste acid treatment plant

Tab.2 Concentration of industrial waste acids from different sources and their usual treatment processes

Various kinds of waste acid from different industrial processes	**Waste acid concentration**	**Treatment process**
Titanium dioxide waste acid	w（H_2SO_4）19%~23%	concentration
Aromatics nitrification waste acid	w（H_2SO_4）60%~70%	concentration
Dyestuff waste acid	w（H_2SO_4）10%~50%	Partly neutralization “or ”concentration
Steel cleaning waste acid	w（H_2SO_4）5%~10%	Recycling→FeSO4【$Fe_2(SO_4)_3$】n
Alkylation waste acid	w（H_2SO_4）85%~90%	regeneration (SAR)
MMA	w（H_2SO_4）40%、w【$(NH_4)_2SO_4$】35%	concentration + regeneration (SAR)
Hydrofluoric acid drying waste acid	w（H_2SO_4）75%~85%	concentration
Chlor alkali waste acid	w（H_2SO_4）75%~80%	concentration “or ” Air lift

Acetylene purifying waste acid	w（H_2SO_4）80%~90%	concentration “or” regeneration (SAR) “or” neutralization

Tab.3 operational cost of Sulphuric Acid Concentration (45%→→→96%)

(A device in Nanjing,china)

	unit consumption		**Unit Price**		**Unit cost (yuan/t)**
Sulphuric acid 45%	2155	kg/t			
Alkali (in kind)	180	kg/t	550	yuan/1000kg	**99**
Qing River water	200	kg/t	0.85	yuan/kg	**170**
circulating water	100	t/t	0.18	yuan/t	**18**
electric	69	kWh/t	0.65	yuan/kWh	**44.85**
Medium pressure steam	0.45	t/t	150	yuan/t	**67.5**
1.1MPa	1.2	t/t	140	yuan/t	**168**
Cost analysis					**3**
maintenance costs					**10**
Depreciation of equipment					**20**
Personnel wages					**28.7**
Management cost					**10**
operational cost					**639.05**

The vacuum concentration process needs two stages of enrichment, from 45% to 65% or 65% to 96%. The operational cost is about 600 yuan / ton (including depreciation).

Tab.4 operational cost of SAR(45%→→→96%) (A device in Nanjing, China)

		unit raw material consumption		**Unit Price**		**Unit cost (yuan/t)**
waste acid	45.00%	2155	kg/t			
Low pressure steam	0.8MPa	80	kg/t	130	yuan/1000kg	**10.4**
electric		95	kWh/t	0.65	yuan/kWh	**61.75**
By-product medium pressure steam	3.2MPa	-800	kg/t	150	yuan/1000kg	**-120**
Qingjiang River water		500	kg/t	0.85	yuan/1000kg	**0.425**
De-oxygen water		1160	kg/t	24	yuan/1000kg	**27.84**
circulating water		82000	kg/t	0.18	yuan/1000kg	**14.76**
Natural gas		230	Nm3/t	2.8	yuan/Nm3	**644**
Cost analysis						**3**
maintenance costs						**3**
Depreciation of equipment						**40**

Personnel wages						**28.7**
Management cost						**10**
operational cost						**723.875**

The operational cost of waste acid regeneration process is about 1000 yuan / ton.
The investigation of the industrial waste acid treatment plant has found that the source of waste acid, the type of impurity content, the initial concentration of waste acid, the concentration of finished acid, the amount of treatment, the steam used, the combustion gas and so on are the factors affecting the process combination, investment and operational cost of the treatment plant. Therefore, it is difficult to collect enough data from the completed projects in line with our task requirements.

In the following work, I intend to set the preconditions for a certain type of waste acid with a starting concentration of 45% w (H_2SO_4), daily treatment amount, steam, and burning gas (calorific value), and ask experts to give rough estimations based on personal experience of different final sulphuric acid concentrations, investment and operating costs.

3. Waste sulfuric acid treatment and vacuum concentration process and its operational cost and investment analysis

Setting up the process condition of waste sulfuric acid concentration, analyzing different final sulfuric acid concentration, its investment and operational cost

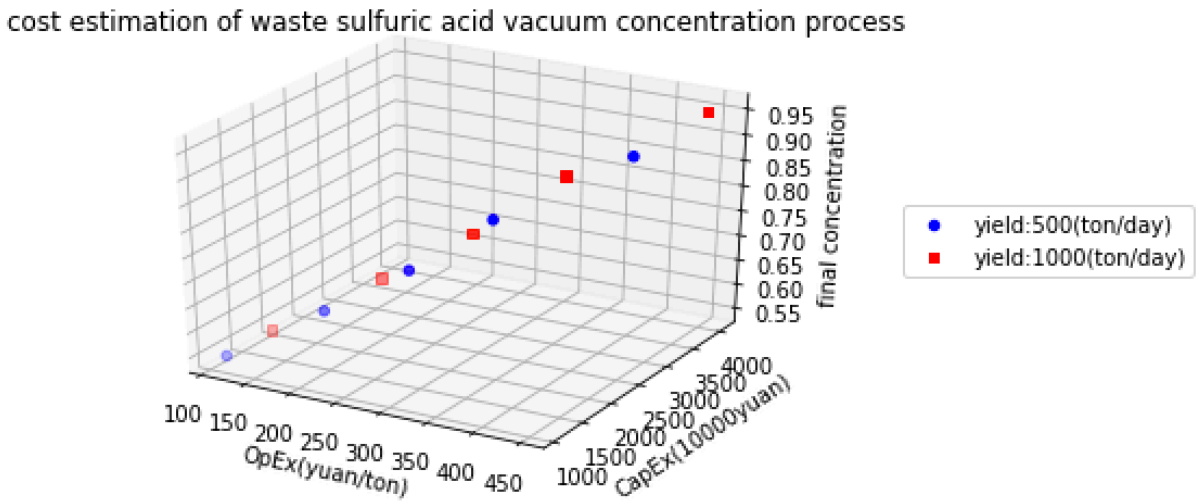
1) cost estimation of waste sulfuric acid vacuum concentration process

Tab.5 cost estimation of waste sulfuric acid vacuum concentration process

Primary concentration	final concentration	yield (ton / day)	CapEx (10000 yuan)	OpEx (yuan / ton)	Remarks
45%	55%	500	1070	114.3	
		1000	1800	112	
45%	65%	500	1400	202.5	
		1000	2350	200	
45%	75%	500	1550	286	
		1000	2630	283	
45%	85%	500	1870	354.6	
		1000	3170	350	
45%	95%	500	2670	450	

		1000	4070	445	

3Dgraph：



2) cost estimation of Spent sulphuric acid regeneration (SAR) process

The feed with 45% concentration of (H_2SO_4) appears to be low in concentration by Spent sulphuric acid regeneration (SAR) process method and can be concentrated first，then use SAR mode.

Because of it's high investment cost, professionals give the following suggestions and estimate the related costs for our task,.

w（H_2SO_4）45% →→w（H_2SO_4）65% using waste acid concentration process;

w（H_2SO_4）45% →→w（H_2SO_4）75% using waste acid concentration process;

w（H_2SO_4）45% →→w（H_2SO_4）85% using two stage concentration process.

w(H_2SO_4)45% →→w(H_2SO_4)95% using two stage concentration and regeneration process(SAR)

Tab.6 cost estimation of spent acid regeneration (SAR)processes

Primary concentration	final concentration	yield (ton / day)	CapEx (10000 yuan)	OpEx (yuan / ton)	备注
45%	65%	500	1441	215	vacuum concentration
		1000	2420	212	
45%	75%	500	1610	300	vacuum concentration
		1000	2720	297	
45%	85%	500	1970	364.6	2 stage

		1000	3320	358	vacuum concentration
45%	95%	500	3600	750	2 stage vacuum concentration + regeneration (SAR)
		1000	6070	745	

3Dgraph：