

**PRELIMINARY DESIGN OF PRECIPITATED SILICA PLANT FROM
SULPHURIC ACID AND SODIUM SILICATE
WITH CAPACITY OF 40,000 TON/ YEAR**



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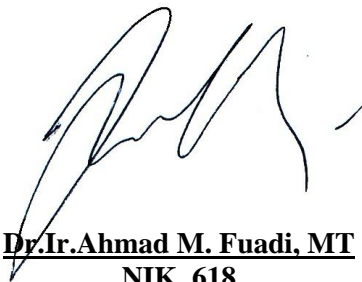
Judul Skripsi : **Preliminary of Precipitated Silica Plant from Sulphuric Acid and Sodium Silicate with Capacity of 40,000 ton/year.**

Naskah artikel tersebut, layak dan dapat disetujui untuk dipublikasikan.

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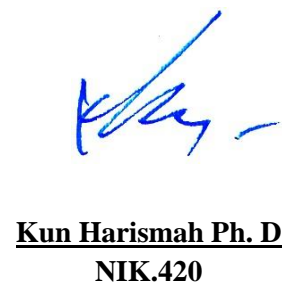
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ABSTRACT

In Indonesia, precipitated silica plant is an industry that can provide a good opportunity for the country. Indonesia has not been able to meet the needs of precipitated silica, so that Indonesia imports from other countries. From 2005 to 2012 Indonesia has exported 89,801.806 tons of precipitated silica, and the capacity for imports are 111,362.3 tons, so the precipitated silica plant is designing of 40,000 tons/year. Precipitated silica (SiO_2) is the oxidation of non-metallic compounds. it has a solid powder form, white, odorless, insoluble in water, and has a crystalline structure. The process of manufacturing of precipitated silica using silicate acidification uses CSTR reactor (continuous stirrer tank reactor). It operates at a temperature of 90°C and at a pressure of 1 atm. This reactor proceeds in the liquid phase, irreversible, and non-adiabatic. The product of the reactor are separated in rotary vacuum filter, and then the result is a cake of SiO_2 . It is dried with dryer.

Utility units of the plant consists of the units of the water provider, the unit of steam supply, electricity and fuel supply unit, and laboratories to maintain the quality of materials and products to conform to the standards. This company is a Limited Incorporation with a system of organizational structure and staff. As a plan, the company is built in Karawang, District Ciampel, and West Java Province. The establishment of the plant requires a total investment (capital investment) amounting to Rp 274,988,392,478.30 and production costs Rp 182,861,209,437.49. Economic analysis obtained BEP 54.8%, SDP 30.6%, 24.31% ROI before tax, ROI after tax (Inc, Ltd) 14.59%. Profit after tax earned Rp 28,550,485,320

Keywords: Precipitated silicate, flow stirred tank reactor.

- **Introduction**

1. Background

Precipitated silica is one of the chemicals that are often used as industrial raw materials, particularly industries that use rubber materials, insecticides, and supporting materials. The industries include food or beverage industry, ceramics industry and water filter. Precipitated silica (SiO_2) is the oxidation of silica, a non-metallic compounds. SiO_2 is a solid powder, white, odorless and insoluble in water except for fluoride acid. Precipitated silica has several crystal structures, like carbon in the form of graphite and diamond, it has the same composition with sand and glass, but the shape of the molecule is a cubic, while the glass has a tetrahedral structure (Ulman, 2005).

Precipitated silica is silica or silica powder that has a non-metallic oxide compound with the chemical formula SiO_2 . Our final

project that we made are supported by previous studies carried out by (Wulandari, 2010) with the title design precipitated silica plant with a capacity of 15,000 tons / year, the reaction takes place in the liquid-liquid phase with the properties a reversible reaction, isothermal conditions, non-adiabatic. The reaction is exothermic so as to maintain a temperature of 60°C in order to keep the reactor is equipped with a cooling jacket. Then (Assafira, 2007) the design of precipitated silica plant acidification process alkali silicate solution with a capacity of 50,000 tons / year, manufacture of precipitated silica with a solution of alkali silicate acidification process is done in a Continuous Stirred Tank Reactor and at a temperature of 80°C and a pressure of 1 atm is equipped with a cooling jacket. Inside the reactor an exothermic reaction between sodium silicate with sulfuric acid. In designing a chemical plant by (Wahyuningsih, 2006) with the title the design of the plant

precipitated silica from sodium silicate and sulphuric acid with a capacity of 16,000 tons / year, the process of manufacture of precipitated silica CSTR held in the reactor. In these reactors the reaction in the liquid phase, irreversible, isothermal, at a temperature of 90°C and a pressure of 1 atm.

In Indonesia, precipitated silica plant is one of the industries that provide good opportunities for the country. Indonesia has not been able to meet the needs of precipitated silica, so that Indonesia still imports from other countries. So far, Indonesia has exported as much 89801.806 tons from 2005 to 2012, and its import needs as much 111,362.3 tons. There is inability of producers to meet all the demand or the dependence on imports from other countries. If the precipitated silica plant is built, there are some benefits.

a. Create jobs for the people of Indonesia

b. Adding foreign exchange devise.

c. Precipitated silica needs can be met without imports from other countries.

d. Encouraging the development of Plant around that use precipitated silica as raw materials.

e. It is expected to penetrate the export market.

2. Selection of the Capacity of the Plant Design

In deciding the capacity of the Plant Design, it must consider some factors, such as:

a. The Needs of Product Marketing in Indonesia

Indonesia is a country that has not been able to meet all the needs of precipitated silica, so that Indonesia imports it from overseas.

b. The Number of Raw Materials

The raw materials of precipitated silica are sulphuric acid and sodium silicate. Sulphuric acid raw material is obtained from PT. Timur Raya Tunggal in Karawang, West Java with a capacity of 49,500 tons / year (www.timurraya.com). Sodium silicate is obtained from PT. Mahkota Indonesia is located in Pulogadung, North Jakarta , with a capacity of 30,000 tons / year (PT. Mahkota Indonesia, 2008).

c. The Existing Capacity of Precipitated Silica Plant

In determining the capacity of the Plant, the researcher must know the data capacity of the existing Plant. The data capacity of the existing Plant can be seen in Table 1.2.

Table 1.2 the Existing Capacity of Precipitated Silica Plant

No	Company	Location	Weight (ton)
1	PT.	Semaran	6.000

	Tensindo Sejati	g, Jawa Tengah	
2	Nippon Silica Industrial	Nanyo, Jepang	40.000
3	PT. Crosfield Indonesia	Pasuruan, Jawa Timur	10.000
4	Rhodia, Inc	Paulina, Brazil	36.000
5	Shougua ng Baote Chemical & Industrial Co., Ltd	Shandong, China	140.000

Based on the data, we can determine the capacity of pre-draft precipitated silica Plant. The capacity is 40,000 tons / year. The 3 reasons 1) heat of the capacity, 2) It can meet domestic needs and the rest can be exported to increase foreign exchange, 3) It is expected to meet its domestic needs.

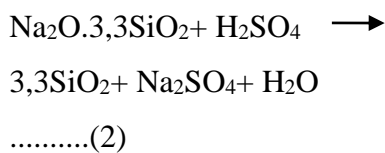
• The Kind of Process

a. Wet Process

1. Acidification Silicate

The process of precipitated silica by neutralization of

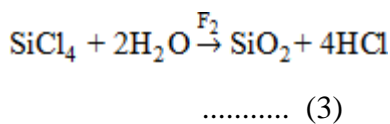
sodium silicate solution with an acid solution (H₂SO₄) is through the process of filtration, drying, milling, and granulation. It produces precipitated silica that has the same size and takes place at temperatures of 90-100°C, the following reactions are:



This process is for the mixing process to avoid the formation of gel (Ulman, 2005).

2. SiCl₄ Reaction With Fluoride

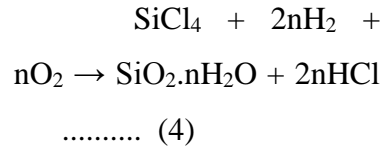
SiCl₄ has high purity that is equal to 99%. Hydrolysis process uses a temperature of 60°C. In the process, need special treatment due to form a gel. The reaction is



b. Dry Process

This process is SiCl₄ evaporation and decomposition with hydrogen at a temperature 1800-

2000°C. Thus, it forms silica acid powder products. The reaction is



1. The Usefulness of Products

The uses of Precipitated Silica are (Ulman, 2005):

- a. The rubber industry use precipitated silica as a reinforcing material
- b. The cosmetics industry use precipitated silica as a compactor and anticaking.
- c. The toothpaste industry use precipitated silica as an additional active ingredient and abrasion agent.
- d. The paper industry use precipitated silica as filler.
- e. As an agent of silicone rubber.

• The Process Stages

In the pre-draft of precipitated silica is done in three stages, Detailed description of the process is as follows
The Preparation of Raw Materials

Sulphuric acid with a purity of 98% put into the storage tanks (T-02) with a pressure of 1 atm and a temperature of 30°C. Then it is pumped (P-05) to the mixer (M-01) to be reconstituted with water to a concentration of 40%. Then it is pumped (P-06) to Reactor (R-01) and Reactor (R-02). It serves to react sodium silicate with sulphuric acid to form a compound of precipitated silica and sodium sulphate.

Sodium silicate with a concentration of 35% is stored in storage tanks (T-01) at a pressure of 1 atm and a temperature of 30°C and then it is pumped (P-03) to Reactor (R-01) and Reactor (R-02), which serves for reacting sodium silicate with sulphuric acid to form a compound of precipitated silica and sodium sulphate.

The Product Formation

Preliminary of the Plant uses a two stirred tank reactor (CSTR). Arranged in series flow stirred tank reactor

(CSTR). The stirred tank reactor is considered that the stirrer is working perfectly, thus producing a uniform concentration of each component of the flow that coming out of the reactor. Stirrer function is to avoid the formation of gel and to accelerate the reaction. Reactor (R-01) resulted in a conversion of 93.65% conversion of reaction out of the Reactor (R-01) and fed to the reactor (R-02) so that the reaction conversion of 99.4%

The Purity Products

Reaction products from the reactor (R-02) in the form of slurry with a temperature of 90°C is pumped (P-08) to a rotary drum filter (RDF-01) which serves to separate the main product (SiO₂) in the form of solids and filtrate. In the process of purification in the filter, it is the formation of cake and washing the cake with water is done. It aims to purify the SiO₂ from the impurities. Filtrate is fed into the Separator

(S-02) and the output of the washing liquid cake fed into a Separator (S-01). Separator (S-01) separates air and fluid that comes out from liquid cake washing results. Separator (S-02) separates air and fluid that comes out from filtrate that comes out of RDF. The resulting filtrate directly channeled toward the UPL. Cake that has washed next to the belt conveyor (BC-01), to be fed to the rotary dryer (RD-01) and to be dried by heating air from the heat exchanger (HE-01). Rotary dryer of precipitated silica, it is brought to Belt Conveyor (BC-02) to be transported to the (BE-01), then Separating solids (dust) from the air that comes out of rotary drier fed by the cyclone separator (CS-01) to separate entrained dust, the dust will fall down towards (BE-02), Bucket Elevator (BE-01), heading Hoper (H-01). From Hopper (H-01) to the ball mill (BM-01) which serves to destroy the product in order to obtain the

desired product, 325 mesh. From the ball mill (BM-01), the product carried by Bucket Elevator (BE-02) to the vibrating screen (SCr-01). It serves to separate products that do not meet the size. Products that do not meet the size will be recycled/fed again towards the ball mill (BM) through belt conveyor (BC-03). Next, for products that fit the size of the head to Silo. It serves to accommodate products of fine silicate solids that come out of screen. Furthermore, Bucket elevators (BE-03) to BIN transport the products (B-01) to accommodate the solid silicate products transport before packing process.

- **Process Equipment Specifications**

- **1. Mixer (M-01)**

- Code :M-01
- Tank Type: Upright tank with stirrer
- Amount :1
- Function : To dilute sulfuric acid solution of 98% in water, so that the

concentration of sulfuric acid decreased to 40% before it is fed into the reactor.

Specification

- Construction materials :
Stainless steel SA 167 type 316
- Inside diameter : 72 in
- Outside diameter :
71.625 in
- Tank Volume : 7.72 m³
- Tank height : 3.31 m
- Tank diameter : 30 ft
- Shell thick : 3/16 in
- Head height : 0.365 m
- Head volume :
0.510 m³
- Stirrer :
Flat blade turbine with 4 baffle
- Motor Power : 15 Hp
- The stirrer speed : 150 rpm
- The depth of the baffle :
0.152 m

2. Heat Exchanger (HE-01)

- Code : HE-01
- Amount : 1
- Function : Heats the air of a temperature of 30 ° C. 174.8 ° C before it is used as drying air in the rotary drier.

Specification

- Construction materials :
Stainless steel SA 316

- Type : Shell tube type 1-2
- Extensive heat transfer :
1103.3 ft²
- Coefficient (UD) :
18.6 Btu/j.ft².°F
- Dirt factor (Rd) :
0.0038 1/(Btu/j.ft².°F)
- RD (Min) : 0.003
- Coefficient of heat transfer for overall clean (UC):
20.1 Btu/j.ft².°F

Shell

- ID : 39 in
- *Baffle* : 32 in
- (Coefficient of heat transfer), ho :
20.3 Btu/j.ft².°F
- Pressure drop side :
1.360 Psi

Tube

- Amount : 362
- DO : 1.25 in
- BWG : 16 BWG
- Pitch : 1.56 in
Square
- (Coefficient of heat transfer), hio : 1500
Btu/j.ft².°F
- Pressure drop sisi : 0.001
Psi

3. Reactor 1

- Code : R-01
- Function : Places to react between sodium silicate and sulfuric acid. It is to form precipitated silica.
- Type : RATB

- Reactor Conversion : 93.65%
- Operational Condition
- Temperature : 90 C
- Pressure : 1 atm
- Heat transfer area 2: 192.71 ft²
- Coil Volume:31.227 ft³
- Coil height:2.489 m

D. Process Supporting Unit & Laboratory

Specification

- Construction materials : Stainless steel SA 167 type 316
- ID : 83.625 in
- OD : 84 in
- Reactor height :3.87 m
- Shell thick :0.16 in
- Head thick :0.19 in
- Type of stirrer :Flat blade turbine 4 battle
- Speed of stirrer :130 rpm
- Motor power :15.21 / 0.86 = 17.68 Hp
- Diameter of impeller :0.708 m
- Depth of baffle :0.177 m
- Amount :2

Coil Cooler

- U_c :459.46 Btu/j.ft².°F
- U_d :193.2 Btu/j.ft².°F
- Heat transfer area : 428.25 ft²

Heat Transfer equipment

- Number of coil :2
- Type :coil
- Length of coil 1 :467.4 ft
- Length of coil 2 :257.1 ft
- Heat transfer area 1: 235.54 ft²

a. Water Process

Total water that is used for the process: 8221 kg/hour

b.Steam Supply Unit

Steam requirement=1410.0 kg / h

c.Power Supply Units

Total=730.91 Kw Fuel

d.Fuel Supply Unit

The total volume of diesel fuel needed = 119.3 l/h

e.Generator

Generator efficiency = 476 kW

E. Conclusion

Based on the operating conditions, precipitated silica plant of sulfuric acid and sodium silicate with capacity of 40,000 tons / year is classified as low-risk plant.

Economic feasibility results are:

a. Profit before tax of Rp

47,584,140,240

b.Profit after tax of Rp

28,550,485,320

c.Return On Investment (ROI)

before tax of 24.31%

d. Return On Investment (ROI)

after tax of 14.59%

e. Pay Out Time (POT) before

tax for the year 2915

f. Pay Out Time (POT) after tax

for 4.067 tahun

g. Break Even Point (BEP) of

54.8% with Shut Down Point

(SDP) 30.6%.

Based on the results of the economic analysis of precipitated silica plant of sulfuric acid and sodium silicate worthy established.

BIBLIOGRAPHY

- <http://karawangkab.bps.go.id> .
Access date March 28, 2015. At 15:00 pm
- Aries, R.S., and Newton, R.D., 1955
“*Chemical Engineering Cost Estimation*”, Mc.Graw-Hill Book Company, Inc., New York.
- Assafira, Maidini. 2007. “*Perancangan Pabrik Precipitated Slicate menggunakan proses Asidifikasi Silica dengan Kapasitas 50.000 ton/tahun*”. Essay. Yogyakarta: Faculty of Engineering, Universitas Islam Indonesia.
- Baasel, W.D. 1974. *Preliminary Chemical Engineering Plant Design*. New York: Elsevier
- Badger, W.L., and J.T. Banchero. 1955. *Introduction to Chemical Engineering*. New York: McGraw-Hill International Book Company
- Brown, G.G., 1950, “*Unit Operation*” , John Willey and Sons, Inc., New York.
- Brownell, L.E., and Young, E.H., 1968, “*Process Equipment Design*”, 1st ed., John Willey and Sons, Inc., New York.
- Bylander, E.G. 1962. Kinetics of Silicon Crystal Growth from SiCl_4 Decomposition, *J. Electrochem. Soc.* 109(12): 1171-1175
- Badan Pusat Statistka Indonesia. 2012. Data Expor Import. <http://www.bps.go.id/exim-frame.php/kat2>. Access date March 28, 2015. At 12:30 pm
- Badan Pusat Statistika Kabupaten Karawang. 2015. Total of Registered Job Seekers According to Education Level per Month Year 2010.
- Coulson, J.H. and Richardson, J.E. 1983, “*Chemical Engineering Design*”, Volume 2, Pergaman Press, Oxford.

- Esch, H., R. Kuhlmann, M. Neumueller, K.Otto, R. Rausch. 1996. *Process For The Production Of Precipitated Silica*, US005484581A, United States Patent. Frankfurt, Jerman
- Evans, F.L.Jr., 1974, "Equipment Design Handbook for Refineries and Chemical Plant", Volume 2, Guilt Publishing Company, Houston, Texas.
- Faith WL, Keyes DB and Clark RR., 1978, "Industrial Chemical", 4th ed., John Wiley and Sons Inc, London.
- Fogler, H.S. 2006. *Elements of Chemical Reaction Engineering*, 4th edition. USA: Pearson Education, Inc,
- Forment, G.F., And Bischoff, K.B., 1990, "Chemical Reactor Analysis and Design" 2nd ed., Jhon Willey & Sons, New York.
- Foust, A.S., C.W. Clump, L.Maus, L.B. Andersen. 1980. *Principles of Unit Operations*, 2nd edition.
- New York: John Wiley & Sons, Inc.
- Geankoplis, C.J. 1993. *Transport Processes and Unit Operations*, 3rd edition. New Jersey: Prentice-Hall International, Inc.
- Green, D.W., R.H. Perry. 2008. *Perry's Chemical Engineer's Handbook*, 8th edition. New York: McGraw-Hill Companies, Inc.
- Hill, C.G. 1977. *An Introduction To Chemical Engineering Kinetics & Reaction*. New York: John Wiley & Sons, Inc.
- Hougen O.A., Watson, Kenneth M, Ragatz, Roland, A. 1945. *Chemical Process Principles Part 1, Material and Energy Balance 2-1*. New York: John Wiley and Sons, Inc.
- Kern, D.Q. 1950. *Process Heat Transfer*. Singapore: McGraw-Hill Book Co.