NATIONAL UNIVERSITY OF ENGINEERING

COLLEGE OF CHEMICAL AND TEXTILE ENGINEERING

CHEMICAL ENGINEERING AREA

Design of a NaSH Production Plant Using H2S

COURSE
PLANT DESIGN

SEMESTER:
2016 – 1

STUDENT:
-BRICEÑO QUINTEROS LUIS JESÚS

PROFESSORS:
- Víctor León Choy
- Rafael Chero Rivas

SUBMISSION DATE:
June 30, 2016

CONTENT

PRODUCTION OF NaSH FROM H_2S

1. SUMMARY

In the present work a study is developed to choose the most appropriate technology for obtaining NaSH (sodium hydrosulfide) from H2S (hydrogen sulfide); The technology chosen is the method of absorption and reaction of hydrogen sulphide from tailings residues, mining residues or combustion wastes from oil companies; Since our market demands a certain amount of NaSH mainly in the mining sector in what leads to flotation, and also in certain sectors that take care of the fertilizers; In our local reality will be used mainly in the mining industry for flotation cells, and since in our country there is not a single plant dedicated to the production of NaSH, that is where our present work is directed.

2. OBJECTIVES

The purpose of this document is to design the main equipment; in our case it was designed to the adsorption towers, and reactor that will be part of the production plant of sodium hydrosulphide; for this purpose the necessary calculations have been made to establish the balance of matter and energy in the equipment.

3. TECHNOLOGIES FOR OBTAINING NaSH

Within the methods of obtaining NaSH can be found the following way.

3.1. NaSH PRODUCTION WITH H_2S RECIRCULATION

Para nuestro proceso de la producción de NaSH a partir de H_2S, tenemos nuestro propio diagrama de bloques.

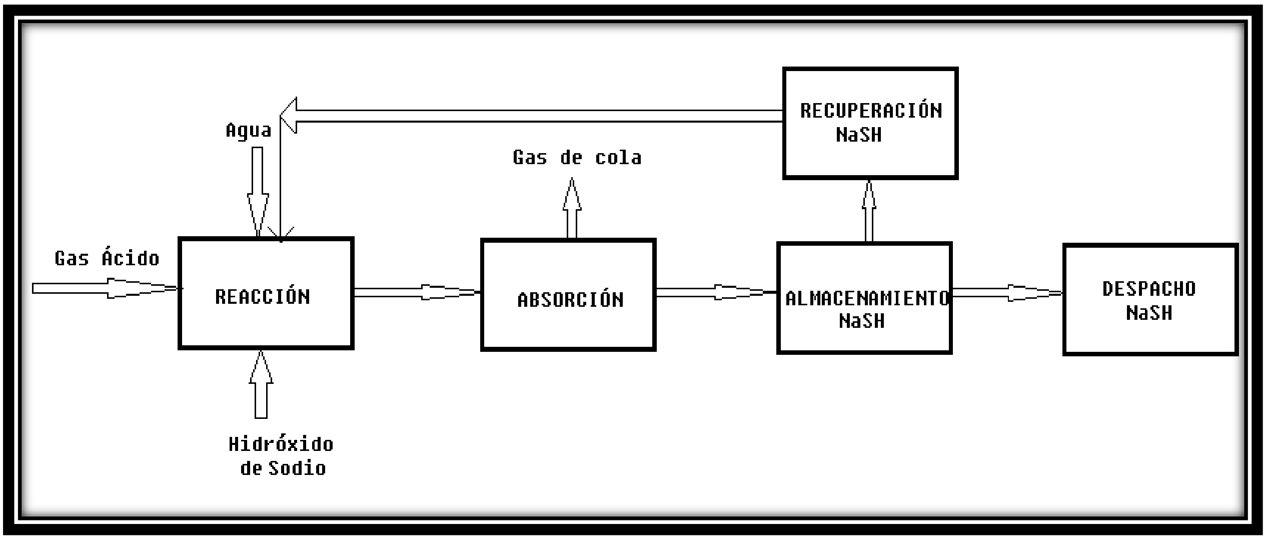


Diagram 1: Process Flow Diagram

3.2. REACTION AND ABSORPTION (SEPARATE PROCESSES)

Finally we opted for this technology as it has a greater efficiency to the reaction absorption of a single process and we see better results both efficient of my finished product and better waste management; basically the waste gases that will be in the process.

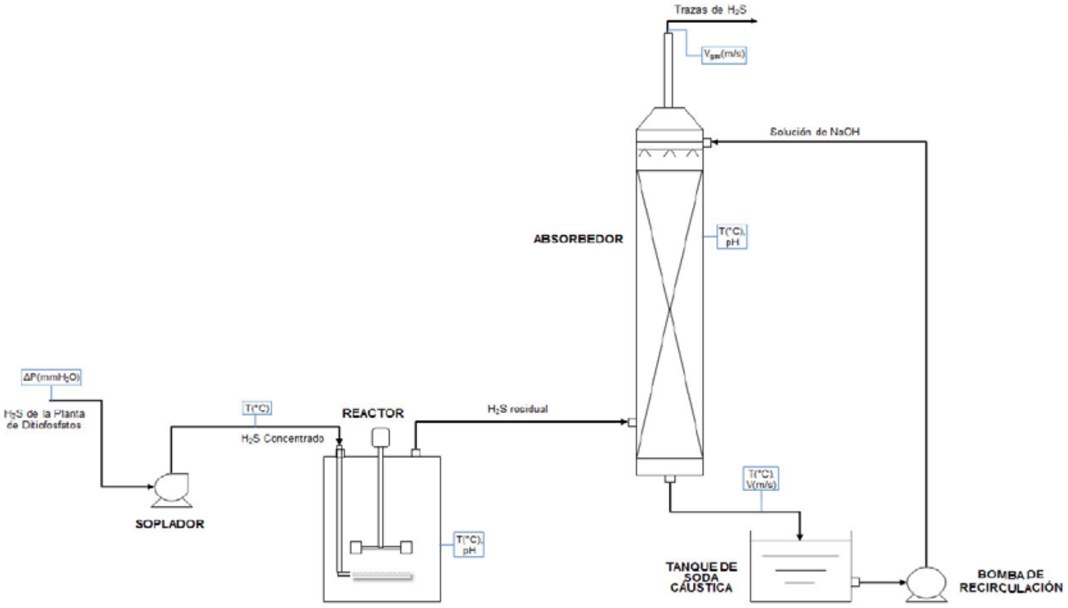


FIGURE 1: NaHS Production [1]

We will stick with the absorption and reaction reaction separately for the advantages already described above.

3.3. DESCRIPTION OF THE TECHNOLOGY

The process of obtaining NaSH from H2S, has the following processes:

- Chemical reaction by agitation.
- Reaction-absorption in filling tower.
- Cooling line cooling for waste gases.
- Decanting.
- Storage

3.3.1. Chemical reaction by agitation

At the heart of our process will be the reactor, where the chemical reaction occurs by agitation. The reason we use this reactor is because although the H2S reaction also occurs in the fill column, but having a reactor, the overall conversion of the process will be greater. In the reactor the NaOH solution and water will enter to mix with the H2S gases and thus be able to react to give the NaHS, then the H2S that remained in the form of gas will be taken to the absorption tower to react again with NaOH.

3.3.2. Reaction-absorption in filling tower

Here goes the current of H2S that leaves the reactor and that has not reacted, when entering in countercurrent with the NaOH another quantity of NaHS is generated that goes directly to the storage being practically traces of H2S that later we must cool so that it does not harm to the environment.

Being a smaller amount to absorb H2S than the initial input since a large part reacted in the reactor then our absorption tower will be smaller than the one it had if the current entered directly into it.

3.3.3. Cooling line for waste gases

In this case the current that has reacted has raised the temperature at the outlet of the absorber, as it is known the gases must leave at a certain temperature according to waste codes for environmental protection. The way to control this temperature is through a cooler in a heat exchanger process which we are including in our process.

3.3.4. Decanting

That stage we will be passing in the storage tank, the gases and volatile substances are coming from the traces of H2S in the current of the product the way to separate those substances is by means of decanting, in such a way that my product line comes out with The highest purity possible.

3.3.5. Storage

NaHS storage tanks should be located in areas with wide ventilation, away from fuels and sources of ignition.

The tanks must be pressurized or have a ventilation system of vapors to an external scrubber, not metallic. Small containers (eg drums, etc.) should not be stored in direct sunlight (increases pressure).

The freezing point of NaHS at high concentration is 16.7 ° C (62 ° F) insulation or possibly heating should be used, as the case may be.

A diesel level can be used to prevent corrosion in steel tanks.

4. MARKET RESEARCH

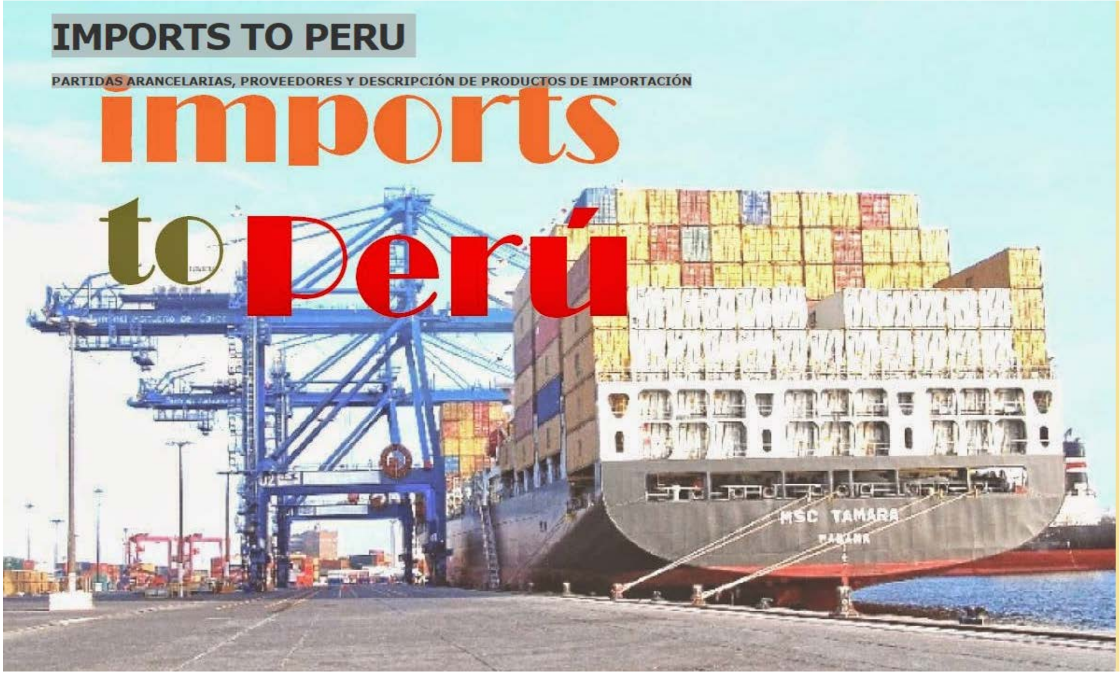
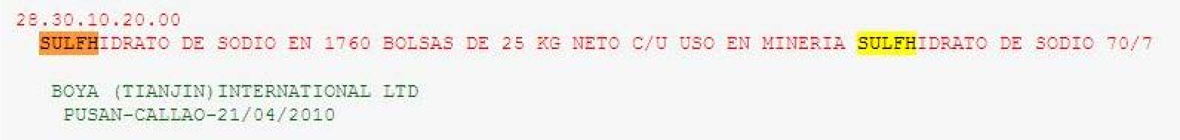


FIGURE 2: IMPORT PERÚ FRONT

According to Import to Peru, we have a certain amount of demand in the last years of NaHS, named in this case as sodium hydrosulfide [2] [3]

Data sheet of imports in Callao port

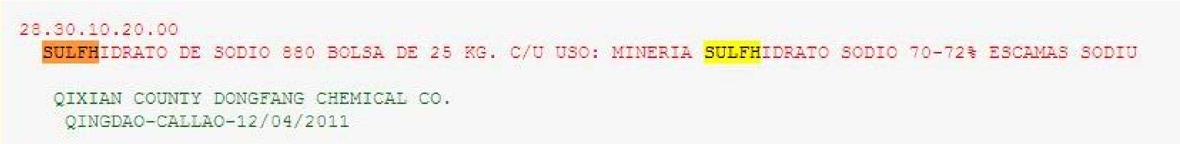
Year 2010



28.30.10.20.00
SULFHIDRATO DE SODIO EN 1760 BOLSAS DE 25 KG NETO C/U USO EN MINERIA SULFHIDRATO DE SODIO 70/7

BOYA (TIANJIN)INTERNATIONAL LTD
PUSAN-CALLAO-21/04/2010

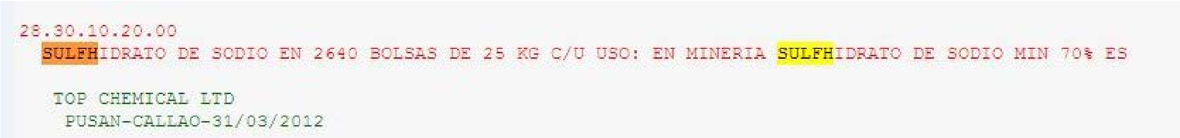
Year 2011



28.30.10.20.00
SULFHIDRATO DE SODIO 880 BOLSA DE 25 KG. C/U USO: MINERIA SULFHIDRATO SODIO 70-72% ESCAMAS SODIU

QIXIAN COUNTY DONGFANG CHEMICAL CO.
QINGDAO-CALLAO-12/04/2011

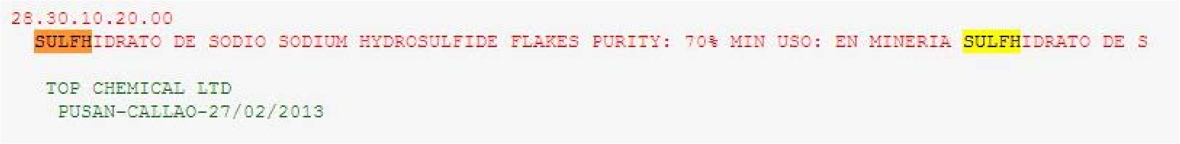
Year 2012



28.30.10.20.00
SULFHIDRATO DE SODIO EN 2640 BOLSAS DE 25 KG C/U USO: EN MINERIA SULFHIDRATO DE SODIO MIN 70% ES

TOP CHEMICAL LTD
PUSAN-CALLAO-31/03/2012

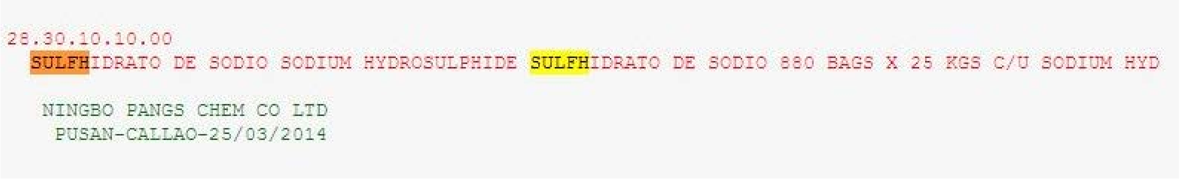
Year 2013



```
28.30.10.20.00
  SULFHIDRATO DE SODIO SODIUM HYDROSULFIDE FLAKES PURITY: 70% MIN USO: EN MINERIA SULFHIDRATO DE S

   TOP CHEMICAL LTD
    PUSAN-CALLAO-27/02/2013
```

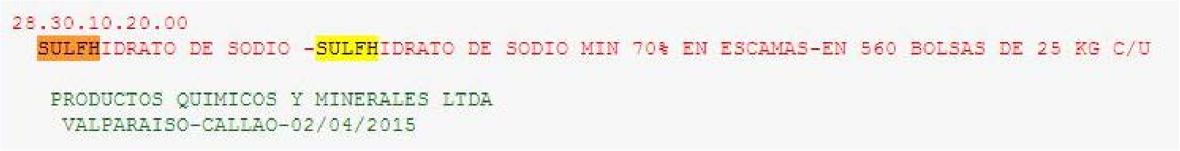
Year 2014



```
28.30.10.10.00
  SULFHIDRATO DE SODIO SODIUM HYDROSULPHIDE SULFHIDRATO DE SODIO 880 BAGS X 25 KGS C/U SODIUM HYD

   NINGBO PANGS CHEM CO LTD
    PUSAN-CALLAO-25/03/2014
```

Year 2015



```
28.30.10.20.00
  SULFHIDRATO DE SODIO -SULFHIDRATO DE SODIO MIN 70% EN ESCAMAS-EN 560 BOLSAS DE 25 KG C/U

   PRODUCTOS QUIMICOS Y MINERALES LTDA
    VALPARAISO-CALLAO-02/04/2015
```

We name it by year, demand and import market of NaHS [4]

TABLE 1

Year	Tons
2010	44000
2011	22000
2012	66000
2013	133056
2014	151500
2015	54000
2016	68250

According to the demand data for years, an approximate production for the domestic sale, meeting the established quality standards.

Since it is a demand for fluctuating slope, then we have as reference the demand of the last year.

5. SELECTION OF TECHNOLOGY

For our process we will use reactor and absorber technology.

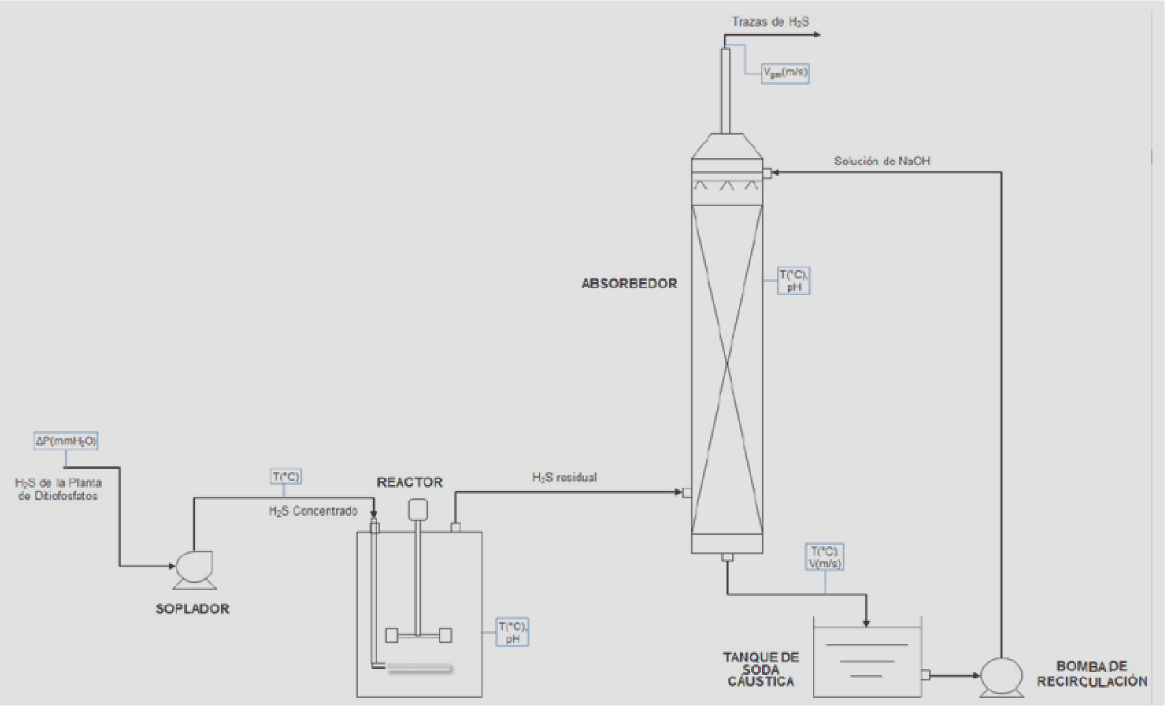


FIGURE 1: NaHS Production [5]

Previously this technology has already been described, in the previous part, but we will emphasize it with certain improvements basically a recovery of gases.
We present an outline of what would be the plant:

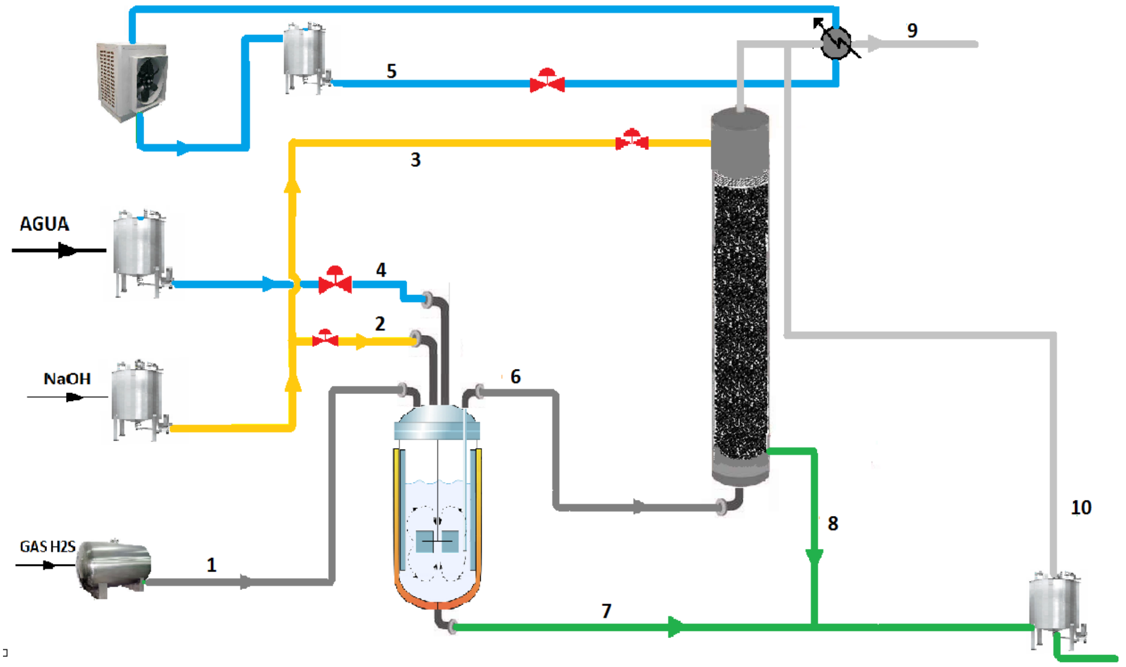


FIGURE 2. Empirical scheme of the process

6. DESCRIPTION OF THE PROCESS LINES

TABLE 2. Components of the lines

LINE	COMPOUND	DESCRIPTION
1	H_2S	It is the H2S input of the refinery waste.
2	NaOH	Sodium hydroxide entering the reactor and the absorption column to kill all of the H2S.
3	NaOH	
4	H_2O	Ion-free water for the reactor.
5	H_2O	Water treated as refrigerant.
6	H_2S	Residual sulfur from the reactor entering the column.
7	NaHS	Final product of the reactor for storage.
8	NaHS	Final product of the column for storage.

The added improvements in technology are the cooling system through a cooler and a heat exchanger that was not in the beginning since the gas outlet temperature had not been considered.

7. H2S PURIFICATION PROCESS

Dimensions of amine and acid gas mixing tanks.
Nº de tanks: 3. (See Annex)

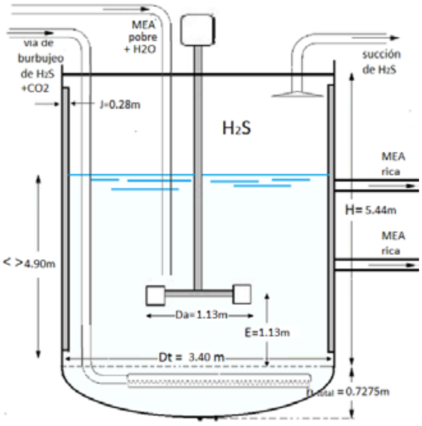


FIGURE 3. Batch reactor of the NaSH production process.

Material carbon steel 8%
Thickness of steel layer 1”
Flash separator to separate amine from acid gases.

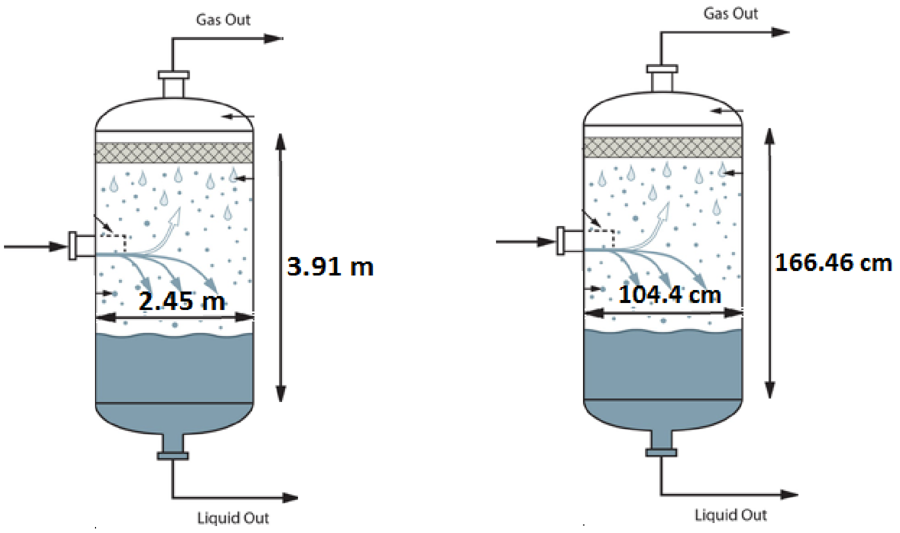


FIGURE 4. Flash separators in the amine process

Material carbon steel 8%
Thickness of the steel layer 5 mm

8. DIAGRAMS

8.1. BLOCKS DIAGRAM

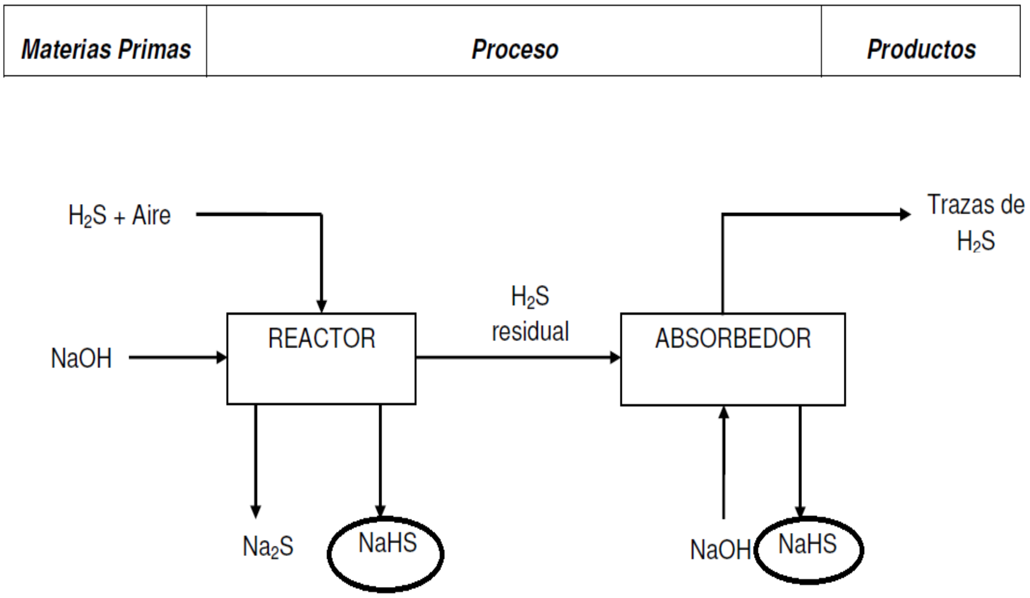
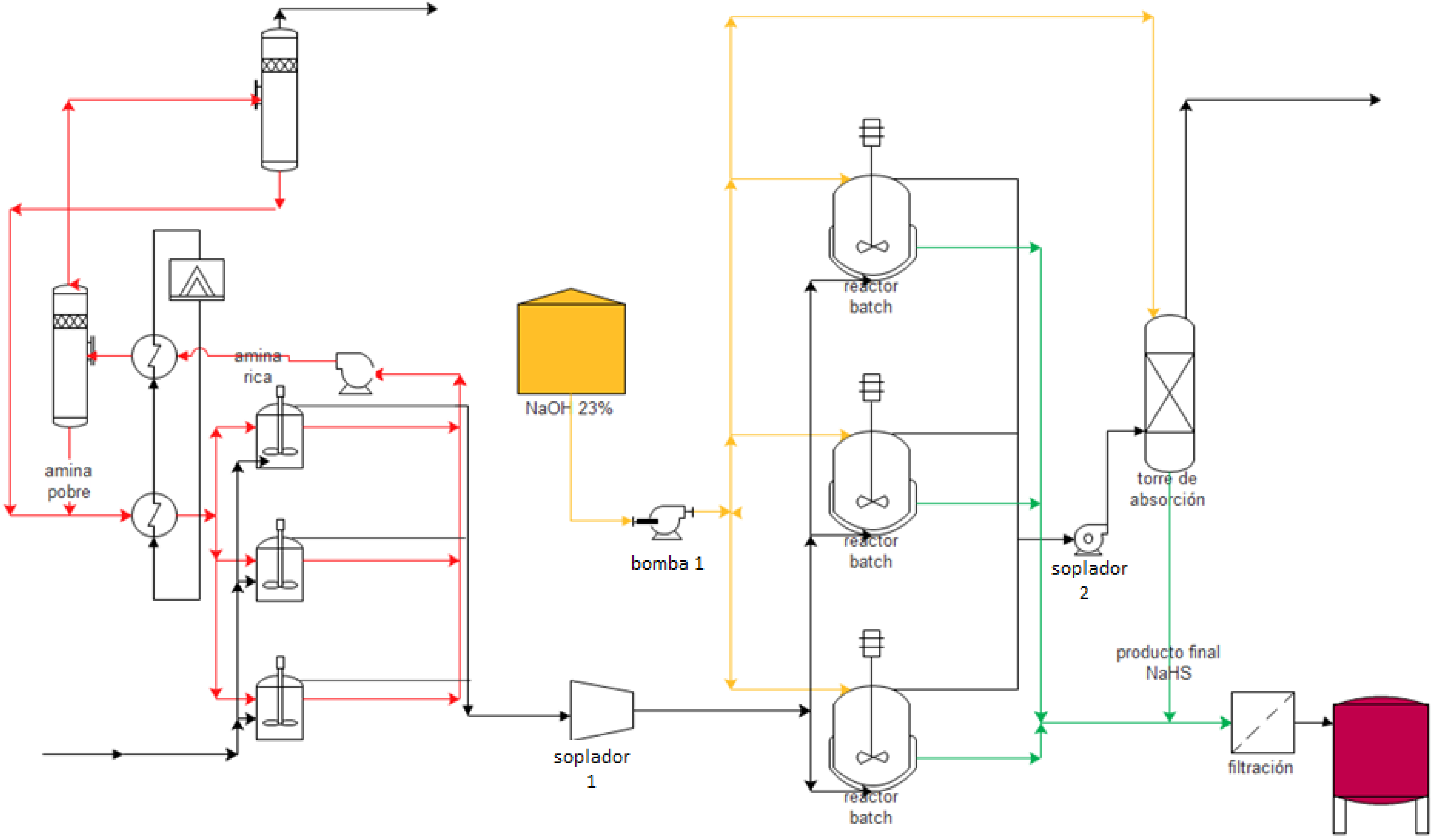


Diagram 2. Block diagram of the production process

Diagram 3. Process diagram



9. EQUIPMENT SPECIFICATION

9.1. REACTOR

TABLE 3: Reactor type

Type	FLOW	CONCENTRATION	RESULT
FLOW REACTOR CONTINUOUS	Improves the amount of finished product.	As for the concentration of output is less efficient.	**OF THE 3 CASES CHOSEN, WE CHOOSE THE BATCH REACTOR, AS IT IS VERY IMPORTANT FOR THE PROCESS TO HAVE A HIGH CONVERSION OF H2S AND THIS IS THE REACTOR BATCH.**
BATCH REACTOR	We have lower flow since we must wait for a certain time.	The concentration is higher than in the previous case since the residence time influences the reactant amount.	
RFP REACTOR	The piston-flow reactor is fairly characteristic of the two above as it has less batch concentration output and less flow than the RFC.		

9.2. FILLING COLUMN

TABLE 4: Column type

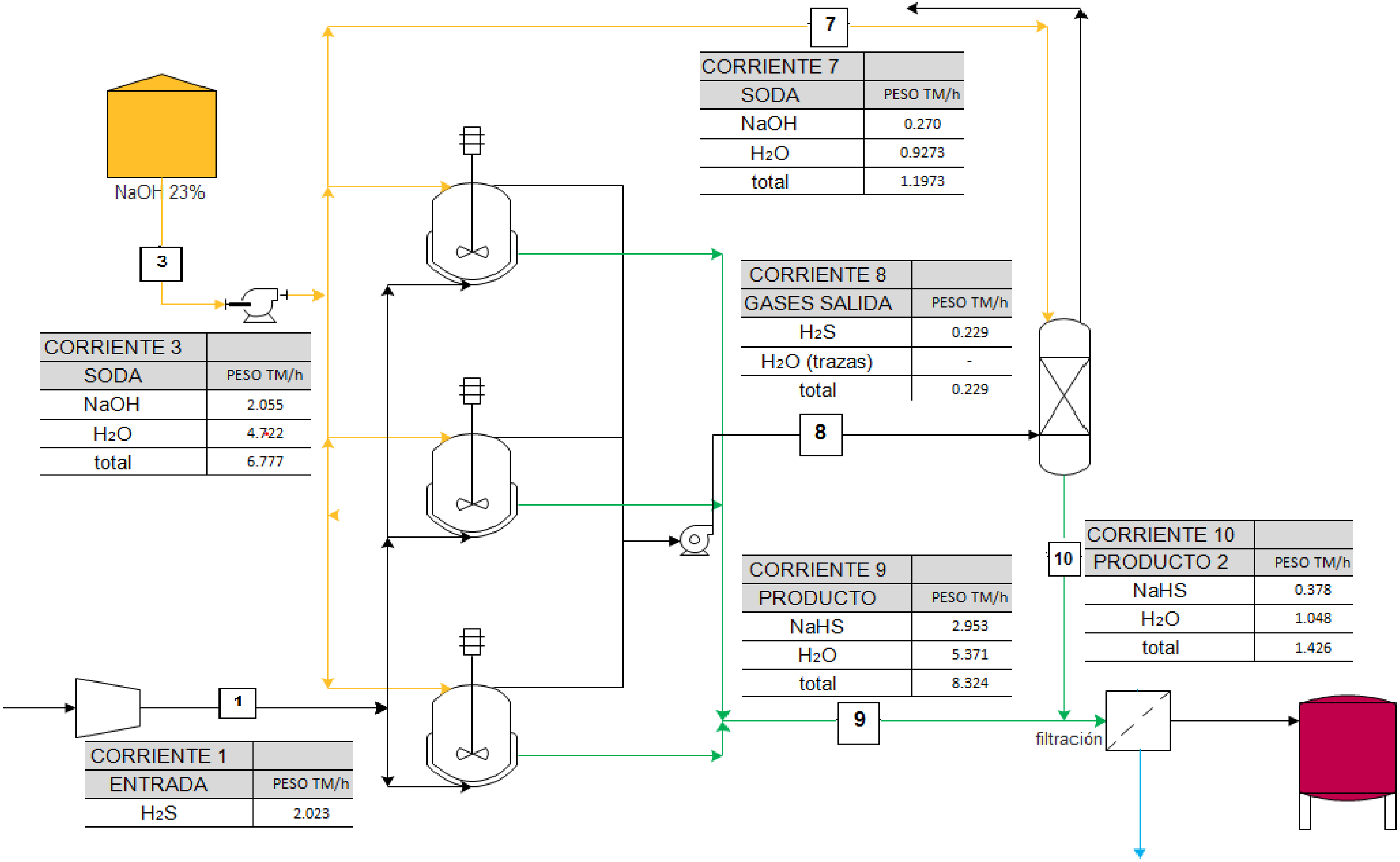
TYPE	CONCENTRATION	TIME	COST
PLATE TOWER	Good efficiency.	It requires more time since it has to go through evaporation and condensation.	It is the one that has the greatest cost not only of manufacturing but of operation.
FILLING TOWER 1 PACKING	Good efficiency.	Lower operating time than the plate tower.	Relatively cheaper than the plate tower.
FILLING TOWER 2 PACKAGING	Good efficiency, slightly higher than 1 pack.	Minor operating time than the plate tower and almost the same as the 1-pack.	Slightly more expensive than 1 pack.
RESULT	When evaluating the 3 cases we do not need the plate tower, and between the two packaged we choose the one of packaging, since when processing the output current of the reactor does not need a high efficiency of process and is more convenient that to use the one of two plates, Relegating only the preference for operating and manufacturing costs.		

10. MASS BALANCE

TABLE 5. Mass Balance of all the lines.

COMPOUND	H2S		NaOH		H2O		NaHS	
CURRENT	WEIGHT (TM/h)	MOLES kmol/h	WEIGHT (TM/h)	MOLES kmol/h	WEIGHT (TM/h)	MOLES kmol/h	WEIGHT (TM/h)	MOLES kmol/h
1	2.023	59.5						
3			2.055	51.38	4.722	262.64		
7			0.270	6.76	0.9273	51.51		
8	0.229	6.76						
9					5.371	298.43	2.953	52.74
10					1.048	58.27	0.378	6.76
11	-	-	-	-	-	-	-	-

DIAGRAM 4. Process diagram with mass balance.



CORRIENTE 7	
SODA	PESO TM/h
NaOH	0.270
H_2O	0.9273
total	1.1973

CORRIENTE 3	
SODA	PESO TM/h
NaOH	2.055
H_2O	4.722
total	6.777

CORRIENTE 8	
GASES SALIDA	PESO TM/h
H_2S	0.229
H_2O (trazas)	-
total	0.229

CORRIENTE 10	
PRODUCTO 2	PESO TM/h
NaHS	0.378
H_2O	1.048
total	1.426

CORRIENTE 9	
PRODUCTO	PESO TM/h
NaHS	2.953
H_2O	5.371
total	8.324

CORRIENTE 1	
ENTRADA	PESO TM/h
H_2S	2.023

11. EQUIPMENT DESIGN

11.1. REACTOR

$$\frac{Da}{Dt}=\frac{1}{3}\Rightarrow\frac{Da}{2.88m}=\frac{1}{3}\Rightarrow Da=0.96m \qquad \frac{J}{Dt}=\frac{1}{12}\Rightarrow\frac{Da}{2.88m}=\frac{1}{12}\Rightarrow J=0.24m$$

$$\frac{E}{Dt}=\frac{1}{3}\Rightarrow\frac{E}{2.88m}=\frac{1}{3}\Rightarrow E=0.96m \qquad \frac{W}{Da}=\frac{1}{5}\Rightarrow\frac{W}{0.96m}=\frac{1}{3}\Rightarrow W=0.32m$$

$$\frac{L}{Da}=\frac{1}{4}\Rightarrow\frac{L}{0.96}=\frac{1}{4}\Rightarrow L=0.24m$$

Having the 5 main measures of the agitator that will be in the batch reactor proceed to make the dimensioned diagram of the reactor:

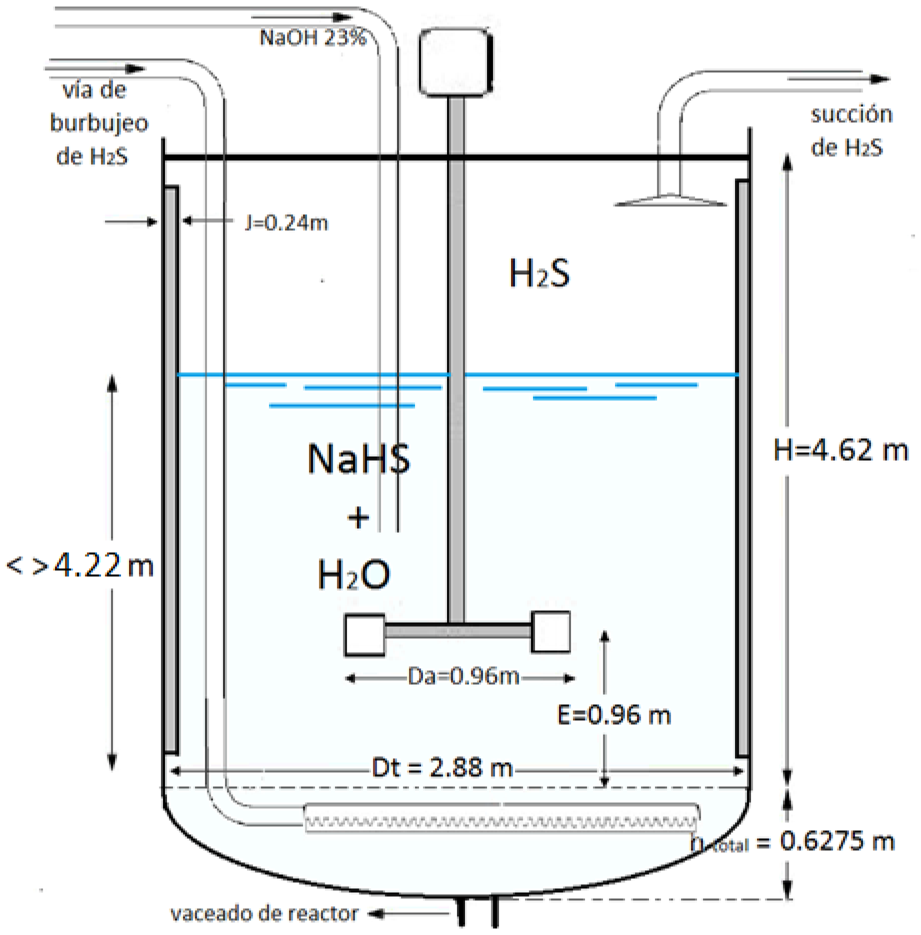


FIGURE 5. Process batch reactor

11.2. ABSORPTION TOWER

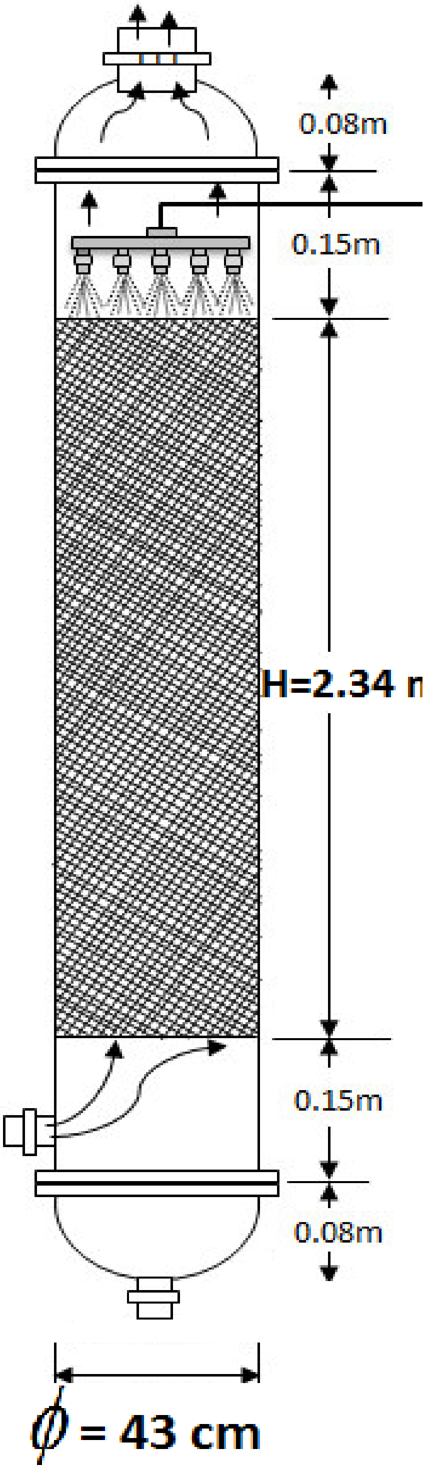
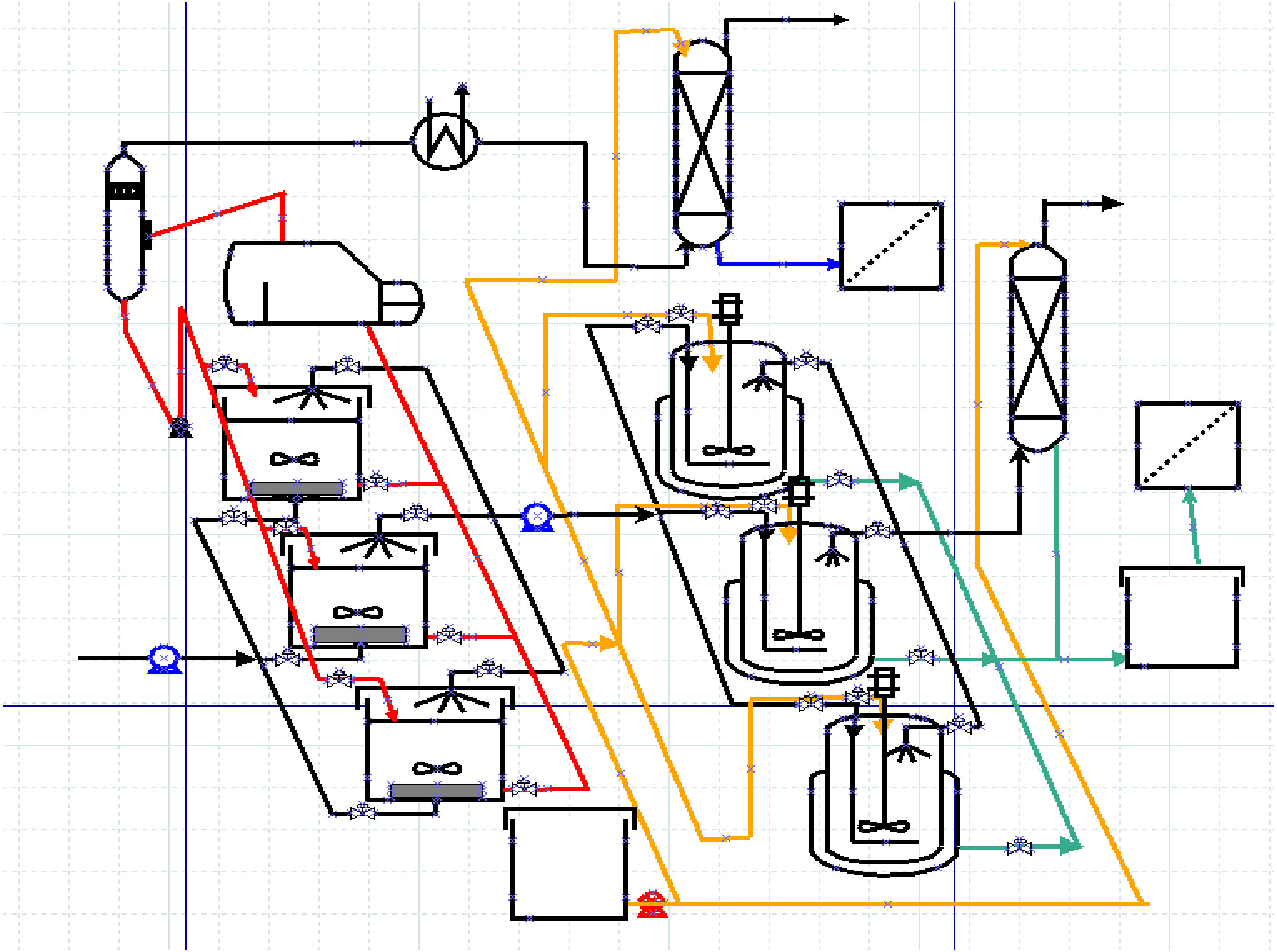


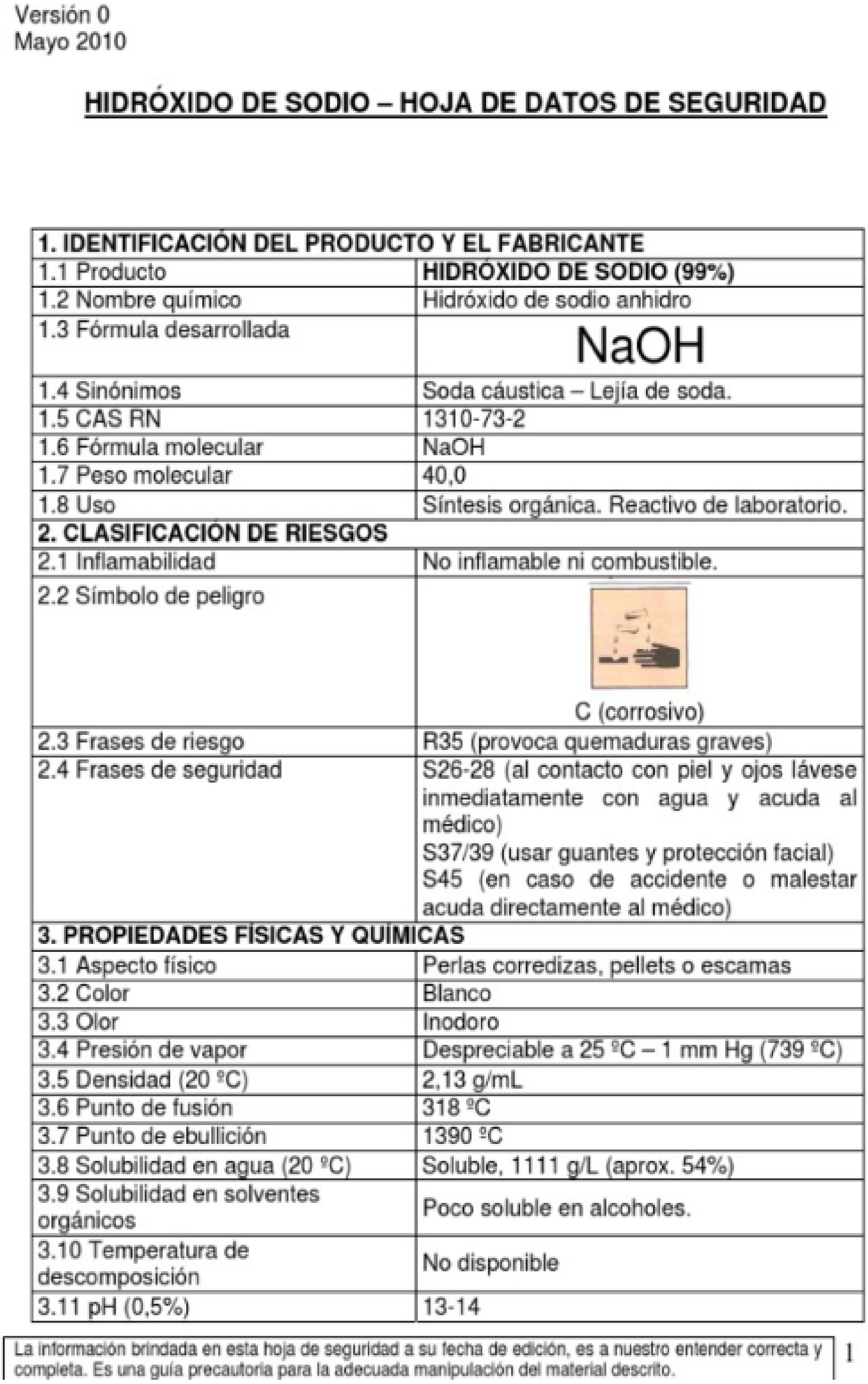
Figure 6. Absorber diagram



ANNEXES

ANNEX A: DATA SHEET, COMPOUNDS IN THE PROCESS

NaOH [6]



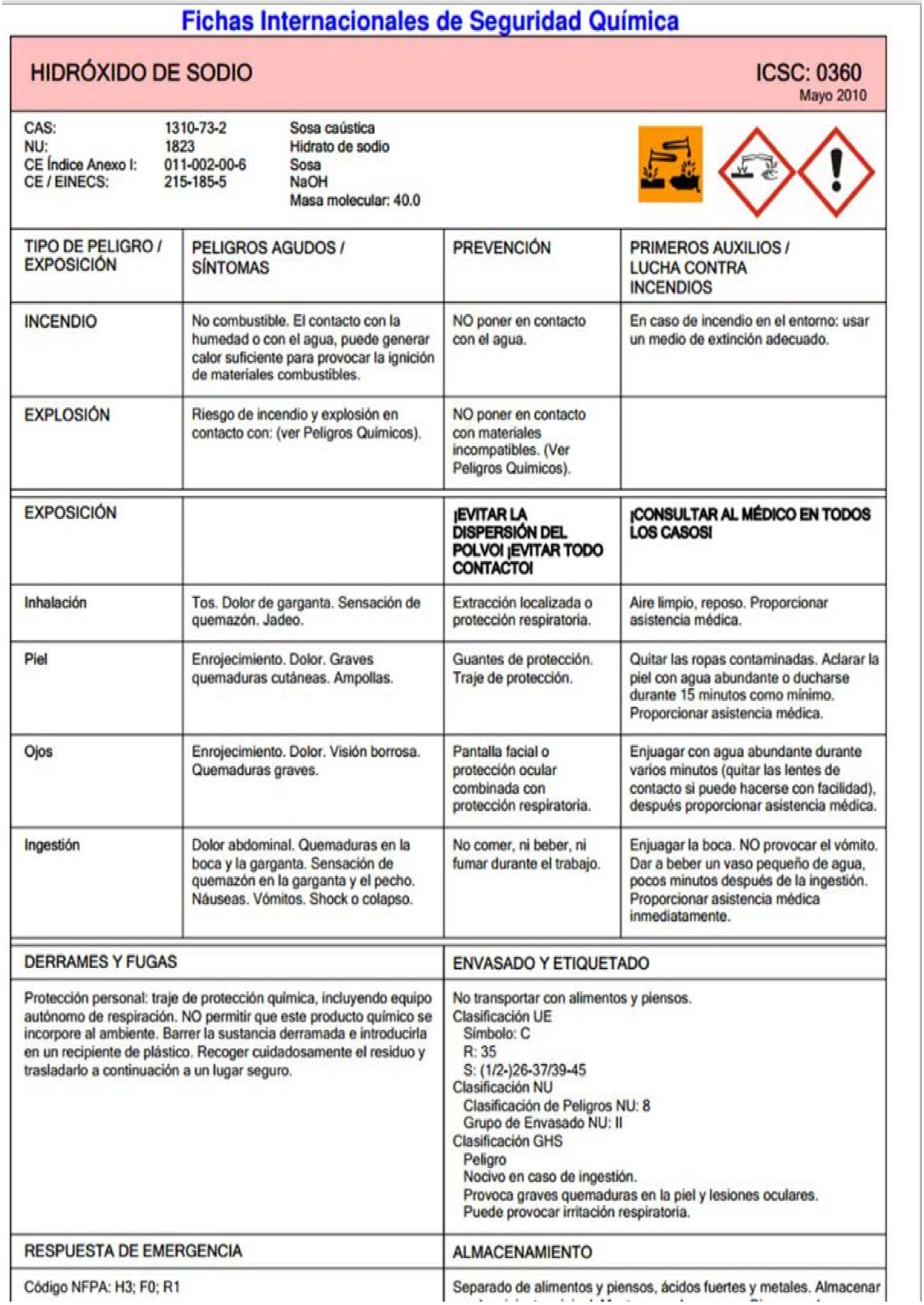
Versión 0
Mayo 2010

HIDRÓXIDO DE SODIO – HOJA DE DATOS DE SEGURIDAD

1. IDENTIFICACIÓN DEL PRODUCTO Y EL FABRICANTE	
1.1 Producto	**HIDRÓXIDO DE SODIO (99%)**
1.2 Nombre químico	Hidróxido de sodio anhidro
1.3 Fórmula desarrollada	NaOH
1.4 Sinónimos	Soda cáustica – Lejía de soda.
1.5 CAS RN	1310-73-2
1.6 Fórmula molecular	NaOH
1.7 Peso molecular	40,0
1.8 Uso	Síntesis orgánica. Reactivo de laboratorio.
2. CLASIFICACIÓN DE RIESGOS	
2.1 Inflamabilidad	No inflamable ni combustible.
2.2 Símbolo de peligro	C (corrosivo)
2.3 Frases de riesgo	R35 (provoca quemaduras graves)
2.4 Frases de seguridad	S26-28 (al contacto con piel y ojos lávese inmediatamente con agua y acuda al médico) S37/39 (usar guantes y protección facial) S45 (en caso de accidente o malestar acuda directamente al médico)
3. PROPIEDADES FÍSICAS Y QUÍMICAS	
3.1 Aspecto físico	Perlas corredizas, pellets o escamas
3.2 Color	Blanco
3.3 Olor	Inodoro
3.4 Presión de vapor	Despreciable a 25 ºC – 1 mm Hg (739 ºC)
3.5 Densidad (20 ºC)	2,13 g/mL
3.6 Punto de fusión	318 ºC
3.7 Punto de ebullición	1390 ºC
3.8 Solubilidad en agua (20 ºC)	Soluble, 1111 g/L (aprox. 54%)
3.9 Solubilidad en solventes orgánicos	Poco soluble en alcoholes.
3.10 Temperatura de descomposición	No disponible
3.11 pH (0,5%)	13-14

La información brindada en esta hoja de seguridad a su fecha de edición, es a nuestro entender correcta y completa. Es una guía precautoria para la adecuada manipulación del material descrito.

1



Fichas Internacionales de Seguridad Química

HIDRÓXIDO DE SODIO | **ICSC: 0360**
Mayo 2010

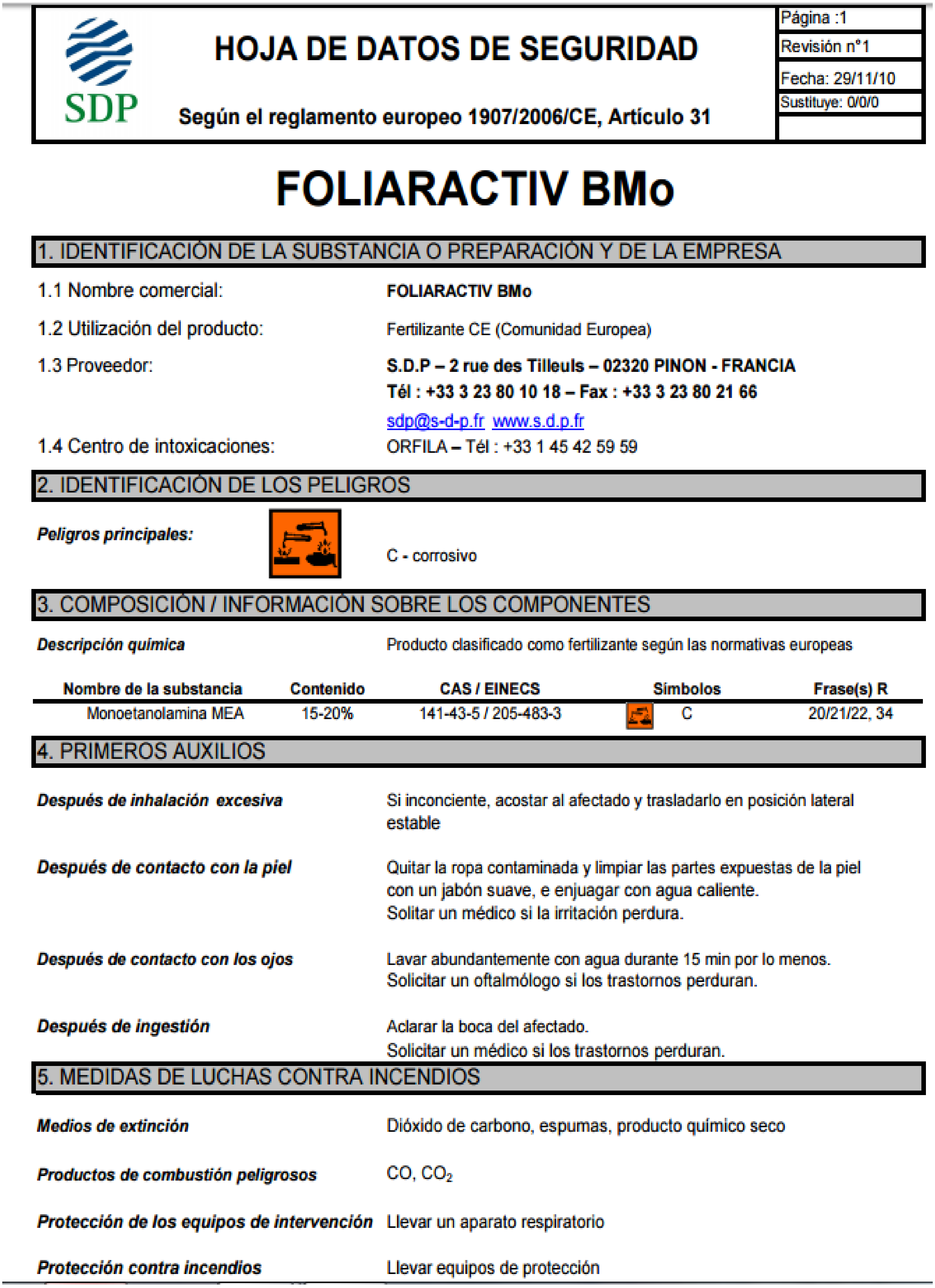
CAS:	1310-73-2	Sosa caústica
NU:	1823	Hidrato de sodio
CE Índice Anexo I:	011-002-00-6	Sosa
CE / EINECS:	215-185-5	NaOH
		Masa molecular: 40.0

TIPO DE PELIGRO / EXPOSICIÓN	PELIGROS AGUDOS / SÍNTOMAS	PREVENCIÓN	PRIMEROS AUXILIOS / LUCHA CONTRA INCENDIOS
INCENDIO	No combustible. El contacto con la humedad o con el agua, puede generar calor suficiente para provocar la ignición de materiales combustibles.	NO poner en contacto con el agua.	En caso de incendio en el entorno: usar un medio de extinción adecuado.
EXPLOSIÓN	Riesgo de incendio y explosión en contacto con: (ver Peligros Químicos).	NO poner en contacto con materiales incompatibles. (Ver Peligros Químicos).	
EXPOSICIÓN		**¡EVITAR LA DISPERSIÓN DEL POLVO! ¡EVITAR TODO CONTACTO!**	**¡CONSULTAR AL MÉDICO EN TODOS LOS CASOS!**
Inhalación	Tos. Dolor de garganta. Sensación de quemazón. Jadeo.	Extracción localizada o protección respiratoria.	Aire limpio, reposo. Proporcionar asistencia médica.
Piel	Enrojecimiento. Dolor. Graves quemaduras cutáneas. Ampollas.	Guantes de protección. Traje de protección.	Quitar las ropas contaminadas. Aclarar la piel con agua abundante o ducharse durante 15 minutos como mínimo. Proporcionar asistencia médica.
Ojos	Enrojecimiento. Dolor. Visión borrosa. Quemaduras graves.	Pantalla facial o protección ocular combinada con protección respiratoria.	Enjuagar con agua abundante durante varios minutos (quitar las lentes de contacto si puede hacerse con facilidad), después proporcionar asistencia médica.
Ingestión	Dolor abdominal. Quemaduras en la boca y la garganta. Sensación de quemazón en la garganta y el pecho. Náuseas. Vómitos. Shock o colapso.	No comer, ni beber, ni fumar durante el trabajo.	Enjuagar la boca. NO provocar el vómito. Dar a beber un vaso pequeño de agua, pocos minutos después de la ingestión. Proporcionar asistencia médica inmediatamente.

DERRAMES Y FUGAS	ENVASADO Y ETIQUETADO
Protección personal: traje de protección química, incluyendo equipo autónomo de respiración. NO permitir que este producto químico se incorpore al ambiente. Barrer la sustancia derramada e introducirla en un recipiente de plástico. Recoger cuidadosamente el residuo y trasladarlo a continuación a un lugar seguro.	No transportar con alimentos y piensos. Clasificación UE Símbolo: C R: 35 S: (1/2-)26-37/39-45 Clasificación NU Clasificación de Peligros NU: 8 Grupo de Envasado NU: II Clasificación GHS Peligro Nocivo en caso de ingestión. Provoca graves quemaduras en la piel y lesiones oculares. Puede provocar irritación respiratoria.

RESPUESTA DE EMERGENCIA	ALMACENAMIENTO
Código NFPA: H3; F0; R1	Separado de alimentos y piensos, ácidos fuertes y metales. Almacenar

MEA [7]



SDP

HOJA DE DATOS DE SEGURIDAD

Según el reglamento europeo 1907/2006/CE, Artículo 31

Página :1
Revisión n°1
Fecha: 29/11/10
Sustituye: 0/0/0

FOLIARACTIV BMo

1. IDENTIFICACIÓN DE LA SUBSTANCIA O PREPARACIÓN Y DE LA EMPRESA

1.1 Nombre comercial:	**FOLIARACTIV BMo**
1.2 Utilización del producto:	Fertilizante CE (Comunidad Europea)
1.3 Proveedor:	**S.D.P – 2 rue des Tilleuls – 02320 PINON - FRANCIA** **Tél : +33 3 23 80 10 18 – Fax : +33 3 23 80 21 66** sdp@s-d-p.fr www.s.d.p.fr
1.4 Centro de intoxicaciones:	ORFILA – Tél : +33 1 45 42 59 59

2. IDENTIFICACIÓN DE LOS PELIGROS

Peligros principales:	C - corrosivo

3. COMPOSICIÓN / INFORMACIÓN SOBRE LOS COMPONENTES

Descripción química	Producto clasificado como fertilizante según las normativas europeas

Nombre de la substancia	Contenido	CAS / EINECS	Símbolos	Frase(s) R
Monoetanolamina MEA	15-20%	141-43-5 / 205-483-3	C	20/21/22, 34

4. PRIMEROS AUXILIOS

Después de inhalación excesiva	Si inconciente, acostar al afectado y trasladarlo en posición lateral estable
Después de contacto con la piel	Quitar la ropa contaminada y limpiar las partes expuestas de la piel con un jabón suave, e enjuagar con agua caliente. Solitar un médico si la irritación perdura.
Después de contacto con los ojos	Lavar abundantemente con agua durante 15 min por lo menos. Solicitar un oftalmólogo si los trastornos perduran.
Después de ingestión	Aclarar la boca del afectado. Solicitar un médico si los trastornos perduran.

5. MEDIDAS DE LUCHAS CONTRA INCENDIOS

Medios de extinción	Dióxido de carbono, espumas, producto químico seco
Productos de combustión peligrosos	CO, CO_2
Protección de los equipos de intervención	Llevar un aparato respiratorio
Protección contra incendios	Llevar equipos de protección

6. MEDIDAS EN CASO DE DISPERSIÓN ACCIDENTAL

Precauciones individuales	Ver parágrafo 8
Precauciones para el medio ambiente	Evitar cualquiera entrada de producto en alcantarillas e en aguas potables
Métodos de limpieza	Secar la superficie y depositar los residuos en contenedores para destrucción. Rociar los residuos con agua con precauciones para limitar la contaminación.

7. MANIPULEO Y ALMACENAMIENTO

Manipuleo	Ventilar la área de trabajo. Evitar el contacto con la piel y los ojos
Almacenamiento	No hay recomendaciones específicas. Guardar el producto en un lugar seco y bien ventilado. Cerrar los envases.
Otras informaciones	Para conservar las calidades del producto, almacenar el producto a temperatura ambiente y en un lugar protegido de las heladas.

8. CONTROLE DE LA EXPOSICIÓN Y PROTECCIÓN INDIVIDUAL

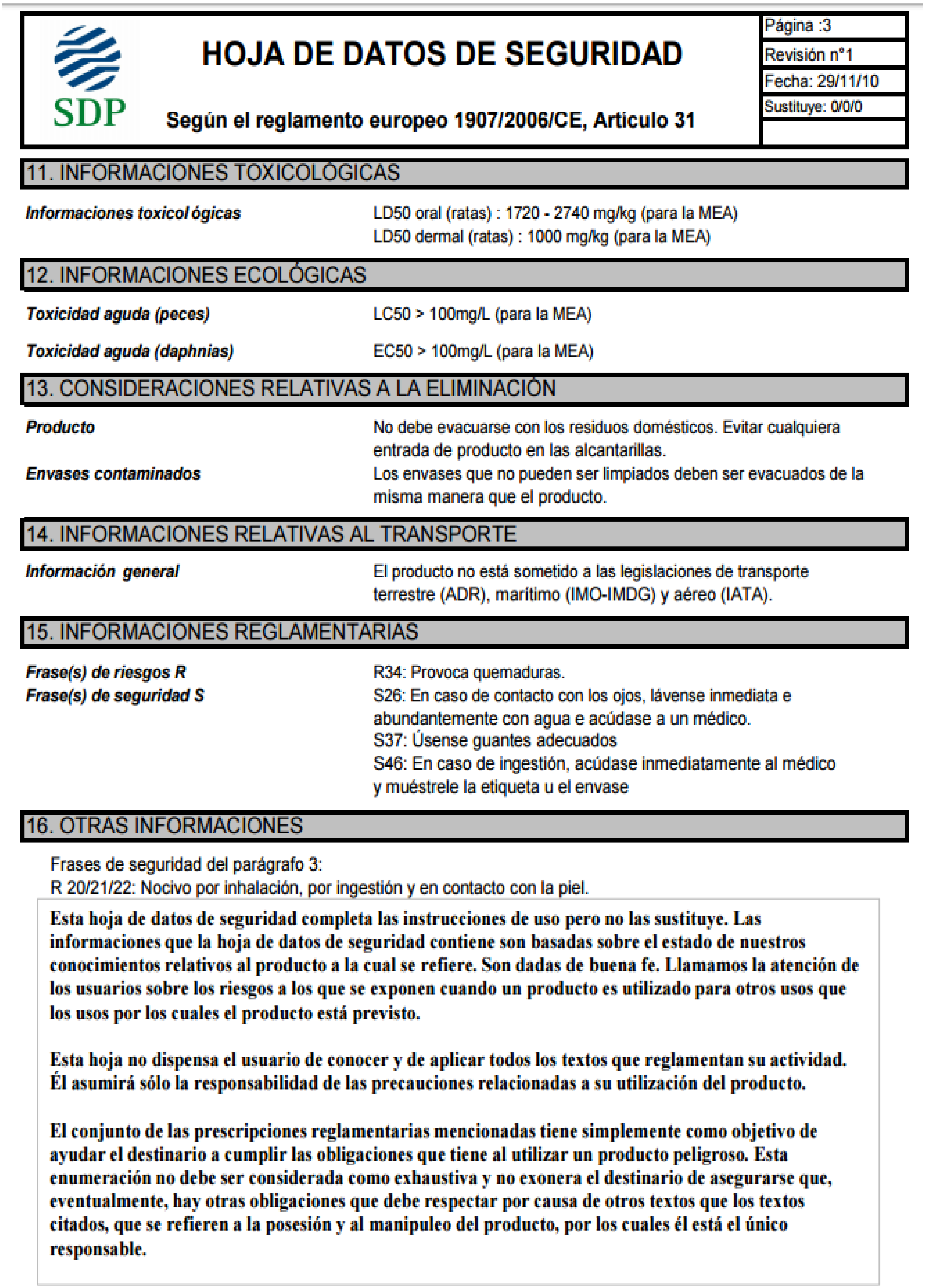
Protección respiratoria	Ninguna protección particular, hacer una ventilación adecuada, sobre todo en lugares cerrados
Protección de las manos	Llevar guantes resistentes a los productos químicos.
Protección de la piel	Vestirse de ropas de protección
Protección de los ojos	Gafas de seguridad con protecciones laterales. Quitar los lentes de contacto.

9. PROPRIEDADES QUÍMICAS Y FÍSICAS

Estado físico a 20°C	Líquido
Color	Marrón oscuro
Olor	Característica
pH a 20 °C	7 a 8
Densidad a 20°C	1,29
Solubilidad en agua	Buena

10. ESTABILIDAD Y REACTIVIDAD

Estabilidad química	Ninguna descomposición si almacenamiento y manipuleo correctos.
Condiciones a evitar	Altas temperaturas
Materias a evitar	Ácidos fuertes



SDP

HOJA DE DATOS DE SEGURIDAD

Según el reglamento europeo 1907/2006/CE, Articulo 31

Página :3
Revisión n°1
Fecha: 29/11/10
Sustituye: 0/0/0

11. INFORMACIONES TOXICOLÓGICAS

Informaciones toxicológicas	LD50 oral (ratas) : 1720 - 2740 mg/kg (para la MEA) LD50 dermal (ratas) : 1000 mg/kg (para la MEA)

12. INFORMACIONES ECOLÓGICAS

Toxicidad aguda (peces)	LC50 > 100mg/L (para la MEA)
Toxicidad aguda (daphnias)	EC50 > 100mg/L (para la MEA)

13. CONSIDERACIONES RELATIVAS A LA ELIMINACIÓN

Producto	No debe evacuarse con los residuos domésticos. Evitar cualquiera entrada de producto en las alcantarillas.
Envases contaminados	Los envases que no pueden ser limpiados deben ser evacuados de la misma manera que el producto.

14. INFORMACIONES RELATIVAS AL TRANSPORTE

Información general	El producto no está sometido a las legislaciones de transporte terrestre (ADR), marítimo (IMO-IMDG) y aéreo (IATA).

15. INFORMACIONES REGLAMENTARIAS

Frase(s) de riesgos R	R34: Provoca quemaduras.
Frase(s) de seguridad S	S26: En caso de contacto con los ojos, lávense inmediata e abundantemente con agua e acúdase a un médico. S37: Úsense guantes adecuados S46: En caso de ingestión, acúdase inmediatamente al médico y muéstrele la etiqueta u el envase

16. OTRAS INFORMACIONES

Frases de seguridad del parágrafo 3:
R 20/21/22: Nocivo por inhalación, por ingestión y en contacto con la piel.

Esta hoja de datos de seguridad completa las instrucciones de uso pero no las sustituye. Las informaciones que la hoja de datos de seguridad contiene son basadas sobre el estado de nuestros conocimientos relativos al producto a la cual se refiere. Son dadas de buena fe. Llamamos la atención de los usuarios sobre los riesgos a los que se exponen cuando un producto es utilizado para otros usos que los usos por los cuales el producto está previsto.

Esta hoja no dispensa el usuario de conocer y de aplicar todos los textos que reglamentan su actividad. Él asumirá sólo la responsabilidad de las precauciones relacionadas a su utilización del producto.

El conjunto de las prescripciones reglamentarias mencionadas tiene simplemente como objetivo de ayudar el destinario a cumplir las obligaciones que tiene al utilizar un producto peligroso. Esta enumeración no debe ser considerada como exhaustiva y no exonera el destinario de asegurarse que, eventualmente, hay otras obligaciones que debe respectar por causa de otros textos que los textos citados, que se refieren a la posesión y al manipuleo del producto, por los cuales él está el único responsable.

H2S [8]

GERENCIA GENERAL SEGURIDAD

Hoja de Datos de Seguridad

HDS Sulfuro de Hidrógeno

INFRA S.A. DE C.V.
Félix Guzmán No. 16 3° Piso. Col. El Parque. C.P. 53398.
Naucalpan de Juárez. Estado de México, México.
TELÉFONO DE EMERGENCIA: 01-800-221-98-44 (24 HORAS)

Clave del Documento: HDS 012 01
Revisión No. : 1
Fecha de Emisión: 2016-04
Fecha de Revisión: 2016-04
Página 1 de 11

1.- Identificación del Producto

Nombre Comercial:	Familia Química [1]:	Inf. Relevante:	Fórmula:
Sulfuro de Hidrógeno	**Hidruro no metálico**	**Gas tóxico** **Gas Inflamable** **Gas irritante** **Gas asfixiante**	**H_2S (Gas)**

Uso Recomendado:
Industrial y profesional. Llevar a cabo evaluación de riesgo antes de usar. Para mayor información sobre su uso contactar al proveedor.

Restricciones de Uso del Producto: [29]
Seguir precauciones establecidas por la CGA para este producto.

2.-Identificación de Peligro o Peligros

Advertencia [26]

Peligros Físicos
Gas inflamable
Gas a presión

Peligros para la salud:
Gas tóxico, irritante y asfixiante.

Peligros para el medio Ambiente:
Muy tóxico para los organismos acuáticos.

Identificador SGA (Consejos de Precaución) [26]

Palabras de advertencia: **"Peligro"**

El Sulfuro de hidrógeno: Es un gas o líquido venenoso, con un olor ofensivo y propiedades irritantes. Es ligeramente más pesado que el aire y la fase líquida es algo menos denso que el agua. La combustión de sulfuro de hidrógeno en aire forma dióxido de azufre y agua.

Indicaciones de Peligro[26,8]:

Peligros Físicos:
H220 – Gases inflamables – Gas extremadamente inflamable – Peligro – Categoría 1.
H280 – Gases a presión – Gas comprimido - Atención; Contiene gas a presión, puede explotar si se calienta.

Peligros para la Salud:
H330 – Toxicidad aguda por inhalación – Mortal si se inhala – Peligro – Categoría 2.
H335 – Toxicidad sistemática específica de órganos diana (exposición única) – Atención – Puede irritar las vías respiratorias – Categoría 3.

Peligros para el Ambiente:
H400 – Peligros para el medio ambiente acuático – Muy tóxico para los organismos acuáticos – Atención – Categoría 1.

Consejos de Precaución[26]:

Prevención:
P210 – Mantener alejado del calor, chispas, llamas al descubierto y superficies calientes. No fumar.
P260 – No respirar polvos, humos, gases, nieblas, vapores y aerosoles.
P271 – Utilizar sólo al aire libre o en un lugar bien ventilado.
P273 – Utilizar sólo al aire libre o en un lugar bien ventilado. No dispersar en el ambiente.
P284 – En caso de ventilación insuficiente, llevar equipo de protección respiratoria.
P391 – Recoger los vertidos.

Intervención:
P304+P340+P315 – EN CASO DE INHALACIÓN: Transportar a la persona al aire libre y mantenerla en una posición que le facilite la respiración.
P310 – Llamar inmediatamente a un CENTRO DE TOXICOLOGÍA/ médico.
P320 – Es necesario un tratamiento específico urgente (si se requiere la administración inmediata de un antídoto).
P377 – Fuga de gas inflamado: no apagar las llamas del gas inflamado si no puede hacerse sin riesgo.
P381 – Eliminar todas las fuentes de ignición, si puede hacerse sin riesgo.

Almacenamiento:

P410+P403 – Proteger de la luz solar. Almacenar en un lugar bien ventilado.
P403+P233 – Almacenar en un lugar bien ventilado. Guardar el recipiente herméticamente cerrado.
P405 – Guardar bajo llave.

Eliminación:
P501 – Eliminar el contenido/recipiente conforme a la reglamentación/normatividad local, regional, nacional e internacional que le aplique.

Clasificación SGA26
Peligros Físicos

Otros Peligros:
Gas Tóxico con daños al ambiente acuático.

Información Nacional y Regional[26,15]
Gas a Presión e Inflamable (SGA; Sistema Global Armonizado, SCT NOM 002)/ Gas extremadamente inflamable (SGA/CGA P23 /ISO 10156).

NaHS [9]

Hoja de Datos de Seguridad del Material

Sección 4: MEDIDAS PARA LOS PRIMEROS AUXILIOS

4.1 OJOS: Inmediatamente enjuague con grandes cantidades de agua por 15 minutos. Mantenga aparatados los parpados durante la irrigación para asegurar que el enjuague sea completo en toda el área del ojo. Obtenga atención medica de inmediato.

4.2 PIEL: Inmediatamente enjuague con grandes cantidades de agua. Remueva la ropa contaminada bajo un baño de ducha. Obtenga atención medica inmediato.

4.3 INGESTIÓN: NO INDUZCA EL VÓMITO. Si la víctima esta consciente, inmediatamente déle dos a cuatro vasos de agua. Si ocurre el vómito, repita la administración de agua. Obtenga inmediatamente atención medica.

4.4 INHALACIÓN: Remueva a la víctima de la atmósfera contaminada. Si se respiró en el área contaminada administre oxígeno. Si paró de respirar, despeje las vías respiratorias y comience resucitación de boca a boca. Si ha parado de latir el corazón, se deberá aplicar masaje externo al corazón. Obtenga atención inmediata.

Sección 5: MEDIDAS A TOMAR EN CASO DE INCENDIO

5.1 PROPIEDADES INFLAMABLES
PUNTO DE INFLAMACIÓN: No inflamable **MÉTODO USADO: NA**

5.2 LIMITES INFLAMABLES Sulfuro de Hidrogeno **LFL**:4% **UFL**:44%

5.3 MEDIDAS DE EXTINCIÓN: Rocío de agua o espuma o lo apropiado para combustibles involucrados en incendio.

5.4 RIESGO PARA INCENDIO Y EXPLOSIVOS: La solución es inflamable. Aunque si estas soluciones son expuestas al calor o ácidos, el sulfuro de hidrogeno será liberado y podría formar mezclas explosivas en el aire (ver lo anterior). Guarde los contenedores/recipientes que esten almacenados en el área de fuego enfriados con rocío de agua. El calentamiento podría causar la explosión del sulfuro de hidrogeno.

Hoja de Datos de Seguridad del Material

Sección 5: MEDIDAS A TOMAR EN CASO DE INCENDIO (Cont.)

5.5 EQUIPO DE INCENDIO: Debido a la posible presencia de gases tóxicos y a la naturaleza corrosiva del producto, debe usarse un aparato para respirar independiente de la demanda de presión para el agua, MSHA/NIOSH (aprobado o equivalente) y el equipo protector completo.

Sección 6: MEDIDAS EN CASO DE ESCAPE ACCIDENTAL

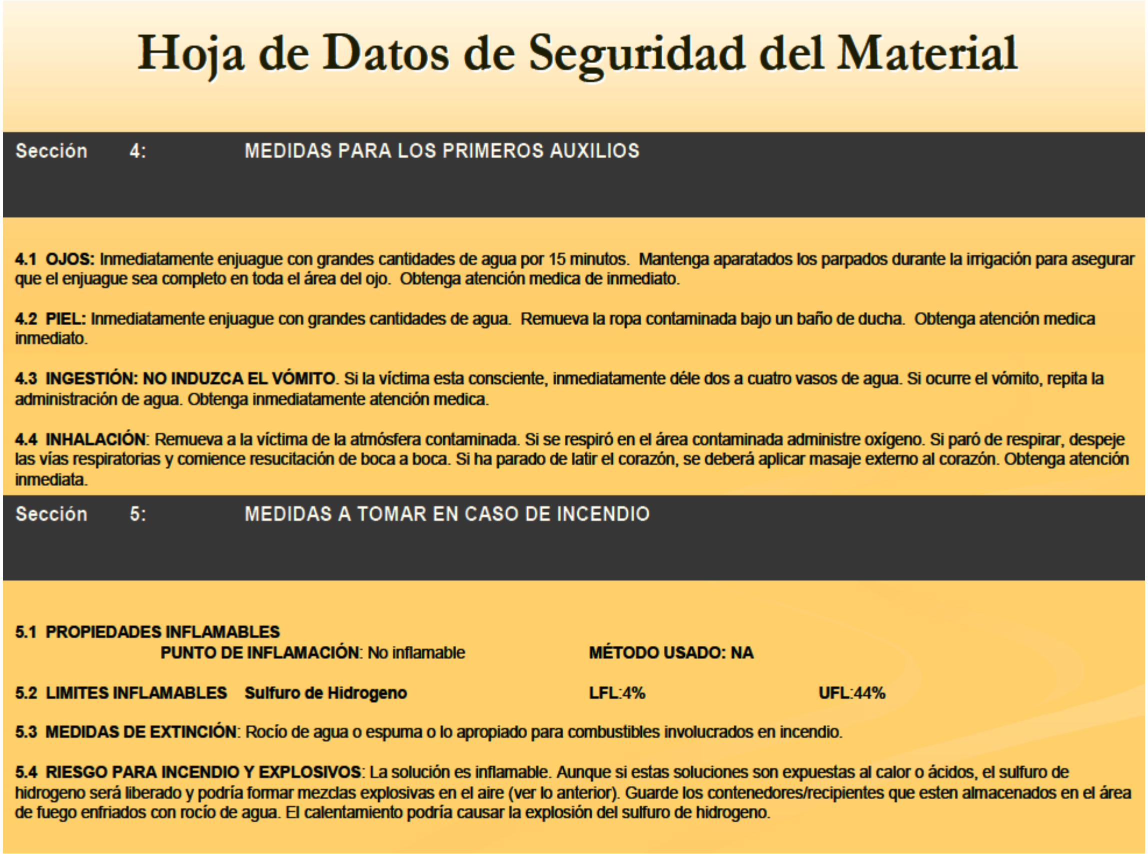
6.1 ESCAPE PEQUEÑO: Aisle y absorba pequeñas liberaciones con arena, tierra u otro absorbente inerte. Oxidice el residuo de sulfuro reactivo con una solución débil (3-5%) de peroxido de hidrógeno. Neutralice la solución con un ácido acético débil si es necesario (~ 5%). NO NEUTRALICE CON ÁCIDOS MINERALES FUERTES, YA QUE ESTE EXPEDIRÁ GRANDES CANTIDADES DE GAS H_2S.

6.2 GRANDES ESCAPES: Use el equipo protector necesario. Recluya el área al personal calificado. Apague el disparador si es seguro hacerlo. Vierta el área de represa para prevenir afluencia a las alcantarillas, drenaje (mezclas potenciales explosivas de hidrógeno sulfuro en espacios recluidos) o superficies de vía fluvial (toxicidad acuática potencial). Recubra lo más posible que pueda de la solución. Trate el material remanente como una pequeña liberación (vea anterior). NO NEUTRALICE CON ÁCIDOS MINERALES FUERTES, YA QUE ESTO EMITIRÁ GRANDES CANTIDADES DE GAS H_2S.

Sección 7: MANEJO Y ALMACENAMIENTO

7.1 MANEJO: Use equipo protector adecuado (ver sección 8). Evite respirar los vapores del producto. Evite contacto con piel y ojos. Use solo en una área bien ventilada. Diluya el producto solo en recipientes cerrados. Lave minuciosamente todos los elementos después de manejo.

7.2 ALMACENAMIENTO: Almacenar en áreas bien ventiladas. No almacene combustibles en el área de almacenamiento de recipientes. Manténgase fuera de cualquier fuente de calor o llama Almacene bolsas y recipientes pequeños fuera de la luz solar directa en temperaturas moderadas [< 80º F (27º C)]. (Ver sección 10.4 para materiales de construcción).



Hoja de Datos de Seguridad del Material

Sección 4: MEDIDAS PARA LOS PRIMEROS AUXILIOS

4.1 OJOS: Inmediatamente enjuague con grandes cantidades de agua por 15 minutos. Mantenga aparatados los parpados durante la irrigación para asegurar que el enjuague sea completo en toda el área del ojo. Obtenga atención medica de inmediato.

4.2 PIEL: Inmediatamente enjuague con grandes cantidades de agua. Remueva la ropa contaminada bajo un baño de ducha. Obtenga atención medica inmediato.

4.3 INGESTIÓN: NO INDUZCA EL VÓMITO. Si la víctima esta consciente, inmediatamente déle dos a cuatro vasos de agua. Si ocurre el vómito, repita la administración de agua. Obtenga inmediatamente atención medica.

4.4 INHALACIÓN: Remueva a la víctima de la atmósfera contaminada. Si se respiró en el área contaminada administre oxígeno. Si paró de respirar, despeje las vías respiratorias y comience resucitación de boca a boca. Si ha parado de latir el corazón, se deberá aplicar masaje externo al corazón. Obtenga atención inmediata.

Sección 5: MEDIDAS A TOMAR EN CASO DE INCENDIO

5.1 PROPIEDADES INFLAMABLES
PUNTO DE INFLAMACIÓN: No inflamable **MÉTODO USADO: NA**

5.2 LIMITES INFLAMABLES **Sulfuro de Hidrogeno** **LFL**:4% **UFL**:44%

5.3 MEDIDAS DE EXTINCIÓN: Rocío de agua o espuma o lo apropiado para combustibles involucrados en incendio.

5.4 RIESGO PARA INCENDIO Y EXPLOSIVOS: La solución es inflamable. Aunque si estas soluciones son expuestas al calor o ácidos, el sulfuro de hidrogeno será liberado y podría formar mezclas explosivas en el aire (ver lo anterior). Guarde los contenedores/recipientes que esten almacenados en el área de fuego enfriados con rocío de agua. El calentamiento podría causar la explosión del sulfuro de hidrogeno.

Hoja de Datos de Seguridad del Material

Sección 5: MEDIDAS A TOMAR EN CASO DE INCENDIO (Cont.)

5.5 EQUIPO DE INCENDIO: Debido a la posible presencia de gases tóxicos y a la naturaleza corrosiva del producto, debe usarse un aparato para respirar independiente de la demanda de presión para el agua, MSHA/NIOSH (aprobado o equivalente) y el equipo protector completo.

Sección 6: MEDIDAS EN CASO DE ESCAPE ACCIDENTAL

6.1 ESCAPE PEQUEÑO: Aisle y absorba pequeñas liberaciones con arena, tierra u otro absorbente inerte. Oxidice el residuo de sulfuro reactivo con una solución débil (3-5%) de peroxido de hidrógeno. Neutralice la solución con un ácido acético débil si es necesario (~ 5%). NO NEUTRALICE CON ÁCIDOS MINERALES FUERTES, YA QUE ESTE EXPEDIRÁ GRANDES CANTIDADES DE GAS H2S.

6.2 GRANDES ESCAPES: Use el equipo protector necesario. Recluya el área al personal calificado. Apague el disparador si es seguro hacerlo. Vierta el área de represa para prevenir afluencia a las alcantarillas, drenaje (mezclas potenciales explosivas de hidrógeno sulfuro en espacios recluidos) o superficies de vía fluvial (toxicidad acuática potencial). Recubra lo más posible que pueda de la solución. Trate el material remanente como una pequeña liberación (vea anterior). NO NEUTRALICE CON ÁCIDOS MINERALES FUERTES, YA QUE ESTO EMITIRÁ GRANDES CANTIDADES DE GAS H2S.

Sección 7: MANEJO Y ALMACENAMIENTO

7.1 MANEJO: Use equipo protector adecuado (ver sección 8). Evite respirar los vapores del producto. Evite contacto con piel y ojos. Use solo en una área bien ventilada. Diluya el producto solo en recipientes cerrados. Lave minuciosamente todos los elementos después de manejo.

7.2 ALMACENAMIENTO: Almacenar en áreas bien ventiladas. No almacene combustibles en el área de almacenamiento de recipientes. Manténgase fuera de cualquier fuente de calor o llama Almacene bolsas y recipientes pequeños fuera de la luz solar directa en temperaturas moderadas [< 80º F (27º C)]. (Ver sección 10.4 para materiales de construcción).

Annex B

AMINES TREATMENT

B.1 H2S PURIFICATION PROCESS

As we have in mind, H2S is entering with CO2, CO2 is an undesirable product in our plant since it also generates unwanted product, is also highly corrosive and also its entry into the NaHS production process would increase the flow of Gas unnecessarily, increasing the costs of manufacturing equipment, by increasing dimensions.

For this we use a technology to purify the CO2 that is entering the process through an absorption by amines.

B.2 USE OF CO2 ABSORPTION TECHNOLOGY

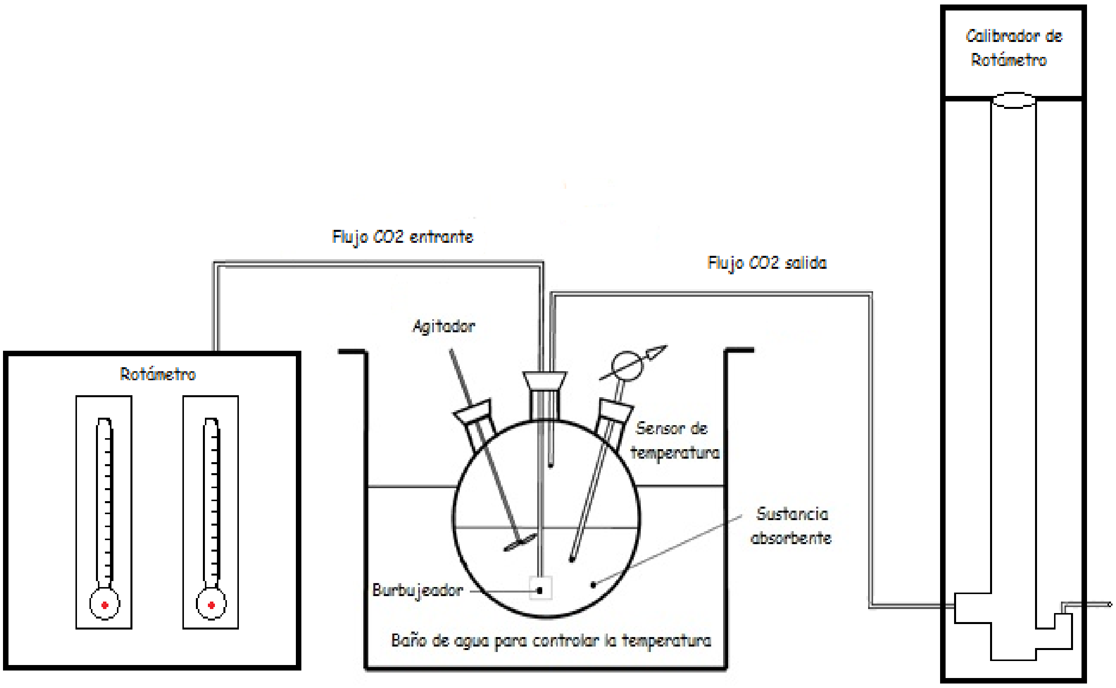


FIGURE 7: Experimental design for determination of absorption capacity in the laboratory with CO2. [10]

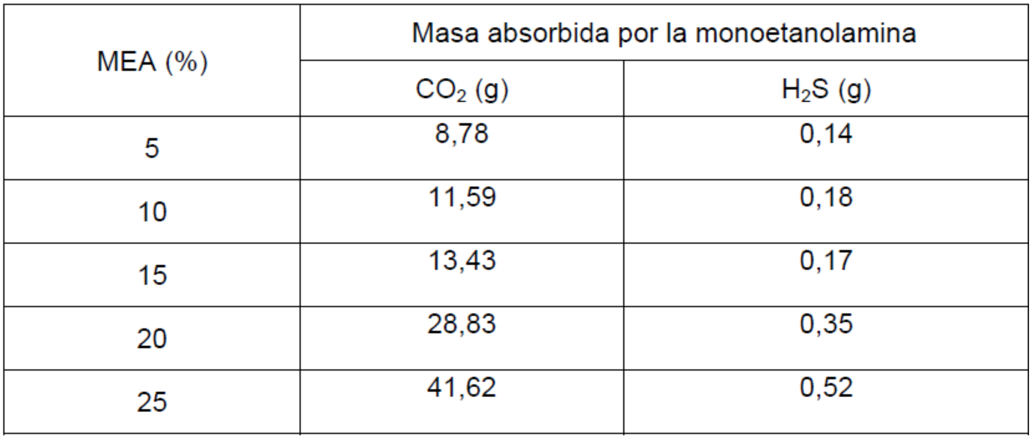
In this case the gas flow in an amine solution with water will be passed, since the amines have a good capacity of absorption of CO2, much superior to the absorption that they have on H2S.

B.3. EXPERIMENTAL PART

The rotameter is calibrated with CO2, with the aid of the rotameter calibrator. Then the same mechanism applied in the field evaluation is continued. The calibrator of the rotameter is used at the outlet, where by blowing through a hose a bubble is generated which tends to ascend, taking the time it takes to travel a certain distance (for this case were 20 cm). Taking the calibrator volume and bubble take-up time, the outgoing CO 2 flow is calculated every minute. It has a maximum outflow rate when the amine reaches its saturation point, and vice versa. From the CO2 inlet and outlet flows, the amount of CO2 absorbed and thus the capacity of the amine to be absorbed is quantified.' [10]

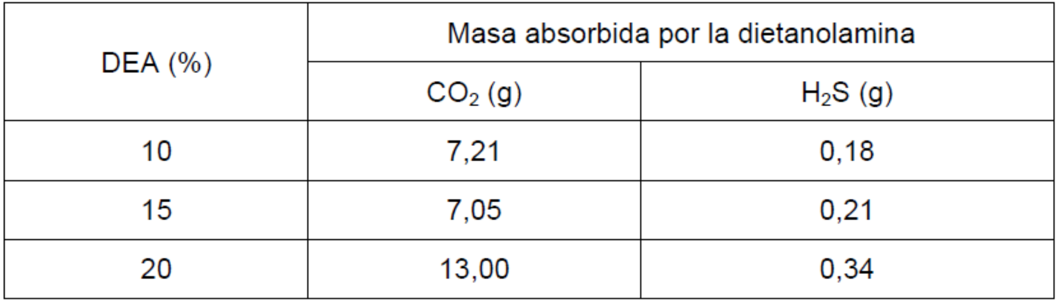
There are two amines that are very absorbent of the CO2 and very little absorbers of H2S, in this case they are MEA (monoethanolamine) and DEA (diethanolamine), for that we have certain experimental data of the proportion of absorption of these gases.

Table 6: Mass absorbed by CO2 and H2S by monoethanolamine[1]



MEA (%)	Masa absorbida por la monoetanolamina	
	CO_2 (g)	H_2S (g)
5	8,78	0,14
10	11,59	0,18
15	13,43	0,17
20	28,83	0,35
25	41,62	0,52

Table 7: Mass absorbed by CO2 and H2S by diethanolamine[2]



DEA (%)	Masa absorbida por la dietanolamina	
	CO_2 (g)	H_2S (g)
10	7,21	0,18
15	7,05	0,21
20	13,00	0,34

Where absorption will be in kg of gas / kg of amine. And of the two options it is evaluated which has the greater absorption ratio of Kg of CO2 / Kg of H2S. It may then be noted that the highest ratio is 25% by weight of MEA with water. And it will be based on this composition to which we will work the absorption.

---

[1] SALAZAR Evaluation of the elimination of CO2 .TACNA - PERÚ 2012 pag 113

[2] SALAZAR Evaluation of the elimination of CO2 .TACNA - PERU 2012. Pag 113

B.4 MEA VOLUME CALCULATIONS FOR CO2 ABSORPTION

$MEA\_25\% = \frac{41.62 g.de.CO_2}{Kg.de.MEA}$ y we have 1340 Kg de CO_2

$$\frac{1340000 \frac{g.de.CO_2}{hora}}{\left(\frac{41.62 g.de.CO_2}{Kg.de.MEA}\right)} = 32196.05 \frac{Kg.de.MEA}{hora}$$

We now calculate the water flow we require if the MEA is 25% by weight.

$\frac{W_{MEA}}{W_{TOTAL}} = 25\%$ also $W_{TOTAL} = W_{AGUA} + W_{MEA}$

Then the weight of water is: W_{AGUA} = 96588.17 Kg/h

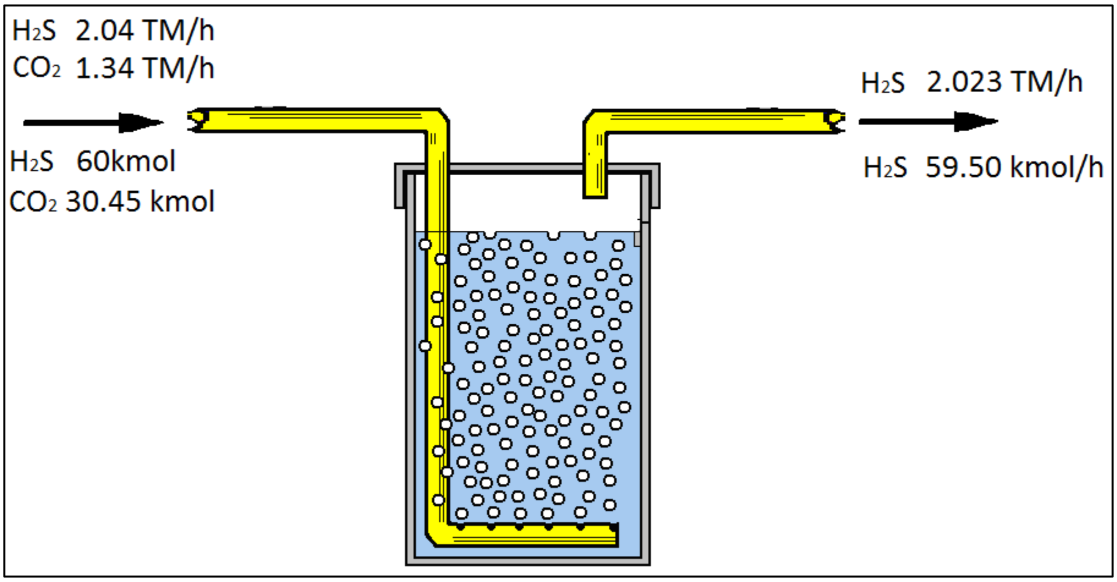


FIGURE 8: CO2 absorption scheme

For this case we already have the amount of H2S and CO2 absorbed and we have in our stream H2S pure gas to enter the true process that is the production of NaHS.

B.5 PROCESS LINE

In this case the process line will be absorbed with the amine and subsequently purified from the amine, passing the absorbed amine by a heating of 100 ° C, which is enough to give off the absorbed gases and return to the expectation of absorbing as many gases as possible.

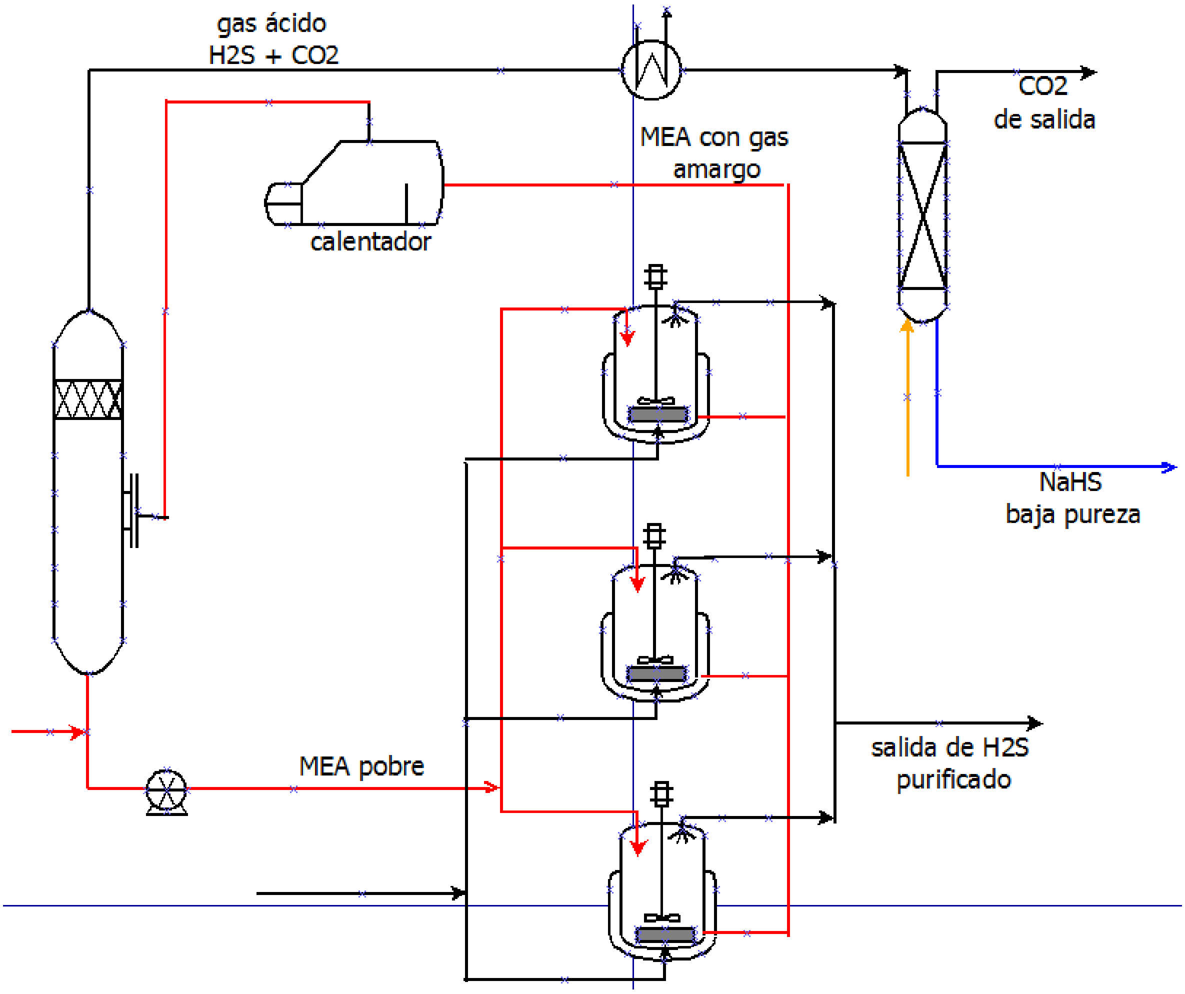
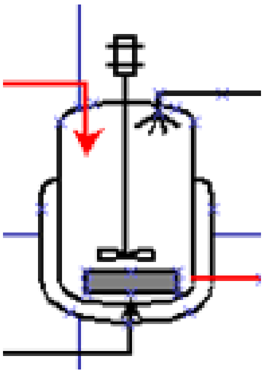


Diagram 5: PURIFICATION PROCESS

Now we will calculate the dimensions and quantities of the products used in the line.

B.6 EQUIPMENT SIZING

B.6.1 AGITATOR



Here we put 5% more MEA than the required one, since it drags a certain quantity of matter in the commune flash.

For this case we have:

$32196.05 \frac{Kg.de.MEA}{hora}$ But we have the MEA at 25% by weight which means we can calculate the amount of water required.

$96588.15 \frac{Kg.de.H_2O}{hora}$ In addition, the gas that is dissolved inside the solution will be 1.34 TM/h de CO_2.

The mass is analyzed inside the stirred mixer for an interval of one hour.

TABLE 8: MAGNITUDES INTO THE TANK

COMPOUND	MASS Kg	DENSITY Kg/m3	VOLUME m3
MEA	32196.05	1019 **[11]**	31.59
AGUA	96588.15	1000	96.588
CO_2	1340	1256.74 **[12]** (diluido)	1.066
H_2S	28	914.9 **[13]**	0.030
TOTAL			129.274

The mass of H2S of 28 kg is considered because the rest is not captured by the MEA and goes to the required process as pure H2S.

Since there are 3 tanks then each tank must handle a volume of 43 m3

But for safety margins is going to give 15% more in volume

Then we design the measurements of the tank according to DIN 28011

H/D = 1.6

$\frac{\pi.H.D}{4} = vol$ Then: $\frac{\pi.H.D^2}{4} = 49.45m^3$

We have:

$$H = 5.44m \Rightarrow D = 3.40m$$

Also the toroid of the base of the reactor is determined, since like all deposit this one must have a base toriesférica, that we will calculate it of the following way:

According to DIN 28011 [14]

H1 = 3.5s where s is the reactor thickness 3- 250 mm

We put 2.5 cm of thickness of the shell of the reactor

H1 = (3.5) (0.025m) = 0.0875m

For the calculation of h2 we have: h2 = 0.1935D - 0.455s

H2 = 0.1935 (3.40) - 0.455 (0.025) = 0.64m

Then htotal = 0.64 + 0.0875 = 0.7275m

We also put a stirrer for the reaction, we will propeller stirrer as they are the most moving to exert the fluid. We have correlations for the helix dimensions and distances of the agitators [15].

$$\frac{D_a}{D_t}=\frac{1}{3} \qquad \frac{H}{D_t}=1 \qquad \frac{j}{D_t}=\frac{1}{12} \qquad \frac{E}{D_t}=\frac{1}{3} \qquad \frac{W}{D_a}=\frac{1}{5} \qquad \frac{L}{D_a}=\frac{1}{4}$$

In addition to general characteristics of the agitator:

- 6-bladed propeller.
- Four deflectors.

As we already have the data of height and diameter of the reactor we proceed to calculate the other dimensions for the agitator and the deflectors.

$$\frac{Da}{Dt}=\frac{1}{3}\Rightarrow\frac{Da}{3.40m}=\frac{1}{3}\Rightarrow Da=1.13m \qquad \frac{J}{Dt}=\frac{1}{12}\Rightarrow\frac{Da}{3.40m}=\frac{1}{12}\Rightarrow J=0.28m$$

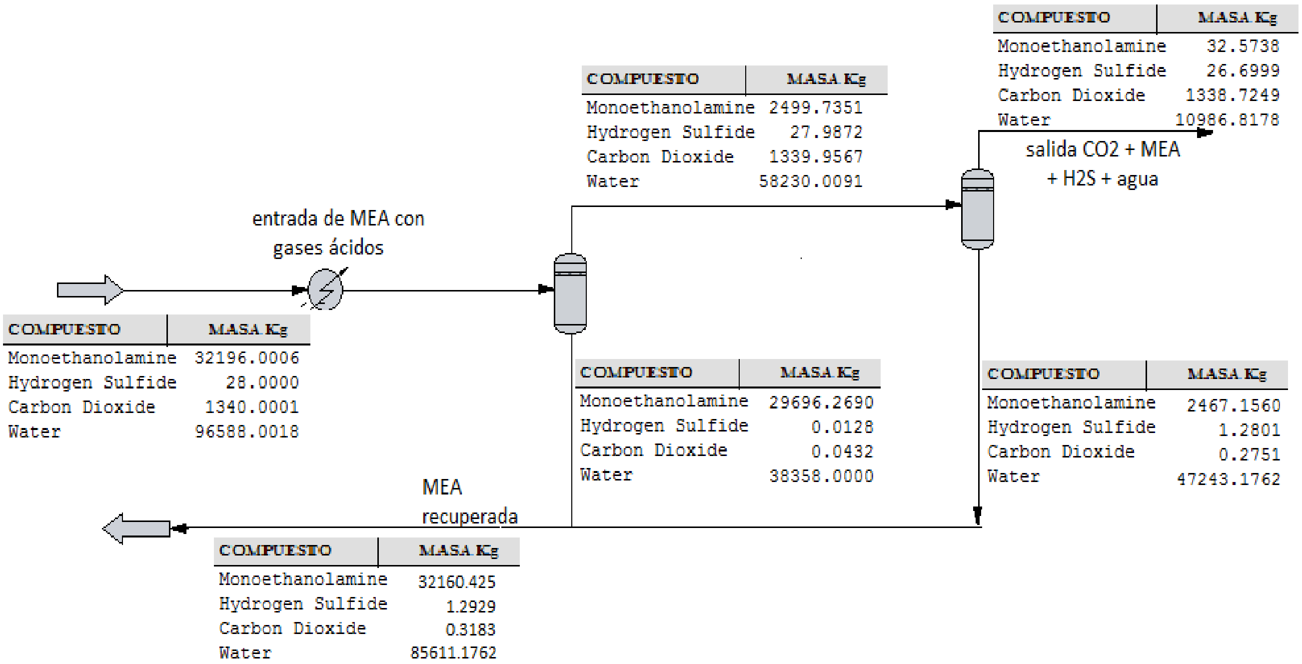
$$\frac{E}{Dt}=\frac{1}{3}\Rightarrow\frac{E}{3.40m}=\frac{1}{3}\Rightarrow E=1.13m \qquad \frac{W}{Da}=\frac{1}{5}\Rightarrow\frac{W}{1.13m}=\frac{1}{3}\Rightarrow W=0.38m$$

$$\frac{L}{Da}=\frac{1}{4}\Rightarrow\frac{L}{1.13}=\frac{1}{4}\Rightarrow L=0.28m$$

B.6.2 ABSORPTION COLUMN TO THE OUTPUT OF THE AMINE PROCESS

For this case it must be taken into account that the maximum possible amount of acid gas must be extracted, and the smallest amount of MEA that will be left in the steam trawl.

The analysis of the flash column that is to be separated by phase separation to the acid gases of the MEA is made.



COMPUESTO	MASA Kg
Monoethanolamine	32.5738
Hydrogen Sulfide	26.6999
Carbon Dioxide	1338.7249
Water	10986.8178

COMPUESTO	MASA Kg
Monoethanolamine	2499.7351
Hydrogen Sulfide	27.9872
Carbon Dioxide	1339.9567
Water	58230.0091

COMPUESTO	MASA Kg
Monoethanolamine	32196.0006
Hydrogen Sulfide	28.0000
Carbon Dioxide	1340.0001
Water	96588.0018

COMPUESTO	MASA Kg
Monoethanolamine	29696.2690
Hydrogen Sulfide	0.0128
Carbon Dioxide	0.0432
Water	38358.0000

COMPUESTO	MASA Kg
Monoethanolamine	2467.1560
Hydrogen Sulfide	1.2801
Carbon Dioxide	0.2751
Water	47243.1762

COMPUESTO	MASA Kg
Monoethanolamine	32160.425
Hydrogen Sulfide	1.2929
Carbon Dioxide	0.3183
Water	85611.1762

Diagram 6. Chemcad Courtesy

B.6.3. FLASH SEPARATORS SIZING

We have the following relation:

$$V_{G\max} = K_S \sqrt{\frac{\rho_L - \rho_G}{\rho_G}}$$ [16] Where:

ρ_G = Gas Density
ρ_L = Liquid Density

Ks = Design Parameter

Which can be obtained from the following table:

Vane Type	Flow Direction	K_S, m/s (ft/s)	Droplet Removal Efficiency	Liquid Load Before Capacity Deteriorates, L/min/m^2 (gal/min/ft^2)
Simple Vane	Upflow	0.15 (0.5)	90+% > 20 microns	84 (2)
Simple Vane	Horizontal	0.20 (0.65)	90+% > 20 microns	84 (2)
High Capacity Vane	Upflow	0.25 – 0.35 (0.82 – 1.15)	95+% > 10 microns	210 (5)
High Capacity Vane	Horizontal	0.3 – 0.35 (1.0 – 1.15)	95+% > 10 microns	210 (5)

Table 9: Ks factor **[17] [18]**

For the case is a vertical flash so we have to choose the most efficient.

Ks = 0.35 m/s

Therefore it is possible to calculate Vg max:

$$V_{G\max} = 0.35\sqrt{\frac{1.0031\,{}^{Kg}\!/\!_{m^3} - 0.98\,{}^{Kg}\!/\!_{m^3}}{0.98\,{}^{Kg}\!/\!_{m^3}}}$$

$$V_{G\max} = 11.19\frac{m}{s} = 40284\frac{m}{h}$$

Taking Vg max, proceed to calculate the diameter given by:

$$D\min = \sqrt{\frac{4}{\pi}\frac{q}{V_{G\max}}}$$

$$D\min = \sqrt{\frac{4}{\pi}\left(\frac{132815.14\,{}^{m^3}\!/\!_{h}}{40284\,{}^{m}\!/\!_{h}}\right)} = 2.04m$$

For security reasons we put a 20% more diameter:
D = 2.45m

We can use the criterion of storage to have the relation L/D= 1.6
L=   3.91 m

To make the calculations of the second flash to remove the MEA that has gone with the current we do the calculations in a similar way to the previous one:

Ks = 0.35 m/s

Therefore it is possible to calculate Vg max:

$$V_{G\max} = 0.35\sqrt{\frac{986.38\,{}^{Kg}\!/\!_{m^3} - 0.8494\,{}^{Kg}\!/\!_{m^3}}{0.8494\,{}^{Kg}\!/\!_{m^3}}}$$

$$V_{G\max} = 11.92\frac{m}{s} = 40918.98\frac{m}{h}$$

Taking Vg max, proceed to calculate the diameter given by:

$$D\min = \sqrt{\frac{4}{\pi}\frac{q}{V_{G\max}}}$$

$$D\min = \sqrt{\frac{4}{\pi}\left(\frac{23785.61\,{}^{m^3}\!/_{h}}{40284\,{}^{m}\!/_{h}}\right)} = 0.867m = 86.70cm$$

For security reasons we put a diameter of 20% more
D = 104.4cm

We can use the criterion of storage to have the relation L/D= 1.6
L= 166.46 cm

ANNEX C

MASS BALANCE OF ALL CURRENTS

C.1. MATERIAL BALANCE

We have to make certain considerations.
In our input current we have H2S and CO2 but for mass balance we are going to consider CO2 since this is at the input of the feed and the assumption we will make will be that the traces of CO2 that react are negligible to the reaction in general Of NaOH and H2S.
Another important consideration is that we assume the entry of H2S and CO2 even though we have other inert or active compounds, but we have it in very small traces and we consider that they will not intervene directly in the process.

C.1.1 BALANCE OF MATTER IN THE REACTOR

Chemical reaction balance is taken.

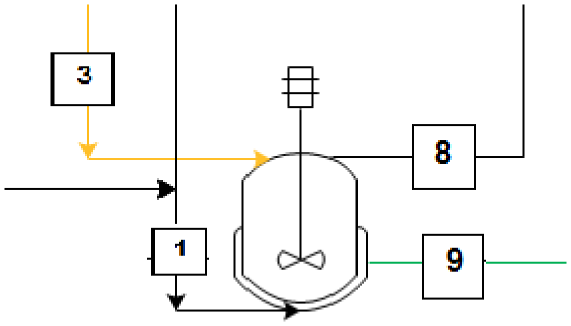


Figure 9. Balance in the reactor.

Data:

eq (1)

$$S_{(\text{SÓLIDO})} + H^{+} \longrightarrow H_2S$$

	$S_{(\text{SÓLIDO})}$	H^{+}	H_2S
balance molar	*1*	*2*	*1*
balance masa	$47\ \frac{TM}{día}$		$49\ \frac{TM}{día}$

Sulfur referent leaving the Pampilla refinery.

Based on the 49 TM / day we make the mass balance of the process.

Reactions occur in the reactor

The general equation for a balance with chemical reactions is:

$$N_s^{salida} - N_s^{entrada} = r_i \quad \textbf{eq (2)}$$

Where:

***Ns*:** Entry or exit to the reactor.

***ri*:** Rate of production / consumption of a given species (s).

For a required weight of 2.04 MT / h we calculate the amount of NaOH required.
We have the entry date [1]

TABLE 10. Current 1

CURRENT 1	COMPOUND			
ENTRY	WEIGHT TM/h	mol%	kmol/h	weight%
H_2S	2.023	100 %	59.5	100%

Now we calculate the amount of NaOH that is going to enter the reactor in stream 3
N moles (H 2 S) = N moles of (NaOH)
N moles of NaOH = 60 Kmol / h
N M = weight of NaOH
(60 kmol / h) * 40 g / mol = 2400 kg / h = 2.4 TM / hr

For our case we use 23% NaOH as it is the adequate concentration for the process to be carried out, it can be altered by raising or lowering this percentage by weight, but we will do so in this way for operating conditions. Phosphoric Acids [1]

TABLE 11. Current 3

CURRENT 3	COMPOSICIÓN			
SODA	WEIGHT TM/h	mol%	kmol/h	weight%
NaOH	2.055	16.25	51.38	30.32
H_2O	4.722	83.75	262.34	69.68
total	6.777	100%	313.72	100%

After the reactions are made then proceed to see the reactor output data to be passed to the absorption column

TABLE 12. Current 8

CURRENT 8	COMPOUND			
GAS OUTLET	WEIGHT TM/h	mol %	kmol/h	weight%
H_2S	0.229	100	6.76	100%
H_2O	-	-	-	-
total	0.229	100%	6.76	100%

In this case the water did not come out through stream 8 or did it in traces, it was because at that pressure and temperature the water is in subcooled liquid and has not evaporated to leave with the gas.

We now analyze the reactor bottoms (NaHS)

TABLE 13. Current 9

CURRENT 9	COMPOUND			
PRODUCT	WEIGHT TM/h	mol%	kmol/h	weight%
NaHS	2.953	15.01	52.74	35.47
H_2O	5.371	84.99	298.43	64.53
total	8.324	100%	351.17	100%

This is the analysis we did to the reactor where we got 2,953 MT / h NaHS now we are going to process the exhaust gas stream from the absorber.

C.1.2 BALANCE OF MATTER IN THE ABSORBER

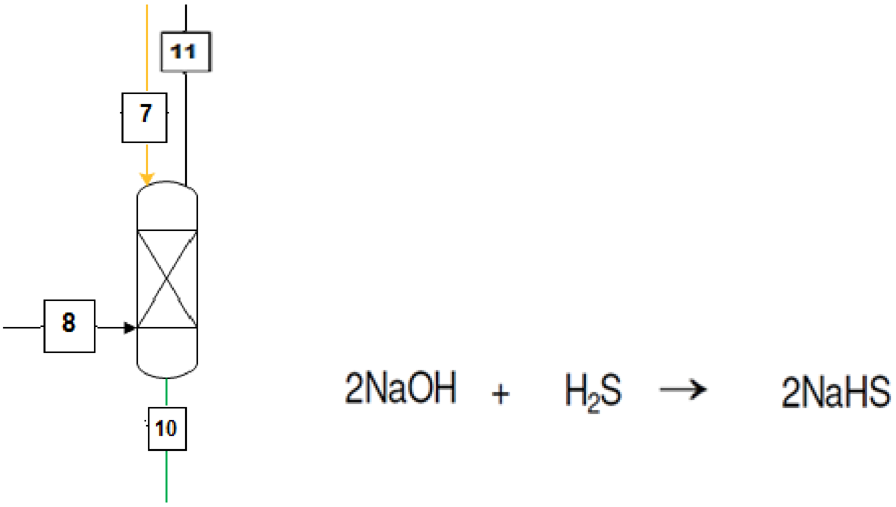


FIGURE 10: Balance in the absorber

The current 7 has the same composition as current 3

TABLE 14. Current 7

CURRENT 7	COMPOUND			
SODA	WEIGHT TM/h	mol%	kmol/h	weight%
NaOH	0.270	11.85	6.76	23
H_2O	0.9273	88.15	51.51	77
total	1.1973	100%	58.27	100%

For the output of the absorber already reacted practically all the H2S
We analyzed the current 11

TABLE 15. Current 11

CURRENT 11	COMPOUND			
WASTE	WEIGHT TM/h	mol%	kmol/h	weight%
H_2S(-)	0.00	0.00	0.00	0

Now we proceed to analyze the current of the product of the absorber of our finished product.

TABLE 16. Current 10

CURRENT 10	COMPOUND			
PRODUCT 2	WEIGHT TM/h	mol%	kmol/h	weight%
NaHS	0.378	10.39	6.76	21.03%
H_2O	1.048	89.61	58.27	78.97%
total	1.426	100%	65.03	100%

ANNEX D

EQUIPMENT DESIGN

D.1 REACTOR

For the reactor it is necessary to know the kinetics of the reaction of NaOH with H2S, since on the basis we can do the calculations of time and volume. We can establish one of the two values to find the other.

For this we do the general mass balance.

Entrada de A − **Salida de A** + **Generación de A (- Consumo A)** = **Acumulación de A**

Where A is H2S since it is the main product we want to transform

For this we go to the kinetic equations:

It's known:

$$(r_A V) = \frac{dN_A}{dt}$$

Where: r_a is the reaction rate of H_2S

N_A is the flow of moles of A

V is the reaction volume and t is the residence time

$$-r_A V = N_{A0}\frac{dX_A}{dt}$$

Now that we have already separated into molar fractions we have to solve the differential equation by the method of separate variables

$$t = \int_0^{X_A} \frac{N_{A0}}{-r_A V} dX$$

We also have to calculate the volume of the reactor as a function of the input mass flow.

Mainly the analysis of reactor design is done in function of mass and not kinetics since the kinetics is very fast, that is why the speed of the process is governed by mass transfer.

The solution of NaOH, H2S and water;

We find the volumes occupied

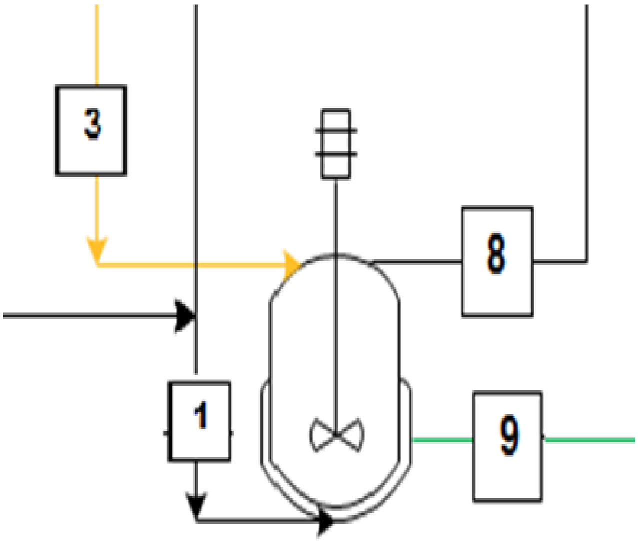
$\rho\ NaOH = 3.16\frac{g}{ml}$ [19]

$\rho\ H2O = 1.00\frac{g}{ml}$

$\rho\ NaSH = 1.8\ \mathrm{g/cm^3}$ [20]

$.\rho\ H2S(l) = 0.914\ \mathrm{g/cm3}.$ [21]

FIGURE 11. Batch Reactor



With the density data we calculate the volume of the batch reactor:

$$\frac{m_{NaOH}}{\rho_{NaOH}} + + \frac{m_{H2O}}{\rho_{H2O}} + \frac{m_{H2S}}{\rho_{H2S}} = Volumen$$

$$\frac{2.055}{3.16} + \frac{4.722}{1} + \frac{1.794}{1.189} = 6881.14\ litros/h$$

In an interval of 4 hours that is what lasts the reaction inside the reactor we have the following volume:

$$\left(6881.14\frac{litros}{h}\right)(4horas) = 27524.53litros$$

Now we calculate the volume of gas that would be given by a numerical calculation of the Van der Walls equation for H2S.

$a = 0.049\ {Jm^3}/{mol^2}$

$b = 0.00004287\ {m^3}/{mol}$

Which are the constants of VDW

For the number of oles that do not react in the reactor and for a pressure of 1 atm it is necessary to calculate that volume occupies the gas.

$\left(p + \frac{an^2}{V^2}\right)(V - nb) = nRT$ for P= 101325 Pa= 1atm.

$$\left(101325Pa+\frac{0.049\frac{Jm^3}{mol^2}*(27040mol)^2}{V^2}\right)\left(V-27040mol*0.00004287\frac{m^3}{mol}\right)=27040*8.3143\frac{Pa.m^3}{mol.K}*298\,\mathrm{K}$$

Solving the equation V = 3.07 m3 which is the volume occupied by the gas

The total volume is now calculated

27.52453 + 3.07 = 30.59 m3

We calculate the reactor dimensions for that volume

We have the ratio L / D = 1.6 ...... [22]

Then we calculate the dimensions of height and diameter of the reactor.

$$\frac{L*\pi D^2}{4}=30.60m^3$$

But we know that L = 1.6D then we have the values L and D

$$D=2.88metros$$
$$H=4.62metros$$

Also the toroid of the base of the reactor is determined, since like all deposit this one must have a base toriesférica, that we will calculate it of the following way:

According to DIN 28011

h1 = 3.5s where s is the reactor thickness 3- 250 mm

We put 2.5 cm of thickness of the shell of the reactor

h1 = (3.5) (0.025m) = 0.0875m

For the calculation of h2 we have: h2 = 0.1935D - 0.455s

h2 = 0.1935 (2.88) - 0.455 (0.025) = 0.54m

Then htotal = 0.54 + 0.0875 = 0.6275m

We also put a stirrer for the reaction, we will propeller stirrer as they are the most moving to exert the fluid. We have the correlations for the dimensions of propellers and distances of the agitators [15]

$$\frac{D_a}{D_t}=\frac{1}{3} \qquad \frac{H}{D_t}=1 \qquad \frac{j}{D_t}=\frac{1}{12} \qquad \frac{E}{D_t}=\frac{1}{3} \qquad \frac{W}{D_a}=\frac{1}{5} \qquad \frac{L}{D_a}=\frac{1}{4}$$

In addition to general characteristics of the agitator:

- 6-Propeller Shaker.

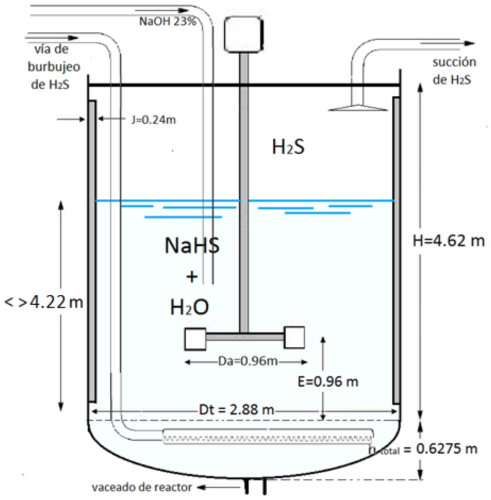
- Four deflector.

As we already have the data of height and diameter of the reactor we proceed to calculate the other dimensions for the agitator and the deflectors.

$$\frac{Da}{Dt}=\frac{1}{3}\Rightarrow\frac{Da}{2.88m}=\frac{1}{3}\Rightarrow Da=0.96m \qquad \frac{J}{Dt}=\frac{1}{12}\Rightarrow\frac{Da}{2.88m}=\frac{1}{12}\Rightarrow J=0.24m$$

$$\frac{E}{Dt}=\frac{1}{3}\Rightarrow\frac{E}{2.88m}=\frac{1}{3}\Rightarrow E=0.96m \qquad \frac{W}{Da}=\frac{1}{5}\Rightarrow\frac{W}{0.96m}=\frac{1}{3}\Rightarrow W=0.32m$$

$$\frac{L}{Da}=\frac{1}{4}\Rightarrow\frac{L}{0.96}=\frac{1}{4}\Rightarrow L=0.24m$$



D.2. ABSORBER

D.2.1 CALCULATION OF THE ABSORBER DIAMETER

The absorber is the equipment designed to convert all the final product of H2S gas that leaves the reactor in order to use it for greater production of product and of passage that can not be thrown its gases to the environment since they are polluting.

ρ H2S=1,189 g/cm3 [21]

We proceed to the calculation to find the diameter of the absorber for this we will make use of the correlations to estimate the speeds of load and flood in towers of filling.

We represent the axes X and Y to find by means of a graph the flood. [23]

$$\frac{G_y^2 * a_v * (\mu_x)^{0.2} * \left({998}/{\rho_x} \right)}{g_c * \varepsilon^3 * \rho_x * \rho_y} \rightarrow ejeX \qquad \frac{G_x}{G_y} * \sqrt{\frac{\rho_y}{\rho_x}} \rightarrow ejeY$$

Where:

G_x**:** Liquid mass speed (kg/m^2-h)

G_y**:** gas mass velocity (kg/m^2-h)

ρ_x**:** density of the liquid (kg/m^3)

ρ_y**:** gas density (kg/m^3)

a_v**:** surface area of the dry filler per unit volume of filler (m^2/m^3)

μ_x**:** viscosity (cP)

ε**:** porosity or fraction of voids of the filling, dimensionless.

Data for the Y axis

ρ_x**:** 1.23 kg/m^3 density of soda diluted to23% **[24]**

Coordinate axis calculation:

$$\frac{G_x}{G_y} * \sqrt{\frac{\rho_y}{\rho_x}} = \frac{1197.3 \frac{Kg}{m^2.h}}{229 \frac{Kg}{m^2.h}} * \sqrt{\frac{1.189 \frac{Kg}{m^3}}{1230 \frac{Kg}{m^3}}} = 0.1625$$

To make the estimates we make our Raschig ring filling of 1 in. X 1 in. Of ceramic [25]

For rasching rings we have
a_v = 190 m^2/m^3
Ɛ = 0.73
Then we find the flood of the tower through the graph:

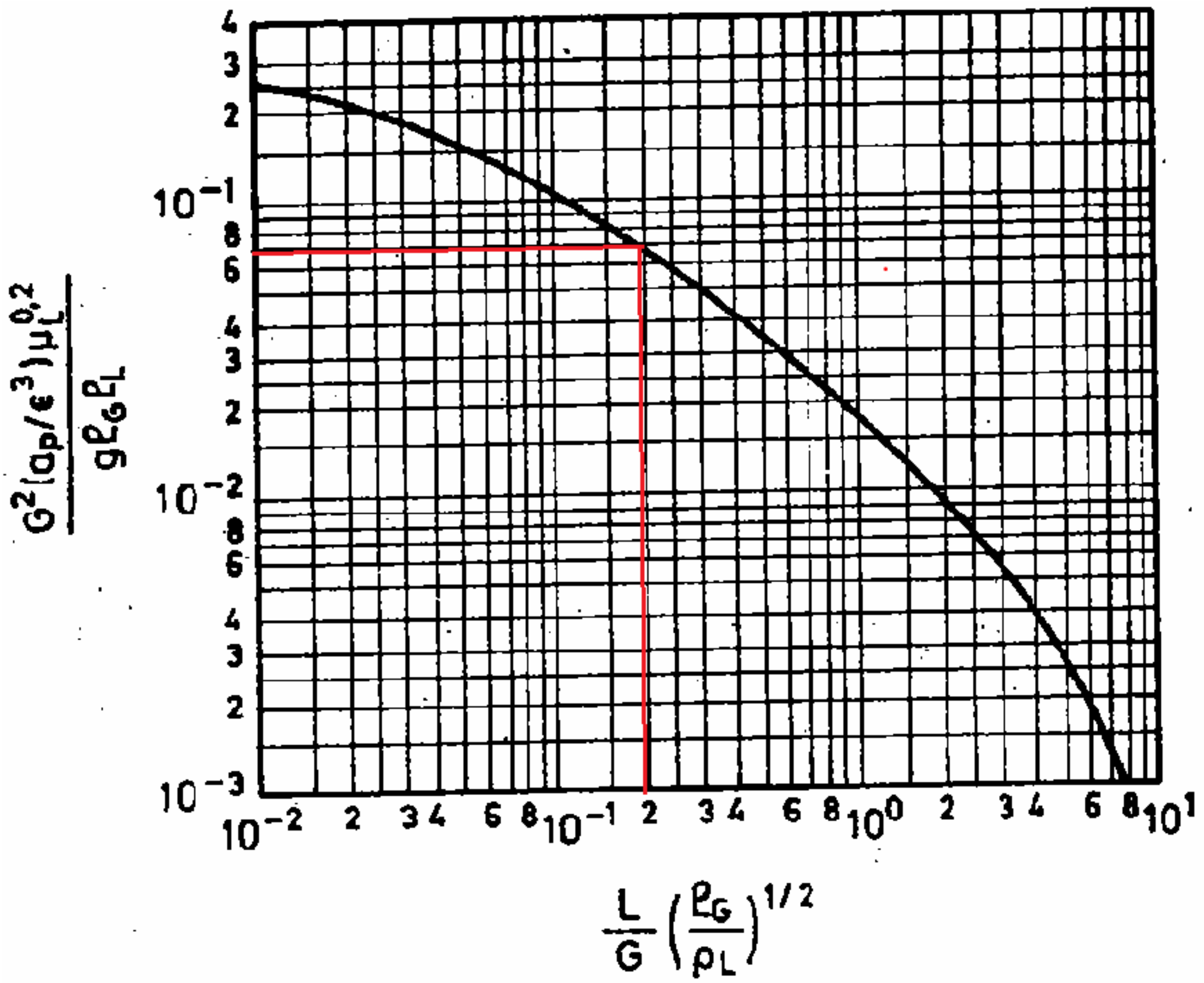


FIGURE 12. Packed Tower Flood [23]

With the help of the graph we can find Gy

$$\frac{G_y^2 * a_v * (\mu_x)^{0.2} * \left(998 \big/ \rho_x \right)}{g_c * \varepsilon^3 * \rho_x * \rho_y} = 0.072$$

Then:
µx = 78 cp [26]

$$G_y^2 = \sqrt{\frac{0.072 * g_c * \varepsilon^3 * \rho_x * \rho_y}{a_v * (\mu_x)^{0.2} * \left(998 \big/ \rho_x \right)}} = \sqrt{\frac{0.072 * 1 \frac{Kgf}{m^2} * 0.73^3 * 1230 \frac{Kg}{m^3} * 1.189 \frac{Kg}{m^3}}{190\, m^2/m^3 * (78cp)^{0.2} * \left(998 \big/ 1230 \right)}}$$

Calculating:

$$G_y = 3334.22 \frac{Kg}{m^2 h}$$

For gas flow with a flood of 60% we have:

P ≈ 1500 Pa/m*0.6 = 900Pa/m

G = 229 kg/hour,

$$área = \frac{G}{G_y} = \frac{229 \frac{Kg}{h}}{0.60 * 3334.22 \frac{Kg}{m^2 h}} = 0.1143 m^2$$

You can also calculate the diameter with the area.

$$diámetro = \sqrt{\frac{4 * área}{\pi}} \quad \text{entonces} \quad \phi = \sqrt{\frac{4 * 0.1143}{\pi}} = 0.3814$$

For safety reasons the safety factor will be 15% [27]

$$\phi_{real =} 0.3814 * 1.15 = 0.43861 m$$

Diameter of the column = 43.8 cm

D.2.2 ABSORBER HEIGHT

For this case we have a chemical reaction in the absorption, which must be considered according to its resistance and speed, is a quick and almost instantaneous reaction so much that the kinetics of the reaction almost does not affect the mass transport absorption process, but this velocity must be quantified by certain kinetic parameters.

What is known is that the reaction occurs in the liquid phase, which means that the greater resistance of mass transfer is in the gas phase, therefore it is the one that controls the absorption process.

Now the rate of reaction in the absorption is to be quantified.
The chemical reaction, whose reaction rate is described rA = kCACB, occurs in the liquid or at the interface, and depends on the relation of the different resistances involved.

If the higher resistance is in the liquid phase, then the rate constant will depend on this resistance.

$$\mathbf{r_A = k_{GA} (p_A - p_{Ai})}$$

Where, the reaction rate is expressed per unit area of interface:

p_A: gas pressure in the fluid
p_{Ai} : es la presión en la interfase
k_{GA}: mass transfer constant.

Now if we analyze in the liquid we have:

$$\mathbf{r_A = K_{AL} (C_{Ai} - C_A)}$$

Where:
***K_{AL}**: mass transfer coefficient in the liquid*
C_{Ai}*:* *concentration of A at the interface*
C_A: concentration in the fluid

Where A is H2S and B is NaHO.

Knowing both equations of constant of speed and taking into account the law of Henry **$p_{Ai} = H_A C_{Ai}$ is** reached to the relation.

$$r_A = \frac{P_A}{\frac{1}{k_{GA}} + \frac{H}{\sqrt{K.C_B.D_A}}} = \frac{P_A}{\frac{1}{k_{GA}} + \frac{H}{k_{Al}.E}} \quad [28]$$

To determine the type of reaction that is carried out in the absorption column, the Hatta (MH) modulus and the increase factor (Ei) must be calculated. From the relationship between these two values and through Figure 8 the type of reaction is defined.

Also the hatta (MH) module is found by the relation:

$$m_H = \sqrt{\frac{K.C_B.D_A}{k_{AL}^2}} \quad [28]$$

And we can calculate the E by the figure:

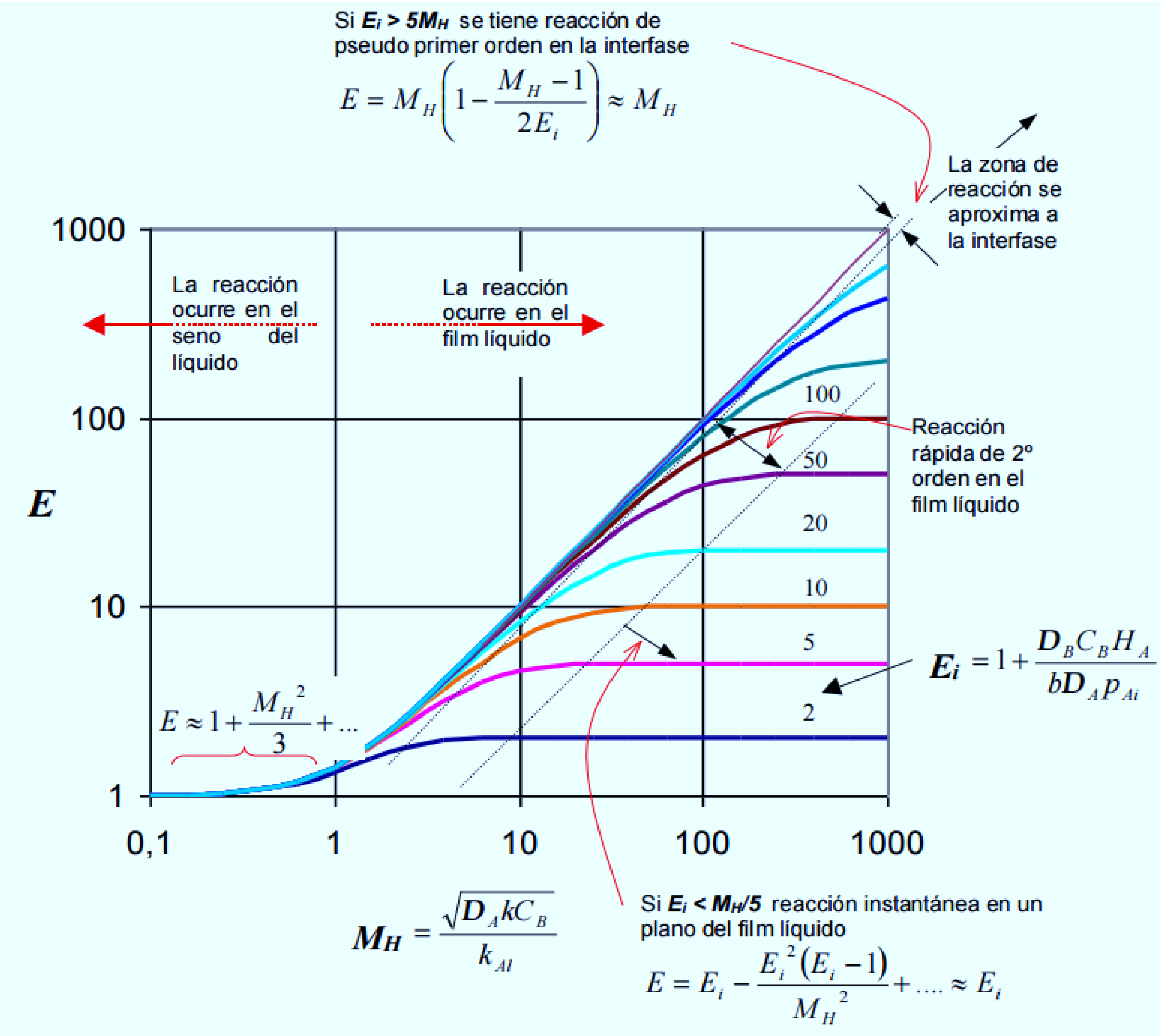


FIGURE 13: The increase factor as a function of the Hatta and Ei modules

For this we have the following data of fluids:

Diffusivity: D_{H2S}: 3, 51·10^{-9} m^2/s [29]

$D_{NaOH.}$ 1.40·10^{-9} m^2/s [29]

H2S Henry constant…. H= 25 bar·m^3/kmol [29]

For both solutes: Liquid phase: K_L= 1, 2·10^{-4} m/s [29]

Gas phase: K_{ga} =0,026 kmol/m^3·bar·s [29]

Kinetic reaction constant k = 9,5·10^3 m^3/kmol·s [29]

The ratio of liquid and gas mass velocities respectively

$$\frac{G_x}{G_y} = \frac{1.1973\, {}^{TM}\!/_{h}}{0.229\, {}^{TM}\!/_{h}} = 5.228$$

To check the effects of the reaction kinetics we calculate the number of hatta:

$$M_H = \frac{\sqrt{D_A.k.C_B}}{k_{AL}} = \frac{\sqrt{D_A.k.C_B}}{k_{GA}.H}$$

Replacing values of the previous data we have:

$$M_H = \frac{\sqrt{\left(3.51*10^{-9}\frac{m^2}{s}\right).\left(9.5*10^3\frac{m^3}{kmol.s}\right).\left(\frac{6750mol}{973L}\right)}}{\left(0.026\frac{M}{bar.s}\right)\left(25\frac{bar}{M}\right)} = 0.02$$

For very low MH under 1 is met that: $E \approx 1 + \frac{M_H^2}{3}$

Therefore: E = 1.00182

The condition of neglecting kinetics is that

E > 5 M_H

Thus it is shown that the kinetics do not affect the reaction.

Now we calculate the height of the tower by the following relation:

$$Z = \frac{G_x}{K_{GA}.P_a.S}.Ln\left(\frac{y_b}{y_a}\right) \quad \text{[37].........} \quad (*)$$

We also know that

$$\frac{1}{K_{GA}} = \frac{1}{a \cdot K_{gA}} + \frac{H}{a \cdot \sqrt{K \cdot C_B \cdot D_A}}$$

Replacing data we have:

$$\frac{1}{K_{GA}} = \frac{1}{190\frac{m^2}{m^3}.0.026\frac{kmol}{m^3.bar.s}} + \frac{25\frac{bar.m^3}{kmol}}{190\frac{m^2}{m^3}.\sqrt{9500\frac{m^3}{kmol.s}.\frac{6750mol}{973L}.\frac{3.51*10^{-9}m^2}{s}}}$$

$$\frac{1}{K_{GA}} = 8.853\frac{bar.m^4.s}{kmol}$$

But according to the design of Robert E traybal the pressure drop for an absorber should be 200 - 400 N / m2

We can put a pressure drop of 350 N / m2 at our discretion

And also ΔP * z = Pa

$$\left(350\,\frac{N}{m^2}\right) * Z = P_a$$

Replacing data in equation (*)

$$Z = \frac{6760\,{}^{mol}\!/_{h}}{\left(0.1129\,\frac{kmol}{bar.m^4.s}\right).350\,\frac{N}{m^2}\,Z\,.\left(0.1143m^2\right)}.Ln\left(\frac{0}{y_a}\right)$$

Z = 2.039 m

Due to safety conditions 15% of the height is added to the filling [27]

Z real = 2.3448 m

To calculate the thickness of the adsorber tower:

$$t = \frac{P\ x\ R}{0.85\ xS - 0.6\ x\ P} \qquad [30]$$

Where :

T = Adsorber tower thickness

P = Pressure of design in psig.

R = Inch Radius.

S = Work effort in psig.

Then :

$$t = \frac{0.1305 psig\ x\ 17.2\ pulg}{0.85\ x 14.49 psig -\ 0.6\ x\ 0.13 psig}$$

$t =$ 0.198 pulg. ≈0.5 mm< 0.5’’

Now go to the calculation of the weight of the tower:

$$W = \rho_{acero} V_{acero} = \left(7850 \frac{Kg}{m^3}\right)\frac{(\pi.2.76m)}{4}.\left((0.435\,\mathbf{m})^2 - (0.43m)^2\right) = 18.4Kg$$

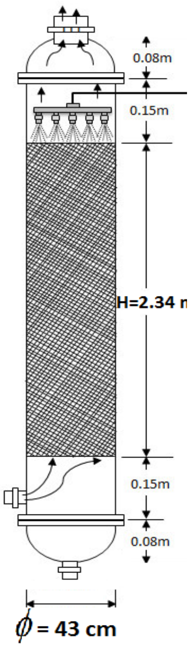


Figure 14. Absorber diagram

ANNEX E

ENERGY BALANCE

For this case we are going to do the balance of energy in the reactor where the bulk of the reaction is going to occur and that is why it is where the greatest energy change occurs, whereas in the column we only treat the gases that came out of the reactor However, as long as there is a reaction there will be changes in temperature, which is very small, that is why in my absorption column I assume that I will have a constant temperature and pressure. Like the previous case in the mass balance, here we will make the energy balance based on the chemical reaction.

This balance will be made based on the concentration of caustic soda to 23%.

The general energy balance equation for a batch process is given as follows:

$$\dot{Q} - \dot{W}_s = \Delta U + \Delta \dot{E}_K + \Delta \dot{E}_P$$

Where:

Q: Heat that goes to the surroundings.

W_S: Work or energy flowing in response to any driving force other than a temperature difference, in this case work on the current will be made by the agitator.

ΔE_k: Kinetic energy, which is due to the movement inside the system.

ΔE_P: Potential energy, caused by the position of the gravitational system, which is very low since only the reactor system is analyzed and not after the exit in the pipes.

ΔU: Internal energy, which will be the energy of the characteristics of the substances found in the control volume.

For this we set the input temperature variables and manipulated variables (output temperatures).[3]

TABLE 17: Entrance to the reactor.

REACTOR	
ENTRANCE	
COMPOUND	Temperature ºC
H_2O	25
H_2S	25
NaOH	25

The next part is to do balance calculations in the reaction

In the literature we have the standard formation enthalpy values for the substances.[4]

COMPOUND	**ENTHALPY OF FORMATION *ΔH_f 25ºC* (kJ/mol)**
$NaOH_{(ac)}$	-469.46
$NaHS_{(ac)}$	-257.91
$H_2S_{(g)}$	-20.18
$H_2O_{(l)}$	-286.03

The values shown are standard conditions, 25 ° C and 1 atm; In the case of the feed the gases and the soda are entering at 21ºC which is the reference temperature that is being set to the environment.

The internal energy (ΔU) is expressed in terms of its relation to the enthalpy (ΔH) as follows.

$$\Delta H = \Delta U + \Delta PV$$

---

[3] Camizán Vigo. Study of the treatment of gaseous emissions of hydrogen sulfide. 2015 pag 110

[4] Lange, John A. Dean, Manual of Chemistry, thirteenth edition, printed in Mexico, pp. 9-30, 9-60, 9-61

In the case of the reactor, the change in pressure and volume is imperceptible, so that it does not alter the relation to neglect it.

$$\Delta H = \Delta U$$

The enthalpies of the incoming and outgoing substances, ie the enthalpy change, are calculated.

In the case of NaOH it will not be possible to calculate since there is no exit of this one and it is entering to the temperature (21ºC) to which the reference is being taken.

$$\Delta \hat{H} = m\int_{T_1}^{T_2} C_p(T)dT$$

But the pressure change is not considered since we are working with liquids and temperatures below 50 ° C and neither the volume since we will be in a constant volume reactor.

Where we define as:

Cp: Heat capacity of the substance.
m: Input and output mass flow.
T: Process temperature, in this case the reactor

On the basis of the heats of reaction the energy generated inside the reactor is to be calculated.

$$\mathbf{H_2S + NaOH \Rightarrow NaHS + H_2O}$$

$$\Delta H_{f(H_2O)} + \Delta H_{f(NaHS)} - \Delta H_{f(H_2S)} - \Delta H_{f(NaOH)} = \Delta H_{f.REACCIÓN}$$

Replacing the data in Table 9 we have:

$$-286.03\frac{kJ}{mol} - 257.91\frac{kJ}{mol} - \left(-20.18\frac{kJ}{mol}\right) - \left(-469.46\frac{kJ}{mol}\right) = \Delta H_{f.REACCIÓN}$$

$$\Delta H_{f.REACCIÓN} = -54.27\frac{kJ}{mol}$$

Having ΔH reaction with negative sign means that the reaction is exothermic, and if we want to bring the output gas stream to the absorber, the current must be cooled by means of a heat exchanger.

For this it is determined how much heat is going to the tower

Then we can deduce the outlet temperature of the current

$$\Delta H_{(25^\circ C)} = m_{NaHS}\int_{25}^{T} Cp_{(T)NaHS}.dT + m_{H_2S}\int_{25}^{T} Cp_{(T)H_2S}.dT + m_{H_2O}\int_{25}^{T} Cp_{(T)H_2O}.dT$$

$$\Delta H_{(25^\circ C)} = 52.74\,\frac{kmol}{h}\int_{25}^{T}\left(286.03\right).dT + 298.43\,\frac{kmol}{h}\int_{25}^{T}\left(286.03\right).dT +$$

$$+6.76\,\frac{kmol}{h}\int_{25}^{T}\left(33.51 * 10^{-3} + 1.547 * 10^{-5}T \;+\; 0.3012 * 10^{-8}T^{2}\right).dT$$

T=25.13ºC

As we can observe the temperature increase is negligible.

The variation of temperature does not vary much relatively, since with that variation there is no change of state.

TABLE 18. Cp values

COMPOUND	HEAT CAPACITY Cp (KJ/mol.ºC)
NaOH	0.1313
Na_2S	0.2903
NaHS	257.91
$H_2S_{(g)}$	$33.51*10^{-3} + 1.547*10^{-5}T + 0.3012*10^{-8}T^2$
$H_2O_{(l)}$	286.03
$CO_{2(g)}$	$45.36 + 8.68*10^{-3}T - 9.619*10^{-5}T^{-2}$

Subsequently you will find the energies that are going to spend the devices in charge of giving movement to all fluid of the process.

E.1 CALCULATION OF THE WORK PERFORMED BY THE AGITATOR IN THE REACTOR

The mixture that takes place inside the reactor driven by a stirrer that in turn receives the energy of a shaft that receives work.

In this section the power required to operate the agitator is calculated.

For the following case the normal agitator, which is 6 blades, is to be used.

CALCULATION OF THE REYNOLDS NUMBER

$$\mathrm{Re} = \frac{nD_i^2\rho}{\mu}$$ [22]

Where:

***n*:** Stirrer revolutions (rps) = 14.3 rps [1]

***D*$_i$:** Diameter of the stirrer (m)

***ρ*:** Density of the solution (kg/m^3) = 1.193 kg/m^3 [31]

***μ*:** Solution viscosity (kg/m.s)

$$\mathrm{Re} = \frac{(14.3rps)(0.43m)^2\left(1193\frac{Kg}{m^3}\right)}{0.0068\frac{kg}{m.s}} = 463878$$

With what can be observed that the flow is turbulent

Then calculate the power that will be:

$$P = \frac{\varphi\rho n^3 D^5}{g}$$ [38]

Where φ is the power number and we find it by the graph:

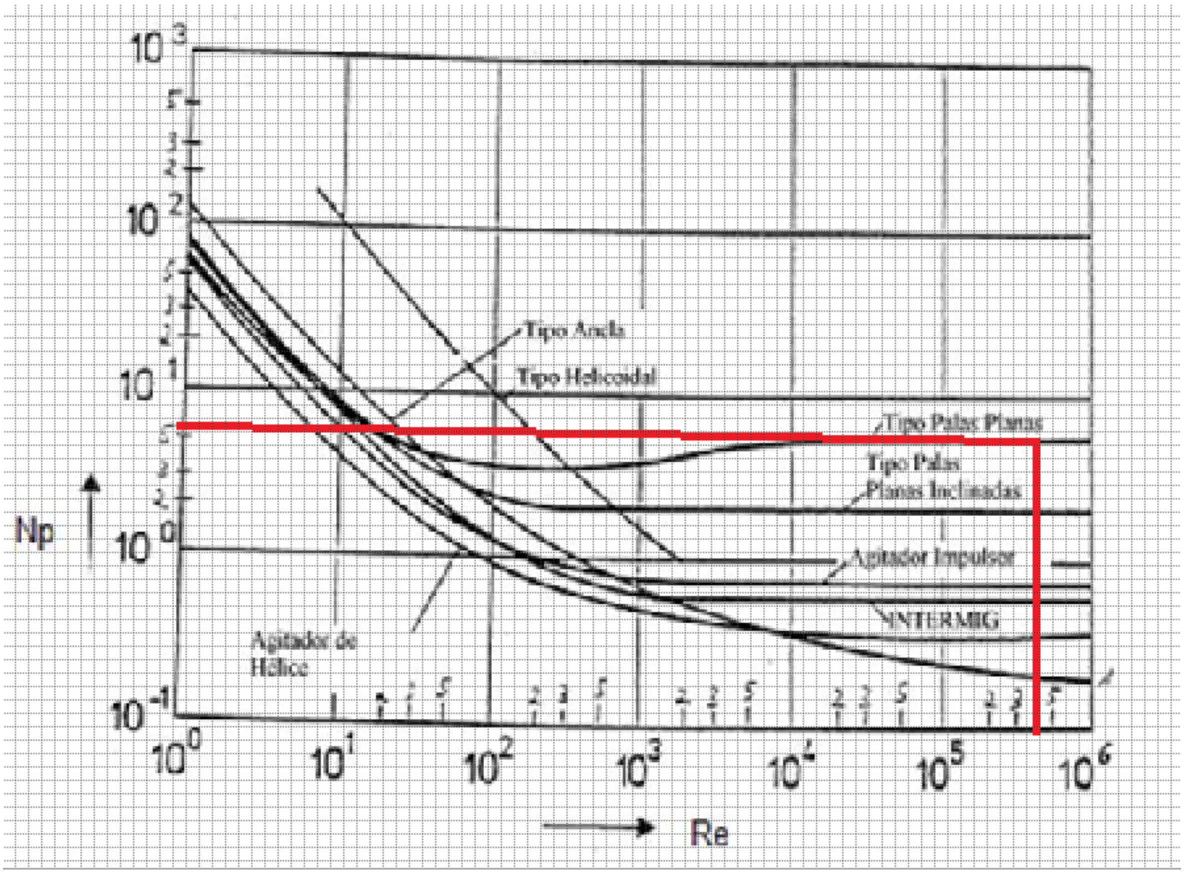


FIGURE 15: NUMBER OF POWER AND NRO OF REYNOLD [32]

Then the power number is determined graphically.

Φ = 5.5

Replacing has:

$$P = \frac{5.5 * \left(1193\frac{Kg}{m^3}\right) * \left(14.3rps\right)^3 * \left(0.43m\right)^5}{9.81\frac{m}{s^2}} = 28753\frac{Kg * m}{s} = 281.77kW$$

Also: 1kJ = 1kW*s

$$P = 281.77\frac{kJ}{s} = 1014372\frac{kJ}{h} = 281.77kW$$

E.2. BLOWER ENERGY BALANCE 1

To calculate the energy required for the blower to bring the H2S gaseous stream through the bottom of the reactor, the pressure in the lower part of the reactor needs to be overcome. Therefore a calculation of the pressure in the lower part of the reactor will be carried out.

Height of liquid = 4.22 m

Calculation of the density of the liquid

$$\frac{m}{vol}=\frac{8571Kg}{6.881m3}=1245.60\frac{Kg}{m^3}$$

Pressure P is:

$$P=\rho gh=1245.60\frac{Kg}{m^3}*9.8\frac{m}{s^2}*4.22m=51488.2Pa$$

P_{gas} = 1atm = 101325 Pa

Total pressure = 101325 + 51488.2 = 152813.2 Pa

Then the blower must have a pressure of 152813.2 Pa.

The work of the blower can be calculated by the following formula:

$$-W_s=\frac{\gamma}{\gamma-1}.\frac{RT}{M}\left[\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}-1\right] \text{[33]}$$

WHERE:

W s= Blower work

γ = Cp / Cv ratio

M= Molar mass of gas (H_2S)

P1 y P2 = inlet and outlet pressures respectively.

R= Universal constant of ideal gases.

T= Temperature at which it is used, in this case at 25 ° C.

$$-W_s=\frac{1.3}{1.3-1}.\frac{8.3143\frac{J}{mol.K}*298\text{K}}{34\frac{g}{mol}}\left[\left(\frac{152813.2}{101325}\right)^{\frac{1.3-1}{1.3}}-1\right]$$

$$-W_s = 31.40\frac{J}{g} = 31.40\frac{kJ}{Kg}$$

Total blower work is 31.40kJ/Kg

$$W = 31.40\frac{kJ}{Kg} * 2023\frac{Kg}{h} = 63522.2\frac{kJ}{h} = 17.64kW = 23.65HP$$

E.3. BLOWER ENERGY BALANCE 2

Pressure P is:

$$P = 1080Pa + 101325Pa = 104925Pa$$

The work of the blower can be calculated by the following formula:

$$-W_s = \frac{\gamma}{\gamma - 1}\cdot\frac{RT}{M}\left[\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]$$

WHERE:

W s= Blower work

γ = Cp / Cv ratio

M= Molar mass of gas (H_2S)

P1 y P2 = Inlet and outlet pressures respectively

R= Universal constant of ideal gases

T= Temperature at which it is used, in this case at 25 ° C

$$-W_s = \frac{1.3}{1.3-1}\cdot\frac{8.3143\frac{J}{mol.K} * 298\,\mathrm{K}}{34\frac{g}{mol}}\left[\left(\frac{152813.2}{101325}\right)^{\frac{1.3-1}{1.3}} - 1\right]$$

$$-W_s = 31.40\frac{J}{g} = 31.40\frac{kJ}{Kg}$$

Total blower work is 31.40kJ/Kg

$$W = 31.40\frac{kJ}{Kg} * 229\frac{Kg}{h} = 7190.6\frac{kJ}{h} = 2.00kW = 2.68HP$$

E.4. POWER BALANCE PUMP 1

The largest pressure drop is calculated throughout the entire process to calculate which pressure drop should be due.

To give an idea we proceed to make a scheme of distribution of pipes, exclusively for the pump 1.

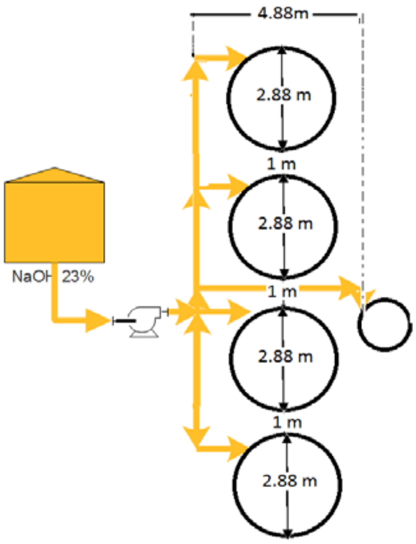


FIGURE 16. NaOH current.

The two inputs of NaOH that is had is the current that enters the absorber and the other one is that enters the reactor.

We calculate the energy that is spent in each pipe to reach the required height.

This requires the physical properties of 23% NaOH for the calculation of expenses by height and friction.

$$\rho_{NaOH\,23\%} = 1.52\, {}^{g}\!/_{ml}$$

$$\mu_{NaOH\,23\%} = 78cPs$$

[26]

Length of pipe 1 + 1 + 2.88 + 1 + 2.88 + 1 + 5 = 14.76 m

We determine the loss of load due to friction in the pipes:

First is the Reynolds number:

$$\mathrm{Re} = \frac{4 * 1.8825\, {}^{Kg}\!/_{s}}{\pi * 0.0254m * 0.78P} = 1209.80$$

So it is seen that it is a laminar fluid.

The friction factor f is 64/Re [**34]**

f=64/1209.80= 0.052

The loss in the largest pipe is now calculated to be 14.76 m.

$$h = f\frac{L}{D}\frac{v^2}{2g} \quad \text{Then} \quad h = 0.052 * \frac{14.76m}{0.0254m} * \frac{2.523\, {}^{m^2}\!/_{s^2}}{2*9.8\, {}^{m}\!/_{s^2}} = 9.81m$$

Also the analysis of the smaller losses:

3 "T" tubes, 3 cubits 90º 1" PVC

$$h = K\frac{v^2}{2g}$$

$$h = h1 + h2 = 3*\left(1.80*\frac{2.523\, {}^{m^2}\!/_{s^2}}{2*9.8\, {}^{m}\!/_{s^2}} + 0.75*\frac{2.523\, {}^{m^2}\!/_{s^2}}{2*9.8\, {}^{m}\!/_{s^2}}\right) = 0.98m$$

Total pressure drop:

$$h_{pérdida} + h_{fluìdo} = 6.45m + 5m + 0.98m = 12.43m$$

$$\Delta P = \rho gh = 1250\frac{kg}{m^3}*9.8\frac{m}{s^2}*12.43m = 151982.5Pa = 1.52bar$$

Calculation of the power of the pump:

$$P_b = \rho gQh = \overset{0}{m}\, gh$$

Where

- Pb is the theoretical power of the pump (W)
- m is the mass flow (kg / s)
- g is the acceleration of gravity (9.81 m / s2)
- hb is the dynamic height of the pump (m)

$$P_b = 1.8825\frac{Kg}{s} * 9.8\frac{\mathrm{m}}{\mathrm{s}^2} * 12.43\,\mathrm{m} = 229.31\,\mathrm{W} = 0.307\,\mathrm{HP}$$

Based on the results obtained for the power of the pump is going to see which model conforms to these specifications.

ANNEX F

EQUIPMENT SELECTION

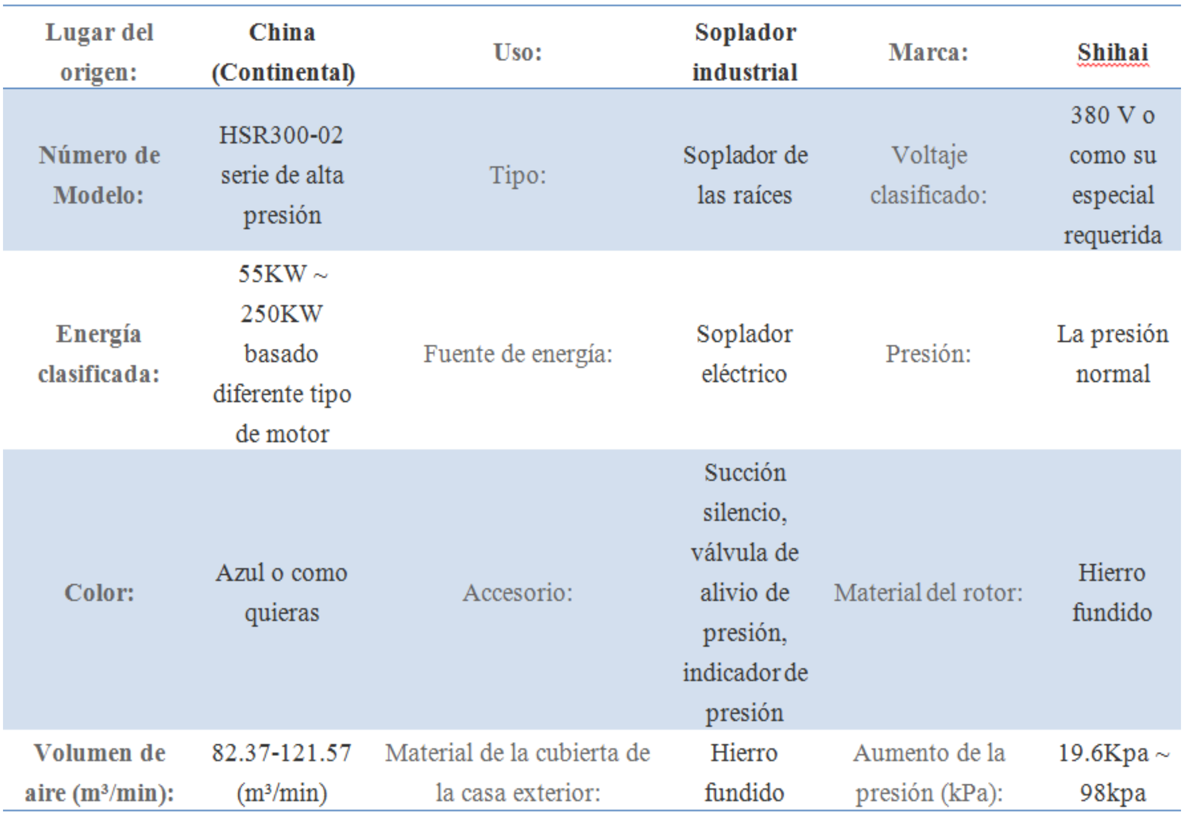
F.1. BLOWER 1

A blower having a power greater than 30 HP and having a pressure variation greater than 52813.2 Pa is required.
The blower is then selected. [35]

FIGURE 17: HSR 302 BLOWER

F.1.1 TECHNICAL CHARACTERISTICS

TABLA 19. BLOWER CHARACTERISTICS



Lugar del origen:	**China (Continental)**	**Uso:**	**Soplador industrial**	**Marca:**	**Shihai**
Número de Modelo:	HSR300-02 serie de alta presión	Tipo:	Soplador de las raíces	Voltaje clasificado:	380 V o como su especial requerida
Energía clasificada:	55KW ~ 250KW basado diferente tipo de motor	Fuente de energía:	Soplador eléctrico	Presión:	La presión normal
Color:	Azul o como quieras	Accesorio:	Succión silencio, válvula de alivio de presión, indicador de presión	Material del rotor:	Hierro fundido
Volumen de aire (m³/min):	82.37-121.57 (m³/min)	Material de la cubierta de la casa exterior:	Hierro fundido	Aumento de la presión (kPa):	19.6Kpa ~ 98kpa

土海贸易 SHIHAI TRADING

Respect for the wise:
Be tolerant to diversity

ZHANGQIU SHIHAI TRADING CO., LTD
章丘士海贸易有限公司 09/10

Part 1. SH-HSR SeriesTrefoil roots Blower

Product features

Product series

SH-HSR40 type Trefoil roots Blower	Flow rate 0.33m^3/min-1.04m^3/min	Boost pressure 9.8kPa-49.0kPa
SH-HSR50C type Trefoil roots Blower	Flow rate 0.57m^3/min-2.01m^3/min	Boost pressure 9.8kPa-49.0kPa
SH-HSR50 type Trefoil roots Blower	Flow rate 0.45m^3/min-2.43m^3/min	Boost pressure 9.8kPa-78.4kPa
SH-HSR65 type Trefoil roots Blower	Flow rate 0.76m^3/min-3.30m^3/min	Boost pressure 9.8kPa-78.4kPa
SH-HSR80 type Trefoil roots Blower	Flow rate 2.07m^3/min-5.23m^3/min	Boost pressure 9.8kPa-78.4kPa
SH-HSR100 type Trefoil roots Blower	Flow rate 2.94m^3/min-9.08m^3/min	Boost pressure 9.8kPa-78.4kPa
SH-HSR125 type Trefoil roots Blower	Flow rate 4.93m^3/min-12.35m^3/min	Boost pressure 9.8kPa-78.4kPa
SH-HSR150C type Trefoil roots Blower	Flow rate 9.12m^3/min-18.04m^3/min	Boost pressure 9.8kPa-58.8kPa
SH-HSR150 type Trefoil roots Blower	Flow rate 9.96m^3/min-27.03m^3/min	[illegible]
SH-HSR175 type Trefoil roots Blower	Flow rate 19.65m^3/min-45.75m^3/min	[illegible]
SH-HSR200 type Trefoil roots Blower	Flow rate 26.33m^3/min-[illegible]	[illegible]
SH-HSR250 type Trefoil roots Blower	Flow rate 56.13m^3/min-91.31m^3/min	Boost pressure 9.8kPa-78.4kPa
SH-HSR300C type Trefoil roots Blower	Flow rate 67.01m^3/min-115.96m^3/min	Boost pressure 9.8kPa-78.4kPa
SH-HSR300 type Trefoil roots Blower	Flow rate 80.52m^3/min-133.31m^3/min	Boost pressure 9.8kPa-78.4kPa
SH-HSR350 type Trefoil roots Blower	Flow rate 76.41m^3/min-177.31m^3/min	Boost pressure 9.8kPa-58.8kPa

Performance table Explain

Flow conversion

$Q_s = 1.0733Q_n$

Pressure conversion

SH-HSR Series of ordinary type roots blower performance parameter table

SH-HSR40 type Trefoil roots Blower

revolution (r/min)	boost pressure (kPa)	Flow rate (m^3/min)	Matching motor		Machine Weight (kg)
			Type	Power (kW)	
1000	9.8	0.45	Y80M1-4	0.55	77
	14.7	0.42	Y80M1-4	0.55	
	19.6	0.39	Y80M1-4	0.55	
	24.5	0.36	Y80M1-4	0.55	
	29.4	0.33	Y80M2-4	0.75	78
1250	9.8	0.65	Y80M1-4	0.55	77
	14.7	0.62	Y80M1-4	0.55	
	19.6	0.59	Y80M1-4	0.55	
	24.5	0.56	Y80M2-4	0.75	78
	29.4	0.53	Y80M2-4	0.75	
	34.3	[illegible]	Y90S-4	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	
	44.1	0.46	Y90S-4	1.1	
	49	0.43	Y90S-4	1.1	
1500	9.8	0.84	Y80M1-4	0.55	77
	14.7	0.81	Y80M2-4	0.75	78
	19.6	0.78	Y80M2-4	0.75	
	24.5	0.75	Y80M2-4	0.75	
	29.4	0.72	Y90S-4	1.1	82
	34.3	0.7	Y90S-4	1.1	
	39.2	0.67	Y90S-4	1.1	
	44.1	0.65	Y90L-4	1.5	86
	49	0.62	Y90L-4	1.5	
1750	9.8	1.04	Y80M2-4	0.75	78
	14.7	1.01	Y80M2-4	0.75	
	19.6	0.98	Y90S-4	1.1	82
	24.5	0.95	Y90S-4	1.1	
	29.4	0.92	Y90S-4	1.1	
	34.3	0.9	Y90L-4	1.5	86
	39.2	0.87	Y90L-4	1.5	
	44.1	0.85	Y90L-4	1.5	
	49	0.82	Y90L-4	1.5	

SH-HSR50C type Trefoil roots Blower

revolution (r/min)	boost pressure (kPa)	Flow rate (m^3/min)	Matching motor		Machine Weight (kg)
			Type	Power (kW)	
1000	9.8	0.82	Y80M2-4	0.75	98
	14.7	0.78	Y90S-4	1.1	102
	19.6	0.73	Y90S-4	1.1	
	24.5	0.69	Y90S-4	1.1	
	29.4	0.65	Y90L-4	1.5	106
	34.3	0.61	Y90L-4	1.5	
	39.2	0.57	Y90L-4	1.5	
1250	9.8	1.22	Y90S-4	1.1	102
	14.7	1.18	Y90S-4	1.1	
	19.6	1.13	Y90S-4	1.1	
	24.5	1.09	Y90L-4	1.5	106
	29.4	1.05	Y90L-4	1.5	
	34.3	1.01	Y100L1-4	2.2	113
	39.2	0.97	Y100L1-4	2.2	
	44.1	0.93	Y100L1-4	2.2	
	49	0.89	Y100L1-4	2.2	
1500	9.8	1.61	Y90S-4	1.1	102
	14.7	1.57	Y90L-4	1.5	106
	19.6	1.52	Y90L-4	1.5	
	24.5	1.48	Y90L-4	1.5	
	29.4	1.44	Y100L1-4	2.2	113
	34.3	1.4	Y100L1-4	2.2	
	39.2	1.36	Y100L1-4	2.2	
	44.1	1.32	Y100L2-4	3	118
	49	1.28	Y100L2-4	3	
1750	9.8	2.01	Y90L-4	1.5	106
	14.7	1.97	Y90L-4	1.5	
	19.6	1.92	Y100L1-4	2.2	113
	24.5	1.88	Y100L1-4	2.2	
	29.4	1.84	Y100L1-4	2.2	
	34.3	1.8	Y100L2-4	3	118
	39.2	1.76	Y100L2-4	3	
	44.1	1.72	Y100L2-4	3	
	49	1.68	Y100L2-4	3	

Note: * the speed of Roots blower can also adopt the coupling drive

F.1.2 CRITERIA OF ELECTION OF THE BLOWER 1

The injection pressure of the gas to the process must pass the calculated minimum pressure, and this blower fulfills this condition, since the required pressure is 52813.2 kPa. If it does not have an efficiency less than or equal to 80%, it also meets the H2S bubbling target at the bottom of the reactor.

F.2. BLOWER 2 [36]

A blower having a pressure variation greater than 1800 Pa is required.
The blower is then selected. And also it is necessary to overcome the atmospheric pressure at the exit of the tower then you have to have a blower with a pressure greater than 104925 Pa.

FIGURE 18. GHBG 36 3R6 BLOWER

F.3. PUMP 1 [39]

Bomba Centrífuga 0.5HP Karson

SKU: 196987-0

FIGURE 19. KARSON 0.5 HP PUMP

DATA SHEET

ATTRIBUTES	DETAIL
14	Use = To pump clean water and non-corrosive liquids. Increases house pressure, accumulation of water in ponds and irrigation of gardens.
Characteristics	Pump made of cast iron, medium - low noise level.
Brand	Karson
Power	0.5 HP
Maximum height	30 m
Minimum range	6 m
Maximum Flow	115 L/m
Engine speed	3450 rpm
Connection type	Monofásico
Suction Diameter	1"
Discharge Diameter	1"
Origin	China

Guarantee	1 year
Recommendations	Install indoors or at least must be protected from the weather, check that the supply voltage matches the voltage of the machine, do not forget to purchase: PVC joint, foot valve, PVC terminal and PVC pipes for the assembly of the bomb.
Type	Centrifugal pumps.

F.4. MEMBRANE [40]

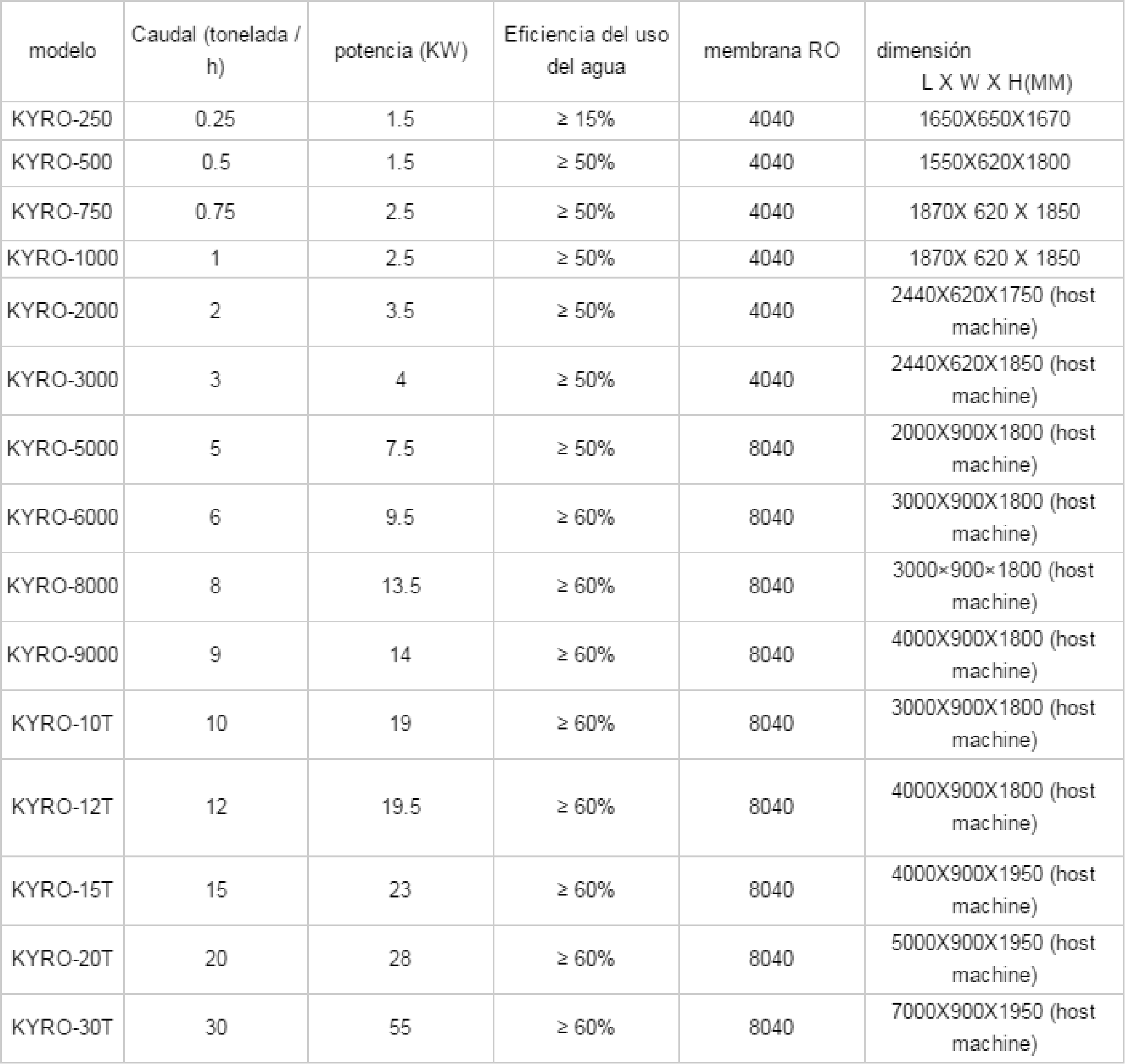
FIGURE 20. Industrial Osmotized Water Purifier

Datos Básicos

Lugar del origen:	China (Continental)	Marca:	Kaiyuan	Número de Modelo:	KYRO-4000 purificador de ag...
tipo:	ósmosis inversa	modelo:	KYRO-4000	capacidad de producción:	4000L/h
bombear:	nacional	esterilizador:	ultravioleta	membrana de ósmosis inversa:	USA DOW
tasa de desalación:	>97%	sistema de pretratamiento:	de fibra de vidrio	uso:	agua potable
garantía:	1 año				

The capacity can be chosen in the following table:

TABLE 20. Capacities



modelo	Caudal (tonelada / h)	potencia (KW)	Eficiencia del uso del agua	membrana RO	dimensión L X W X H(MM)
KYRO-250	0.25	1.5	≥ 15%	4040	1650X650X1670
KYRO-500	0.5	1.5	≥ 50%	4040	1550X620X1800
KYRO-750	0.75	2.5	≥ 50%	4040	1870X 620 X 1850
KYRO-1000	1	2.5	≥ 50%	4040	1870X 620 X 1850
KYRO-2000	2	3.5	≥ 50%	4040	2440X620X1750 (host machine)
KYRO-3000	3	4	≥ 50%	4040	2440X620X1850 (host machine)
KYRO-5000	5	7.5	≥ 50%	8040	2000X900X1800 (host machine)
KYRO-6000	6	9.5	≥ 60%	8040	3000X900X1800 (host machine)
KYRO-8000	8	13.5	≥ 60%	8040	3000×900×1800 (host machine)
KYRO-9000	9	14	≥ 60%	8040	4000X900X1800 (host machine)
KYRO-10T	10	19	≥ 60%	8040	3000X900X1800 (host machine)
KYRO-12T	12	19.5	≥ 60%	8040	4000X900X1800 (host machine)
KYRO-15T	15	23	≥ 60%	8040	4000X900X1950 (host machine)
KYRO-20T	20	28	≥ 60%	8040	5000X900X1950 (host machine)
KYRO-30T	30	55	≥ 60%	8040	7000X900X1950 (host machine)

BIBLIOGRAPHY

[1] Amparo Janeth Camizán Vigo. Study of the treatment of gaseous emissions of hydrogen sulphide at pilot and industrial level.2015 pag 104

[2] http://importstoperu.blogspot.pe/2014/04/25032014-a.html

[3] http://importstoperu.blogspot.pe/2011_05_06_archive.html

[4]https://www.datosperu.org/comercio-exterior-de-diamond-corporacion-sa-20101085351-en-la-partida-28-en-la-operacion-de-importaciones.php

[[5] Amparo Janeth Camizán Vigo. Study of the treatment of gaseous emissions of hydrogen sulphide at pilot and industrial level.2015 pag 117

[6]http://www.insht.es/InshtWeb/Contenidos/Documentacion/FichasTecnicas/FISQ/Ficheros/301a400/nspn0360.pdf

[7]http://www.chemotecnica.com/sgc/files/hoja%20de%20seguridad%20FOLIARACTIV%20BMo.pdf

[8] http://www.fosfoquim.cl/index.php?op=detalle-productos&lang=esp&id=1

[9]http://www.insht.es/InshtWeb/Contenidos/Documentacion/FichasTecnicas/FISQ/Ficheros/1701a1719/icsc1710.PDF

[10] Jean Lui Salazar Cuaila. EVALUATION OF THE ELIMINATION OF CO2 AND H2S BY ENDULZING BIOGAS USING ALCANOLAMINE AQUEOUS SOLUTIONS. UNT Tacna.17.11.2012

[11] http://www.oxiteno.com.br/cms/media/26699/ethanolamine-leather-esp.pdf

[12]http://www.phelectronica.com.ar/imgs/pdf/Influencia%20de%20CO2%20Disuelto.pdf

[13] http://www.ecured.cu/Sulfuro_de_Hidr%C3%B3geno

[14] http://www.mtstainlesssteel.com/news.php?nid=33

[15] Principles of unitary operations. Edition 13. Publisher Company Editorial Continental, 1980 No. of pages 704 pages

[16] http://www.jmcampbell.com/tip-of-the-month/spanish/?p=1487

[17] Bothamley, M., “Gas-Liquid Separators – Quantifying Separation Performance Part 2,” SPE Oil and Gas Facilities, pp. 35 – 47, Oct. 2013

[18] Campbell, J.M., Gas Conditioning and Processing, Volume 2: The Equipment Modules, 9th Edition, 2nd Printing, Editors Hubbard, R. and Snow–McGregor, K., Campbell Petroleum Series, Norman, Oklahoma, 2014.

[19] http://www.quimica.unam.mx/IMG/pdf/2hsnaoh.pdf

[20]http://www.insht.es/InshtWeb/Contenidos/Documentacion/FichasTecnicas/FISQ/Ficheros/1701a1719/icsc1710.PDF

[21] http://www.formulacionquimica.com/H2S/

[[22] Mccabe Warren L., Smith Julian Unit Operations in Chemical Engineering, seventh edition, Mc Graw Hill / Interamericana Editores S.A. De C.V., Mexico, chap. 8, chap. 9.

[23] Ocon García Joaquín, Tojo Barreiro Gabriel, Problems of Chemical Engineering. Basic Operations, Volume II, p. 48-49.

[24] http://www.ecosmep.com/cabecera/upload/fichas/6251.pdf

[25] Robert E. Treybal, Mass Transfer Operations. McGraw-Hill, 1980, issue 2 page 220

[26] http://www.oppac.es/fds/Sodio%20hidroxido%2025.pdf

[27] Peters Max S., Timmerhaus Klaus D., Plant Design, MGH, 1980-1968-1958, p.34-37, cap. 11

[28]http://www.fing.edu.uy/iiq/reactores/cursos/irq1/materiales/SISTEMAS_HETEROGENEOS_2010.pdf

[29] G. Astarita and F. Gioia. Hydrogen sulphide chemical absorption. 1964

[30] Chemical Engineering Processes, ULRICH pag 278

[31]http://www.insht.es/InshtWeb/Contenidos/Documentacion/FichasTecnicas/FISQ/Ficheros/1701a1719/icsc1710.PDF

32] Authors R. K. Sinnott, Gavin Towler Issue 5 Chemical Engineering Design Butterworth-Heinemann / IChemE series Volume 6 of Chemical Engineering, John Metcalfe Coulson.

[33] Thermodynamics. Yunus A. Çengel. Edition 7. McGraw-Hill Interamericana de España S.L., 2012.ISBN 607150743X, 9786071507433. 1040 pages.

[34] Fluid mechanics: fundamentals and applications. Yunus A. Cengel, John M. Cimbala. McGraw-Hill, 2006. ISBN 9701056124, 9789701056127. 992 pages.

[35] https://spanish.alibaba.com/product-gs/three-leaves-roots-air-blower-1531232891.html

[36] http://www.directindustry.es/prod/dongguan-foersheng-intelligent-m-e-co-ltd/product-161746-1762979.html#product-item_1762983

[37] https://www.uclm.es/area/ing_rural/Acero/Textos/EA_Bases_p.pdf

[38] Fluid mechanics. Robert L. Mott. Ed Pearson Education, 2006. ISBN 9702608058, 9789702608059. 626 pages page 245.

[39] https://spanish.alibaba.com/img/4000LPH-purificador-de-agua-osmotizada-industrial-300003911934.html

[40] http://www.sodimac.com.pe/sodimac-pe/product/1969870/Bomba-Centrifuga-0.5HP/1969870

OTHER SOURCES

- http://repositorio.upct.es/bitstream/handle/10317/137/Anexo+6+Calculo+de+recipientes+a+presion.pdf;jsessionid=270C0B9FB4F69AD4A44F2A036B9A007F?sequence=5

- Fluid mechanics. Robert L. Mott. Translated by Javier Enríquez Brito. Ed Pearson Education, 2006 ISBN 9702608058, 9789702608059 No. of pages 626 pages page 24

- White, Frank (2008). Fluid Mechanics (6th edition). McGraw-Hill.

- VEGA Ramos, José Luis. Analysis, design and implementation of a H2S gas recovery system in storage tanks of NASH in a hydrocarbon plant. Monography (Mechanical Engineering of Fluids). Lima, Peru: Universidad Nacional Mayor de San Marcos, 2014.

  Ricardo Armijo, Rodrigo Méndez. Production of Nash from H_2 S of waste.
  Department of Chemical Engineering and Biotechnology
  IQ5306- Reactors II .2014

- https://www.datosperu.org/comercio-exterior-de-diamond-corporacion-sa-20101085351-en-la-partida-28-en-la-operacion-de-importaciones.php

- Design of an absorption tower for the production of NaHS from H2S. David Meneses Vega. 2012.

- TDC, LLC 1916 Farmerville Hwy. Ruston LA 71270.