

FOULING REDUCTION BY USING HOT CAUSTIC CIRCULATION THROUGH PLATE TYPE OR GASKETED TYPE HEAT EXCHANGER

Submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering / Technology degree in B.Tech Chemical Engineering.

By

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DEPARTMENT OF CHEMICAL ENGINEERING

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

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JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119**

October - 2021



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DEPARTMENT OF CHEMICAL ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **LOGESH S(38690007)** and **A MOHAMMED ANSARE(38690008)** who carried out the project entitled **"FOULING REDUCTION BY USING HOT CAUSTIC CIRCULATION THROUGH PLATE HEAT EXCHANGER OR GASKETED TYPE HEAT EXCHANGER "** under our supervision from June 2021 to October 2021.

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We LOGESH S(38690007) and A MOHAMMED ANSARE(38690008) hereby declare that the Project Report entitled “ FOULING REDUCTION BY USING HOT CAUSTIC CIRCULATION THROUGH PLATE HEAT EXCHANGER OR GASKETED TYPE HEAT EXCHANGER ” done by us under the guidance of Dr. J. ARAVIND KUMAR PH.D., at Sathyabama institute of science and technology, Jeppiar nagar, Rajiv Gandhi Salai, Chennai-600 119 is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Chemical Engineering.

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ABSTRACT

Plate and frame or gasket type heat exchanger was fouled by polymer material. Due to fouling, cooling delay and heat transfer will not takes place between cooling water side and product side. So we need to reduce the cooling delay, fouling and production loss. We should do the caustic cleaning in heat exchanger for the reduction of fouling. This is the mitigation for fouling reduction.

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1: INTRODUCTION

The Plate type Heat Exchanger is widely used in all chemical industry in order to exchange the heat energy from one fluid stream to another fluid stream. In the Plate type heat exchanger hot fluid stream is passed in one side and cold fluid passed to the next plate of plate type Heat Exchanger. This plate type Heat Exchanger handle only low and medium viscous fluid. This heat exchanger is easy to handle. In the heat exchanger fouling will occur because of the nature of fluid. This fouling reduce the heat exchange rate of the heat exchanger. Our project is to discuss and give clear objet about the cleaning of Plate type heat exchanger.

1.1: THE ADVANTAGES OF PLATE HEAT EXCHANGERS:

- High heat transfer coefficients
- smaller heat transfer surfaces
- lower fouling due to high fluid turbulences (self-cleaning effect)
- significantly smaller required installation and maintenance space
- less weight
- simplified clean ability especially for GPHE
- lower starting costs
- closer temperature
- counter-flow operation for GPHE

In Figure 1.1. this Plate type Heat Exchanger is comparably much effective in heat transfer, occupied space is less, easy to handle and cleaning also much easy. This type of heat exchanger does not required to do insulation around the heat exchanger. The fouling on the top of the plate will reduce the heat exchange co-efficient. The increase in pressure drop between the inlet to the outlet which indicates the fouling occurred in the plate. This can be removed by manual hydro-blasting in traditional method. This type hydro-blasting may result in personal injuries to the worker and effects the EHS standard of the company. Our project Hot caustic circulation eliminates the manual interaction with the equipment so the worker remain safely handle the plant.

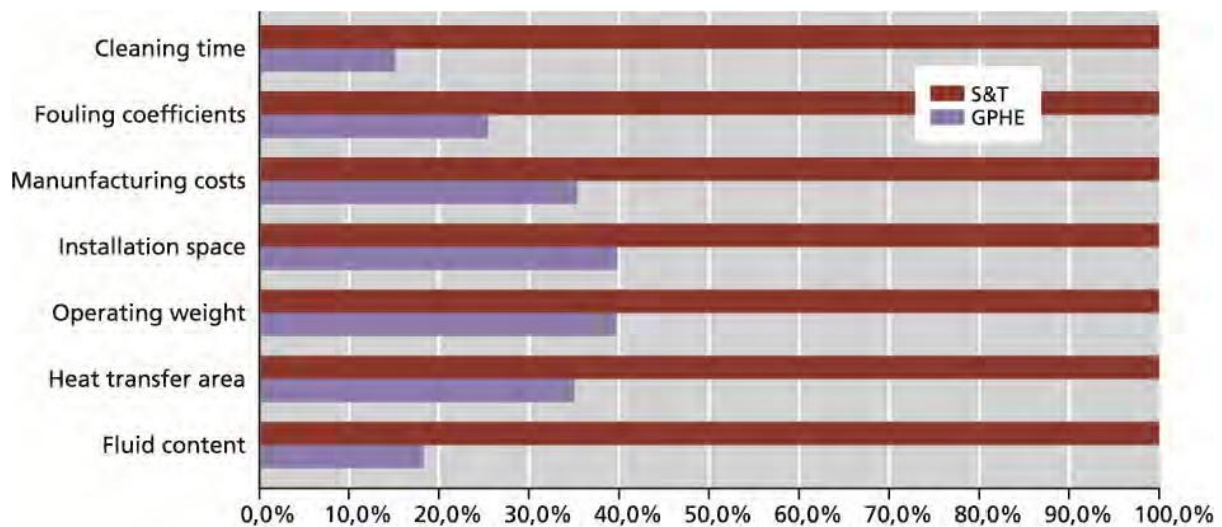


Figure: 1.1 Plate heat exchanger fouling data diagram

This fouling on the surface of plates in the plate type heat exchanger is done on periodic interval to in order to increase the productivity of the plant. When the plant run continuously it reduces the plant expense and increase its income.

The continuous maintenance of the heat exchanger will result to decrease the integrity of the equipment, some accessories may get defected so this cause to failure of the equipment while in running process and it result to injury of worker. Huge investment waste to the company and also its affects the growth of company and less productive.

Advantages of Caustic cleaning:

- To reduce the man-machine interaction.
- Time saving compare to manual cleaning.
- To eliminate the Hydro blasting.
- To eliminate the gasket and accessories change.
- Cost saving and time saving
- To save the water.

Disadvantage of Caustic cleaning:

- Disposal of spent caustic.
- Consumption of steam.
- In a timely manner to do the caustic cleaning.

1.2 DEFINITION OF FOULING:

Fouling is a process of accumulation of substance from the product, which leads to low flow of material stream and cooling substance stream which flow in to the Plate type Heat exchanger. This cost to higher cycle time of product , increase the loss of time, affects asset utilization and many more.

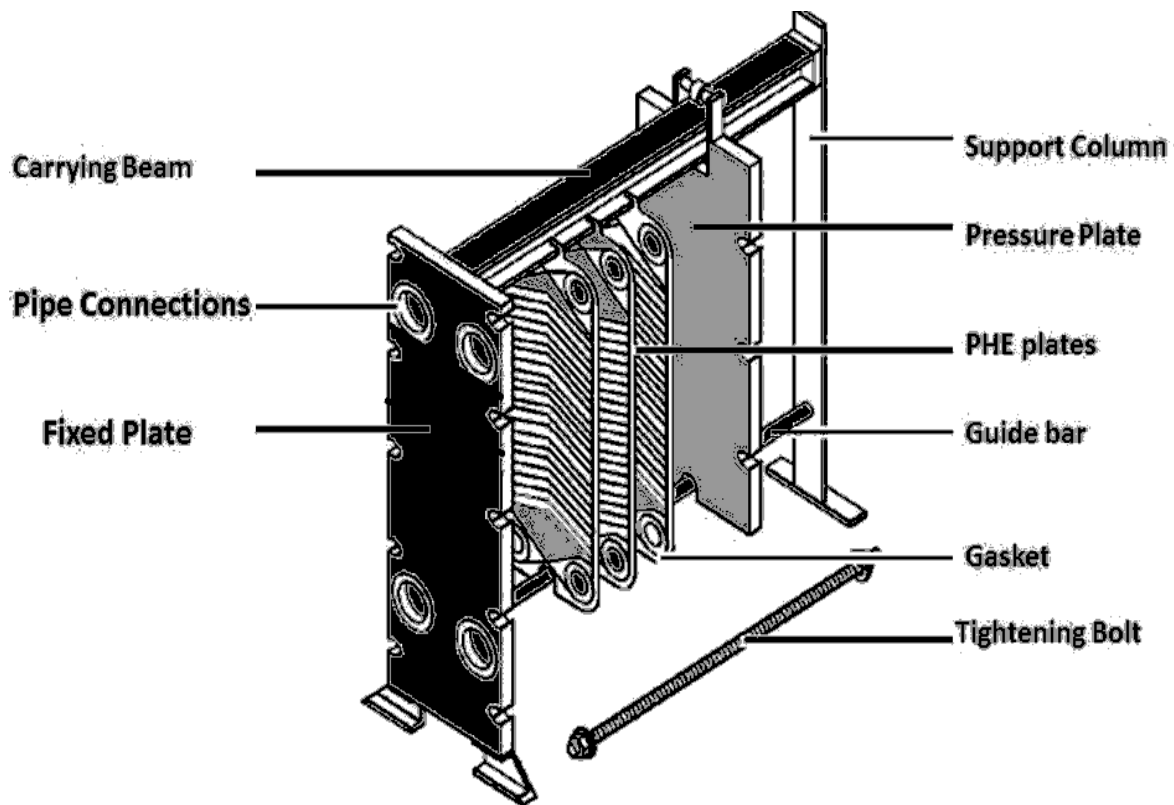


Figure: 1.2 Plate heat exchanger

1.2.1: PHE SPECIFICATIONS:

- | | |
|-------------------------------|----------------------|
| 1. MOC | : SS316L |
| 2. Design pressure | : 10 bar |
| 3. Design temperature | : 180 degree celsius |
| 4. Thickness of plate | : 0.4 mm |
| 5. Maximum Heat transfer area | : 1 meter square |
| 6. Number of plates | : 100 |

1.3 TYPES OF FOULING:

The most regularly happening sorts of fouling and maturing in clean handling fall into four primary sorts:

1.3.1: Incrustation: the aggregation of a hull or covering of handled liquids, minerals, or cleaning specialists on the outer layer of hotness exchanger parts.

1.3.2: Scaling: a sort of incrustation brought about by calcium carbonate, calcium sulfate, and silicates.

1.3.3: Sediment: Comes from consumption items, metal oxides, residue, alumina, and diatomic organic entities (microalgae) and their stool.

1.3.4: Biological growth: Sources of bio fouling incorporate microorganisms, nematodes, and protozoa.

1.4 COMMON TYPES OF FOULING:

1.4.1: CRYSTALLIZATION:

The testimony or development of gems on a surface, in some cases alluded to as scaling, is frequently connected with fluid frameworks,

Before crystallization start, it is important to have states of super immersion, i.e., broke down strong focuses over the immersion dissolvability at a specific temperature. The super immersion gives the "main thrust" for precipitation to happen. As a rule, the level of super immersion included is tiny; its area will rely particularly upon the temperature circulation inside the hotness of exchanger between the mass liquid and surface's temperatures.

Two solvency's of salts in water are perceived. Ordinary dissolvability (Sodium chloride or Na_2SO_4) show expanded solvency as the arrangement temperature is raised, with the goal that when a soaked arrangement is cooled super immersion can happen followed by precipitant. Fouling from typical dissolvability salts is logical when these arrangements are cooled. Opposite solvency salts (e.g., Calcium carbonate, $\text{Mg}_2(\text{SO}_4)$), then again, have diminished dissolvability when temperature is raised. Therefore, as the temperature of an immersed arrangement builds, super immersion and precipitant will happen. Fouling or scaling because of opposite solvency salts is plausible when arrangements of these salts are warmed. Moreover,

the solvency of opposite dissolvability salts overall is very low, so that somewhat little temperature changes are probably going to cause fouling issues. The issue is exceptionally predominant in cooling water frameworks because of the alleged hardness salts typically present in the water. There are two contributory variables:

1. As the cooling system happens the temperature of the water rises. On the off chance that the water is now soaked even a little temperature rise prompts precipitation.

2. In cooling water frameworks, the strategy used to eliminate undesirable hotness is to vanish a portion of the water in a cooling pinnacle or splash lake. The deficiency of water fume thinks the disintegrated salts so immersion is before long accomplished with the ensuing expanded chance of precipitation of sparingly dissolvable salts. To balance this fixation impact, a portion of the soaked water is eliminated in the alleged "blow down" release, to be supplanted with new "make up" water.

The scale created on heat exchanger surfaces because of crystallization from water is frequently constant and hard to eliminate, albeit in certain examples, it is delicate, looking like a slop that is all the more effortlessly eliminated from the surface. The state of the store especially relies upon the conditions, especially of temperatures that win near the strong surfaces. The shade of scale relies especially upon the framework in question. In cleaner frames, the shading is close to white, however shading can be conferred to the scale from follow compounds in the framework, e.g., oxides of iron that might give dark (magnetite) or red (haematite) colors.

1.4.2: PARTICLE DEPOSITION:

Molecule collection on heat exchanger surfaces is a typical fouling wonder. A wide scope of molecule sizes might be engaged with the testimony interaction. The beginning of the particles fluctuates. In certain occasions (e.g., water and raw petroleum), the particulate matter might be innate in liquid stream.

In ignition frameworks, particulate matter (e.g., the mineral matter in coal) might be delivered as the flammable parts are singed. The mineral particles go ahead with the pipe gasses and are stored on the hotness exchanger surfaces. It is additionally conceivable in ignition frameworks, that, if the burning system isn't sufficiently controlled, inadequate burning happens and particles of unburnt carbon are

conveyed in the gas stream. The high temperatures winning in burning frameworks might imply that some particulate matter is as fluid drops that harden as they are cooled. Agglomeration and compound response of the particles with vaporous parts in the pipe gas can add to the intricacy of the fouling system. In some cycle streams, temperature impacts lead to synthetic responses which produce enormous particles (e.g., polymers) as particulate matter fit for being kept on surfaces.

1.4.3: BIOLOGICAL GROWTH ON SURFACES:

Bio fouling of hotness exchanger surfaces is for the most part falls in two gatherings: full scale fouling and miniature fouling. As a rule, watery conditions are involved, for example, may be found in a cooling water framework. Water begins from a characteristic source like a stream or the ocean. For the most part large scale fouling is related with living animals like mussels and barnacles. It is likewise feasible for vegetation, for example, ocean weed to become joined and develop on surfaces. Full scale fouling is regularly capable—albeit not solely—in the utilization of ocean water. Miniature fouling is the consequence of the connection and development of microorganisms on surfaces. Taking everything into account, the microorganisms included are typically microbes. Different microorganisms that might be found in cooling water frameworks incorporate growths and green growth. Green growth need a wellspring of light. In nature this is daylight; so these organisms are to be found in uncovered districts, for instance, the bowl under a cooling tower. Organisms, then again, might be found on the inward design of a cooling tower. The design of the pinnacle can be harmed and obliterated by parasitic movement.

In spite of the fact that green growth and parasites may not develop on heat exchanger surfaces, they might in any case be the wellspring of stores on the hotness move surfaces. With the progression of time, either living or dead green growth or organisms might become withdrawn upstream of the hotness exchanger just to store in the downstream hardware. Under the conditions, this natural material might give a reasonable supplement to supporting bacterial movement. As a rule, the outer layer of hotness exchangers in cooling water frameworks is great for microbial development. The watery medium contains supplements, it is circulated air through because of entry through a cooling pinnacle or splash lake, and the temperature is close to the ideal for most extreme organic movement, i.e., in the reach 20-50°C. The ozone layer related with fouling from microorganisms is described by a thick,

hydrated material regularly almost straightforward, yet more normally shaded by microorganisms, or by different impurities in the water (e.g., oxides or hydroxides of iron). One more typical element of bio films is that they are lopsided and deformable under the activity of the water stream. Under specific conditions filamentous designs develop out from the surface and are allowed to waver inside the streaming water. Bio films are famously hard to eliminate from surfaces, yet on the off chance that they precipitously bog off the surface as do occur during activity, the pieces of bio film can cause blockages downstream. Exceptionally thick bio films with genuine ramifications for heat move and tension drop are conceivable under great conditions.

The presence of a bio film on a metal surface might advance consumption. The neighborhood conditions under the bio film are probably going to be not the same as those in the mass stream, this is especially relevant to the pH. The movement of the living material is probably going to bring down the nearby pH that could start erosion. Moreover, under a biofilm, because of the limitations on entrance of mass liquid, galvanic cells might be set up that upgrades, maybe just locally, the pace of erosion.

1.4.4: CHEMICAL REACTION FOULING:

The gathering of stores might happen as the aftereffect of compound responses at or almost a hotness exchanger surface. Since compound responses are generally improved by raised temperatures, substance response fouling might be capable where a receptive liquid is being warmed. Under these conditions, the sluggish layers of liquid close to the hotness move surface are likely to generally high temperatures.

Fouling because of the occurrence of substance responses can happen in a wide scope of interaction streams and over a wide scope of temperature, i.e., from close surrounding to temperatures related with burning conditions.

Cycles where substance response is liable for store arrangement, incorporate food handling (e.g., the purification of milk), oil refining (e.g., preheating unrefined petroleum before essential refining), and synthetic assembling that includes polymerization responses. Indeed, even in ignition, the contaminations contained in the first fuel (e.g., coal or burnable waste) may bring about substance responses related to corrosive gases, for example, SO₂ and SO₃ contained in the pipe gases. Fragmented burning might prompt the age of ash particles that store on heat move

surfaces. Free revolutionaries might be liable for chain responses in natural fluids that eventually lead to store arrangement. These instances of compound response exhibit the wide scope of substances that might be viewed as being stores from synthetic responses. Subsequently, the stores might be delicate and friable or hard and hard to eliminate contingent upon the compound responses included and the conditions.

2: AIM & SCOPE

2.1: AIM:

To eliminate the manual hydro blasting of Plate type Heat Exchanger,
Increase the efficiency of Heat Exchanger.

2.2: SCOPE:

- To improve the productivity.
- To increase the cooling efficiency.
- To increase the batch cycles.
- To decrease the cooling delay.
- To decrease the Man-Machine interaction.

3: EXPERIMENTAL METHODOLOGY

Plate type Heat Exchangers are utilized in the compound business to trade the hotness starting with one liquid then onto the next liquid. The constant utilization of the Heat Exchanger brings about low proficient in heat move between the hot and cold liquid. This low effectiveness is recognized by heat move rate become low. The liquid stream inside the framework becomes decreased. Tension measure mounted of gulf and outlet of the hotness exchanger shows a lot of differential strain. Clump process duration goes high. The above said issues will happen simultaneously. To amending the fouling inside the Heat Exchanger can done by manual hydro impacting and compound cleaning.

3.1: MEASURING PARAMETERS & EQUIPMENTS:

3.1.1: Heat move:

Due to the protecting properties of fouling, heat move can fall outside of working particulars.

3.1.2: Pressure drop:

Tension drop increments between heat exchanger gulf and outlet might show frictional obstruction or hindered stream ways brought about by fouling stores. Checking are the most ideal way of investigating and identify fouling in heat exchangers. Equipments are measure and report basic factors that can demonstrate heat exchanger scaling.

3.1.3: Temperature transmitters:

Screen the temperature of liquids going through heat exchangers. Temperature drops might show loss of hotness move brought about by fouling.

3.1.4: Pressure transmitters:

Identify pressure drops between heat exchanger delta and outlet.

3.1.5: Flow meters:

Demonstrate diminishes that might be brought about by develop of fouling material in lines and plates.

3.2: METHODS OF CLEANING:

3.2.1: Manual cleaning strategy:

Its set aside significantly more effort to cleaning nearly mechanized cleaning strategy. The cleaning is finished by hydro impacting.

3.2.2: Hot caustic cleaning method (fully automated):

This is mechanized cleaning technique its take less time relatively manual cleaning.

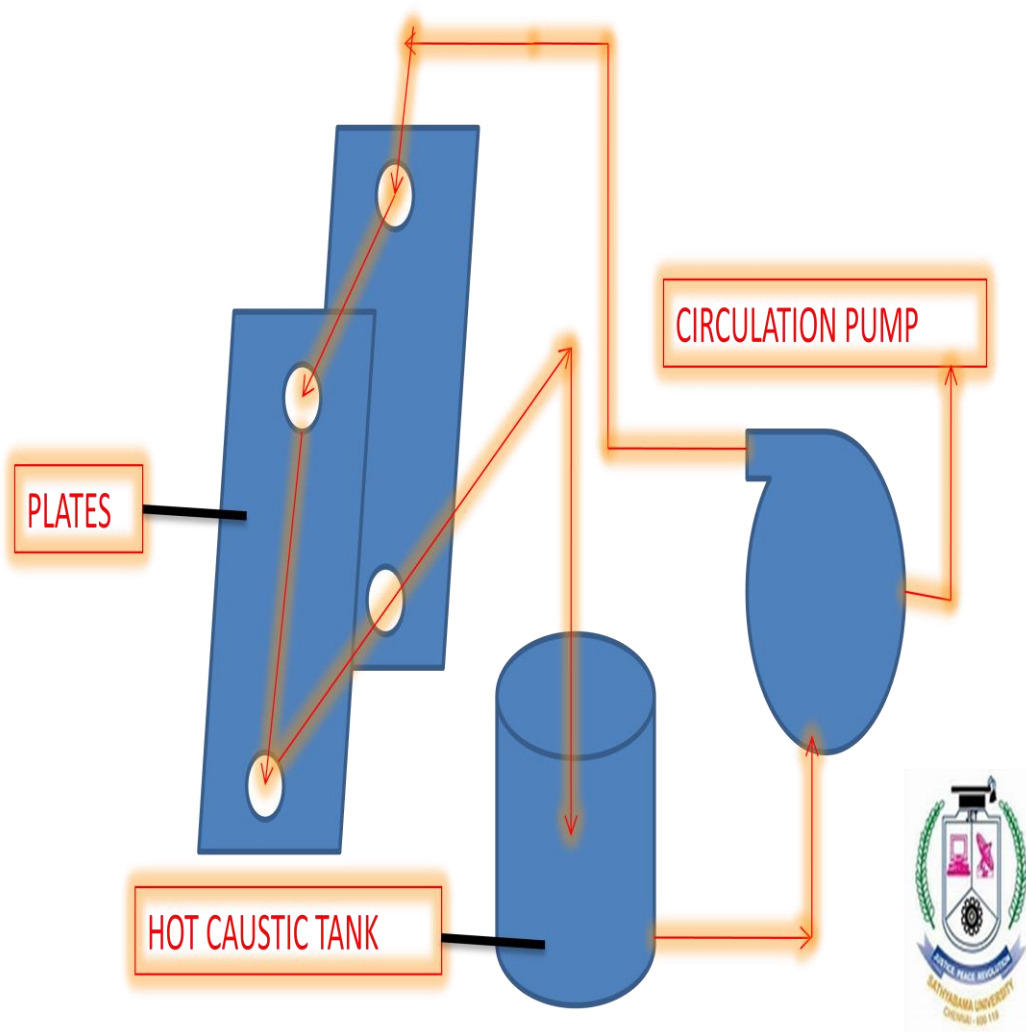


Figure 3.2 Hot Caustic Cleaning Process Flow Diagram

Table 3.2.2.1: Hot caustic cleaning Trial-1:

Flow rate	200 M3/HR
Temperature range	50-60 C
Strength	0-15%
Duration	24 HOURS
Pressure drop	2.9 BAR

Time (hour)	Inlet pressure (bar)	Outlet pressure (bar)	Differential pressure (bar)
00:00	8	1.6	6.4
03:00	7.2	1.2	6
06:00	6.6	1	5.6
09:00	5.8	0.9	4.9
12:00	5.2	0.7	4.5
15:00	4.9	0.6	4
18:00	3.7	0.5	3.2
21:00	3.6	0.5	3.1
24:00	3.3	0.4	2.9

Table 3.2.2.2: Hot caustic cleaning Trial-2:

Flow rate	300 M3/HR
Temperature range	60-70 C
Strength	15-25%
Duration	24 HOURS
Pressure drop	1.8 BAR

Time (hour)	Inlet pressure (bar)	Outlet pressure(bar)	Differential pressure (bar)
00:00	7	1.2	5.8
03:00	6.2	1	5.2
06:00	5.9	0.8	4.1
09:00	4.6	0.8	3.6
12:00	3.4	0.6	2.8
15:00	2.9	0.5	2.4
18:00	2.7	0.5	2.2
21:00	2.2	0.4	1.8
24:00	2.2	0.4	1.8

Table 3.2.2.3: Hot caustic cleaning Trial-3:

Flow rate	350 M3/HR
Temperature range	60-70 C
Strength	15-25%
Duration	24 HOURS
Pressure drop	1.5 BAR

Time (hour)	Inlet pressure (bar)	Outlet pressure(bar)	Differential pressure (bar)
00:00	7	1.2	5.8
03:00	6.2	1	5.2
06:00	5.9	0.8	4.1
09:00	4.6	0.8	3.6
12:00	3.4	0.6	2.8
15:00	2.9	0.5	2.4
18:00	2.7	0.5	2.2
21:00	2.2	0.7	1.5
24:00	2.2	0.7	1.5

Table 3.2.2.4: Hot caustic cleaning Trial-4:

Flow rate	400 M3/HR
Temperature range	70-85 C
Strength	25-40%
Duration	24 HOURS
Pressure drop	0.8 BAR

Time (hour)	Inlet pressure (bar)	Outlet pressure(bar)	Differential pressure (bar)
03:00	8.4	2.8	5.6
06:00	6.8	2.3	4.5
09:00	5.3	1.4	3.9
12:00	4.1	1.1	3
15:00	3.2	0.8	2.4
18:00	2.3	0.7	1.6
21:00	1.9	0.7	1.2
24:00	1.6	0.4	0.8

3.2.2.4 : ENERGY BALANCE FOR HEAT EXCHANGER:

$$m_h C_{ph} (T_{h1} - T_{h2}) = m_c C_{pc} (T_{c2} - T_{c1})$$

m_{h1} = mass flow rate of hot fluid

m_c = mass flow rate of cold fluid

T_{h1} = Inlet temperature of hot fluid

C_{ph} = Specific heat of hot fluid (2.06 J/Kg C)

C_{pc} = Specific heat of cold fluid (4.187 J/Kg C)

T_{h2} = Outlet temp of hot fluid (70°C)

T_{c2} = Outlet temp of cold fluid (50°C)

T_{c1} = Inlet temp of cold fluid (36°C)

$$500 \times 2.06(100-70) = 530 \times 4.187(50-36)$$

30900	31067.54
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3.3: HOT CAUSTIC CLEANING STARTUP PROCEDURE:

1. Ensure the strength and solids of caustic solution are within the range. If not within the range adjust the solution.
2. Heat the caustic solution up to 70-85 degree Celsius.
3. Ensure the remaining valves are closed except the caustic valves.
4. Ensure plate heat exchanger cooling water inlet and outlet is closed.
5. Once the temperature is reached start the caustic cleaning.
6. Proceed up to 24 hours and note the pressure every three hours.
7. Stop the caustic cleaning pressure drop reached less than 0.8 and proceed to pump out and neutralisation.
8. After stop the caustic cleaning pump out caustic solution to storage tank.

3.4: NEUTRALISATION PROCESS AFTER HOT CAUSTIC CLEANING:

After the hot caustic cleaning, the hot caustic material pumps out to the storage tank. Start the neutralisation process, we are using acetic acid is the neutralising agent.

pH - 8 to 9

3.4.1: Neutralisation after hot caustic cleaning Trial-1:

Charge 5 kg of acetic acid 100 kg of water charged through the PHE and circulate 1 hour, after take the sample check the PH.

pH - 11.8

3.4.2: Neutralisation after hot caustic cleaning Trial-2:

Charge 7 kg of acetic acid and 100 kg of Water charged and circulate 1 hour through PHE. Take the sample check the PH.

pH - 9.4

3.4.3: Neutralisation after hot caustic cleaning Trial-3:

Charge 10 kg of acetic acid and 100 kg of Water charged and circulate 1 hour through PHE. Take the sample check the PH.

pH - 9

3.4.4: Neutralisation after hot caustic cleaning Trial-4:

Charge 10 kg of acetic acid and 100 kg of Water charged and circulate 1 hour through PHE. Take the sample check the PH.

pH - 8.9

3.4.5: Neutralisation after hot caustic cleaning Trial-5:

Charge 10 kg of acetic acid and 100 kg of Water charged and circulate 1 hour through PHE. Take the sample check the PH.

pH - 8.6

3.5: WATER SIDE FOULING REDUCTION:

The water side fouling reduction is done by chemical cleaning by the help of external pump circulation through heat exchanger for 4 hours. There are different types of cleaning methods available. But we are using sodium hypochlorite cleaning method.

3.6: SODIUM HYPOCHLORITE CLEANING PROCESS FLOW DIAGRAM FOR WATER SIDE:

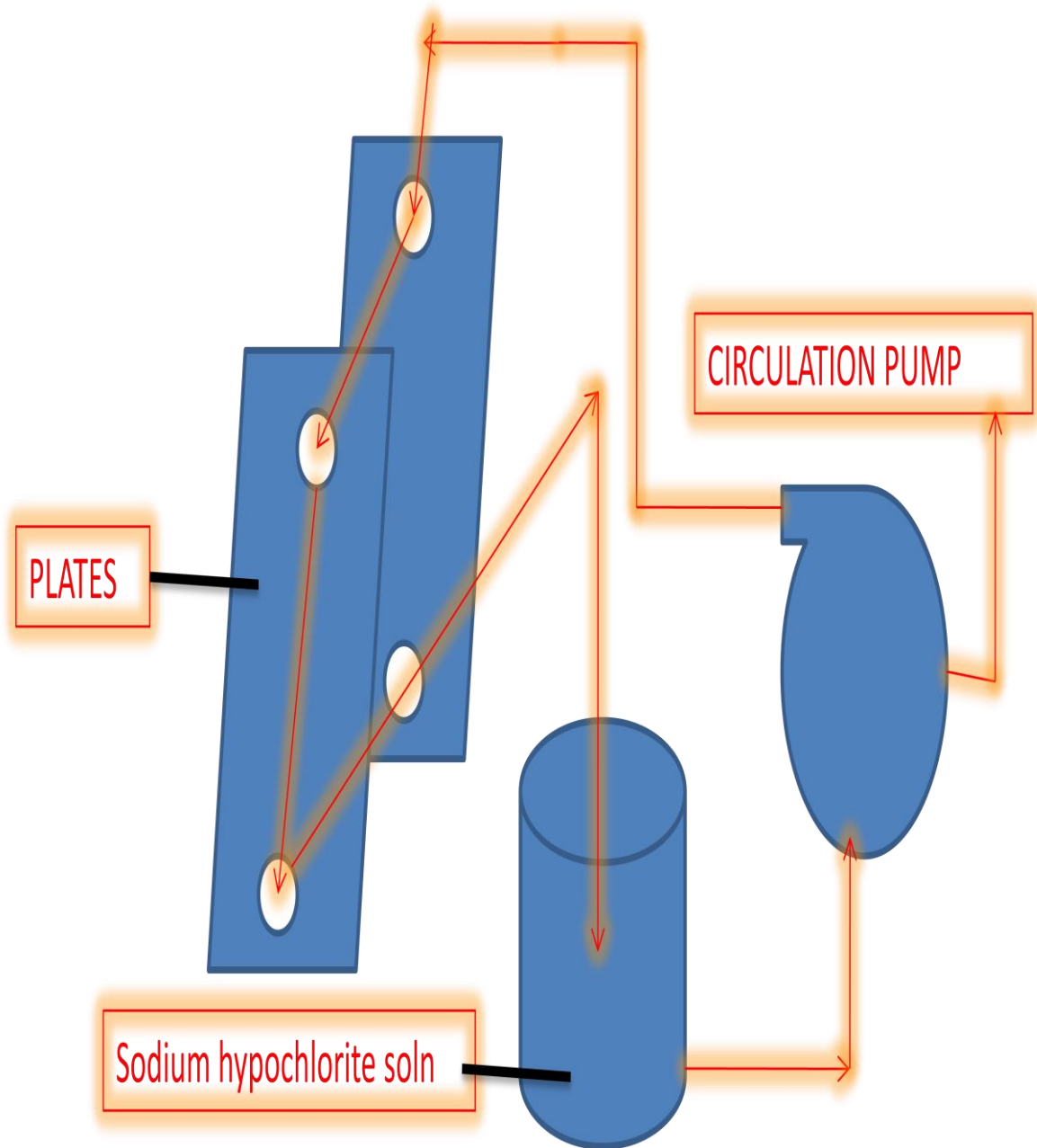


Figure 3.6

Table 3.6.1: Sodium hypochlorite cleaning process Trial-1

pH = 6.5 -7.5
 Temperature = 45 - 50 C
 Duration = 4 HOURS

S.NO	Timing(HOUR)	Temperature(°C)	pH
1.	1	50	7.52
2.	2	48	7.14
3.	3	45.3	6.87
4.	4	44.8	6.61

Table 3.6.2: Sodium hypochlorite cleaning process Trial-2

pH = 5.5 - 6.5
 Temperature = 60 - 65 C
 Duration = 4 hours

S.NO	Timing(HOUR)	Temperature(°C)	pH
1.	1	65	6.47
2.	2	62.9	6.21
3.	3	62	5.83
4.	4	59.2	5.74

Table 3.6.3: Sodium hypochlorite cleaning process Trial-3

pH = 4.5 -5.5 (below 3.5 lead to corrosion)
 Temperature = 70 -75 C
 Duration = 4 hours

S.NO	Timing(hour)	Temperature(°C)	pH
1.	1	75	5.56
2.	2	73.2	5.32
3.	3	72	4.73
4.	4	70.4	4.49

3.7: NETURALISATION PROCESS AFTER SODIUM HYPOCHLORITE CLEANING:

After sodium hypochlorite cleaning neutralization done with sodium bicarbonate and hot water circulation.

3.7.1: Neutralising with sodium bicarbonate and hot water Trial-1

pH adjustment = 7-9 (if not within spec do again neutralisation)

Duration = 1 hour

3.7.2: Neutralisation after sodium hypochlorite cleaning Trial-2

pH Adjustment = 5.4 (If not within spec do again neutralisation)

Duration = 1 hour

3.7.3: Neutralisation after sodium hypochlorite cleaning Trial-3

pH adjustment = 6.8 (If not within spec do again neutralisation)

Duration = 1.30 hour

3.7.3: Neutralisation after sodium hypochlorite cleaning Trial-4

pH adjustment = 7.3 (If not within spec do again neutralisation)

Duration = 1.30 hour

3.7.4: Neutralisation after sodium hypochlorite cleaning Trial-5

pH adjustment = 7.8 (If not within spec do again neutralisation)

Duration = 1.30 hour

3.7.5: Neutralisation after sodium hypochlorite cleaning Trial-6

pH adjustment = 8.1

Duration = 1.30 hour

4: HEAT EXCHANER RESULT AND DISCUSSION

4.1: PHE PLATES BEFORE HOT CAUSTIC CLEANING:

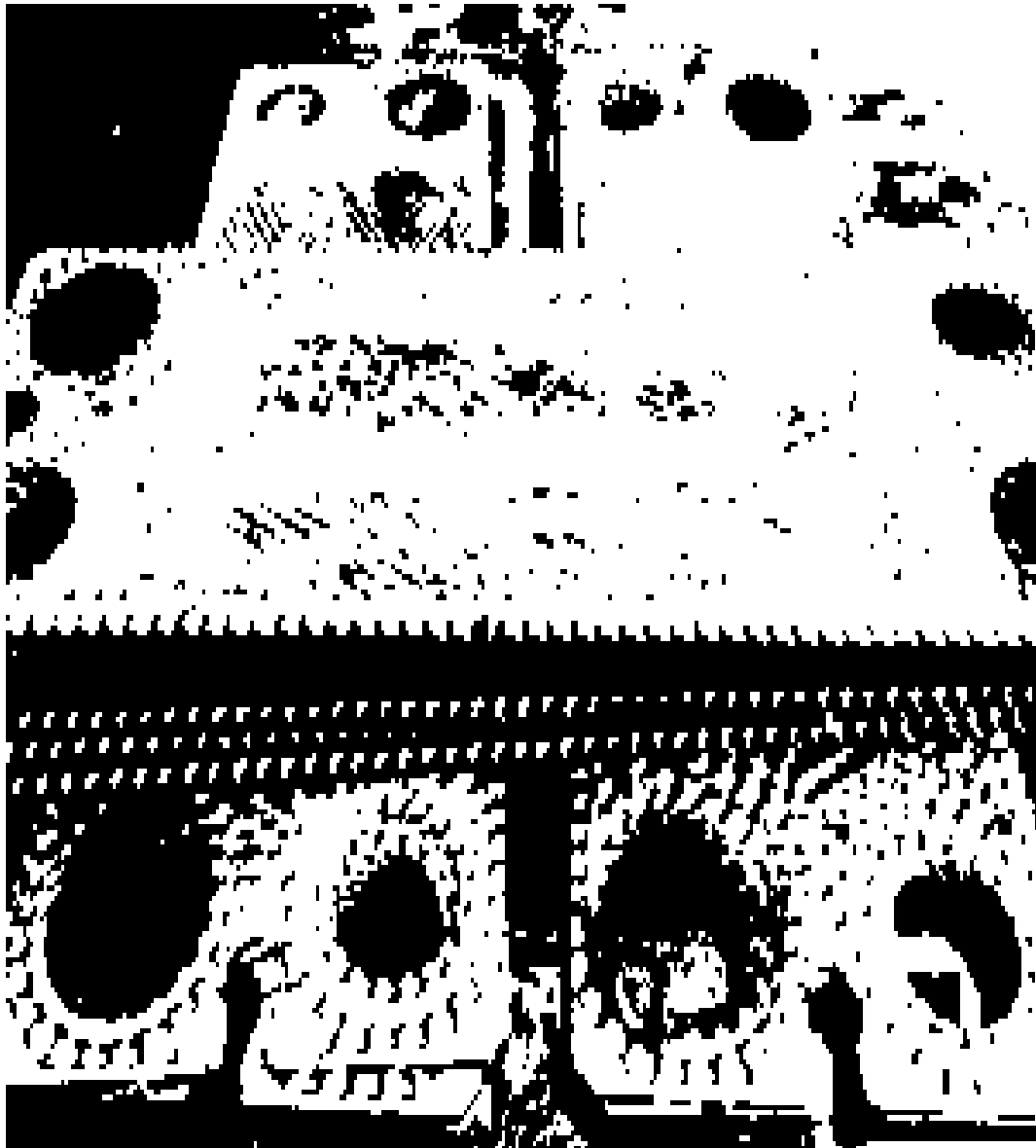


Figure: 4.1 PHE plates before hot caustic cleaning.

4.2: PHE PLATES AFTER HOT CAUSTIC CLEANING:



Figure: 4.2 PHE plates after hot caustic cleaning

4.3: PHE PLATES BEFORE SODIUM HYPOCHLORITE CLEANING:

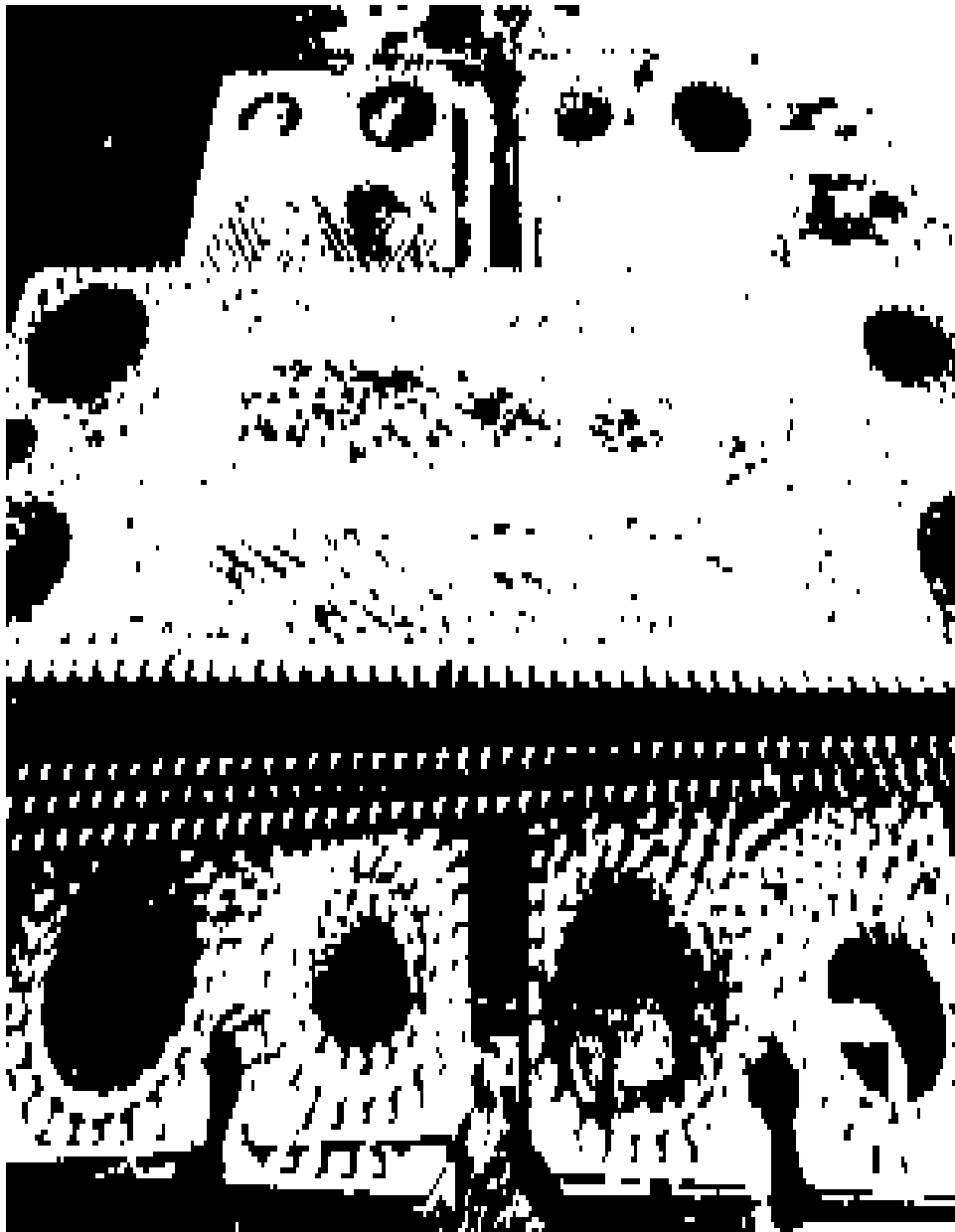


Figure: 4.3 PHE plates before sodium hypochlorite cleaning

4.4: PHE PLATES AFTER SODIUM HYPOCHLORITE CLEANING



Figure: 4.4 PHE plates after sodium hypochlorite cleaning

4.5: KEY PROCESSING FACTORS:

4.5.1: Fluid speed:

By and large, fouling diminishes at higher liquid speeds in light of the fact that expanding stream speed builds the liquid shear pressure, which causes more evacuation of stores. For more considerable stores, expanding the stream speed past a specific point may not diminish fouling altogether. On account of extremely amazing stores, expanding stream speed might not have any impact.

4.6: FOULING MECHANISMS:

The fundamental component engaged with the gathering of stores on surfaces of hotness exchangers may by and large be considered to include three phases:

1. The foulant or the specialists or contaminations (e.g., microbes, strong particles or destructive specialists) that lead to store arrangement, approach the surface from the mass through the gooey sub layer adjoining the hotness exchanger surface, across which the liquid is streaming. The standards of mass exchange apply.
2. At the surface, attachment can occur including various components including the collaboration of surface powers, compound responses and underlying direction.
3. Once kept on a superficial level, the material might be liable to powers that minimal or debilitate the store. The nature of the store is probably going to be time subordinate.

These three phases will be impacted by various framework boundaries, yet mainly these are related with liquid stream, hotness and mass exchange. As an outcome, the cycle whereby a surface becomes fouled and the store kept up with, is intricate coming about because of the collaboration of various variables. In spite of the fact that it is very uncommon for a solitary component to apply, it is helpful to analyze independently the instruments momentarily referenced before to have an enthusiasm for the impacts of the framework factors included.

4.7: THE IMPACT OF FOULING:

Fouling lessens the measure of hotness trade that can happen. This decreased hotness trade prompts a large group of different issues, including diminished

effectiveness, reduced item quality, neighborhood problem areas, gear breakdowns, wellbeing concerns and expanded recurrence of support and fixes.

Fouling likewise causes issues with water stream. Since fouling will in general be a lot more unpleasant than the smooth surfaces of lines and metal parts, it frequently obstructs the development of water. Hindered water stream can cause failures and tension drops and reduce the hotness exchanger's presentation in general.

One of the super business results of fouling is drastically expanded upkeep costs. Since develop on your hotness exchanger's surfaces will in general speed up the pace of corruption, the hotness exchanger will probably require more incessant cleanings and more broad and expensive fixes.

Fouling can likewise expand costs by making your hotness exchanger less proficient. At the point when your hotness exchanger works less proficiently, it devours significantly more ability to do a similar measure of warming, so you'll probably see an expansion in your service bills if your hotness exchanger becomes fouled.

4.8: THE COST OF FOULING:

Except if the issue of fouling is perceived at the plan stage and satisfactory advances taken to guarantee that the issue is contained, genuine working and support hardships might result that add to the expense of creation. Crisis closure might be vital on the grounds that the hotness exchanger quickly loses heat move effectiveness or more probable, the stream can't be kept up with because of the exorbitant tension drop produced by the presence of the store. A further result of the great constrains important to drive the liquid through the exchanger might be disappointment of joints and pressing's, and expanded mileage on the related siphons. Moreover, the presence of stores might empower consumption of the hidden metal with the requirement for early substitution.

Every one of the elements straightforwardly inferable from fouling address expanded support costs that might be impressive now and again. Where fouling is capable, at some point or another, it will be important to clean the hotness exchanger. Not exclusively will the cleaning system include work costs, it might require extraordinary gear, especially if substance cleaning is involved. Extra hardware including siphons,

tanks, pipelines and valves might be required, synthetics bought and the cleaning system might deliver effluents that require treatment before release.

Customary cleaning strategies, for example, tube penetrating, surface brushing and high strain water flying will likewise include some monetary interest notwithstanding the expense of the related work. Except if satisfactory safeguards are taken, the cleaning system might bring about harm to the hotness exchanger. In certain occasions where stores are persevering and hard to eliminate, harm might be unavoidable.

Extra upkeep and cleaning implies that the cycle should be closed down to permit access except if reserve hardware has been given. As a result, there is a time of lost creation which addresses a deficiency of profit from the capital interest in the process gear overall and diminished benefit. Lost creation because of impromptu shut down because of any reason including fouling; can have a significant impact where there is sharp rivalry.

It likewise must be recollected that ceaseless challenges with the activity of an interaction plant, particularly heat exchangers subject to extreme fouling, will influence the assurance of the workforce. It very well might be especially so where creation rewards and motivations are involved. The result of these worries might be an overall bringing down of a feeling of obligation, helpless housekeeping and slack mentalities. The expenses are hard to evaluate, however there will be an expense punishment related with these work force issues.

The issue of fouling has prompted medicinal advances that might remember for line cleaning or the utilization of added substances. The object is to forestall fouling happening or to diminish its consequences for the presentation of the hotness exchanger being referred to. Relief by whatever means will include extra costs either as far as capital for the related hardware or the acquisition of treatment synthetic compounds. The expense of hotness exchanger fouling can be impressive albeit much relies upon the idea of the liquids being taken care of, the plan of the hotness exchanger and the conditions under which it is worked.

The financial punishments portrayed above might be summed up:

A few factors add to fouling, including

- ❖ Water pH,
- ❖ Product thickness
- ❖ The harshness of part surfaces, among numerous others.

4.9: KEY FOULING FACTORS:

Dairy applications incorporate fats, sugars, and proteins that add to fouling. In food and refreshment applications, particulate matter can cluster and stop up, and in drug applications, corrective and drug particles created during handling can stick and amass.

4.10: DETECTION OF FOULING IN HEAT EXCHANGERS

Fouling discovery commonly happens by actual assessment or by checking framework execution. Actual investigation remembers estimating the fouling's thickness for plates, lines, or cylinders.

Cleaning is needed to keep up with heat exchanger proficiency. Cleaning-In-Place (CIP) hardware courses cleaning synthetic substances and washes to flush inside surfaces of hotness exchangers without dismantling them.

4.11: IMPORTANCE OF FLOW RATE DURING CLEANING:

The legitimate stream rate guarantees the compelling mechanical activity of liquids during cleaning. A few makers suggest at least 1 ft/sec speed across heat exchanger plates, however necessities change by producer.

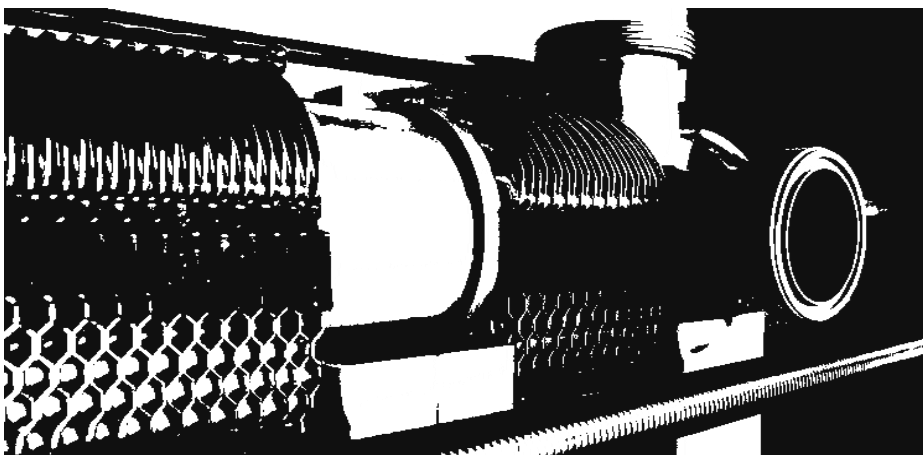


Figure 4.8 Plate heat exchanger diagram

4.12: CLEANING AGENTS TO USE, BY PURPOSE INCRUSTATION, SCALING:

Clean the incrustation or scaling is a course of rub-up calcium carbonate, silicates and calciumsulfate from plate surfaces. Cleaning operator should be viable with both the plate metal and the creation of gaskets.

In titanium and hardened steel plates, never use hydrochloric corrosive. Likewise, never use water of more than 300 ppm of chlorine during the planning of cleaning arrangements. For each situation where chlorination of non-titanium gear can't be stayed away from, counsel your hardware provider.

4.12.1: REMOVING SEDIMENT:

Residue most generally comprises of metal Oxides, sediment, Alumina, and Diatomic life forms and their stool. Residue amasses on the grounds that hotness sets minerals and different particles free from liquids during handling cycles, and those settle and store on heat move surfaces. You ought to never utilize hydrochloric corrosive with tempered steel or titanium plates in light of the fact that the corrosive causes general erosion, pitting, and stress consumption breaking.

4.12.2: REMOVING BIOLOGICAL GROWTH:

When utilizing the heat exchangers to expand the temperature of handled food sources and organic development like microbes, protozoa and nematodes can happen. Eliminating the development requires a similar regard for plate and gasket synthesis as incrustation. Makers can give more itemized data about cleaning and disinfection for explicit gear.

4.13: CHEMICAL CLEANING BASICS:

CIP administrators normally follow four stages in the compound cleaning process:

4.13.1: Alkaline clean: eliminates the development of natural materials

4.13.2: Rinse: For the most part finished with high-stream water flusher to eliminate free garbage and remaining buildup from the basic advance

4.13.3: Acid cleaning: Helps break up and relax fouling materials all the more profoundly

4.13.4: Final wash: Draining the hotness exchanger, disengaging the CIP unit

4.14: RECOMMENDED LIMITS FOR CLEANING SOLUTIONS:

5% by volume caustic at a maximum of 70°C

0.5% by weight acid solution at a maximum of 70°C

4.15: THE CIP PROCESS FOR PLATE AND FRAME HEAT EXCHANGERS:

The basic process for CIP is a one-person job that includes. Connecting a CIP unit to the heat exchanger. Mixing and heating water and cleaning chemicals.

4.15.1: Alkaline mix: circulating to remove build-up of organic materials

4.15.2: Rinse: In generally completed with high-flow water flusher is to remove loosen debris and remaining residual from the alkaline step.

4.15.3: Acid mix: circulating to dissolve and soften fouling materials more deeply

5: SUMMARY AND CONCLUSION

Finally, we eliminated the manual hydro blasting cleaning for the Heat Exchanger by our project. This project will reduce the man machine interaction that leads to unsafe actions.

Our evaluated Hot caustic cleaning for the Heat exchanger will reduce the fouling and improve the productivity and cost optimum (reduced man power, equipment damage & Gasket cost as well) .Cleaning circulation through Plate heat exchanger for Water side fouling is reduced by using sodium hypochlorite solution.

REFERENCES

1. Arsenyeva O., Tovazhnyansky L., Kapustenko P., Khavin G., 2011, The generalized correlation for friction factor in crisscross flow channels of plate heat exchangers, *Chemical Engineering Transactions*, 25, 399– 404.
- Arsenyeva O.P., Crittenden B., Yang M., Kapustenko P.O., 2013, Accounting for the thermal resistance of cooling water fouling in plate heat exchangers. *Applied Thermal Engineering*, 61(1), 53-59.
2. Arsenyeva O.P., Tovazhnyanskyy L.L., Kapustenko P.O., Demirskiy O.V., 2012, Heat transfer and friction factor in criss-cross flow channels of plate-and-frame heat exchangers. *Theoretical Foundations of Chemical Engineering*, 46(6), 634-641.
- Arsenyeva O.P., Čuček L., Tovazhnyanskyy L.L., Kapustenko P.O., Savchenko Y.A., Kusakov S.K., Matsegora O.I., 2016, Utilisation of waste heat from exhaust gases of drying process. *Frontiers of Chemical Science and Engineering*, 10(1), 131-138.
3. Bott T. R. (1990) *Fouling Notebook*, Instn. Chem. Engrs. DOI: [10.1016/0260-8774\(93\)90078-X](https://doi.org/10.1016/0260-8774(93)90078-X)
4. Bott T. R. (1995) *Fouling of Heat Exchangers*, Elsevier, Amsterdam
5. Chenoweth, J. M., (1990) Final report of the HTRI/TEMA Joint Committee to Review the Fouling Section of the TEMA Standards. *Heat Trans. Eng.*, 11, 1. 73-107. DOI: [10.1080/01457639008939724](https://doi.org/10.1080/01457639008939724)
6. Crittenden B.D., Yang M., Dong L., Hanson R., Jones J., Kundu K., Klochok E., Arsenyeva O., Kapustenko P., 2015, Crystallization Fouling with Enhanced Heat Transfer Surfaces. *Heat Transfer Engineering*, 36(7-8), 741-749.
- Gough M., Farrokhpahan S., Bulatov I., 2013, Retrofit process heat transfer enhancement to upgrade performance, throughput and reduced energy use. *Clean Technologies and Environmental Policy*, 15(3), 423-431.
7. Hewitt G. F., Shires G. L. and Bott T. R. (1994) *Process Heat Transfer*, CRC Press, Boca Raton.
8. Julio del Angel Soto, Martín T. Martínez G., José Luis Magaña. Theoretical-Experimental Study of the Effect of the External Plates on the Thermal Performance of a Plate Heat Exchanger. *Chemical Engineering and Science*.

2015; 3(1):12-18. doi: 10.12691/ces-3-1-3.

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9. Kapustenko P., Arsenyeva O., Dolgonosova O., 2011, The Heat and Momentum Transfers Relation in Channels of Plate Heat Exchangers, Chemical Engineering Transactions, 25, 357–362. Klemeš J.J., Varbanov P.S., 2013, Process intensification and integration: an assessment. Clean Technologies and Environmental Policy, 15(3), 417-422.
10. Klemes J.J., Arsenyeva O., Kapustenko P., Tovazhnyanskyy L., 2015, Compact Heat Exchangers for Energy Transfer Intensification: Low Grade Heat and Fouling Mitigation. CRC Press, Boca Raton, FL, USA. Panchal C.B., Knudsen J.G., 1998, Mitigation of Water Fouling: Technology Status and Challenges. Advances in Heat Transfer, 31, 431 – 474. Yang M., Crittenden B., 2012, Fouling thresholds in bare tubes and tubes fitted with inserts. Applied Energy, 89, 67–73.
11. Theoretical-Experimental Study of the Effect of the External Plates on the Thermal Performance of a Plate Heat Exchanger
12. Z. H. Ayub, Plate Heat Exchanger Literature Survey and New Heat Transfer and Pressure Drop Correlations for Refrigerant Evaporators, Heat Transfer engineering, Vol. 25, No. 4, 2003, 3-16. has been cited by the following article.