Report of Cooperative Education

1. **Modification of a Pipeline in Motor Gasoline Recovery for VOCs Emission Reduction**
2. **Installation of Coalescers to Separate Small Particles and Water from Jet Fuel**
3. **Installation of ESVs at Crude Oil Storage Tanks**

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รายงานสหกิจศึกษาฉบับสมบูรณ์

1. การปรับปรุงระบบท่อในการนำกลับน้ำมันแกโซลีนเพื่อลดการปลดปล่อยสารประกอบอินทรีย์ระเหยง่าย
2. การติดตั้งอุปกรณ์ Coalescers เพื่อแยกอนุภาคขนาดเล็กและน้ำจากน้ำมันเชื้อเพลิงอากาศยาน
3. การติดตั้งวาล์วฉุกเฉินที่ถังเก็บน้ำมันดิบ

นางสาวจิ๊ฟนี่ย์ คชสวัสดิ์

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Cooperative Titles:

Project I Modification of a Pipeline in Motor Gasoline Recovery for VOCs Emission Reduction

Project II Installation of Coalescers to Separate Small Particles and Water from Jet Fuel

Project III Installation of ESVs at Crude Oil Storage Tanks

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Abstract

In this report consists of 3 projects. Normal practice for motor gasoline recovery is to separate water contaminated in base gasoline (GB) during GB blending to GB-95 and GB-91. In GB quality control sampling, draining water from GB rich phase (water-oil phase) or draining GB from water rich phase (oil-water phase) must be considered. The transfer of residual GB to the oily-water pond, which is an open-air system, causes the VOCs emission and over workload at the oily-water pond. To reduce the VOCs emission and over workload at the oily-water pond, the modification of the existing pipeline and installation of a 4-inch diameter pipe for a total distance of 100 m from P-1501A and P-1501B pumps to T-935A/B slop oil tanks were studied. In case of draining GB from water rich phase, the draining oil-water phase to the oily-water pond passing GB-95 and GB-91 recovery units, drums A and B cause a longer transfer time and manual work, respectively. To reduce transfer time at the recovery units and avoid manual work at drums A and B, the installation of a 4-inch diameter pipe for a total distance of about 550 m from T-916A and T-977 slop tanks passing P-9341 and P-9343 pumps to the oily-water pond were studied. The detail results to resolve the aforementioned problems were demonstrated herein. However, no any solution was required in case of draining water from GB rich phase as the contaminated water can be separated by the recovery units. The GB is returned to GB storage tanks and the oil-water phase is sent to the oily-water pond.

In project II, the coalescer separates the small particles and water from jet fuel. Currently, the coalescers was used in 3 cases consisting of (1) Rundown of jet fuel from plant 3 to major group tanks, (2) Rundown of jet fuel from plant 3 to minor group tanks, and (3) Transfer of jet fuel from minor group tanks to major group tanks. The coalescers were not enough while case 1 and case 3 are operated simultaneously. To separate small particles and water from jet fuel to serve case 1 and case 3 simultaneously, the new coalescers would be installed. The role of new coalescers was transfer of jet fuel from minor group tanks to major group tank by using P-977 and P-975 pumps. The velocity of jet fuel in new pipelines and pressure drop were considered. The calculation showed that the velocities of jet fuel in new pipelines from P-977 and P-975 pumps to major group tank were 2.0 m/s and 1.0 m/s, respectively. The both velocities were less than 2.4 m/s, so the erosion in the pipeline did not appear. Moreover, the calculation of pressure drop indicates that discharge pressure of P-977 and P-975 pumps were high enough to transfer jet fuel from minor group tanks to major group tanks.

In project III, the refining capacity of BCP would be increased in the future, so they require more crude oil. Increase of the crude oil capacity caused overfilling at crude oil storage tanks. In addition, the safety integrity level (SIL) study of crude storage tanks was found that the SIL of each tank are equal to 1. To reduce SIL and prevent overfilling at crude oil storage tanks, increasing safeguarding system of crude oil storage tanks were studied. From the study, it found that safety instrumented systems (SIS) should be installed at crude oil storage tanks. The SIS consisted of level indicator (LI), level transmitter (LT), level indicator alarm (LIA), and ESV. The level of crude in the storage tank is measured by LI then the signal will be sent signal to LT. LT will convert the signal to an electrical signal and sent to LIA. LIA is set at 90% of the maximum capacity of crude storage tank, accounting to API 2350 standard. LIA will receive the electrical signal from LT and compare it with the setting point. If the signal equals the setting point, LIA will send digital signal to ESV. Then, ESV will be shut off to prevent crude oil storage tank overfilling.

Keywords: Motor gasoline recovery, VOCs, coalescer, ESV, $NPSH_A$, $NPSH_R$, SIS, LI, LT, and LIA

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Also, I would like to thank my advisor, Assoc. Prof. Dr. Anchaleeporn Waritswat Lothongkum, for giving suggestion and teaching until my projects will successful.

Finally, I would like to thank my family and my friends for encouragement and support when I have a problem. I hope this research will be useful for anyone who is interested in it.

Juffnee Khotsawat

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CHAPTER I

INTRODUCTION

1.1 Background

Bangchak Corporation Public Company (BCP) has a core business of petroleum refining, including spans procurement of crude oil from domestic and overseas sources, and refining the products into standardized products. The current capacity is 120,000 barrels per day. In addition, there are other businesses such as, power production from solar energy, biomass energy, petroleum exploration and production.

Motor gasoline is widely used for automobiles and motorcycles. The motor gasoline recovery is to separate water from base gasoline (GB) during GB blending to GB-95 and GB-91. To control the quality of GB, it is sampled at the bottom of each tank via roof drains and sent to drums A and B without passing the recovery units. In GB quality control sampling, it must be considered draining water from GB rich phase (water-oil phase) or draining GB from water rich phase (oil-water phase). The residual GB from quality control sampling is sent to the oily-water pond leading to the VOCs emission and over workload at the oily-water pond, which can be solved by modification of the pipeline to send the GB from drums A and B directly to the O-908, a drum for oil separation, and bypass the oily-water pond. However, the GB from water rich phase in storage tanks are drained to slop tanks, the GB recovery units, drums A and B, and the oily-water pond, respectively. This leads to a longer transfer time at the GB-95 and GB-91 recovery units and manual work at drums A and B. The modification of pipeline to drain GB from water rich phase directly to the oily-water pond and bypass the recovery units is proposed.

In the jet fuel storage, the small particles and water are separated from jet fuel by coalescers. Jet fuel storage tanks are divided into 2 groups, it consists of major group and minor group. There are 3 cases of jet fuel storage, (1) Rundown of jet fuel from plant 3 passing coalescers to major group tanks, (2) Rundown of jet fuel from plant 3 passing coalescers to minor group tanks and transfer to major group tanks, and (3) Transfer of jet fuel from minor group tanks passing coalescers to major group tanks. Currently, there are only two coalescers. The coalescers are not enough while case 1 and case 3 are operated simultaneously. Therefore, this work is necessary to install new coalescers for operation.

Nowadays, the crudes at BCP off-site area contains unloading crudes from trucks, trains, and piers. The relatively high flow rate of unloading crudes from piers is approximately 1,000 m^3/h. In the future, the 3E project (Efficiency, Energy, and Environment Improvement Project) will be completed then the crude oil refining capacity will be increased too. Increase of the crude oil refining capacity increases the crude oil demand volume causing overfill of crude storage tanks. From the study of safety integrity level (SIL) of crude oil storage tanks by BCP, it is concluded that SIL of crude oil storage tanks are equal to 1. So, it should be installed emergency shutdown valves (ESVs) at crude oil storage tanks. Furthermore, it should be studied about installation of ESVs to prevent overfilling of crude from storage tanks to the atmosphere and increases safeguarding system of crude oil storage tanks.

1.2 Objectives

Project I Modification of a Pipeline in Motor Gasoline Recovery for VOCs Emission Reduction

1) To reduce the VOCs emission and over workload at the oily-water pond by modification the existing pipeline and installation of the new pipelines

2) To reduce transfer time at the GB-95 and GB-91 recovery units and to avoid manual work at drums A and B by installation of the new pipelines

Project II Installation of Coalescers to Separate Small Particles and Water from Jet Fuel

1) To separate small particles and water from jet fuel to serve case 1 and case 3 simultaneously by installation the new coalesces and the new pipelines

2) To transfer jet fuel in major group tanks by installation of the new pipelines

Project III Installation of ESVs at Crude Oil Storage Tanks

1) To prevent crude oil storage tanks overfilling by installation of emergency shutdown valves

1.3 Scopes of Work

1.3.1 Study of the pipelines design and principles of fluid mechanics

1.3.2 Calculation of the fluid velocities and the pressure drop in the pipelines

1.3.3 Study of safety instrumented system.

1.3.4 Study of overfill protection for storage tanks

1.4 Project Outputs

1.4.1 Understand the pipelines design and pipe size selection.

1.4.2 Understand safety instrumented system.

CHAPTER II

LITERATURE REVIEW

2.1 Motor Gasoline

Motor gasoline is a fuel for engine widely used for automobiles and motorcycles. Motor gasolines of Bangchak Corporation Public Company (BCP) contain gasohol 95, 91, E85 and E20.

Base gasoline (GB) is used as a base to combine with ethanol in order to produce gasohol. Bangchak Corporation Public Company offer 2 grades of base gasoline

- RON 95 base gasoline (GB-95)
- RON 91 base gasoline (GB-91)

2.2 Motor Gasoline Recovery [Bangchak Corporation Public Co., LTD, 2018]

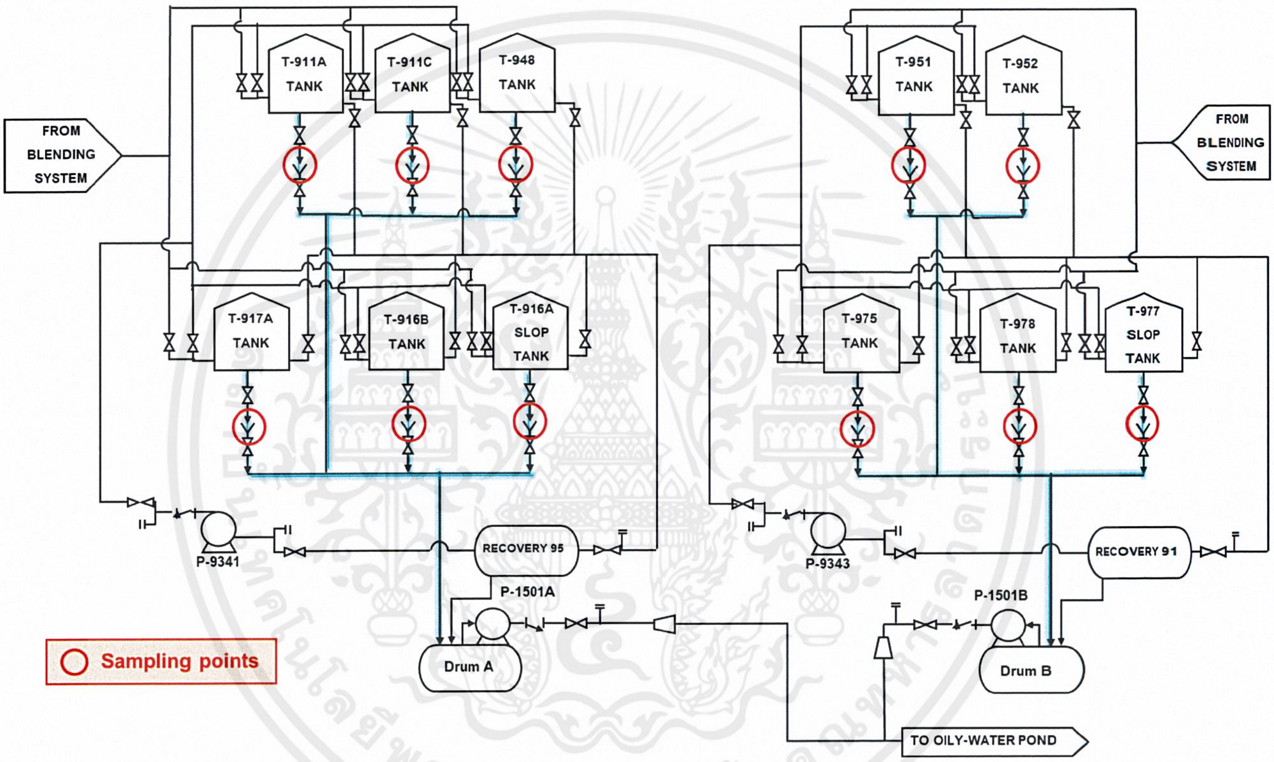
The motor gasoline recovery is to separate water contaminated in base gasoline (GB) during GB blending to GB-95 and GB-91. In GB quality control sampling, draining water from GB rich phase (water-oil phase) or draining GB from water rich phase (oil-water phase) must be considered. The motor gasoline recovery consists of base gasoline 95 and base gasoline 91 units. Each unit contain storage tanks, slop tanks, recovery units. The recovery units use for separate water from oil.

Storage tanks of GB

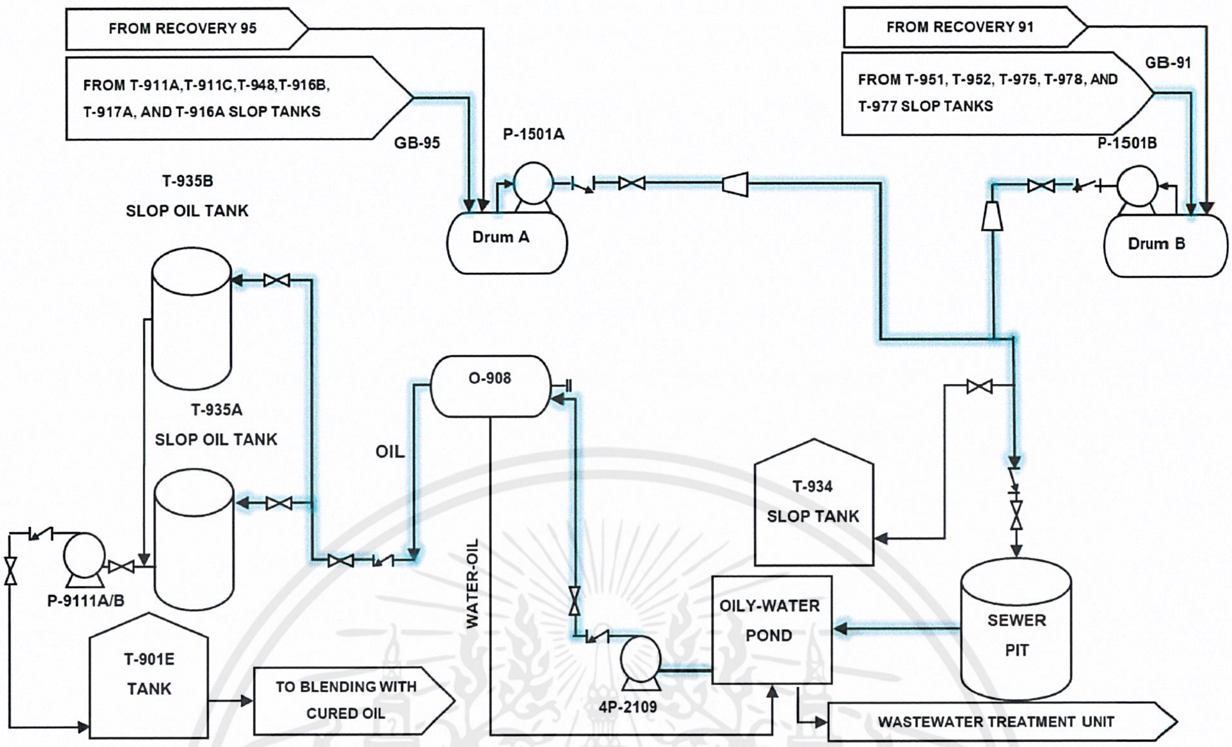
- GB-95 storage tanks consist of T-911A, T-911C, T-948, T-917A, and T-916B tanks. T-916A is slop tank.
- GB-91 storage tanks consist of T-951, T-952, T-975, and T-978 tanks. T-977 is slop tank.

2.2.1 Case: GB quality control sampling

GB-95 is sampled at the bottom of T-911A, T-911C, T-948, T-917A, T-916B and T-196A slop tanks via roof drains and sent to drum A as shown in Figure 2.1 (a). Then, GB-95 is sent to the oily-water pond through a sewer pit by P-1501A pump. In the part of GB-91unit, GB-91 is sampled at the bottom of T-951, T-952, T-975, T-977 slop and T-978 tanks via roof drains and sent to drum B as shown in Figure 2.1(a). Then GB-91 is sent to the oily- water pond through a sewer pit by P-1501B pump. After that, the oil in the oily- water pond is skimmed by a skimmer and sent to the O-908 drum by 4P-2109 pump. The O-908 drum separates water from oil. The oil is then sent to T-935A/B slop oil tanks while the oil-water is sent to the oily-water pond. as shown in Figure 2.1(b)



(a)



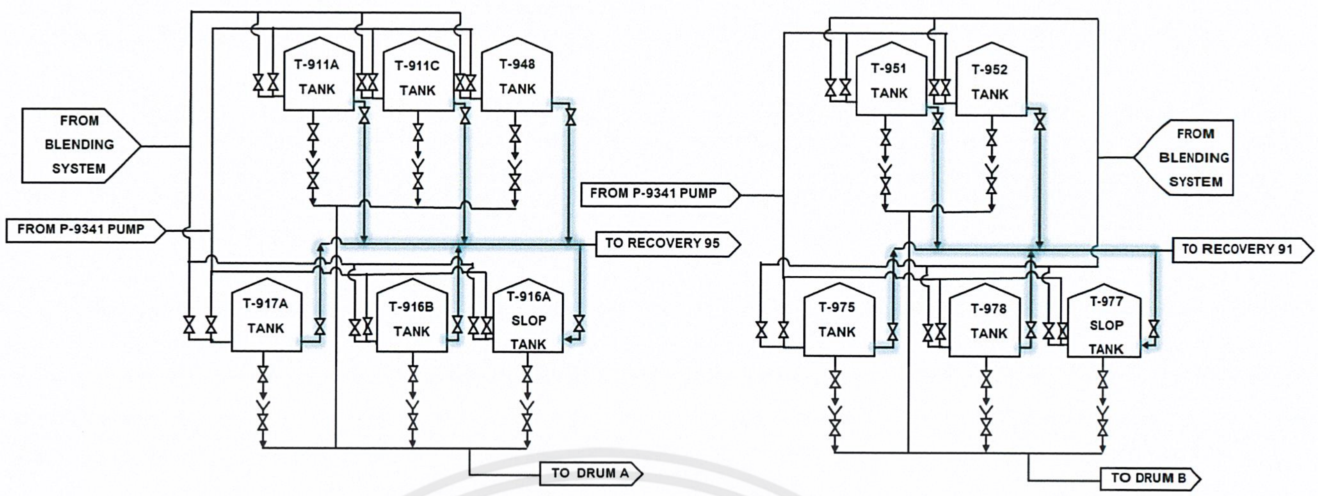
(b)

Figure 2.1 Simplified diagram of existing motor gasoline recovery in case of GB quality control sampling

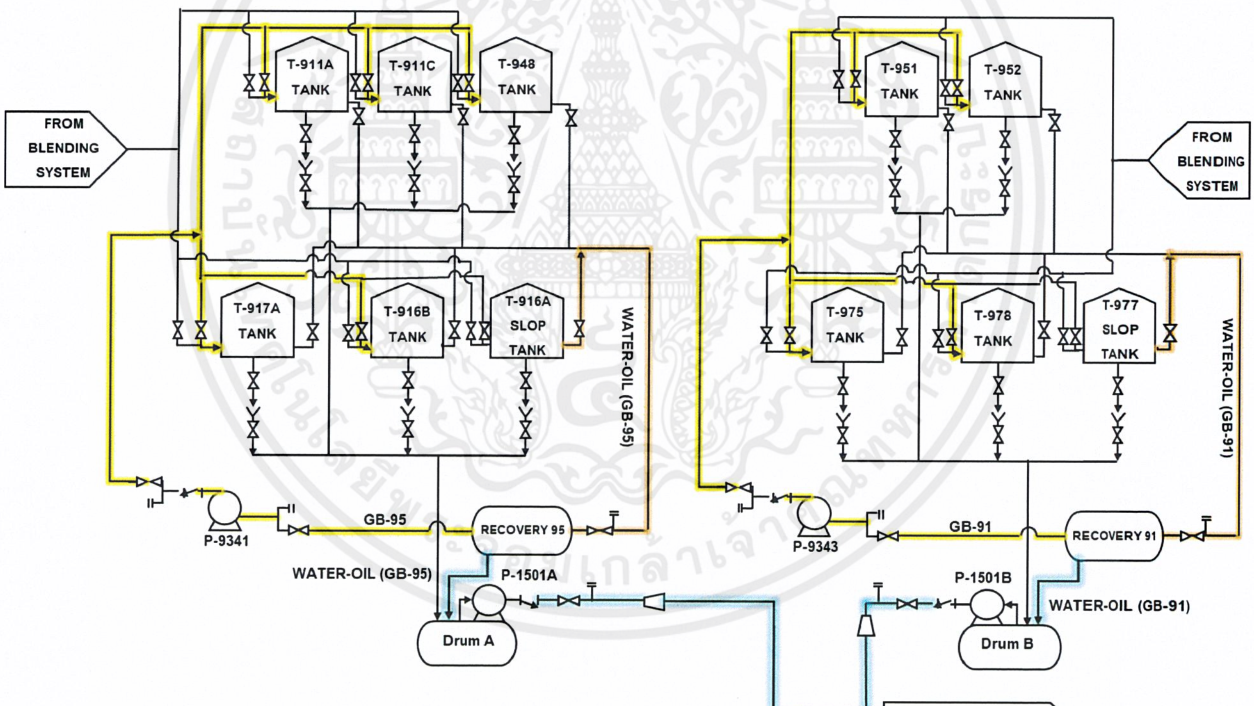
2.2.2 Case: Draining water from GB rich phase (water-oil phase)

The water-oil phase from GB-95 and GB-91 storage tanks will be drained to T-916A and T-977 tanks, respectively as shown in figure 2.2(a).

When T-916A and T-977 tanks are full, water-oil phase is drained to recovery as shown in Figure 2.2(b) (Orange line). The recovery will separate the water from oil. Then, GB-95 and GB-91 are returned to the GB-95 group and GB-91 group storage tanks by P-9341 and P-9343 pumps, respectively as shown in Figure 2.2(b) (Yellow line). The separated water is then sent to the oily-water pond by P-1501A and P-1501B pumps as shown in Figure 2.2(b) (Blue line).



(a)



(b)

Figure 2.2 Simplified diagram of existing motor gasoline recovery in case of draining water from GB rich phase

2.2.3 Case: Draining GB from water rich phase (oil-water phase)

The oil-water phase from GB-95 and GB-91 storage tanks are also drained to T-916A and T-977 tanks, respectively as shown in Figure 2.3. In case T-916A and T-977 slop tanks are full, the oil-water are sent to the oily-water pond same as case of draining water-oil phase.

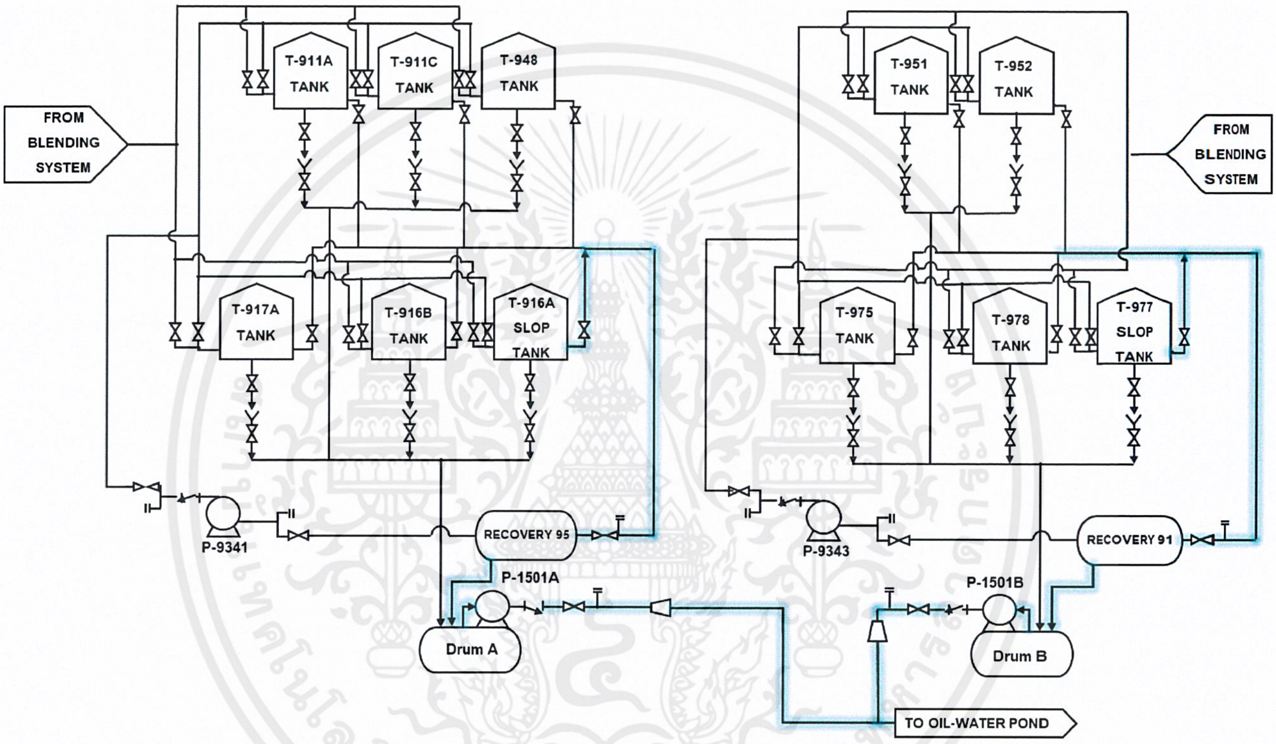


Figure 2.3 Simplified diagram of existing motor gasoline recovery in case of draining GB from water rich phase

2.3 The J-9421 Coalescers System [Bangchak Corporation Public Co., LTD, 2018]

The function of J-9421 coalescers system is to separate small particles and water from jet fuel. Jet fuel storage tanks are divided into 2 groups, major group and minor group.

- Major group: T-941, T-942 and T-943 tanks
- Minor group: T-944 and T-945 tanks

There are 3 cases of jet fuel storage.

2.3.1 Case 1: Rundown of jet fuel from plant 3 passing coalescers to major group tanks as shown in Figure 2.4.

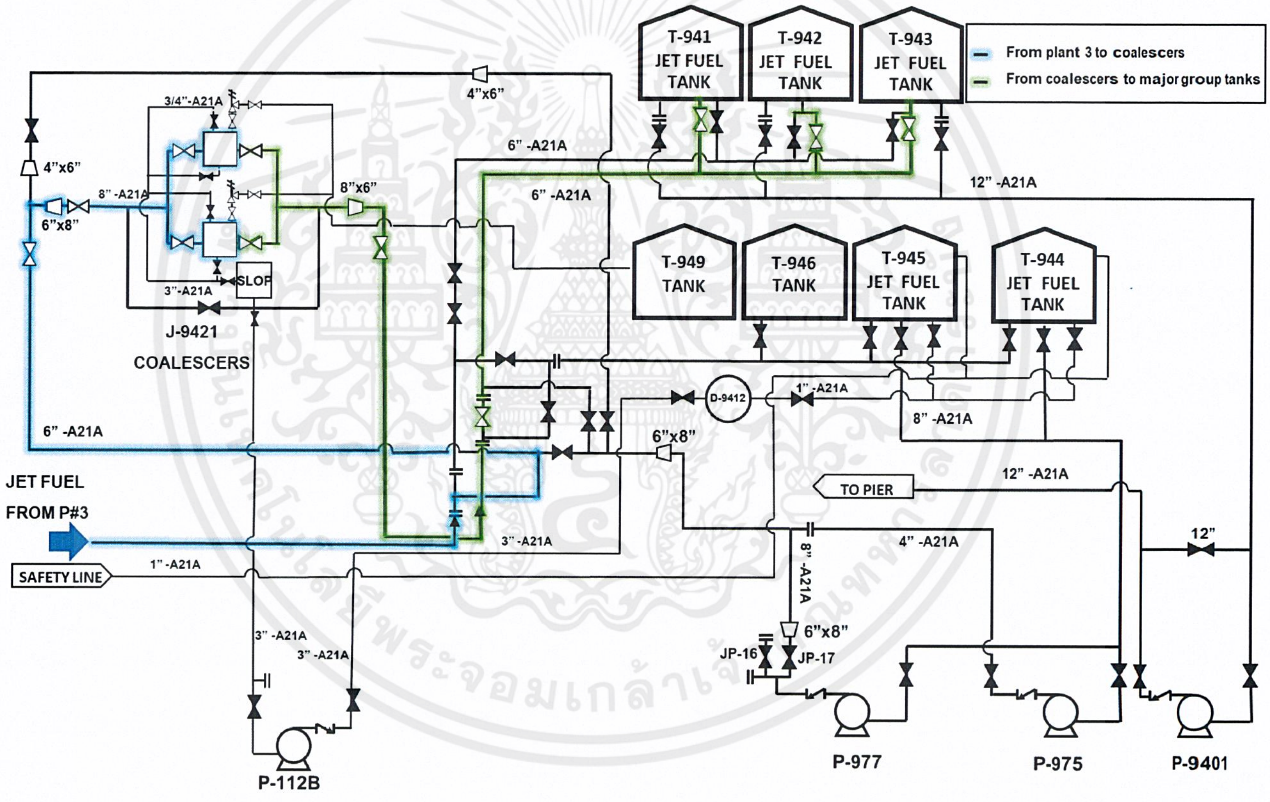


Figure 2.4 Simplified diagram of existing coalescers system in case 1

2.3.2 Case 2: Rundown of jet fuel from plant 3 passing coalescers to minor group tanks and transfer to major group tanks as shown in Figure 2.5.

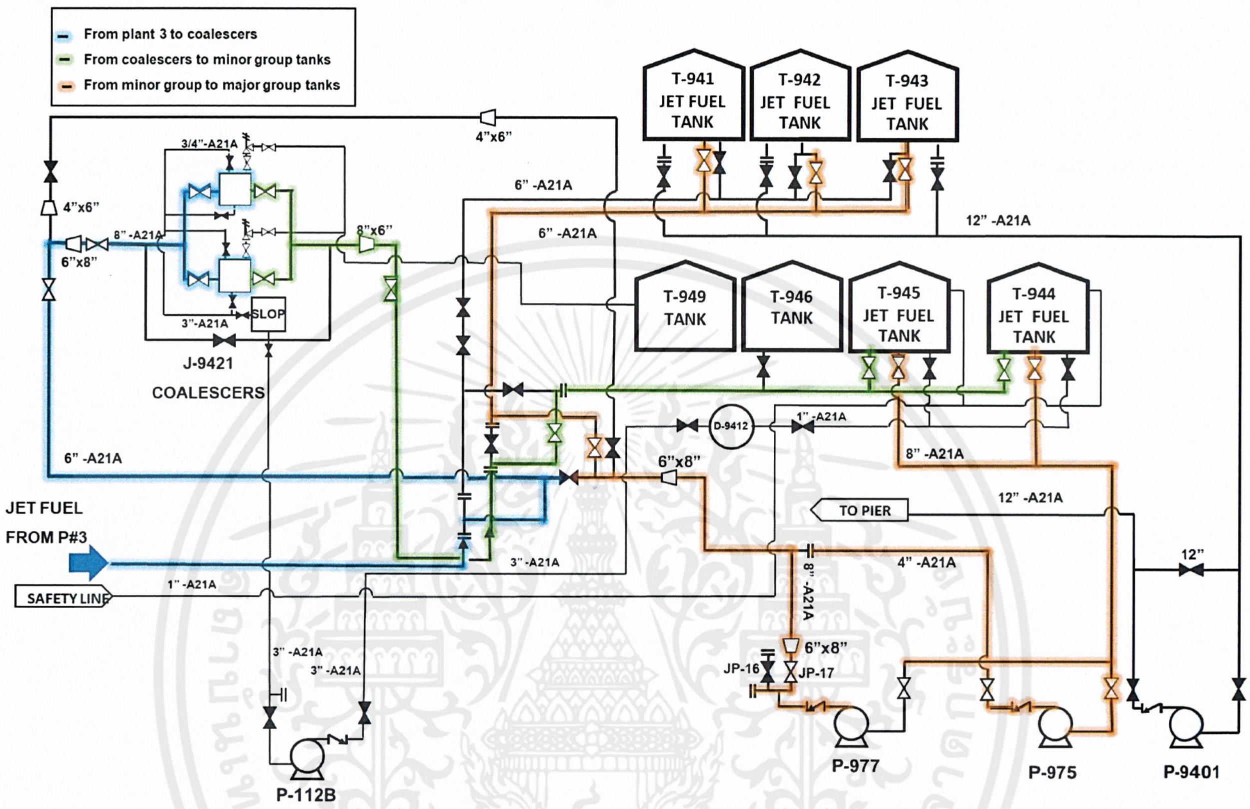


Figure 2.5 Simplified diagram of existing coalescers system in case 2

2.3.3 Case 3: Transfer of jet fuel from minor group tanks passing coalescers to major group tanks as shown in Figure 2.6.

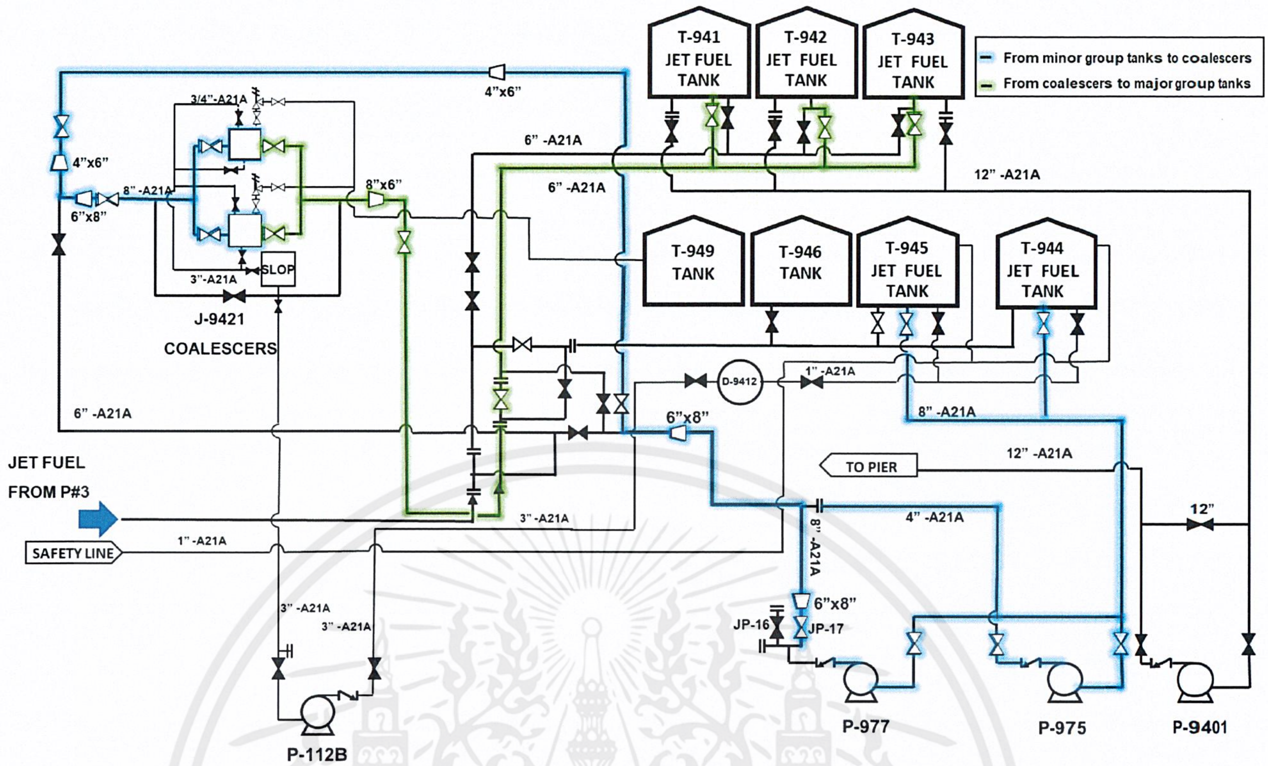


Figure 2.6 Simplified diagram of existing coalescers system in case 3

2.4 Calculation of Pipe Diameter [ดุลยโชติ, 2548]

The diameter of the pipe depends on the velocity of the fluid in the pipeline. In addition, the velocity is not allowed to exceed 2.4 m/s, according to Rule of Thumb for Chemical Engineers for prevention of erosion within the pipelines.

The fluid velocity in the pipeline can be calculated by the equation of continuity for incompressible flow as shown in the Equation 2-1

$$Q = vA \tag{2-1}$$

$$A = \frac{\pi D^2}{4} \tag{2-2}$$

where

Q = Flow rate (m^3/s)

A = Surface area (m^2)

v = Velocity (m/s)

D = Diameter (m)

2.5 Calculation of the Pressure Drop [Munson, et al., 2009]

2.5.1 Reynolds number (Re)

The Reynolds number is the ratio of the inertia force on an element of fluid to the viscous force on an element as shown in the Equation 2-3

$$\mathrm{Re} = \frac{\rho v D}{\mu} \tag{2-3}$$

where

Re = Reynolds number

v = Velocity (m/s)

ρ = Density (kg/m^3)

D = Diameter (m)

μ = Viscosity (Pa·s)

2.5.2 Friction factor (f)

The friction factor is given by explicit alternative to Colebrook formula as shown in the Equation 2-4

$$\frac{1}{\sqrt{f}} = -1.81\log\left[\left(\frac{\varepsilon/D}{3.7}\right)^{1.11} + \frac{6.9}{\mathrm{Re}}\right] \tag{2-4}$$

where

Re = Reynolds number

D = Inside diameter (m)

f = Fanning friction factor

ε = Relative roughness (mm)

2.5.3 Head losses (h_L)

The head loss in the pipelines consist of the head loss due to viscous effects in the straight pipes, termed the major loss ($h_{L\,major}$), and the head loss in the various pipe components, termed the minor loss ($h_{L\,minor}$) as shown in the equation 2-5

$$h_L = h_{Lmajor} + h_{L\,minor} \tag{2-5}$$

2.5.4 Major Loss ($h_{L\,major}$)

Major loss can be calculated by friction deepening on the pipe surface, pipe size, fluid velocity and the pipe length. If the roughness of pipe surface, the pipe length and the fluid velocity are high, the loss of energy is high too.

$$h_{Lmajor} = f\frac{L}{D}\frac{v^2}{2g} \tag{2-6}$$

The equation 2-6, called the Darcy–Weisbach equation, is valid for any fully developed, steady, incompressible pipe flow.

where

f = Fanning friction factor

L = Total length (m)

D = Inside diameter (m)

v = Velocity (m/s)

g = Gravitational acceleration (m/s^2)

2.5.5 Minor Loss ($h_{L\,minor}$)

The fluid passing through various types of joints affects to minor loss in the pipeline. However, if the pipeline is very long, this minor loss will be negligible.

$$h_{L\min or} = K_L \frac{v^2}{2g} \tag{2-7}$$

where

K_L = loss coefficient

v = Velocity (m/s)

g = Gravitational acceleration (m/s^2)

Therefore, the head losses (h_L) equation as equation 2-8

$$h_{Lmajor} = \frac{v^2}{2g}\left[\frac{fL}{D} + \sum K_L\right] \tag{2-8}$$

2.5.6 The pressure drop

The discharge pressure of fluid from the pipeline must be higher than the pressure at the destination point. Otherwise, the fluid in the pipeline system cannot discharge. The pressure drop in the pipeline is given by the energy equation as equation 2-9

$$\frac{v_1^{\,2} - v_2^{\,2}}{2g} + \frac{P_1 - P_2}{\rho g} + Z_1 - Z_2 = h_L \tag{2-9}$$

where

h_L = Head losses (m)

v = Velocity of fluids (m/s)

$P_1 - P_2$ = Pressure drop in pipe (Pa)

ρ = Density of fluid (kg/m^3)

Z = Height (m)

g = Gravitational acceleration (m/s^2)

2.6 The Available Net Positive Suction Head ($NPSH_A$) [Munson, et al., 2009]

Cavitation causes damage in the pump. The cavitation can be prevented by controlling the available net positive suction head ($NPSH_A$). The $NPSH_A$ must be higher than the required net positive suction head ($NPSH_R$)

The $NPSH_R$ of each pump depend on the properties of the pump appearing in the data sheet of the pump from the manufacturer. To install the new pipeline at the suction pump, the $NPSH_A$ will be calculated by using the Equation 2-10.

$$NPSH_A = \frac{P_{atm}}{\rho g} \pm Z_1 - \frac{P_v}{\rho g} - h_L \tag{2-10}$$

where

P_{atm} = Atmospheric pressure (Pa)

h_L = Head losses (m)

Z_1 = Height of the fluid surface above the pump impeller (m)

P_v = Vapor pressure of fluid (Pa)

2.7 Valves [Munson, et al., 2009]

The main function of the valve is to open - close the flow channel. In addition, some valves are also used to control the flow rate or other special functions such as reversing valves and pressure reducing valves etc.

2.7.1 Gate valve

The gate valve works by sliding the cover up-down, in which the on-off must be rotated. Several valve rods are available, including the up-down valve stem, Rising stem) and the valve stem (non-rising stem). Gate valve Suitable for opening or closing only. The advantage of gate valve is that there is a downward pressure due to the flow channel in the straight line and the fluid can flow in both directions. While the disadvantage is that it is large, slow-closing and not suitable for use in the flow.

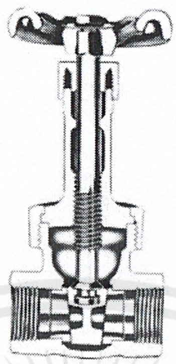
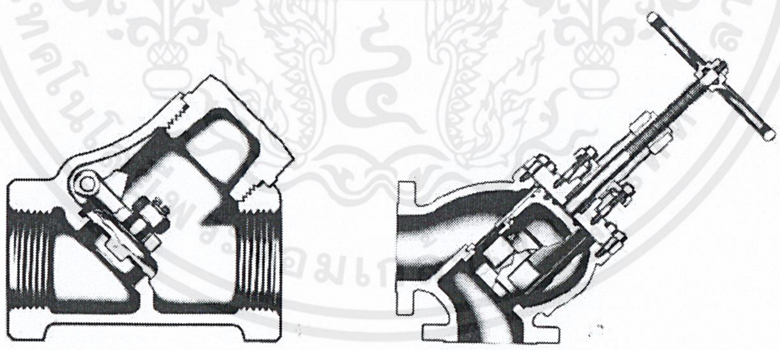


Figure 2.7 Gate valve

Reference: Munson, et al. (2009)

2.7.2 Check valves

Check valves are one of the most important components in the pipeline system. They are responsible for controlling the flow in the same direction. Check valves have a variety of forms, such as swing check valves and stop check valve.



(a) (b)

Figure 2.8 Check valve: (a) swing check valves and (b) stop check valve

Reference: Munson, et al. (2009)

2.8 Types of Chemical Storage Tanks [พรวิภา และคณะ, 2559]

At present, the chemical storage tanks used in the industrial sector can be divided into 3 types as shown in Figure 2.9

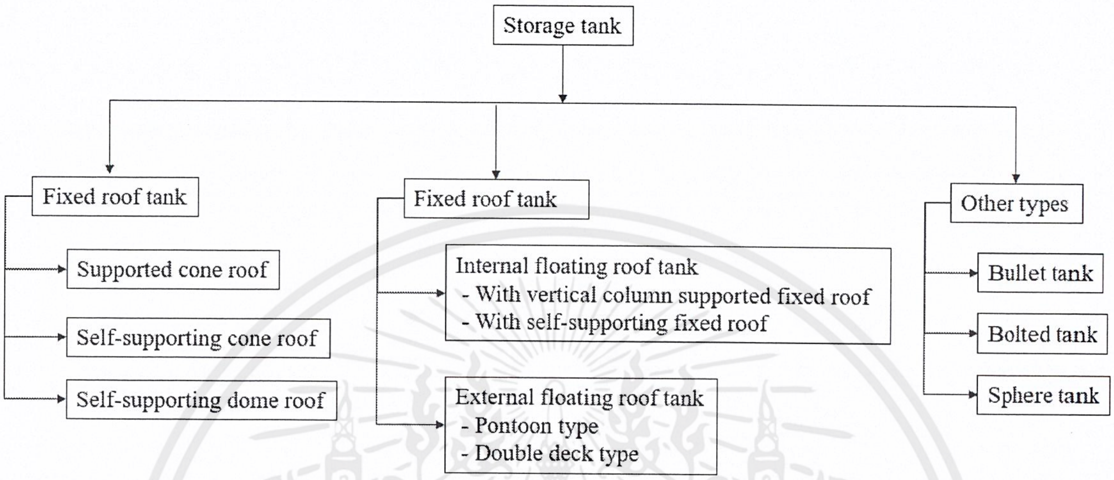


Figure 2.9 Types of chemical storage tanks

Reference: พรวิภาและคณะ (2559)

For flammable liquid storage tanks can be used as Fixed roof tank and Internal floating roof tank

2.8.1 Fixed roof tank

This type of tank is mostly used to store products or chemicals that do not contain volatile properties at ambient temperatures or conditions that store such chemicals, for example lubricants or chemicals.

2.8.1.1 Supported cone roof tank is a tank that has a cone-shaped roof structure and has one roof design as follows.

- Type 1: There is a rafter placed on the girder and have columns for the weight of the roof

- Type 2: There is a rafter on the trusses to get the weight of the roof, which may have a support pole or no support pole.

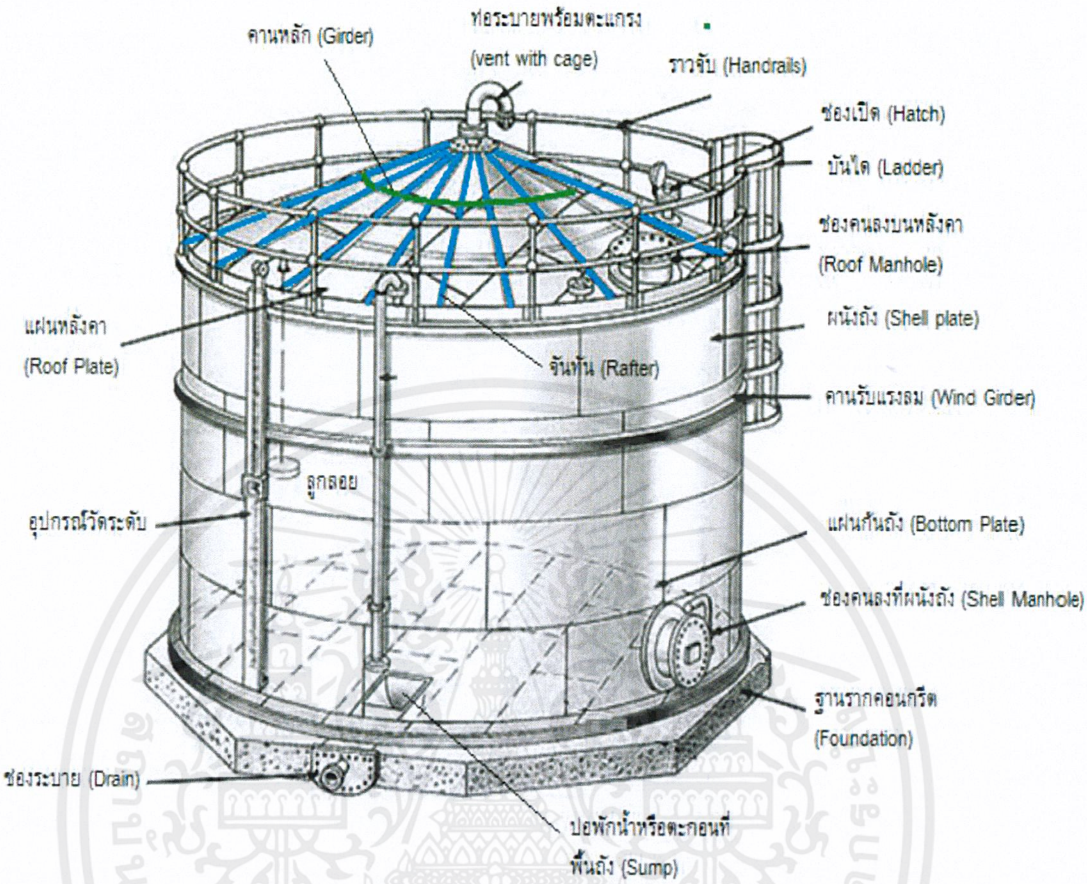


Figure 2.10 Supported cone roof tank

Reference: พรวิภาและคณะ (2559)

2.8.1.2 Self-supporting cone roof tank is the roof of the tank the roof of the tank that has a conical structure and a roof design where the roof is responsible for the weight and load that comes to load without other structures to help increase the weight of the roof in addition to the load point at the edge of the tank only.

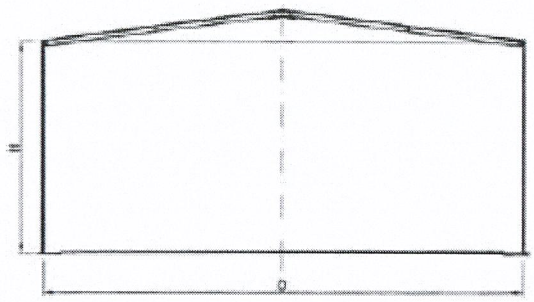


Figure 2.11 Self-supporting cone roof tank

Reference: พรวิภาและคณะ (2559)

2.8.1.3 Self-supporting dome roof tank is the roof that has a dome structure and designed by the roof to accept the weight and load that has been done without other structures to help increase the weight of the roof. In addition to the load point at the edge of the tank only.

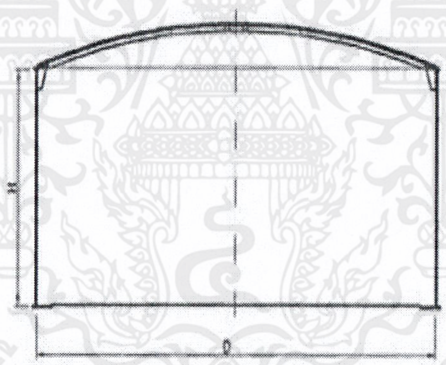


Figure 2.12 Self-supporting dome roof tan

Reference: พรวิภาและคณะ (2559)

2.8.2 Floating roof tank

Floating roof tank, the roof of the tank will not be attached, but can be moved up and down according to the changing fluid level. This type of tank has advantages that can help reduce the risk of danger from the accumulation of chemical vapor pressure in the space above the liquid stored inside the tank.

For this type of tank, it can be used to store liquids with a design pressure of less than 17.2 psi at that working condition. Pressure tanks or additional of vapor recovery systems are installed. In addition, these types of tanks can also be used to store liquids with flash points below ambient temperatures or conditions that store chemicals, including liquids that are likely to be charged from static electricity, which can be divided into 2 types as follows:

2.8.2.1 External floating roof tank

This type of tank is designed for storing liquids or chemicals that general atmospheric pressure has an open top roof style. The roof can move up or down according to the level of liquid inside the tank Which is mostly recommended for tanks with a diameter greater than or equal to 15 meters.

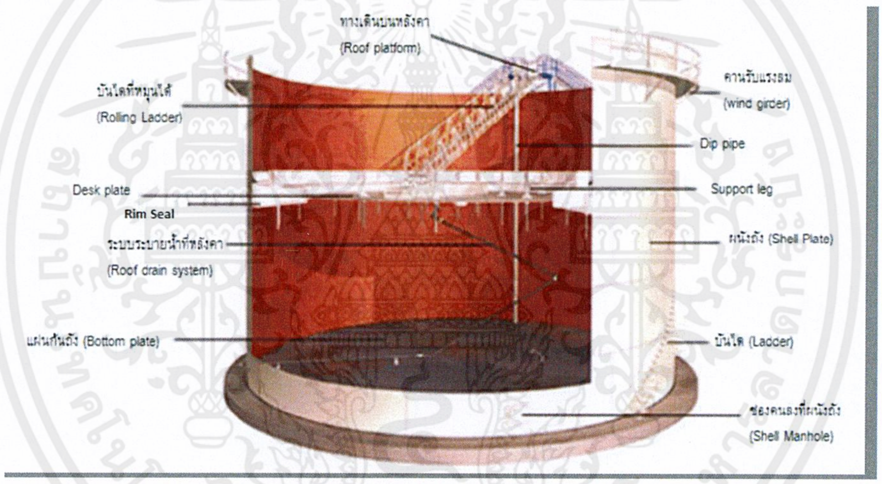


Figure 2.13 External floating roof tank

Reference: พรวิภาและคณะ (2559)

2.8.2.2 Internal floating roof tank

This type of tank has been developed from a general external mobile roof type tank with a non-moving roof on the top of the moving roof to help prevent lightning strikes on the roof of the chemical storage tank. The gap between non-moving roofs and mobile roofs is designed for use in circulation and transfer air to the external environment. With this design, it helps to reduce the accumulation of chemical vapors or liquids stored in chemical storage tanks. And reduce the chance of ignition of such vapors.

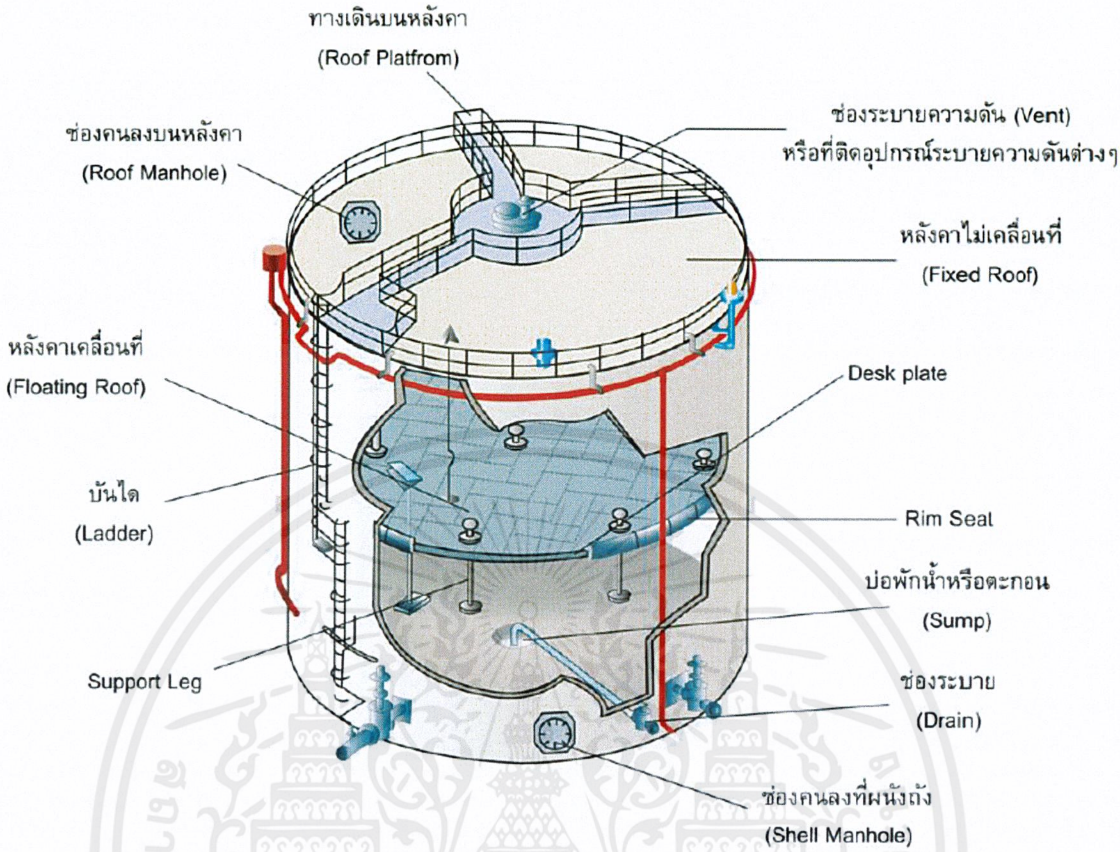


Figure 2.14 Internal floating roof tank

Reference: พรวิภาและคณะ (2559)

2.9 Layer of Protection Analysis (LOPA) [Hyatt, 2004]

In the manufacturing processes, there are a lot of risk that may occur during production such as fire, explosion or leakage of hazardous chemicals. The LOPA is a risk assessment of the production process to prevent risks by increasing the level of protection. The layer of protection can be divided as shown in Figure 2.15 as follows

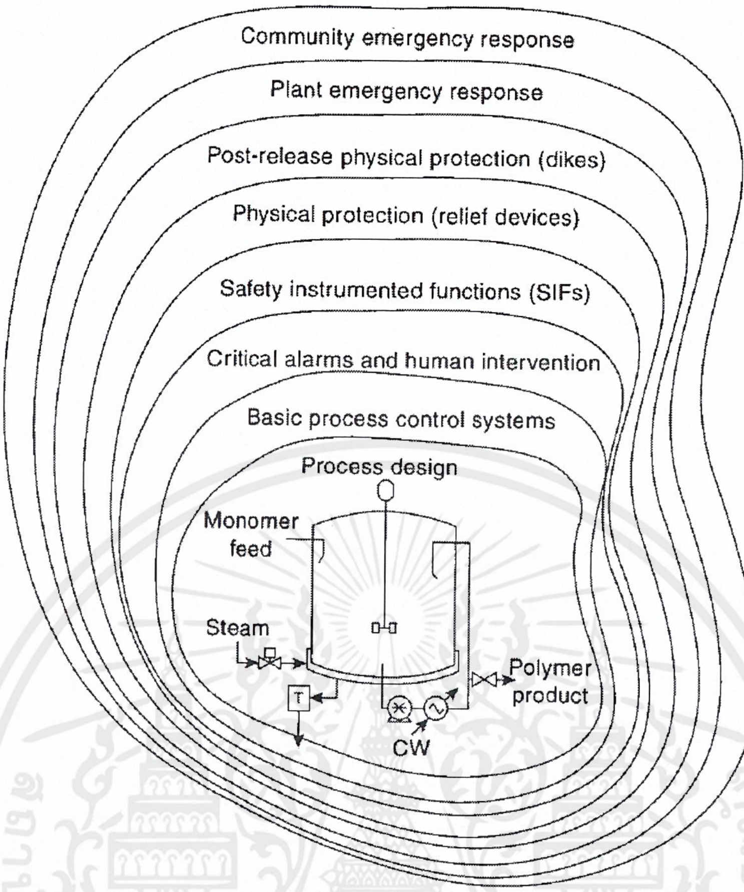


Figure 2.15 Layers of protection to lower the frequency of a specific accident scenario

Reference: Crowl and Louvar (2559)

2.9.1 Process Design

Protection process design should be inherent safety that means the process without the need for additional equipment.

2.9.2 Basic Process Control System, BPCS

The basic control Process system (BPCS) is to control the production process smoothly by measuring and controlling various variables.

2.9.3 Critical Alarm

Protected by Critical Alarm and human intervention to deal with the manufacturing process control system based on objective factors cannot be controlled.

2.9.4 Safety instrumented functions

Protected by safety instrumented functions of safety instrumented system. This system will operate independently from the basic control system. The reliability of the safety control system will be found in the form of errors, hazards and safety levels.

2.9.5 Physical protection

Physical protection is installation of safety relief valve and rupture disc etc.

2.9.6 Post-release Physical protection

Post-release Physical protection is quickly released to the outside, including the construction of walls and explosion-resistant walls, etc.

2.9.7 Plant Emergency response

2.9.8 Community Emergency response

2.10 Basic Process Control System (BPCS) [ทวิช, 2548]

Basic Process Control System means bringing together measuring instruments and controllers to act as tools for use in industrial plants to monitor and control the production process smoothly according to the purpose of the production process, which has various process variables that are controlled. Basic process control system consists of sensing element, controller, and final element

2.10.1 Sensing element

Sensing element is a device used to measure the state of a production process and is responsible for changing variables from production processes to electrical signals or other standard signals to send data of various variables to the controller and to display the variable values at the unit. Display control results so that operators can observe changes and control these variables.

2.10.2 Controller

The Controller will control the variable from the production process to the desired value by receiving the signal from the measuring device in order to compare with the specified value and then processing and then sending an analog signal or standard electrical signal to the final element to adjust the process parameters to the required values.

2.10.3 Final element

The final element is a device that is used to change the standard electrical signal from the controller to control the production process variables.

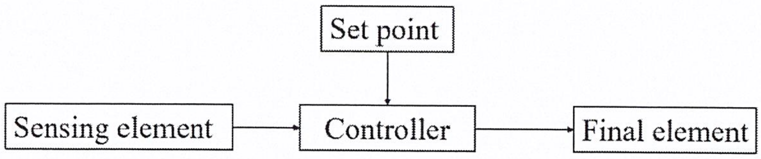


Figure 2.16 Basic process control system

Reference: ทวิช (2548)

2.11 Safety Instrumented Systems (SIS) [ทวิช, 2548]

Safety Instrumented Systems are control systems that take the process to a safe state on identification of conditions, if no action were taken could eventually give rise to a hazard. SIS consists of sensing element, logic solver, and final element.

2.11.1 Sensing element is instrument that use to measure the condition of the process and change various process parameters to be an electrical signal to be sent to logic solver.

2.11.2 Logic solver is the part used to manipulate the logic of the system to be used to control the production process to be in a safe state when abnormal.

2.11.3 Final element is instrument that is used to change the electrical signal from the processor to turn off and on the final instrument.

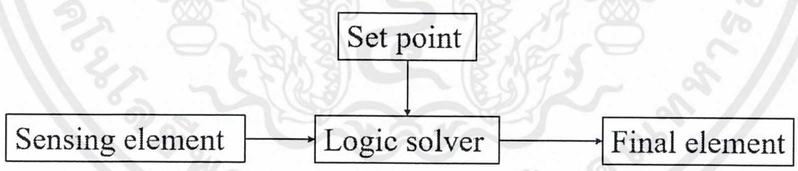


Figure 2.17 Safety instrumented system

Reference: ทวิช (2548)

CHEPTER III

METHODOLOGY

Project I Modification of a Pipeline in Motor Gasoline Recovery for VOCs Emission Reduction

3.1 Study of the Motor Gasoline Recovery

3.1.1 In case of GB quality control sampling, GB-95 and GB-91 are drained from GB-95 and GB-91 storage tanks to drums A and B without passing the recovery unit. Then it that sent to the oily-water pond causes the VOCs emission and workload at the oily-water pond increase. The VOCs emission can be reduced by modification and installation of a pipeline to send GB directly to the O-908 drum and bypass to the oily-water pond.

3.1.2 In case of draining oil-water phase, oil-water is drained from GB-95 and GB-91 storage tanks to T-916A and T-977 slop tanks, respectively. In case T-916A and T-977 slop tanks are full, the oil-water are sent to the oily-water pond same as case 2 (draining water-oil phase) leading to longer time at the GB recovery units and manual workload at drums A and B. The manual work can be avoided by modification of a pipeline to drain oil-water directly to the oily-water pond and bypass the recovery units.

3.2 Study of the Route to Design of the Pipeline in Motor Gasoline Recovery

3.2.1 In case of the GB quality control sampling, study the route to design the pipeline from discharge of P-1501A pump and discharge of P-1501B pump to the O-908 drum.

3.2.2 In case of draining oil-water, study the route to design the pipeline from T-916A and T-977 slop tanks to the oily-water pond.

3.3 Calculation of the Fluid Velocity and Pressure Drop in Motor Gasoline Recovery

3.3.1 Calculation the fluid velocity in the pipelines of motor gasoline recovery

Case: GB quality control sampling

- Calculate the velocity of GB-95 from P-1501A pump to T-935B slop oil tank.

- Calculate the velocity of GB-91 from P-1501B pump to T-935B slop oil tank.

Case: Draining GB from water rich phase (oil-water phase)

- Calculate the velocity of oil-water phase from P-9341 pump to the oily-water pond.

- Calculate the velocity of oil-water phase from P-9343 pump to the oily-water pond.

The fluid velocities in the new pipelines are calculated. In addition, the velocity is not allowed to exceed 2.4 m/s, according to Rule of Thumb for Chemical Engineers for prevention of erosion within the pipelines. The fluid velocity in the pipeline can be calculated by the equation of continuity for incompressible flow as shown in the Equation 2-1

$$Q = vA \tag{2-1}$$

where

Q	=	Flow rate (m^3/s)
A	=	Surface area (m^2)
v	=	Velocity (m/s)

3.3.2 Calculation the pressure drop of motor gasoline recovery

The destination pressure from the newly installed piping system must be higher than the pressure at the destination. Therefore, the fluid inside the pipeline can flow by pressure.

Case: GB quality control sampling

- Calculate the pressure drop of GB-95 from P-1501A pump to T-935B slop oil tank.

- Calculate the pressure drop of GB-91 from P-1501B pump to T-935B slop oil tank.

Case: Draining GB from water rich phase (oil-water phase)

- Calculate the pressure drop of oil-water phase from P-9341 pump to the oily-water pond.

- Calculate the pressure drop of oil-water phase from P-9343 pump to the oily-water pond.

The pressure drop in the pipe is given by the energy equation as Equation 2-9

$$\frac{v_1^2 - v_2^2}{2g} + \frac{P_1 - P_2}{\rho g} + Z_1 - Z_2 = h_L \quad (2\text{-}9)$$

where

h_L = Head losses (m)

v = Velocity of fluids (m/s)

$P_1 - P_2$ = Pressure drop in pipe (Pa)

ρ = Density of fluid (kg/m^3)

Z = Height (m)

g = Gravitational acceleration (m/s^2)

3.4 Calculation of the Available Net Positive Suction Head of Motor Gasoline Recovery

Cavitation in the pump is the one of causes to pump damage. Prevention of cavitation occurring has rule for checking by the available net positive suction head ($NPSH_A$) higher more than the required net positive suction head ($NPSH_R$)

Which each pump has $NPSH_R$ is not the same depending on the properties of the pump. Generally, the $NPSH_R$ will show the data sheet of that model pump from the manufacturer. To installation the pipeline to the pump entrance, the $NPSH_A$ will be different according to the situation.

Case: Draining GB from water rich phase (oil-water phase)

- Calculate the NPSHA from T-916A and T-977 slop tanks to suction of P-9341 and P-9343 pumps.

$NPSH_A$ is given by Equation 2-10 as follows

$$NPSH_A = \frac{P_{atm}}{\rho g} \pm Z_1 - \frac{P_v}{\rho g} - h_L \qquad (2\text{-}10)$$

where

P_{atm} = Atmospheric pressure (Pa)

h_L = Head losses (m)

Z_1 = Height of the fluid surface above the pump impeller (m)

P_v = Vapor pressure of fluid (Pa)

Project II Installation of Coalescers to Separate Small Particles and Water from Jet Fuel

3.5 Study of Coalescer Jet Fuel

In the coalescers jet fuel system, it is not possible to use coalescers in rundown of jet fuel from plant 3 to major group tanks and transfer of jet fuel from minor group tanks to major group tanks simultaneously. Then, it is proposed to install the new coalescers in the system for simultaneous operation.

3.6 Calculation of the Fluid Velocity and Pressure Drop in Coalescers Jet Fuel

3.6.1 Calculation of the fluid velocity in the pipeline in coalescer jet fuel

The jet fuel velocities in the new pipelines are calculated from P-977 and P-975 pumps to major group tanks. In addition, the velocity is not allowed to exceed 2.4 m/s, according to Rule of Thumb for Chemical Engineers for prevention of erosion within the pipelines.

The fluid velocity in the pipeline is given by equation of continuity for incompressible flow as Equation 2-1

$$Q = vA \qquad (2\text{-}1)$$

where

Q = Flow rate (m^3/s)

A = Surface area (m^2)

v = Velocity (m/s)

3.6.2 Calculation the pressure drop in coalescer jet fuel

The destination pressure from P-977 and P-975 pumps to major group tank must be higher than the pressure at the destination. Therefore, the fluid inside the pipelines can flow by pressure.

The pressure drop in the pipe is given by the energy equation as Equation 2-9

$$\frac{v_1^2 - v_2^2}{2g} + \frac{P_1 - P_2}{\rho g} + Z_1 - Z_2 = h_L \qquad (2\text{-}9)$$

where

h_L = Head losses (m)

v = Velocity of fluids (m/s)

$P_1 - P_2$ = Pressure drop in pipe (Pa)

ρ = Density of fluid (kg/m^3)

Z = Height (m)

g = Gravitational acceleration (m/s^2)

3.7 Calculation of the Available Net Positive Suction Head in Coalescer Jet Fuel

Cavitation in the pump is the one of causes to pump damage. Prevention of cavitation occurring has rule for checking by the available net positive suction head ($NPSH_A$) higher more than the required net positive suction head ($NPSH_R$)

Which each pump has $NPSH_R$ is not the same depending on the properties of the pump. Generally, the $NPSH_R$ will show the data sheet of that model pump from the manufacturer. To installation the pipeline to the pump entrance, the $NPSH_A$ will be different according to the situation.

In this project, the $NPSH_A$ is calculated from the slop to suction pump of P-112B pump. $NPSH_A$ is given by Equation 2-10

$$NPSH_A = \frac{P_{atm}}{\rho g} \pm Z_1 - \frac{P_v}{\rho g} - h_L \qquad (2\text{-}10)$$

where

P_{atm}	=	Atmospheric pressure (Pa)
h_L	=	Head losses (m)
Z_1	=	Height of the fluid surface above the pump impeller (m)
P_v	=	Vapor pressure of fluid (Pa)

Project III Installation of ESVs at Crude Oil Storage Tanks

3.8 Study of Existing Safeguarding System of Crude Oil Storage Tanks

Existing safeguarding system of crude oil storage tanks found that LAHH provided but no safety instrumented system (SIS). Thus, SIS is installed at crude storage tanks.

3.8 Study about Safety Instrumented System for Crude Oil Storage Tanks

Safety instrumented system consists of sensing element, logic solver, and final element. So that, it must choose the safety instrument for crude oil storage tanks.

CHAPTER IV

RESULTS AND DISCUSSION

Project I: Modification of a Pipeline in Motor Gasoline Recovery for VOCs Emission Reduction

From the modification and installation of a pipeline in motor gasoline recovery, it can be divided into 2 case: GB quality control sampling and draining oil-water phase.

4.1 Design of a New Pipeline in Motor Gasoline Recovery

4.1.1 Design of the new pipeline in case of GB quality control sampling

In this design starts from the discharge of P-1501A pump and discharge of P-1501B pump to T-935A/B.

4.1.1.1 Point 1: Discharge of P-1501A pump, enlargers size 3"x4" is installed to change size of diameter pipe from 3-inch to 4-inch. Enlargers size 4"x6" is installed to connect in 6-inch diameter pipe as shown in Figure 4.1.

4.1.1.2 Point 2: Discharge of P-1501B pump, enlargers size 3"x4" is installed to change size of diameter pipe from 3-inch to 4-inch. Enlargers size 4"x6" is installed to connect in 6-inch diameter pipe as shown in Figure 4.1.

4.1.1.3 Point 3: 3-inch diameter pipe is changed to 4-inch diameter pipe and tee way pipe is installed to connect 3-inch diameter pipe to T-934 tank and 4-inch diameter pipe to O-908. Gate valve and check valve are installed as shown in Figure 4.1

4.1.1.4 Point 4: Exit of the O-908 drum, 3-inch diameter pipe is changed to 4-inch diameter pipe as shown in Figure 4.1.

3-inch of diameter pipe is changed to 4-inch to reduce velocity as Rule of Thumb for Chemical Engineers (Velocity < 2.4 m/s) for prevent erosion within the pipeline.

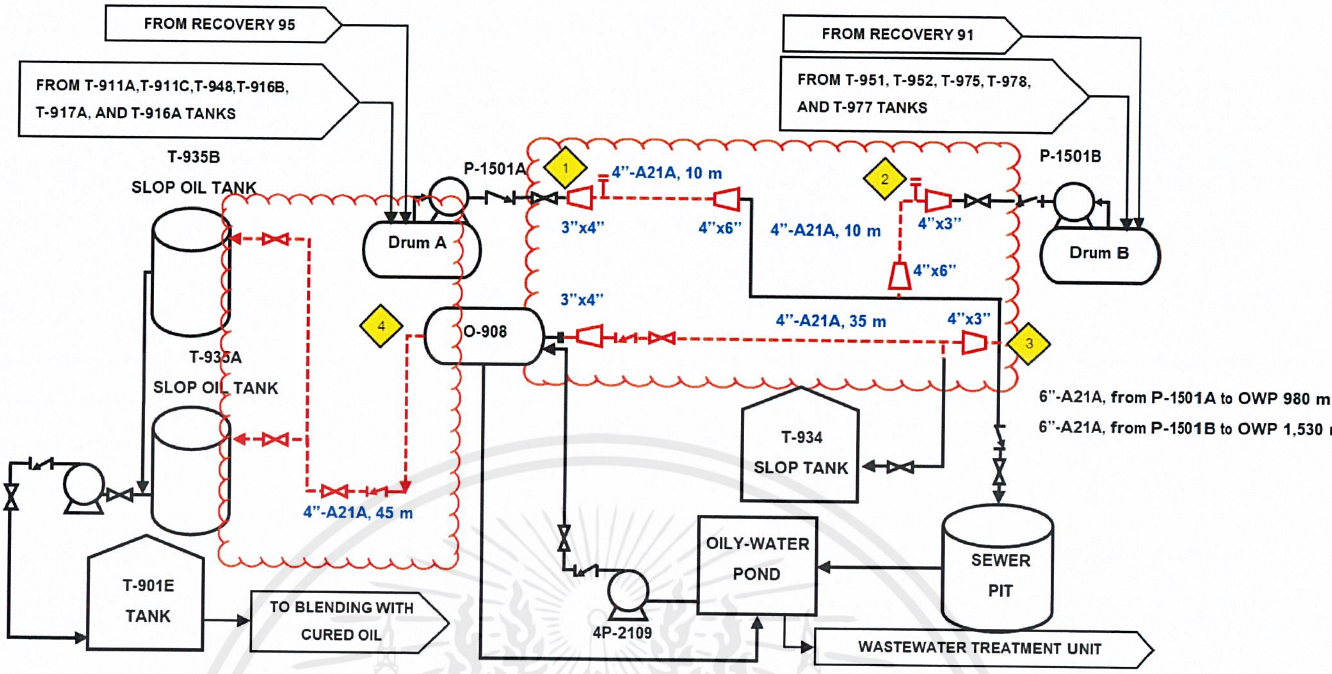


Figure 4.1 Design of the new pipeline in case of GB quality control sampling

4.1.2 Design of the new pipeline in case of draining oil-water phase

In this design starts from the bottom of T-916A slop tank to the discharge of P-1501A pump and from the bottom of T-977 slop tank to the discharge of P-1501B pump

4.1.2.1 Point 5: Bottom of T-916A slop tank, 4-inch diameter pipe is tied in to point 6 (Suction of P-9341 pump) and 4-inch gate valves are installed as shown in Figure 4.2.

4.1.2.2 Point 7: Discharge of P-9341 pump, 4-inch diameter pipe is installed to connect point 1 (Discharge of P-1501A pump) and 4-inch of gate valve and check valve are installed. Minimum flow line is installed at P-9341 pump to reduce flow rate as shown in Figure 4.2.

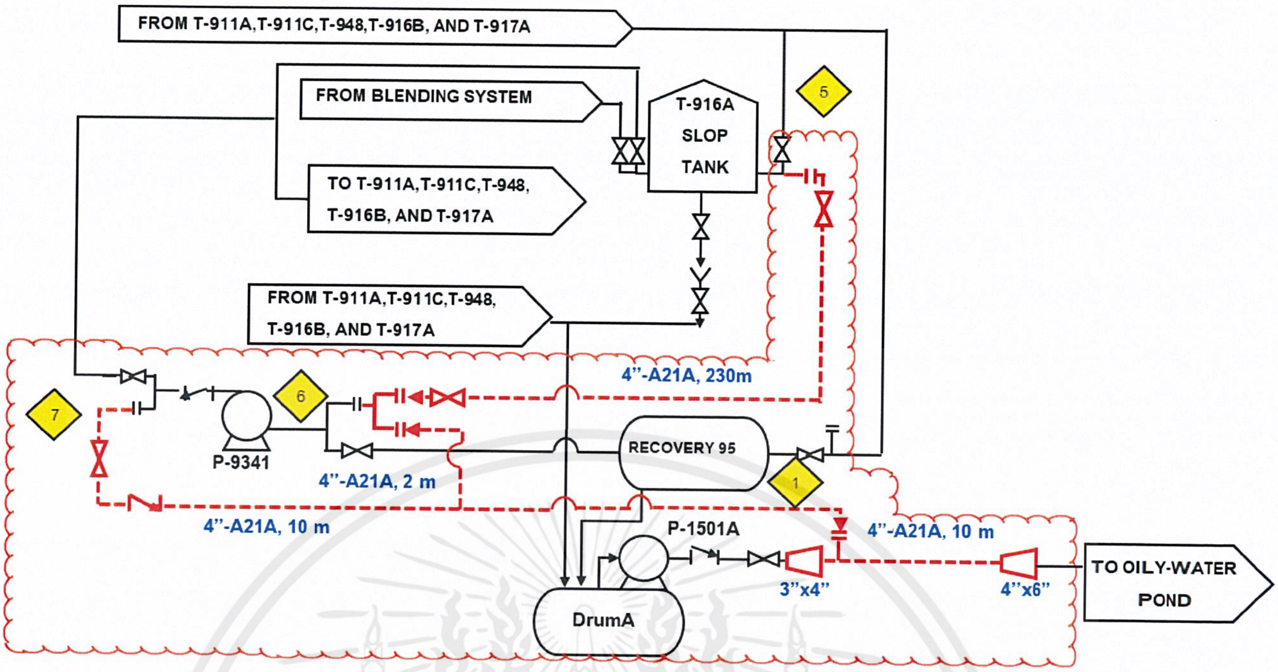


Figure 4.2 Design of the new pipeline in case of draining oil-water phase of GB-95

4.1.2.3 Point 8: Bottom of T-977 slop tank, 4-inch diameter pipe is tied in to point 9 (Suction of P-9343 pump) and 4-inch gate valves are installed as shown in Figure 4.3.

4.1.2.4 Point 10: Discharge of P-9343 pump, 4-inch diameter pipe is installed to connect point 2 (Discharge of P-1501B pump) and 4-inch of gate valve and check valve are installed. Minimum flow line is installed at P-9343 pump to reduce flow rate as shown in Figure 4.3.

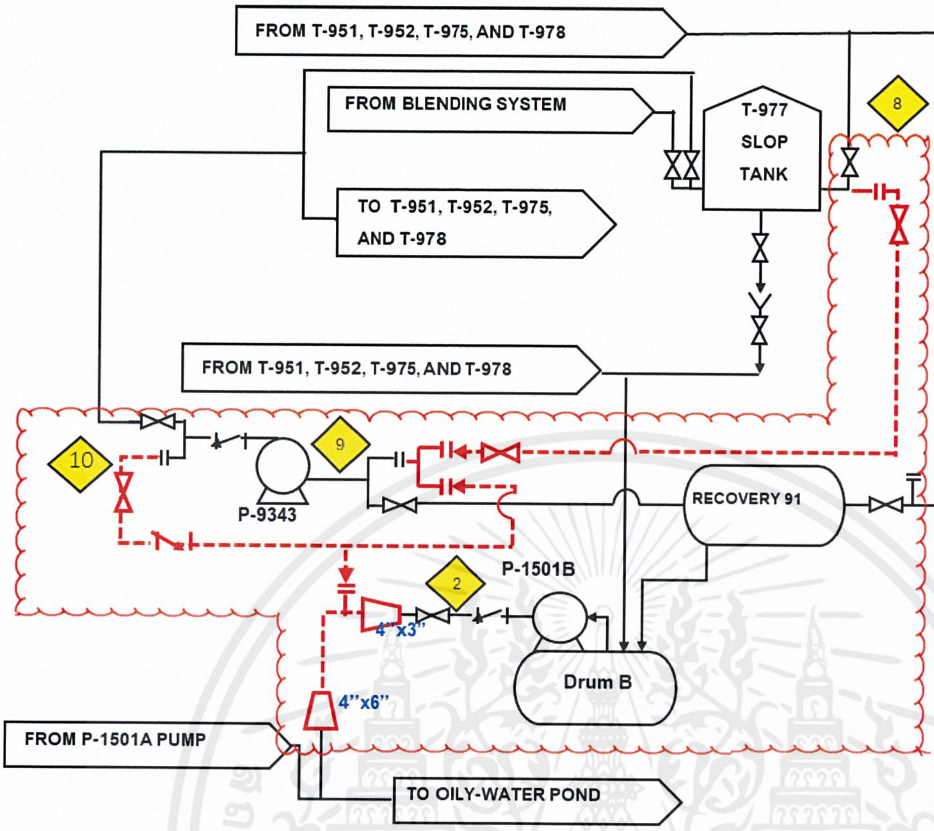


Figure 4.3 Design of the new pipeline in case of draining oil-water phase of GB-91

4.2 Calculated Results of the Fluid Velocity and Pressure Drop in Motor Gasoline Recovery

The fluid velocities in the new pipeline are calculated by continuity equation for incompressible flow and the pressure drop are calculated by energy equation.

4.2.1 Calculated results of fluid velocities and pressure drop in case of GB quality control sampling.

In the calculation, the distance used for calculation is 1.5 times of the distance in the plot plan to be safety factor in the piping system. The distance according to the Figure 4.4 is from P-1501A pump to T-935B slop oil tank and Figure 4.5 is from P-1501B pump to T-935B slop oil tank.

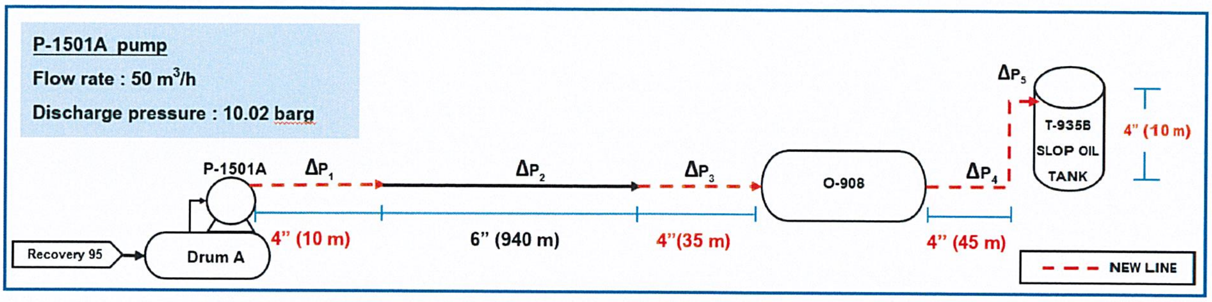


Figure 4.4 Distance from P-1501A pump to T-935B slop oil tank

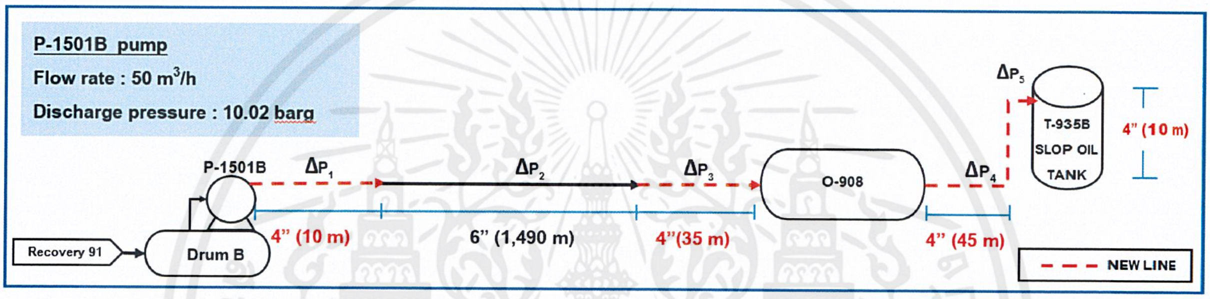


Figure 4.5 Distance from P-1501B pump to T-935B slop oil tank

Table 4.1. The velocities and pressure drop of GB from P-1501A and P-1501B pumps to T-935B slop oil tank

	Flow rate (m^3/h)	Velocity in new pipelines (m/s)	Discharge pressure (barg)	Pressure drop (bar)						The inlet pressure at T-935B (barg)
				ΔP_1	ΔP_2	ΔP_3	ΔP_4	ΔP_5	Total	
P-1501A to T-935B	50	1.7	10.02	0.03	0.31	0.09	0.11	1.00	1.54	8.48
P-1501B to T-935B	50	1.7	10.02	0.03	0.49	0.09	0.11	1.00	1.72	8.30

From Table 4.1 shows that the velocities of GB in the new pipelines are 1.7 m/s. They are less than 2.4 m/s, according to Rule of Thumb for Chemical Engineers. The inlet pressure at T-935B slop oil tank are 8.48 and 8.30 barg greater than pressure inside (0 barg). Thus, discharge pressure of P-1501A and P-1501B pumps are high enough to deliver GB to T-935B slop oil tank.

4.2.2 Calculated results of fluid velocities and pressure drop in case of draining oil-water phase

In the calculation, the distance used for calculation is 1.5 times of the distance in the plot plan to be safety factor in the piping system. The distance according to the Figure 4.6 is from P-9341 pump to the oily-water pond and Figure 4.7 is from P-9343 pump to the oily-water pond.

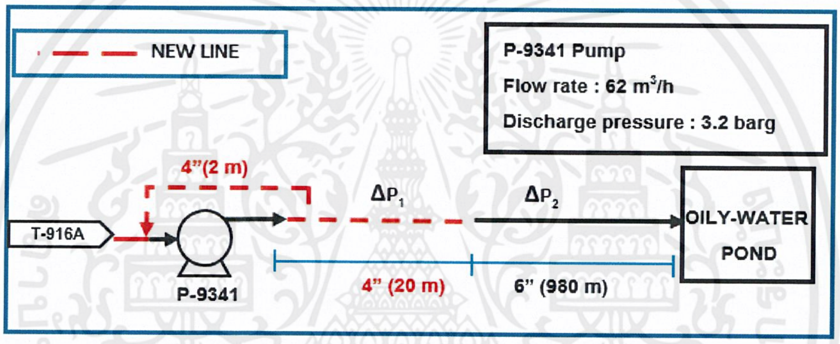


Figure 4.6 Distance from P-9341 pump to the oily-water pond

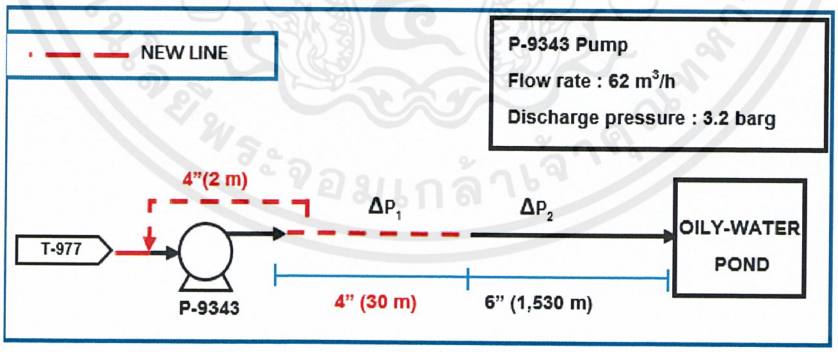


Figure 4.7 Distance from P-9343 pump to the oily-water pond

Table 4.2. The velocities and pressure drop of oil-water phase from P-9341 and P-9343 pumps to the oily-water pond

	Flow rate (m^3/h)	Velocity in new pipeline (m/s)	Discharge pressure (barg)	Pressure drop (bar)			The intel pressure at oily-water pond (barg)
				ΔP_1	ΔP_2	Total	
P-9341 to oil-water pond	31	1.0	3.2	0.02	0.08	0.10	3.10
P-9343 to oil-water pond	31	1.0	3.2	0.03	0.21	0.24	2.96

From Table 4.2 shows that the velocities of oil-water in the new pipes are 1.0 m/s. They are less than 2.4 m/s, according to Rule of Thumb for Chemical Engineers. The inlet pressure at oily-water pond are 3.05 and 2.96 barg greater than pressure inside (0 barg). Thus, discharge pressure of P-9341 and P-9343 pumps are high enough to drain oil-water to the oily-water pond.

4.3 Calculated Results of the Available Net Positive Suction Head ($NPSH_A$) in Motor gasoline recovery

In case of draining oil-water phase, the available net positive suction head needs to be calculated as new pipes are installed into the suction of pumps. The $NPSH_A$ will be calculated from the bottom of the T-916A slop tank to the suction of P-9341 pump and the bottom of the T-977 slop tank to the suction of P-9343 pump are calculated using the distance used for calculation is 1.5 times of the distance in the plot plan to be safety factor in the piping system. The distance according to the Figure 4.8 is from bottom of T-916A slop tank to suction of P-9341 pump and the Figure 4.9 is from bottom of T-977 slop tank to suction of P-9343 pump.

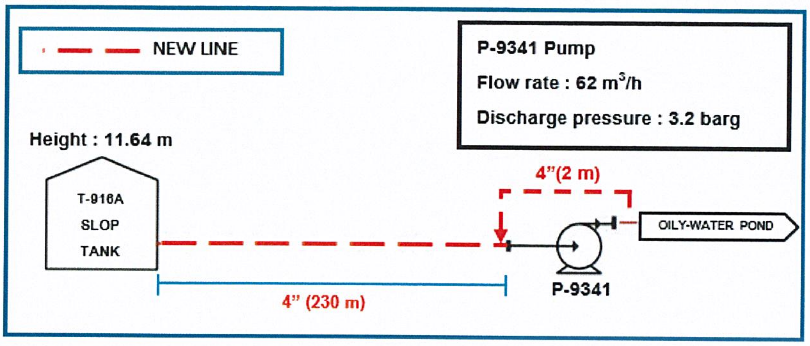


Figure 4.8 Distance from bottom of T-916A slop tank to suction of P-9343 pump

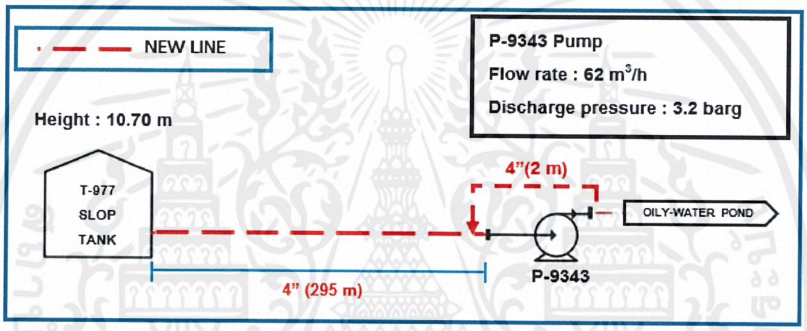


Figure 4.9 Distance from bottom of T-977 slop tank to suction of P-9343 pump

Table 4.3. The $NPSH_A$ from T-916A and T-977 slop tanks to suction of P-9341 and P-9343 pumps

	Flow rate (m^3/h)	**Velocity (m/s)**	**Absolute pressure on the fluid (m)**	**Static suction pressure (m)**	**Vapor pressure of the fluid (m)**	**Friction losses in the suction pipeline (m)**	**$NPSH_A$ (m)**	**$NPSH_R$ (m)**
T-916A to suction of P-9341 pump	31	1.0	1.01	0.16	0.06	0.24	0.87	0.29
T-977 to suction of P-9343 pump	31	1.0	1.01	0.11	0.06	0.30	0.76	0.29

From Table 4.3, found that $NPSH_A$ from the bottom of the T-916A slop tank to the suction of P-9341 pump is 0.87 m and the T-977 slop tank to the suction of P-9343 pump is 0.76 m which $NPSH_A$ are greater than $NPSH_R$, so no cavitation in the pumps.

Project II Installation of Coalescers to Separate Small Particles and Water from Jet Fuel

4.4 Design of the Pipelines for the Coalescer Jet Fuel

4.4.1 Point 1: Discharge of P-975 pump, straight pipeline is changed to tee way pipe and connect into the new coalescers as shown in Figure 4.10.

4.4.2 Point 2: Valve JP-16 and JP-17, 8-inch diameter pipe is installed from JP-16 valve to the new coalescers, combined with line from P-975 pump as shown in Figure 4.10.

4.4.3 Point 3: Tie in line, outlet line of the new coalescers are tied in with line of discharge pump of P-977 at JP-17 valve as shown in Figure 4.10.

4.4.4 Point 4: The new coalescers are installed, the outlet line of the new coalescers are tied in with point 3 and slop is installed as shown in Figure 4.10.

4.4.5 Point 5: Drain line is installed from the slop to point 5 (Suction of P-112B pump) as shown in Figure 4.10.

4.4.6 Point 6 and Point 7: 6-inch gate valve are installed as shown in Figure 4.10.

4.4.7 Point 8: Transfer Line, 4-inch gate valve, and 8-inch diameter pipe are installed to transfer from major group tanks to coalescers as shown in Figure 4.10.

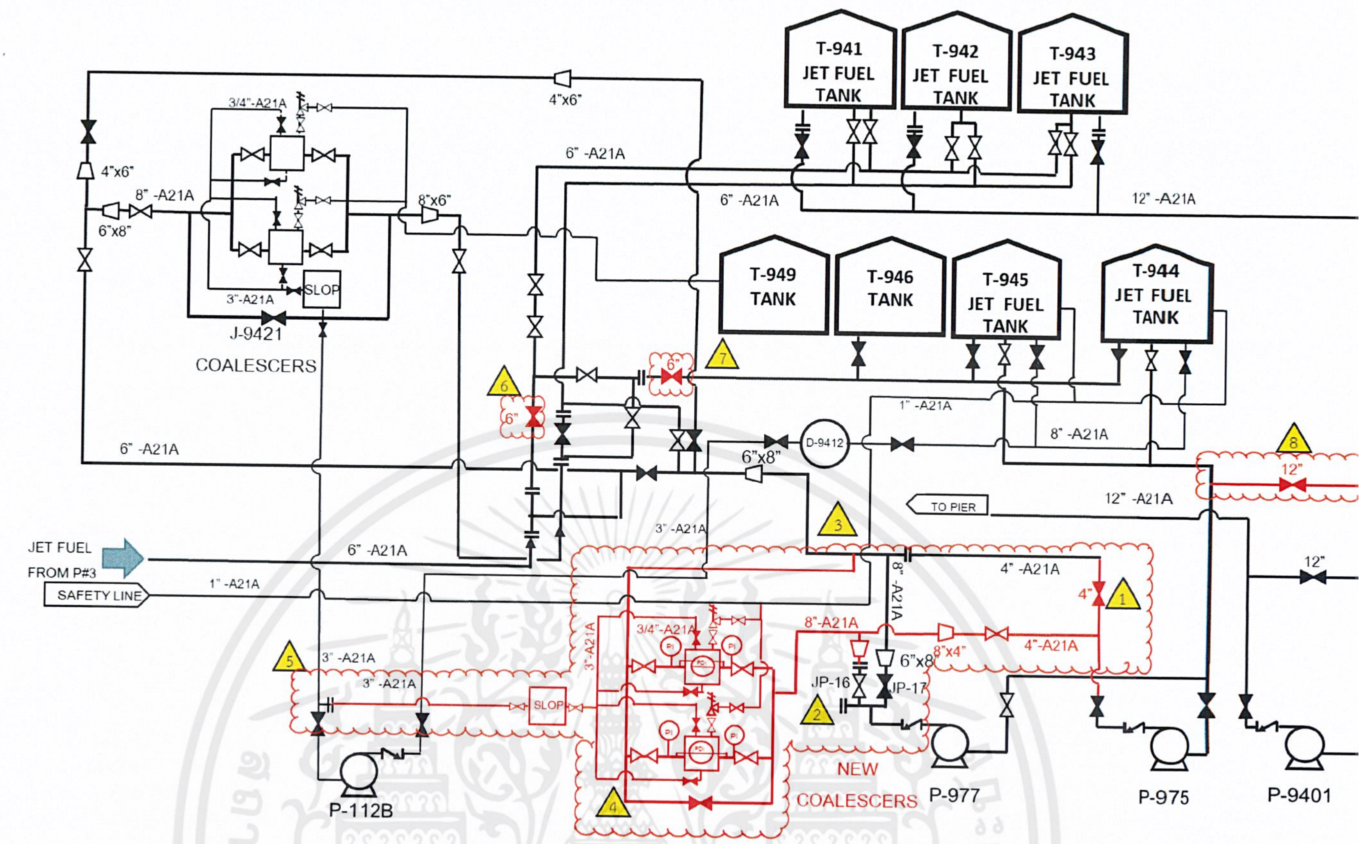


Figure 4.10 Design of the new coalesces and pipelines in coalescers jet fuel

4.5 Design of the New Coalescers

The new coalescers are designed according to the current coalescers with air eliminator, pressure safety valve and drain line as shown in Figure 4.11 and 4.12.

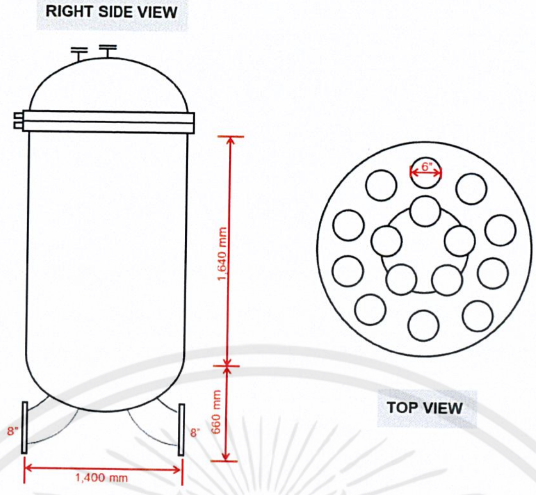


Figure 4.11 Design of new coalescer

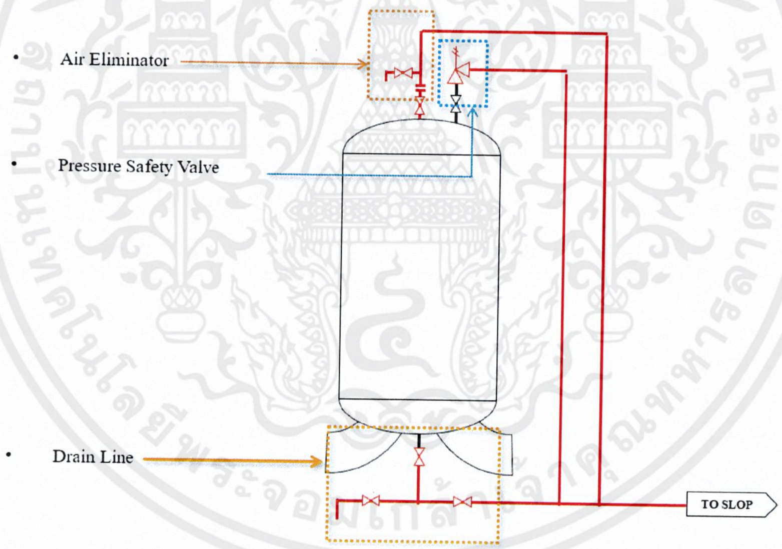


Figure 4.12 Equipment installed on new coalescer

4.6 Design of the Slop

The slop is designed according to the slop currently available in Figure 4.13.

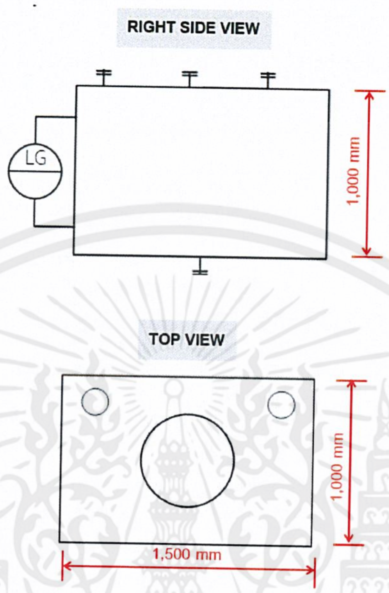


Figure 4.13 Design of slop

4.7 Calculated Results of Fluid Velocities and Pressure Drop in Coalescer Jet Fuel

4.7.1 Calculated results of velocity and pressure drop of jet fuel from P-977 pump to T-943 tank.

The velocity and pressure drop are calculated from the P-977 pump to T-943 tank because it has the most distance and the distance used for calculation is 1.5 times of the distance in the plot plan to be safety factor in the piping system. The distance according to the Figure 4.14 is from P-977 pump to T-943 tank.

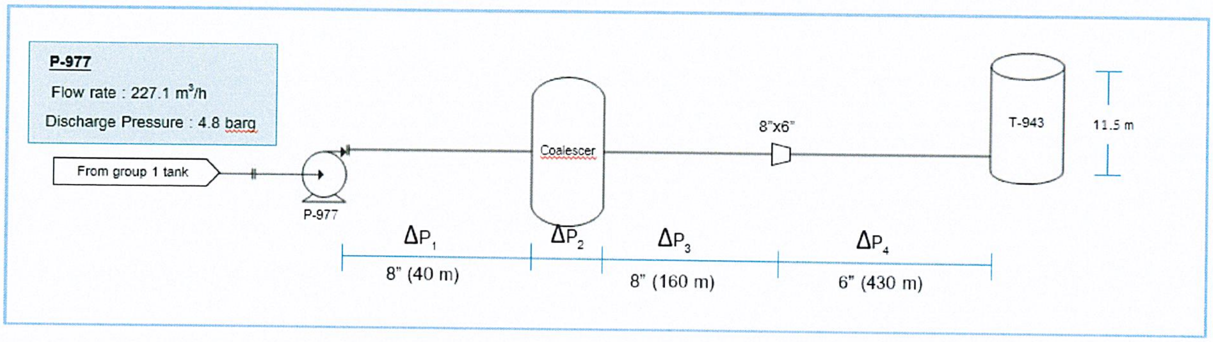


Figure 4.14 Distance from P-977 pump to T-943 tank

Table 4.4. The velocity and pressure drop of jet fuel from P-977 pump to T-943 tank

	Flow rate (m^3/h)	Velocity in new pipeline (m/s)	Discharge pressure (barg)	Pressure drop (bar)					The inlet pressure at T-943 (barg)
				ΔP_1	ΔP_2	ΔP_3	ΔP_4	Total	
P-977 to T-943	227.1	2.0	4.8	0.05	1.03	0.21	2.2	3.49	1.31

From Table 4.4 shows the velocity of jet fuel in 8-inch diameter pipe is 2.0 m/s less than 2.4 m/s, according to rule of thumb for chemical engineers and the inlet pressure of the T-943 tank is 1.31 barg greater than the max level pressure is 0.9 barg. Therefore, the discharge pressure of P-977 pump is high enough to transfer jet fuel to the T-941, T-942, and 943 tanks.

4.7.2 Calculated results of velocity and pressure drop of jet fuel from P-975 pump to T-943 tank.

The velocity and pressure drop are calculated from P-975 pump to T-943 tank because it has the most distance and the distance used for calculation is 1.5 times of the distance in the plot plan to be safety factor in the piping system. The distance according to the Figure 4.15 is from P-975 pump to T-943 tank.

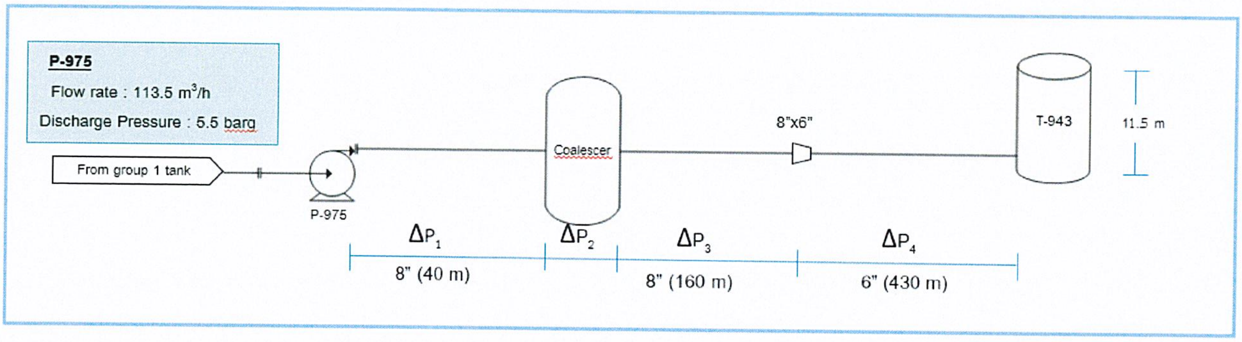


Figure 4.15 Distance from P-975 pump to T-943 tank

Table 4.5. The velocity and pressure drop of jet fuel from P-975 pump to T-943 tank

	Flow rate (m^3/h)	Velocity in new pipeline (m/s)	Discharge pressure (barg)	Pressure drop (bar)					The inlet pressure at T-943 (barg)
				ΔP_1	ΔP_2	ΔP_3	ΔP_4	Total	
P-975 to T-943	113.5	1.0	5.5	0.01	1.03	0.06	0.60	1.70	3.80

From Table 4.5 shows that the velocity of jet fuel in 8-inch diameter pipe is 1.0 m/s less than 2.4 m/s, according to rule of thumb for chemical engineers and the inlet pressure of the T-943 tank is 3.80 barg greater than the max level pressure is 0.9 barg. Therefore, the discharge pressure of P-975 pump is high enough to transfer jet fuel to the T-941, T-942, and 943 tanks.

4.8 Calculated Results the Available Net Positive Suction Head in Coalescer Jet Fuel

The available net positive suction head needs to be calculated as new pipelines are installed into the suction of pumps. The $NPSH_A$ will be calculated from the slop to suction of P-122B pump is calculated using the distance used for calculation is 1.5 times of the distance in the plot plan to be safety factor in the piping system.

Table 4.6. The $NPSH_A$ of jet fuel from the slop to suction of P-122B pump

	Flow rate (m^3/h)	Velocity (m/s)	Absolute pressure on the fluid (m)	Static suction pressure (m)	Vapor pressure of the fluid (m)	Friction losses in the suction pipeline (m)	$NPSH_A$ (m)	$NPSH_R$ (m)
Slop to suction of P-122B pump	9.7	0.60	10.39	0.10	0.09	0.27	10.13	3.30

From Table 4.6, found that $NPSH_A$ from slop to suction of P-122B pump is 10.13 m which $NPSH_A$ is greater than $NPSH_R$, so no cavitation in the pumps.

Project III Installation of ESV at Crude Oil Storage Tanks

4.9 The Results of Safety Instrumented System at Crude Storage Tanks

Instruments are installed, it consists of sensing element is level indicator, logic solver is level indicator alarm and final element is emergency shutdown valve.

Level indicator will measure level of crude in the storage tank and sent signal to level transmitter. Level transmitter will convert the signal into an electrical signal and sent electrical signal to level indicator alarm. Level indicator alarm is set point to 90% of the maximum capacity of crude storage tank. LIA will receive the electrical signal from LT and compare it with the setting point. If the signal equals the setting point, LIA will send digital signal to ESV. ESV will be shut off to prevent tank overfilling.

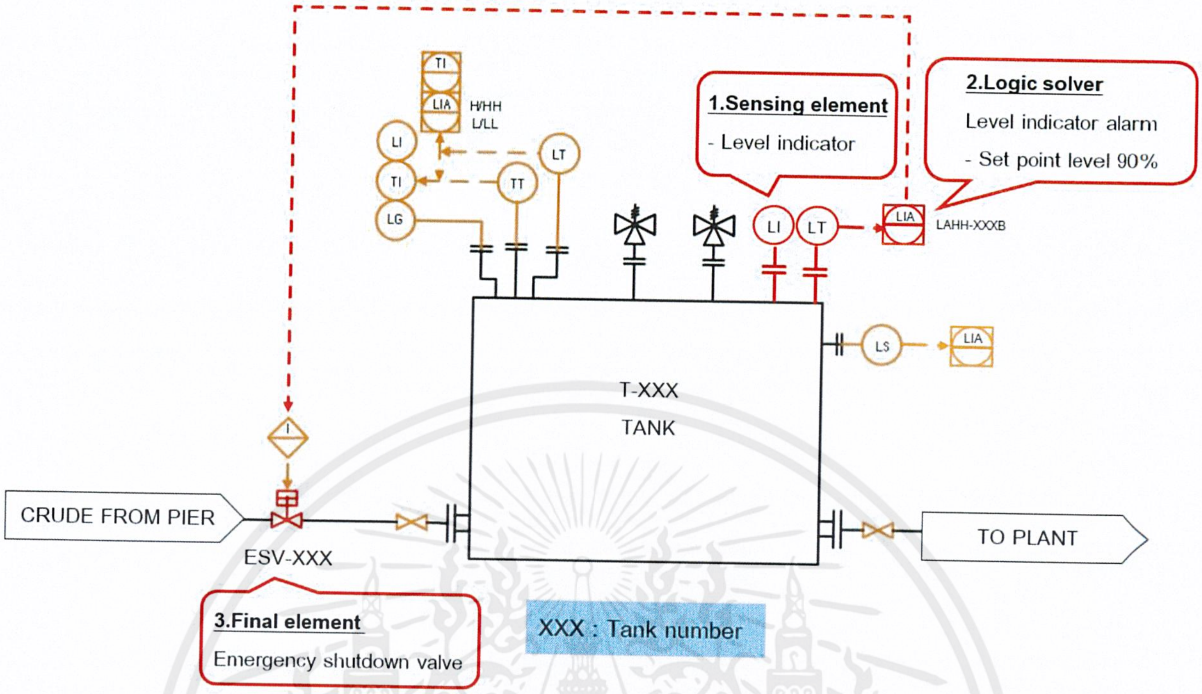


Figure 4.16 Simplified diagram of developed safeguarding system of crude storage tanks.

4.10 The Results of Alarm Setting of Automatic Tank Gauging (ATG)

Table 4.7 Alarm setting of automatic tank gauging (ATG)

Equipment	H Alarm* (89%) (mm)	HH Alarm * (89.5%) (mm)	HH Alarm ** (90%) (mm)
T-964	12,691	12,763	12,834
T-965	12,772	12,843	12,915
T-966	12,798	12,870	12,942
T-983	12,789	12,861	12,933
T-984	15,005	15,090	15,174
T-985	15,059	15,143	15,228
T-986	14,988	15,072	15,156
T-987	14,952	15,036	15,120
T-988	14,925	15,009	15,093

H Alarm*: High alarm setting of existing level indicator alarm.

HH Alarm*: High high alarm setting of existing level indicator alarm.

HH Alarm**: High high alarm setting of new level indicator alarm.

From Table 4.7 shows the alarm setting of automatic tank gauging (ATG). T-964, T-965, T-966, T-983, T-984, T-985, T-986, and T-987 tank are crude storage tanks that type of storage tanks are internal floating-roof tank. Crude storage tanks have LIAs, which will be set to high alarm, high high alarm. The high alarm setting of existing level indicator alarm will be set to 89% of the maximum capacity of crude storage tank. The high high alarm setting of existing level indicator alarm will be set to 89.5% of the maximum capacity of crude storage tank. And the high high alarm setting of new level indicator alarm will be set to 90% of the maximum capacity of crude storage tank, according to API 2350.

CHAPTER V
CONCLUSIONS AND SUGGESTIONS

Project I: Modification of a Pipeline in Motor Gasoline Recovery for VOCs Emission Reduction

5.1 Conclusion

Modification of a pipeline for motor gasoline recovery, it can be divided into 2 case. In case of GB quality control sampling, GB quality is controlled. The VOCs emission and workload at the oily-water pond will be reduced by modification the existing pipeline and installation the new pipeline from P-1501A and P-1501B pumps to T-935B slop oil tank. The fluid velocity in the new pipe is 1.7 m /s. It less than 2.4 m/s, according to Rule of Thumb for Chemical Engineers for prevent erosion within the pipeline and discharge pressure of P-1501A and P-1501B are high enough to deliver oil to T-935A/B slop oil tank. In case of draining oil-water phase, time at GB recovery units and manual work at drum A will be reduced by installation the new pipeline from T-916A slop tank passing P-9341 pump to the oily-water pond. Time at GB recovery units and manual work at drum B will be reduced by installation the new pipeline from T-977 slop tank passing P-9343 pump to the oily-water pond. The fluid velocity in the new pipe is 1.0 m/s. It less than 2.4 m/s, according to Rule of Thumb for Chemical Engineers for prevent erosion within the pipeline and discharge pressure of P-9341 and P-9343 are high enough to drain oil-water to oily-water pond and that $NPSH_A$ from the bottom of the T-916A slop tank to the suction of P-9341 pump is 0.87 m and the T-977 slop tank to the suction of P-9343 pump is 0.76 m which $NPSH_A$ are greater than $NPSH_R$, so no cavitation in the pump.

5.2 Suggestion

The level alarm device should be installed to reduce manual work at drums A and B.

Project II Installation of Coalescers to Separate Small Particles and Water from Jet Fuel

5.3 Conclusion

Installation of the coalescer jet fuel, height and diameter inside of coalescer are 1,640 mm and 1,065 mm, respectively. Filters of coalescer are filter coalescer MOD. I-656C5TB and filter separator MOD. SO-633VA5. In case for transfer of jet fuel from minor group tank passing new coalescer to major group tank by P-977 pump, the velocity of jet fuel in 8-inch diameter pipe is 2.0 m /s less than 2.4 m/s for prevent erosion within the pipeline and the inlet pressure of the T-943 tank is 1.31 barg greater than the max level pressure is 0.9 barg. Therefore, the discharge pressure of P-977 pump is enough to transfer jet fuel to the T-941, T-942, and T-943 tanks.

In case for transfer of jet fuel from minor group tank passing new coalescer to major group tank by P-975 pump, the velocity of jet fuel in 8-inch diameter pipe is 1.0 m /s less than 2.4 m/s for prevent erosion within the pipeline and the inlet pressure of the T-943 tank is 3.80 barg greater than the max level pressure is 0.9 barg. Therefore, the discharge pressure of P-975 pump is high enough to transfer jet fuel to the T-941, T-942, and 943 tanks. In addition, $NPSH_A$ from slop to suction of P-122B pump is 10.13 m which $NPSH_A$ is greater than $NPSH_R$, so no cavitation in the pump.

5.4 Suggestion

Some of the existing pipelines that is in use has a higher velocity than 2.4 m/s, it should consider more.

Project III Installation of ESV at Crude Oil Storage Tanks

5.5 Conclusion

From study of installation of SIS at crude storage tanks for overfill of crude storage tank, it was found that instruments are installed, it consists of sensing element is level indicator, logic solver is level indicator alarm and final element is emergency shutdown valve. The high high alarm setting of new level indicator alarm will be set to 90% of the maximum capacity of crude storage tank, according to API 2350 standard.

5.6 Suggestion

The high alarm setting and high high alarm setting of existing level indicator alarm are of similar value, it should consider again.

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พรวิภา คลังสิน, ณฐินี ศรีเนตร, นันทวัฒน์ จรัสโรจน์ธนเดช, ไพบูลย์ ต้นศิริอนุสรณ์, ชำนิ โมสกุล, ทวัญ สุจริตวงศานนท์, และคณะ. 2559. **คู่มือมาตรฐานการออกแบบ การสร้าง การติดตั้ง การใช้งาน การตรวจสอบ และการบำรุงถังเก็บสารเคมีอันตราย (Storage tank) ประเภทสารไวไฟ**. สำนักงานเทคโนโลยีความปลอดภัย กรมโรงงานอุตสาหกรรม

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APPENDIX

APPENDIX A
Raw Data

Appendix A shows the information used as a basis or used to the reference of calculating the desired values, divided into 2 parts according to the content of project.

Table A.1 Fluid characteristics data of water [Cengel and Boles, 2015]

Type	Water
Phase	Liquid
Temperature (°C)	35
Density (kg/m^3)	994
Viscosity (Pa·s)	0.00077
Vapor pressure (kPa)	5.62

Table A.2 Fluid characteristics data of GB [Bangchak Corporation Public Co., LTD, 2018]

Type	Base gasoline
Phase	Liquid
Temperature (°C)	35
Density (kg/m^3)	682
Viscosity (Pa·s)	0.44
Vapor pressure (kPa)	54.5

Table A.3 Fluid characteristics data of jet fuel [Bangchak Corporation Public Co., LTD, 2018]

Type	Jet fuel
Phase	Liquid
Temperature (°C)	30
Density (kg/m^3)	803
Viscosity (Pa·s)	0.00064
Vapor pressure (kPa)	0.7

Table A.4 Diameter, Wall Thickness, and Relative roughness of Carbon steel - Schedule 40 [ASME B36.10M, 2004]

Carbon steel - Schedule 40				
Diameter (inch)	Outside Diameter)inch(	Inside Diameter)inch(	Wall Thickness)inch(	Relative roughness (mm)
½	0.84	0.622	0.109	$1.9\text{x}10^{-3}$
¾	1.05	0.824	0.113	$1.4\text{x}10^{-3}$
1	1.315	1.049	0.133	$1.1\text{x}10^{-3}$
1 ¼	1.66	1.38	0.14	$8.6\ \text{x}10^{-4}$
1 ½	1.9	1.61	0.145	$7.3\ \text{x}10^{-4}$
2	2.375	2.067	0.154	$5.7\ \text{x}10^{-4}$
2 ½	2.875	2.469	0.203	$4.7\ \text{x}10^{-4}$
3	3.5	3.068	0.216	$3.8\ \text{x}10^{-4}$
4	4.5	4.026	0.237	$2.9\ \text{x}10^{-4}$
5	5.563	5.047	0.258	$2.3\ \text{x}10^{-4}$
6	6.625	6.065	0.28	$1.9\ \text{x}10^{-4}$
8	8.625	7.981	0.322	$1.4\ \text{x}10^{-4}$
10	10.75	10.02	0.365	$1.1\ \text{x}10^{-4}$

Diameter)inch(	Outside Diameter)inch(	Inside Diameter)inch(	Wall Thickness)inch(	Relative roughness (mm)
12	12.75	11.938	0.406	9.9×10^{-5}
14	14	13.124	0.437	9.0×10^{-5}
16	16	15	0.5	7.9×10^{-5}

Table A.5 The maximum capacity of crude storage tank [Bangchak Corporation Public Co., LTD, 2018]

Equipment	MAX Level (mm)
T-964	14,260
T-965	14,350
T-966	14,380
T-983	14,370
T-984	16,860
T-985	16,920
T-986	16,840
T-987	16,800
T-988	16,770

APPENDIX B

Example of Calculation of Fluid Velocity and Pressure Drop

Appendix B shows example of calculation for velocity and pressure drop of oily-water from P-9341 to the oily-water pond. Calculation data from Appendix A and Figure 4.6.

Part I Calculation of section 1

- **Find surface area of pipe**

Inside diameter of 4-carbon steel is 4.026 in (0.102 m) from Table A.3

$$A = \frac{\pi D^2}{4} \qquad (2\text{-}2)$$

$$A = \frac{\pi (0.102)^2}{4} \quad \text{m}^2$$

$$A = 8.17\times10^{-3} \quad \text{m}^2$$

- **Find velocity of fluid in pipe**

From Equation 2-1

$$Q = vA \qquad (2\text{-}1)$$

where

Q = 31 m^3/h (0.0086 m^3/s)

A = $8.17\times10^{-3}\,\text{m}^2$

0.0086 m^3/s = $v(8.17\times10^{-3}\,\text{m}^2)$

v = 1.0 m/s

- **Find Reynolds number**

From Equation 2-3

$$\text{Re} = \frac{\rho v D}{\mu} \qquad (2\text{-}3)$$

where

v = 1.0 m/s

ρ = 994 kg/m^3

D = 0.102 m

μ = 0.77 Pa·s

$$\text{Re} = \frac{(994)(1.0)(0.102)}{0.77}$$

$$\text{Re} = 138{,}477$$

- **Find friction factor (*f*)**

From Equation 2-4

$$\frac{1}{\sqrt{f}} = -1.81\log\left[\left(\frac{\varepsilon/D}{3.7}\right)^{1.11} + \frac{6.9}{\text{Re}}\right] \qquad (2\text{-}4)$$

where

Re = 138,477

D = 0.102 m

ε = 2.9 x 10^{-7} m

$$\frac{1}{\sqrt{f}} = -1.81\log\left[\left(\frac{2.9\times10^{-7}/0.102}{3.7}\right)^{1.11} + \frac{6.9}{138477}\right]$$

$$f = 0.0168$$

- **Find the head losses (h_L)**

From Equation 2-8

$$h_L = \frac{v^2}{2g}\left[\frac{fL}{D}\right] \qquad (2\text{-}8)$$

where

f = 0.0168

L = 20 m

D = 0.102 m

v = 1.0 m/s

g = 9.81 (m/s^2)

$$h_L = \frac{(1.0)^2}{2(9.81)}\left[\frac{(0.0168)(20)}{0.102}\right] \text{ m}$$

$$h_L = 0.1848 \quad \text{m}$$

- **Find pressure drop (ΔP)**

  From Equation 2-9

$$\frac{v_1^2 - v_2^2}{2g} + \frac{P_1 - P_2}{\rho g} + Z_1 - Z_2 = h_L \qquad (2\text{-}9)$$

Assumptions

1. $Z_1 = Z_2 = 0$; Ground level
2. $v_2 >> v_1$; $v_1 = 0$

$$-\frac{v_2^2}{2g} + \frac{P_1 - P_2}{\rho g} = h_L$$

$$\therefore \frac{\Delta P}{\rho g} = h_L + \frac{v_2^2}{2g}$$

where

h_L = 0.1848m

v_2 = 1.0 m/s

ρ = 994 kg/m^3

g = 9.81 m/s^2

$$\frac{\Delta P}{(994)(9.81)} = 0.1848 + \frac{(1.0)^2}{2(9.81)}$$

$$\Delta P = 1802 \text{ Pa } (0.02 \text{ bar})$$

Part II Calculation of section 2

- **Find surface area of pipe**

Inside diameter of 6-carbon steel is 6.625 in (0.168m) from Table A.3

$$A = \frac{\pi D^2}{4} \tag{2-2}$$

$$A = \frac{\pi (0.168)^2}{4} \text{ m}^2$$

$$A = 0.022 \text{ m}^2$$

- **Find velocity of fluid in pipe**

From Equation 2-1

$$Q = vA \tag{2-1}$$

where

Q = 31 m^3/h (0.0086 m^3/s)

A = 0.022 m^2

$$\therefore 0.0086 = v(0.022)$$

$$v = 0.39 \text{ m/s}$$

- **Find Reynolds number**

From Equation 2-3

$$\text{Re} = \frac{\rho v D}{\mu} \tag{2-3}$$

where

v = 0.39 m/s

ρ = 994 kg/m^3

D = 0.168 m

μ = 0.77 Pa·s

$$\text{Re} = \frac{(994)(0.39)(0.168)}{0.77}$$

$$\text{Re} = 84{,}152$$

- **Find friction factor (*f*)**

From Equation 2-4

$$\frac{1}{\sqrt{f}} = -1.81\log\left[\left(\frac{\varepsilon/D}{3.7}\right)^{1.11} + \frac{6.9}{\text{Re}}\right] \qquad (2\text{-}4)$$

where

Re = 84,152

D = 0.168 m

ε = 2.9 x 10^{-7} m

$$\frac{1}{\sqrt{f}} = -1.81\log\left[\left(\frac{2.9\times10^{-7}/0.168}{3.7}\right)^{1.11} + \frac{6.9}{84.152}\right]$$

$$f = 0.0147$$

- **Find the head losses (h_L)**

From Equation 2-8

$$h_L = \frac{v^2}{2g}\left[\frac{fL}{D}\right] \qquad (2\text{-}8)$$

where

f = 0.0147

L = 980 m

D = 0.168 m

v = 0.39 m/s

g = 9.81 (m/s²)

$$h_L = \frac{(0.39)^2}{2(9.81)}\left[\frac{(0.0147)(980)}{0.168}\right] \quad \text{m}$$

$$h_L = 0.6543 \quad \text{m}$$

- **Find pressure drop (ΔP)**

  From Equation 2-9

$$\frac{v_1^{\,2} - v_2^{\,2}}{2g} + \frac{P_1 - P_2}{\rho g} + Z_1 - Z_2 = h_L \qquad (2\text{-}9)$$

Assumptions

1. $Z_1 = Z_2 = 0$; Ground level
2. $v_2 >> v_1$; $v_1 = 0$

$$-\frac{v_2^{\,2}}{2g} + \frac{P_1 - P_2}{\rho g} = h_L$$

$$\therefore \frac{\Delta P}{\rho g} = h_L + \frac{v_2^{\,2}}{2g}$$

where

h_L = 0. 6543 m

v_2 = 0.39 m/s

ρ = 994 kg/m³

$g \quad = \quad 9.81\ m/s^2$

$$\frac{\Delta P}{(994)(9.81)} = 0.6543 + \frac{(0.39)^2}{2(9.81)}$$

ΔP = 8108 Pa (0.08 bar)

Total pressure drop: $\Delta P_T = \Delta P_{S1} + \Delta P_{S2}$

$\Delta P_T = 0.02 + 0.08$ bar

$\Delta P_T = 0.10$ bar

Pressure at inlet T-935B = Pressure at discharge of P-9343 pump - Total pressure drop

= 3.2 – 0.1 bar

= 3.1 bar

APPENDIX C

Example of Calculation for The Available Net Positive Suction Head

Appendix C shows example of calculation for the $NPSH_A$ of T-916A tank to suction of P-9341 pump. Calculation data from Appendix A and Figure 4.8.

- **Find surface area of pipe**

Inside diameter of 4-carbon steel is 4.026 in (0.102 m) from Table A.3

$$A = \frac{\pi D^2}{4} \qquad (2\text{-}2)$$

$$A = \frac{\pi (0.102)^2}{4} \quad m^2$$

$$A = 8.17 \times 10^{-3} \quad m^2$$

- **Find velocity of fluid in pipe**

From Equation 2-1

$$Q = vA \qquad (2\text{-}1)$$

where

Q = 31 m^3/h (0.0086 m^3/s)

A = 8.17×10^{-3} m^2

$$\therefore 0.0086 = v(0.00817)$$

$$v = 1.0 \text{ m/s}$$

- **Find Reynolds number**

From Equation 2-3

$$\text{Re} = \frac{\rho v D}{\mu} \qquad (2\text{-}3)$$

where

ν = 1.0 m/s

ρ = 994 kg/m^3

D = 0.102 m

μ = 0.77 Pa·s

$$\mathrm{Re} = \frac{(994)(1.0)(0.102)}{0.77}$$

$$\mathrm{Re} = 138{,}477$$

- **Find friction factor (*f*)**

From Equation 2-4

$$\frac{1}{\sqrt{f}} = -1.81\log\left[\left(\frac{\varepsilon/D}{3.7}\right)^{1.11} + \frac{6.9}{\mathrm{Re}}\right] \qquad (2\text{-}4)$$

where

Re = 138,477

D = 0.102 m

ε = 2.9 x10^{-7} m

$$\frac{1}{\sqrt{f}} = -1.81\log\left[\left(\frac{2.9\times10^{-7}/0.102}{3.7}\right)^{1.11} + \frac{6.9}{138477}\right]$$

$$f = 0.0168$$

- **Find the head losses (h_L)**

From Equation 2-8

$$h_L = \frac{v^2}{2g}\left[\frac{fL}{D}\right] \qquad (2\text{-}8)$$

where

f = 0.0168

L = 295 m

D = 0.102 m

v = 1.0 m/s

g = 9.81 (m/s²)

$$h_L = \frac{(1.0)^2}{2(9.81)}\left[\frac{(0.0168)(295)}{0.102}\right] \quad \text{m}$$

$$h_L = 0.24 \quad \text{m}$$

- **Find NPSH$_A$**

  From Equation 2-10

$$\frac{v_1^{\ 2} - v_2^{\ 2}}{2g} + \frac{P_1 - P_2}{\rho g} + Z_1 - Z_2 = h_L \qquad (2\text{-}10)$$

where

P_{atm} = 101,325 Pa

h_L = 0.24 m

Z_1 = 9.63 m

P_v = 5,620 Pa

$$NPSH_A = \frac{101{,}325}{(994)(9.81)} + 9.63 - \frac{5{,}620}{(994)(9.81)} - 0.24 \ \text{m}$$

$$NPSH_A = 0.87 \ \text{m}$$

APPENDIX D

Cost Estimation of Modification a Pipeline in Motor Gasoline Recovery for VOCs Emission Reduction

Table D.1 Cost estimation of Project I by Engineering Service Division

No.	Descriptions	Total (Baht)
Design & documents		
1	Detail design	25,000
2	Other analysis	50,000
3	Documents and drawings	25,000
Piping		
4	Materials	780,000
5	Welding and installation	1,570,000
6	Non-Destructive Examination (NDE)	70,000
7	Hydrostatic test & flushing	191,000
8	Coating	163,000
9	Insulation	-
10	Pipe support	500,000
11	Scaffolding	16,000
12	Contingency 15%	510,000
Grand Total		**3,900,000**

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