BACHELOR THESIS & COLLOQUIUM – ME-141502

Technical and Economical Analysis as the Use Of PVC Pipe On Domestic System as an Alternative Material Component To Galvanized Steel Pipe

Name : Angya Prambiksono
NRP : 4213 101 034

Supervisor:
1st Supervisor: Ir. Hari Prastowo, M.Sc.
2nd Supervisor: Ir. Dwi Priyanta, M.SE.

DEPARTMENT OF MARINE ENGINEERING
FACULTY OF MARINE TECHNOLOGY
INSTITUT TEKNOLOGI SEPULUH NOPEMBER
SURABAYA
2017

BACHELOR THESIS & COLLOQUIUM – ME-141502

Analisa Teknis dan Ekonomis Penggunaan Pipa PVC Pada Domestik Sistem Sebagai Komponen Material Alternatif Pengganti Pipa Baja Galvanis

Name : Angya Prambiksono
NRP : 4213 101 034

Supervisor:
1st Supervisor: Ir. Hari Prastowo, M.Sc.
2nd Supervisor: Ir. Dwi Priyanta, M.SE.

DEPARTMENT OF MARINE ENGINEERING
FACULTY OF MARINE TECHNOLOGY
INSTITUT TEKNOLOGI SEPULUH NOPEMBER
SURABAYA
2017

APPROVAL FORM

Technical and Economical Analysis as the Use Of PVC Pipe On Domestic System as an Alternative Material Component To Galvanized Steel Pipe

BACHELOR THESIS

Submitted to Comply One of The Requirement to Obtain a Bachelor of Engineering Degree
on
Laboratory of Marine Machinery & System (MMS)
S-1 Program Department of Marine Engineering
Faculty of Marine Technology
Institut Teknologi Sepuluh Nopember

Prepared by:
ANGYA PRAMBIKSONO
NRP. 4213 101 034

Acknowledged by Bachelor Thesis Supervisor:

1. **Ir. Hari Prastowo, M.Sc.**
   NIP. 1965 1030 1991 02 1001 (.....)

2. **Ir. Dwi Priyanta, M.SE.**
   NIP. 1968 0703 1994 02 1001 .....

SURABAYA
July , 2017

"This page intentionally left blank"

APPROVAL FORM

Technical and Economical Analysis as the Use Of PVC Pipe On Domestic System as an Alternative Material Component To Galvanized Steel Pipe

BACHELOR THESIS

Submitted to Comply One of The Requirement to Obtain a Bachelor of Engineering Degree
on
Laboratory of Marine Machinery & System (MMS)
S-1 Program Department of Marine Engineering
Faculty of Marine Technology
Institut Teknologi Sepuluh Nopember

Prepared by:
ANGYA PRAMBIKSONO
NRP. 4213 101 034

Approved by
Acknowledged by Head Department of Marine Engineering

( )

Dr.Eng. M. Badruz Zaman, ST. MT.
NIP. 1977 0802 2008 01 1007

"This page intentionally left blank"

APPROVAL FORM

Technical and Economical Analysis as the Use Of PVC Pipe On Domestic System as an Alternative Material Component To Galvanized Steel Pipe

BACHELOR THESIS

Submitted to Comply One of The Requirement to Obtain a Bachelor of Engineering Degree
on
Laboratory of Marine Machinery & System (MMS)
S-1 Program Department of Marine Engineering
Faculty of Marine Technology
Institut Teknologi Sepuluh Nopember

Prepared by:
ANGYA PRAMBIKSONO
NRP. 4213 101 034

Approved by
Representative of Hochschule Wismar in Indonesia

( )

Dr.-Ing. Wolfgang Busse

"This page intentionally left blank"

DECLARATION OF HONOUR

I, Who signed below hereby confirm that:

This final project report has been written without any plagiarism act, and confirmed consciously that all the data's. concepts, design, references, and material this report own by Marine Machinery and System Laboratory (MMS) in department of Marine Engineering ITS which are the product of research study and reserve the right to use of for further research study and its development.

Name : Angya Prambiksono

NRP : 4213 101 034
Bachelor Thesis Title : Technical and Economical Analysis as the Use Of PVC Pipe On Domestic System as an Alternative Material Component To Galvanized Steel Pipe
Department : Double Degree Marine Engineering

If there is plagiarism act in the future, I will fully responsible and receive the penalty given by ITS according to the regulation applied

Surabaya, July 2017

Angya Prambiksono

"

This page intentionally left blank"

Technical and Economical Analysis as the Use Of PVC Pipe On Domestic System as an Alternative Material Component To Galvanized Steel Pipe

Student Name : Angya Prambiksono
NRP : 4213 101 034
Department : Double Degree Marine Engineering
Supervisor : Ir. Hari Prastowo, M.Sc.
-

ABSTRACT

Piping is an important part on the ship. There are many systems that work inside the ship, and the systems is almost entirely in direct contact with the piping. Not all types of pipes that can be used for a system inside the ship, but it must pipe with certain quality standards and has been certified and declared eligible by class or other accredited standards. One system that uses pipes are domestic water system (sanitary system), where Domestic water system is a water distribution system (fresh water) in the vessel used by the crew to meet the needs of drinking water and cooking, for bathing, washing and others. For the needs of the WC (water closed) system used sea water (sea water) is supplied to each deck has a bathroom. Sanitary system becomes important and the main requirement for the daily needs of the crew. Without the sanitary system, it is certain that the vessel would be very uncomfortable for occupancy.

The use of pipe for domestic water systems on ships generally use type cast iron pipe. Due to this type of pipe material characteristics that are well suited to the environmental conditions that existed at the ship, such as resistance to vibration, pressure, and temperature are working on a ship environment. However, the characteristics of the cast iron pipe should be found wanting in the form of the rather expensive price. Thus in this study will be analyzed testing of PVC pipe as the pipe is used as an alternative to domestic water piping system.

Selection of PVC as an alternative material because the material PVC pipe would benefit costs are cheaper, but in use on board, PVC pipes also have to first be able to withstand the pressure, temperature and other characteristics that exist in the vessel. It would require some testing such as test material in PVC pipe. The results of these tests if the PVC proved to be feasible to be used for domestic water system on the vessel then will be analyzed costs, both material costs, operating costs, the cost of installation and maintenance.

The results of technical analysis (testing the strength of materials) and the results of the cost analysis is what will be the final outcome of this study to answer whether the PVC pipe can actually be an alternative for domestic water pipe system on the vessel. Presentation of engineering analysis and economic analysis will be a table or chart the data.

Keywords – ***Ship Sanitary System, Galvanized Steel Pipe, PVC Pipe , Technical Analysis, Economic Analysis.***

Technical and Economical Analysis as the Use Of PVC Pipe On Domestic System as an Alternative Material Component To Galvanized Steel Pipe

Student Name : Angya Prambiksono
NRP : 4213 101 034
Department : Double Degree Marine Engineering
Supervisor : Ir. Hari Prastowo, M.Sc.
-

ABSTRAK

Pipa merupakan bagian penting di kapal. Ada banyak sistem yang bekerja di dalam kapal, dan sistemnya hampir seluruhnya bersentuhan langsung dengan perpipaan. Tidak semua jenis pipa yang bisa digunakan untuk sistem di dalam kapal, tapi harus disambung dengan standar kualitas tertentu dan telah disertifikasi dan dinyatakan layak standar kelas atau terakreditasi lainnya. Salah satu sistem yang menggunakan pipa adalah sistem air dalam negeri (sistem sanitasi), dimana sistem air domestik adalah sistem penyaluran air (air tawar) di kapal yang digunakan oleh awak kapal untuk memenuhi kebutuhan air minum dan memasak, untuk mandi, mencuci dan lain-lain. . Untuk kebutuhan WC (water closed) sistem yang digunakan air laut (sea water) yang dipasok ke masing-masing dek memiliki kamar mandi. Sistem sanitasi menjadi penting dan kebutuhan utama untuk kebutuhan sehari-hari para kru. Tanpa sistem sanitasi, sudah pasti kapal tersebut akan sangat tidak nyaman untuk hunian.

Penggunaan pipa untuk sistem air dalam negeri pada kapal umumnya menggunakan pipa besi cor tipe. Karena karakteristik material pipa jenis ini yang sesuai dengan kondisi lingkungan yang ada di kapal, seperti ketahanan terhadap getaran, tekanan, dan suhu, bekerja pada lingkungan kapal. Namun, karakteristik pipa besi cor harus dicari dalam bentuk harga yang agak mahal. Dengan demikian dalam penelitian ini akan dianalisis pengujian pipa PVC karena pipa tersebut digunakan sebagai alternatif sistem perpipaan air domestik.

Pemilihan PVC sebagai bahan alternatif karena bahan pipa PVC akan menguntungkan biaya yang lebih murah, namun di gunakan di atas kapal, pipa PVC juga harus terlebih dahulu mampu menahan tekanan, suhu dan karakteristik lain yang ada di kapal. Ini akan membutuhkan beberapa pengujian seperti bahan uji di pipa PVC. Hasil pengujian ini jika PVC terbukti layak untuk digunakan untuk sistem air domestik di atas kapal maka akan dianalisis biaya, baik biaya material, biaya operasi, biaya pemasangan dan perawatan.

Hasil analisis teknis (pengujian kekuatan material) dan hasil analisis biaya adalah apa yang akan menjadi hasil akhir penelitian ini untuk menjawab apakah pipa PVC sebenarnya bisa menjadi alternatif sistem pipa air domestik di kapal. Presentasi analisis teknik dan analisis ekonomi akan menjadi tabel atau grafik data.

Keywords – ***Sistem Sanitari Kapal, Pipa Galvanized Steel, Pipa PVC , Analisa Teknis, Analisa Ekonomis***

PREFACE

Praise Allah SWT the Almighty for all the many blessings, who gives intelligent, strength, health and favors for the author to be able to finish this bachelor thesis. Appreciation is also extended to all those who have contributed to and assisted in the writing of this bachelor thesis. Gratitude is given to:

1. Mr. Dr. Eng. M. Badrus Zaman, S.T, MT. as Head Department of Marine Engineering FTK-ITS, Surabaya.

2. Mr. Ir. Dwi Priyanta, MSE as Secretary of Double Degree Marine Engineering Program also as advisor in this bachelor thesis who have a lot to give aid knowledge and preparation of this bachelor thesis.

3. Mr. Ir. Hari Prastowo, M.Sc. as advisor in this bachelor thesis workmanship that has provided meaningful assistance, tireless guidance, patience and motivation.

The author hoped this bachelor thesis is able to contribute to the knowledge, experience for the readers, and information for them to know the benefit that can be an alternative to replace PVC pipe galvanized pipes for domestic water systems on ships.

The thesis author acknowledged that there are deficiencies caused by the lack of experience. Therefore the author expects readers to provide inputs that may be beneficial for this paper contribution.

Surabaya, July 2017

Author

This page intentionally left blank"

TABLE OF CONTENTS

LIST OF FIGURE

This page intentionally left blank"

LIST OF TABLE

CHAPTER 1
INTRODUCTION

1.1. Background

Piping is an essential part on the ship. There are many systems, that operate inside the ship, and the systems have nearly the entire direct contact with the piping. One system that uses pipes is domestic water system (sanitary system). Domestic water system is a water distribution system in the ship. Domestic water systems are used for drinking water, cooking, bathing, washing and other needs. Sanitary system becomes important and this is the main necessity for the daily needs of the crew. Without the sanitary system, it is certain that the vessel would be very uncomfortable for occupancy.

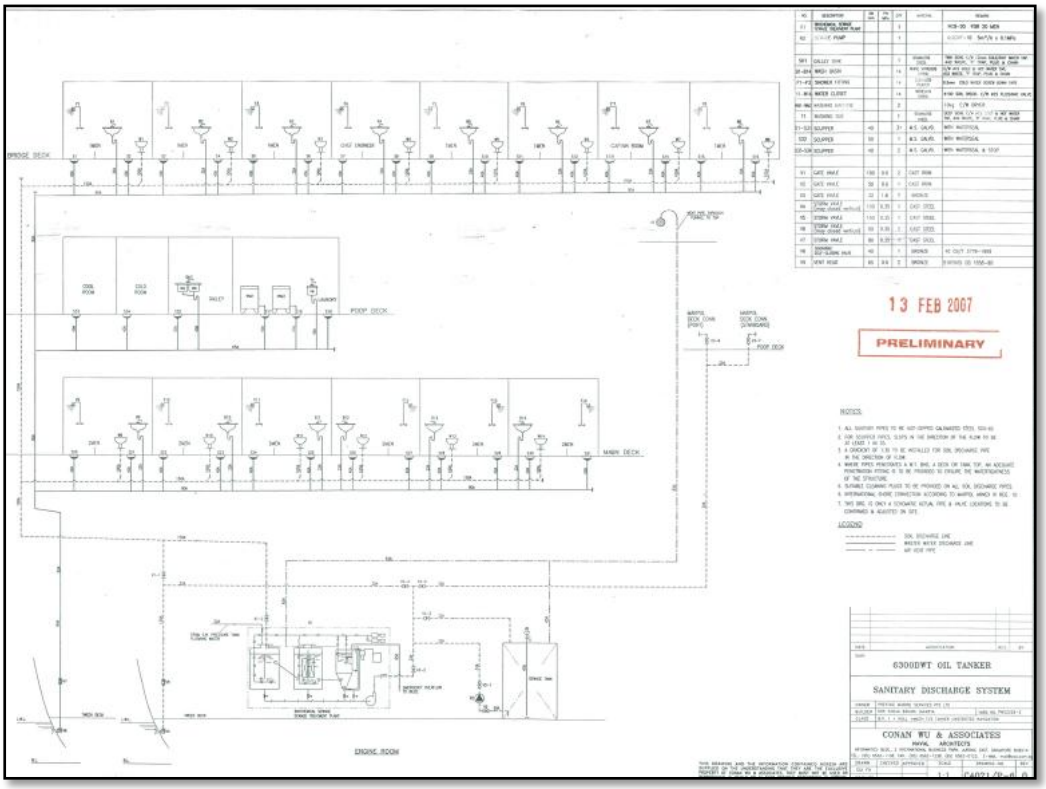


Figure 1.1 Sanitary Discharge Systems[1]

[1] *MT. Vanda*

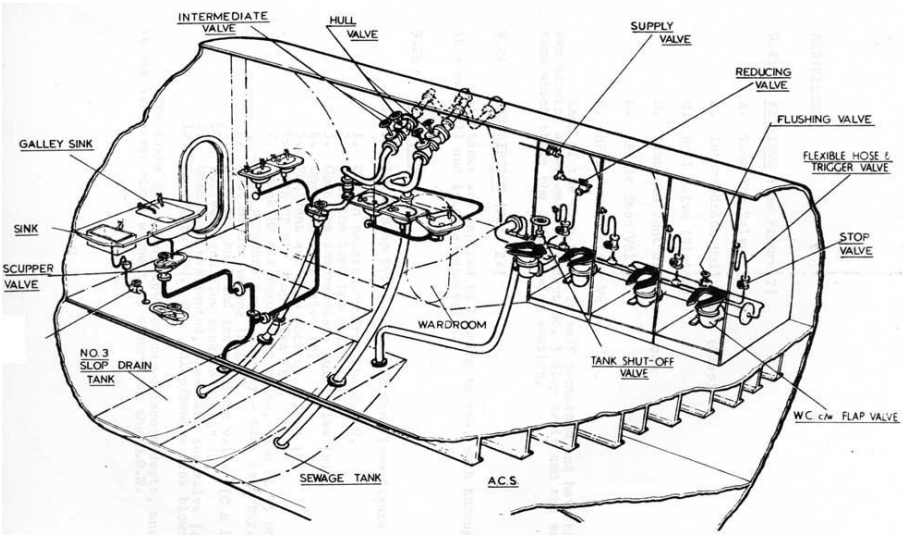


Figure 1.2. Sanitary system In the deck[2]

All types of pipes inside the ship comply to class rules. Every pipe material is classified based on pressure and temperature. The class recommends galvanized pipe. Including the use of sanitary pipes on ships using galvanized pipe. Which Galvanized have excellent material strength. However, the high material strength make galvanized pipe become very expensive. Thus, it also makes the price of shipbuilding to be expensive.

Table 1.1 Classes of piping system[3]

Classes of Piping System						
Piping System For	**Class I[1)]**		**Class II[1)]**		**Class II[1)]**	
	p (bar)	**t (°C)**	**p (bar)**	**t (°C)**	**p (bar)**	**t (°C)**
Steam, thermal oil	> 16	or > 300	≤ 16	and ≤ 300	≤ 7	and ≤ 170
Fuel Oil, lubricating oil, flammable hydraulic oil	> 16	or > 150	≤ 16	and ≤ 150	≤ 7	and ≤ 600
Other media[2)]	> 40	or > 300	≤ 40	and ≤ 300	≤ 16	and ≤ 200

[2] *C.F. 'O' Class Submarines - Miscellaneous Systems and Equipment, describes ten of the systems aboard Oberon class submarines*

[3] *DNV, "RULES FOR CLASSIFICATION OF SHIPS NEWBUILDINGS, MACHINERY AND SYSTEMS, DNV PART 4 CHAPTER 6"*

Table 1.1 Classes of piping system[3]

Classes of Piping System						
Piping System For	**Class I[1)]**		**Class II[1)]**		**Class II[1)]**	
	p (bar)	**t (°C)**	**p (bar)**	**t (°C)**	**p (bar)**	**t (°C)**
p = Design pressure, as defined in Sec.6 A 303 t = Design temperature, as defined in Sec.6 A.304 1) For class II and III piping both specified condition shall be met, for class I piping one condition only is sufficient. 2) Cargo oil pipes on oil carriers and open ended pipes (drain, overflows, vents, boiler escape pipe, etc.) independently of the pressure and temperature, are pertaining to class III. 3) Cargo piping systems for flammable liquids on Offshore Supply Vessels are pertaining to the same pipe class as fuel oil systems. Outside Machinery spaces of Category A. class II piping is sufficient.						

That is why we need an innovation to reduce the cost of shipbuilding. Innovation to replace galvanize pipe with other type of pipe to be used in the sanitary system is possible to help reducing the cost of production and maintenance of the ship. The other types of pipe are PVC as an alternative to galvanized pipes. Although the PVC pipe should also have special specifications for use in the marine industry, the value of the price is be cheaper.

Plastic pipe / PVC pipe can be used for sanitary systems, where sanitary piping may be made of plastic, using plastic welded joints. The use of plastic pipes elsewhere in a system is restricted because of the requirement to pass a standard test for fire-resistance. In addition, it is not needed to use a high pipe specification in the sanitary system, as long as the pipe specification is sufficient with pressure and temperature level that are not too high. In addition, the use of PVC pipe for this alternative is only used for sanitary systems in superstructure. Thus, the use of PVC pipe is considered good for the sanitary system.

1.2. Statement of Problems

Based on the description above the statement problem of this thesis are:

1. Class requires certain pipe materials, which are galvanized or steel pipe.
2. For system that allowed for not using galvanized (e.g using sanitary system for alternative material)?
3. PVC can be used.
4. What kind method to testing PVC pipe?
5. PVC property compares to galvanize.

6. If PVC is applied, any specific concerned?
7. Any modification installation for using PVC?
8. What about the procurement and installation cost of PVC and Galvanized?
9. Has PVC been qualified as an alternative to galvanized?

1.3. Research Limitation

To get the focus of the research, it is required to have several limitations problem. Restrictions of such problems are:

1. The cost analysis which will be involving initial cost (material & installation cost) as well as operation cost (maintenance & repair cost).
2. The focus research is not analyzing the fluid flow in a pipe.
3. Use BKI and DNVGL Class rules.

1.4. Research Objectives

As in the analysis, there will be some objectives, which are:

1. To Analyzing the use of PVC pipe material to be applied to sanitary system in terms of strength and installation onboard.
2. To comparing the PVC pipe (property, system to modify, material strength) to Galvanized.
3. To analyzing the cost of the use of PVC in marine application. The analysis includes the cost of material, installation, maintenance & repair.
4. To analyzing the material and initial cost comparison between the galvanized pipe and PVC pipe.

1.5. Research Benefits

The results of a comparative analysis of the piping cost between PVC pipe and galvanized pipe, and the generated profit that can be utilized by industry, especially the shipbuilding industry. The advantages are:

1. Knowing the cost comparison galvanized pipe with PVC pipe.
2. Knowing the comparative cost of maintenance and operational between galvanized pipe and PVC pipe.

CHAPTER 2
LITERATURE STUDY

2.1. Selecting a Ship

Selection of ships carried out as research objects. Therefore, the sanitary system to be examined comes from a particular ship type. It is intended to facilitate research. In this thesis, the vessel chosen was MV. Sinar Sabang. MV Sinar Sabang is a container ship that has a shipping line route in Singapore - Surabaya, where the ship has a schedule to anchoring on every Saturday and Sunday at the port of Surabaya. MV. Sinar Sabang ship will become the object of the research about sanitary pipe system. MV. Sinar Sabang is chosen because it is under the management of PT. Samudera Indonesia Ship Management, which is this ship gets an excellent treatment, the ship data is still incomplete, and the size of the ship that is eagerly great very exciting to be selected as the object of the research on sanitary system of the ship.

Figure 2.1. MV. Sinar Sabang[1]

[1] *http://www.shipspotting.com/gallery/photo.php?lid=1016303*

Principal dimensions:

- Type : Container
- Name : Sinar Sabang
- Built : 2008
- Flag : Singapore
- Size : 166 x 27 m
- Gross Tonnage : 18321 t
- Draft : 10,9 m
- Deadweight : 23350 t

2.2. Collecting Data

2.2.1. Galvanized Pipe

Galvanized steel or iron is a traditional piping material in the plumbing industry for the conveyance of water and wastewater. The term "galvanizing" once is referred to hot-dipped galvanizing, in other words is a total immersion in molten zinc after pretreatment cleaning. This technology affords a reasonable level of internal and external protection to the metal pipe. The use of galvanized steel or iron as a conduit for drinking water is a greater problem where the water flow is slow or static for periods of time due to rust discoloration caused by internal corrosion.[2]

Figure 2.2. Galvanized Pipe[3]

[2] *who.int/water_sanitation_health/.../plumbing10.pdf*

[3] *http://www.altfab.com/product_groups.asp?productgroup=TC-MPA-03*

Table 2.1. PVC Pipe Properties[4]

PVC Pipe Properties		
Properties	Value	Unit
allowance for corrosion (C)		mm
allowance for manufacturing tolerance (t)		mm
allowance for bending (b)		mm
weld efficiency factor (v)		
design pressure (Pc)		bar
max permissible design stress (σ)		N/mm2
tensile strength (σ_t) (20°C)	515	MPa
Specific Gravity	1,4	g/cm
Elongation (%) (20°)	40	%
Longitudinal Reversion % (150°)	5	%
Dichloromethane Resistance Test (16°C/20 menit)		
Vicat Softening Temperature (° C)		
Hydrostatic Pressure Test, (AW) Pressure resistance 1 min, 2,0 Mpa		
Coefficient of linier expansion	17	mm/m.°K
Thermal conductivity	16.3	W/m.°K
Modulus of elasticity	193	GPa
Surface resistance	720	ohm

2.2.2. PVC (Polyvinyl chloride)

Polyvinyl chloride is a thermoplastics material, which consists of PVC resin compounded with varying proportions of stabilizers, lubricants, fillers, pigments, plasticizers and processing aids. Different compounds of these ingredients have been developed to obtain specific groups of properties for different applications. However, the major part of each compound is PVC resin. The technical terminology for PVC in organic chemistry is poly (vinyl chloride): a polymer i.e. chained molecules of vinyl chloride. The brackets are not used in common literature and the name is commonly abbreviated to PVC. The common terminology is used throughout this publication. Where the discussion refers to a specific type of PVC pipe, that type which it will be explicitly identified as

[4] PVC Wavin

detailed below. Where the discussion is general, the term "PVC pipes" will be used to cover the range of PVC pipe materials in this manual.[5]

Figure 2.3. Marine PVC pipe[6]

Plastic pipe is a tubular section, or hollow cylinder, made of plastic. It is usually, but not necessarily, of circular cross-section, used mainly to convey substances, which can flow — liquids and gases (fluids), slurries, powders and masses of small solids. It can also be used for structural applications; hollow pipes are far stiffer per unit weight than solid members.

Plastic pipe systems fulfill a wide variety of service requirements. These requirements are precisely described in a complete set of European Product Standards for each application alongside their specific characteristics.
For example:

- Conveyance of drinking water: Hygienic requirements
- Conveyance of gas: Highest Safety requirements
- Plastic pipes for radiant heating and floor heating: Temperature resistance over decades
- Sewer applications: High chemical resistance
- Highly-resistant to corrosion, abrasion and chemicals

[5] *(Vinidex Pty Limited, PVC Pressure Pipe & Fittings Technical Manual)*
[6] *Gourg Fischer Piping Systems Broschure*

- Strong, durable, flexible and lightweight
- Longer-length pipe with leak-proof joints
- Lower labor requirements for installations
- Significant overall cost savings
- Long lifetime
- Reliability and safety

The advantage from plastic pipe material, besides installation is much faster, is plastic offers the possibility of pre- fabrication, which radically reduces installation time on board. Plastic enables installations with a small amount of tools in a small amount of space. Technical specialists are not always required. That is another significant benefit. Plastic is also lighter than steel pipes.

Table 2.2. Weight Comparison[7]

Kg	Pipe Diameter			
	D 25	**D 50**	**D 110**	**D 160**
Plastic	*16*	*53*	*248*	*550*
Carbon Steel	*119*	233	*737*	1093
Stainless Steel	79	197	505	*1542*
Copper	59	*292*	*747*	-
Savings Plastic to Steel	*103*	*239*	*489*	*992*

Type of PVC pipe that will be used must be the type of pipe that has been set by the class. On GL rules classification, the use of plastic pipes is arranged in part 1 chapter 2, section 11, where the plastic pipe should be approved for piping systems that included in pipe class III only. The use of plastic pipes should also be qualified based on to their fire endurance that it has to be classified at level 1 to level 3. Fire endurance level is a dry piping that have been passed the test for a minimum duration without loss of integrity. Level 1 is one hour long, level 2 is 30 minutes, and level 3 is 30 minutes in wet condition.

[7] *Gourg Fischer Piping Systems Broschure*

Table 2.3. Fire endurance requirements matrix[8]

Piping Systems	Location										
Designation	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
Sanitary/Drains/Scuppers											
Deck drains (internal)	$L1^{4}$	$L1^{4}$	NA	$L1^{4}$	0	NA	0	0	0	0	0
Sanitary drains (internal)	0	0	NA	0	0	NA	0	0	0	0	0
Scupper and discharge (overboard)	$0^{1.8}$	$0^{1.8}$	$0^{1.8}$	$0^{1.8}$	$0^{1.8}$	0	0	0	0	$0^{1.8}$	0

Locaton definitions :

A Machinery spaces of category	Machinery spaces of category A as defined in SOLAS Regulation II-2/Reg. 3,31
B Other machinery spaces and pumprooms	Spaces other than category A machinery spaces and cargo pump rooms, containing propulsion machinery, boilers, steam and internal combustion engines, generators and major electrical machinery, pumps, oil filling stations, refrigerating, stablising, ventilation, and air-conditioning machinery and similar spaces and trunks to such spaces
C Cargo pump rooms	Spaces containing cargo pumps and entrances and trunks to such spaces
D Ro-ro cargo holds	Ro-ro cargo holds are ro-ro cargo spaces and special category as defined in SOLAS Reg. II-2/Reg. 3, 41, 46.
E Other dry cargo holds	All Spaces other than ro-ro cargo holds used for non-liquid cargo and trunks to such spaces
F Cargo tanks	All spaces used for liquid cargo and trunks to such spaces
G Fuel oil tanks	All spaces used for oil (excluding cargo tanks) and trunks
H Ballast water tanks	All spaces used for ballast water and trunks to such spaces
I Cofferdams, voids, etc.	Cofferdams and voids are those empty spaces between two bulkheads, separating two adjacent compartments
J Accomodation, service	Accommodation spaces, service and control station as defined in SOLAS Regulation II-2/Reg.3, 1,45
K Open decks	Open deck spaces as defined in SOLAS Regulation II-2/Reg. 9,2.3.3.2 (10)

On DNV, Pipes made by plastic materials are accepted if they have high oil resistance, low thermo plasticity, satisfactory mechanical strength, and are flame retardant. The fire endurance requirements specify plastic pipes according to Table A1. The permitted use and the requirements for the piping are in conformance with IMO Resolution A.753(18)

[8] *GL, Rules I Ship Technology, Part 1 Seagoing Ships, Chapter 2 Machinery Installation, Section 11.*

"Guidelines for the Application of Plastic Pipes on Ships" except for the requirements for smoke generation and toxicity.

The minimum nominal of external pressure for a plastic pipe is 1 bar and must be determined by dividing the collapse test pressure by a safety factor of 3. The nominal internal pressure for a plastic-pipe should be determined by dividing the short-term hydrostatic test failure pressure by a safety factor of 4, or the long-term hydrostatic (> 100 000 h) test failure pressure by a safety factor 2.5 which is lesser. Plastic pipe temperature limits and pressure reductions are indicated in Table A7. The limits may be extended on basis of acceptable documentation from the pipe manufacturer. The permissible temperatures are stated for long term service. Short periods of marginally higher temperatures may be accepted by case to case considerations.[9]

Table 2.4. Table A1 Fire Endurance Requirements Matrix[10]

Table A1 Fire Endurance Requirements Matrix											
Piping Systems	Location										
	A	B	C	D	E	F	G	H	I	J	K
	Machinery spaces of category	Other machinery spaces	Cargo pump rooms	Ro-ro cargo holds	Other dry cargo holds	Cargo tanks	Fuel oil tanks	Ballast water tanks	Cofferdams, voids spaces, pipe tunnel and	Accomodation service and control spaces	Open decks
Fresh Water											
Cooling Water, essential services	L3	L3	NA	NA	NA	NA	0	0	0	L3	L3
Condensate return	L3	L3	L3	0	0	NA	NA	NA	0	0	0
Non-essential system	0	0	0	0	0	NA	0	0	0	0	0
Sanitary and Drains and Scuppers											
Deck drains (internal)	L1[4]	L1[4]	NA	L1[4]	0	NA	0	0	0	0	0
Sanitary drains (internal)	0	0	NA	0	0	NA	0	0	0	0	0

[9] *(RULES FOR CLASSIFICATION OF SHIPS NEWBUILDINGS, MACHINERY AND SYSTEMS, DNV PART 4 CHAPTER 6, SECTION , A 700 Plastic pipes)*

[10] *(RULES FOR CLASSIFICATION OF SHIPS NEWBUILDINGS, MACHINERY AND SYSTEMS, DNV PART 4 CHAPTER 6, SECTION , A 700 Plastic pipes)*

Table 2.4. Table A1 Fire Endurance Requirements Matrix[10]

Table A1 Fire Endurance Requirements Matrix											
Piping Systems	Location										
	A	B	C	D	E	F	G	H	I	J	K
	Machinery spaces of category	Other machinery spaces	Cargo pump rooms	Ro-ro cargo holds	Other dry cargo holds	Cargo tanks	Fuel oil tanks	Ballast water tanks	Cofferdams, voids spaces, pipe tunnel and	Accomodation service and control spaces	Open decks
Scupper and discharge (overboard)	$0^{1.8}$	$0^{1.8}$	$0^{1.8}$	$0^{1.8}$	$0^{1.8}$	0	0	0	0	$0^{1.8}$	0
Abbreviations : L1 Fire endurance test in dry conditions, 60 minutes, Appendix 1 of IMO Res. A.753(18) L2 Fire endurance test in dry conditions, 30 minutes, Appendix 1 of IMO Res. A.753(18) L3 Fire endurance test in dry conditions, 30 minutes, Appendix 2 of IMO Res. A.753(18) 0 No fire endurance test required NA Not applicable											

Table 2.5. A1 Fire Endurance Requirements Matrix[11]

Material	**Nominal Pressure[1)] Pn (bar)**	**Permissible working pressure (bar)**						
		-20 to 0°C	**30°C**	**40°C**	**50°C**	**60°C**	**70°C**	**80°C**
PVC	10		7.5	6				
	16		12	9	6			
ABS	10	7.5	7.5	7	6			
	16	12	12	10.5	9	7.5	6	
HDPE	10	7.5	6					
	16	12	9.5	6				
According to recognized standard for water supply on shore								

2.3. Sanitary Pipe System Analyzing

Sanitary systems or can be called domestic water system is a water distribution system (fresh water) in the vessel used by the crew to meet the demand for drinking water and cooking, for bathing, washing, etc. As for the need in the WC (water closed), then the planning system uses the same system of fresh water is supplied to each bathroom. Both systems have the basis of above services work the same when using an automatic

[11] *DNV, "Rules For Classification Of Ships Newbuildings, Machinery And Systems DNV Part 4 Chapter 6 A 700"*

pump for supplying fluid to the tank which already has a pressure (hydropore) supplied from the compressed air system. Compressed air is planned to have a head and a pressure sufficient to supply water to the place that entails, including bathrooms, laundry room, galley, and a washbasin. Pumps operated automatically by switching the pressure that works based on the desired level of water. (Taylor)

Sanitary pipe used to remove water from the deck and to remove water that has been used from places a shower, dry cleaners, bars food and beverage, kitchen, warehouse, and so has a special specification. Sanitary pipe diameters are between 50-150 mm, planned sanitary pipe diameter is 100 mm (3 ") with a thickness of 4.2 mm.

Sanitary pipes that are used on different ships with sanitary pipe specifications are used on land. Specifications use all types of pipes on the vessel using pipe specifications that have been set by the class, including for sanitary piping system. One class that regulates the use of the sanitary pipe is BKI Volume III.

BKI Volume III, which regulates plumbing materials generally, should be resistant to corrosion either on the inside or on the outside. The results showed no solid impurities floating, colored, and pollute the surrounding water. Thus, the right choice for piping sanitary system is galvanized pipe.

2.3.1. Selecting Galvanized and PVC Material

The selecting of material is intended to determine the calculation of the sanitary pipe selection specifications. Selecting of galvanized pipe must be adapted to the original pipe on the ship. Likewise, the selection of pvc pipe must be adapted to the original pipe on the ship. Pipe material selection is done by calculating the diameter of the pipe. Where the pipe diameter calculation using the formula:

$$Q = A \times v \quad \text{..... (2.1)}$$
$$= \pi \times dH2 / 4 \times v$$
$$dH = (Q \times 4 / \pi \times v)^{1/2}$$

Where =
Q = ballast Pump capacity
A = area of pipe

V = flow velocity (2-4) m/s
dH = main Pipe of Diameter

For PVC pipe also calculate the wall thickness. Wall thickness calculation intended to determine the minimum thickness requirements on a pvc pipe. Where to calculate pvc pipe wall thickness is using the formula:

$$\mathbf{S = So + c + t + b} \qquad \text{..... (2.2)}$$

Where =
S = minimum thickness required [mm]
So = calculated thickness [mm]
C = allowance for corrosion [mm]
T = allowance for manufacturing tolerance [mm]
B = allowance for bending [mm]

To get the value of So, can using the formula:

$$\mathbf{So = (da \,.\, Pc)/(20.\ \sigma.v + Pc)} \qquad \text{..... (2.3)}$$

Where =
So = calculated thickness [mm]
da = outside diameter [mm]
v = weld efficiency factor
Pc = design pressure [bar]
Σ = max permissible design stress [N/mm2]
is to be taken from the lowest value of the followings :

- σ : R(at)/2.7
  R(at) = spec'fd min tensile strength at ambient temperature
- σ : E(t)/1.6
  E(t) = spec'fd lower yield strength, or 0.2% proof stress at design temperature
- σ : Sr/1.6
  Sr = ave'ge stress to produce rapture in 100 000 hrs at the design temperature

In the sanitary system, the value of wall thickness on galvanized pipe can simply use the calculation results classification rules. As for wall thickness galvanized pipe accordance data on DNV GL.

2.3.2. Original Data Analyzing

Data analysis is carried out between the galvanized and pvc pipes that have been chosen with the original pipe. Where, galvanize and pvc pipe will be analyzed whether the accordance with original pipe on the ship. This is carried for the selection of specification of galvanized and pvc pipe is not far from the original pipe specifications.

The analyzed data is data of the thickness of the pipe and the pipe diameter of the original pipe. Analysis of the original pipe with galvanized and pvc pipe is what will go into the calculation stage, Where this calculation phase will go into Chapter 4. This analysis will determine whether technically pvc pipe can be used for sanitary system on the ship or not. If the calculation is acceptable with the original data, then the galvanized and pvc pipe will have to be used on the ship.

2.4. Economical Data Analysis & Comparison

Economical data analysis done after selecting galvanized and pvc pipe. Further economic analysis cost analysis galvanized steel and pvc. Analysis of data taken from galvanized and pvc pipe prices in the market. It also carried out an analysis of the cost of installation and maintenance of galvanized and pvc pipe. Once it is done comparative material costs, installation and maintenance of galvanized and pvc. It is intended to figure out which is the material is more economic.

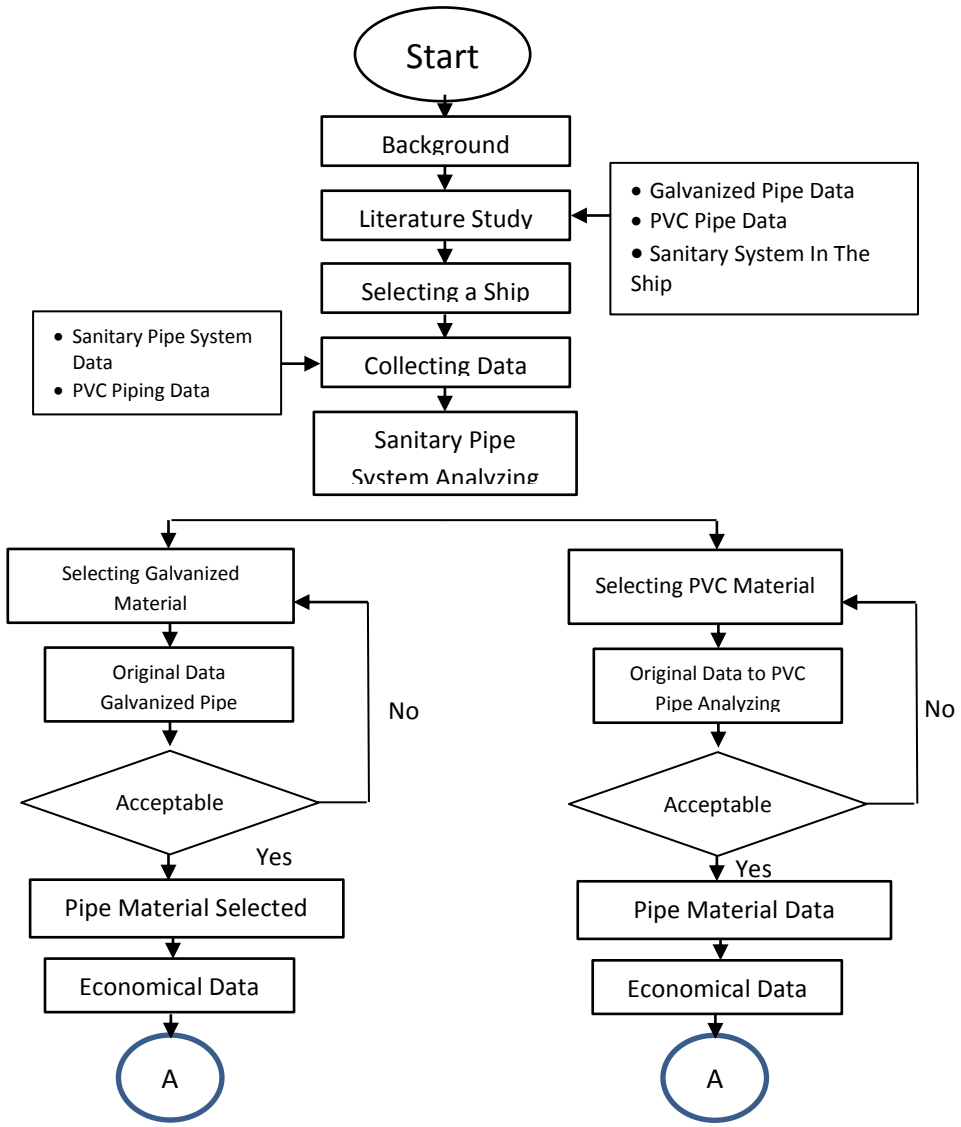
2.5. Conclusion

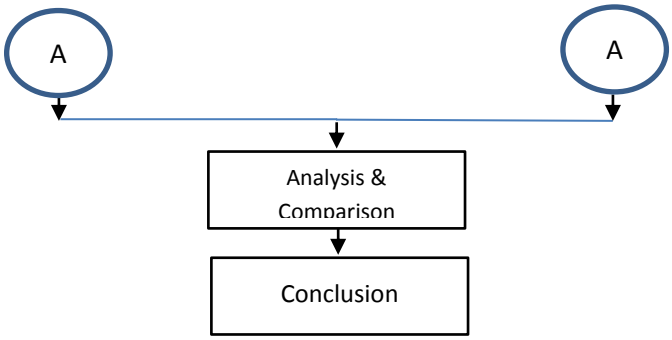
The conclusion contains short summary of the results of this thesis. Where will deliver more efficient pipe material between galvanized and pvc. In addition, installation and maintenance cost of delivering the most cost between galvanized and pvc. The conclusion is based on data calculation in chapter 4 and theory in chapter 2.

CHAPTER 3
METHODOLOGY

3.1. Methodology Flow Chart

Methodology flow chart is the steps that will take to complete the thesis. Starting from stating the problem, literature study, collecting data, analyze the data, and making some conclusions. Here is the detail of the methodology flow chart:





3.2. Description of Methodology Flow Chart

3.2.1. Background

Background is the initial process to find some problems that will be discussed in this thesis. The objective of the thesis is to find some advice or suggestion for the problem that will be discussed. In this case, raising the issue of galvanized pipes is expensive and has excessive specifications for use in sanitary systems

There are differences and differences between sanitary systems on board and on land. Above all, Sanitary systems on the ground like at home, hotels and other buildings both use pipes. Where pipe sanitary building system on land use plastic material. The discharge of water is also not much different. The thing that could be the reason for the plastic pipe can be used for the sanitary system on the ship. The destination is a shipboard pipe must use materials that have been approved by the class. Thus, the class must approve the used plastic pipe. It also must be proven plastic pipe material used has the power that is able to work on the ship This is the background of the research using pvc pipe as an alternative to galvanized pipe.

3.2.2. Literature Study

After some problems are found, literature study must be performed. Literature study is to find some theories and facts about the problems. The problem discussed is the use of PVC pipe as an alternative material to replace the galvanized pipe. So the first literature study discusses about galvanized pipes, Includes showing galvanized pipe properties.

Next is to discuss about PVC pipe. The discussion begins by first explaining what a pvc pipe is. Where PVC (polyvinyl chloride) is a thermoplastics material consisting of PVC resin compounded with varying proportions of stabilizers, lubricants, fillers, pigments, plasticisers and processing aids. The literature study also explains some of the advantages of plastics. Moreover, explained that plastic pipe used as a distributor of drinking water.

The most important thing in this literature study is to show that plastic pipe can be used on board. In other words, the class has approved plastic pipe. Rules Classification used is DNVGL. Where DNVGL describes the use of plastic pipes is arranged in part 1 chapter 2, section 11, where the plastic pipe should be approved for piping systems that included in pipe class III only. The use of plastic pipes should also be qualified based on to their fire endurance that it has to be classified at level 1 to level 3. Fire endurance levels of plastic pipes are displayed through the Fire Endurance Requirements Matrix table. After that, the literature study discusses the analysis of sanitary systems on the ship. This analysis aims to study the sanitary system on the ship.

Then the selection of pvc and galvanized steel pipe material. Selection of this material is to choose the diameter and thickness of the pipe in accordance with the existing pipe on the ship. The selection is based on the calculation of pipe diameter and pipe thickness. However, the selection of galvanized steel pipe thickness follows the rules of the class rules. So the selected galvanized steel pipe thickness is not based on manual calculation. The selection of galvanized steel pipe diameter is only to show the calculation on the existing pipe. As well as a benchmark that the selection of pipe diameter has been in accordance with the existing pipe. Then the calculation diameter galvanized steel pipe also as a benchmark in the selection of PVC pipe diameter. After getting the PVC pipe diameter requirement, next is calculate the thickness of PVC pipe.

The results of this calculation will later be a reference in choosing PVC pipe material. After that, the literature study on the literature study will discuss about economic analysis. In this analysis will look for material costs, installation, and maintenance on PVC and Galvanized steel pipes. After that, the results of the analysis will be compared between the two and sought to know which one is more economical. The literature study

can be formed in papers, journals, thesis, data, or books that related to this problem. For the sanitary system data on the ship, the data is taken directly to MV. Sinar Sabang. So, data of sanitary uses the original data on the ship.

3.2.3. Selecting a Ship

This thesis discusses the use of PVC pipe material as an alternative to replacing galvanized steel pipes in sanitary systems, the pipe material. In other words replace existing pipes with PVC pipes. Then the system required of sanitary data on the ship. To facilitate this thesis, then selected one ship as the object of research. So the sanitary system on this vessel will be analyzed. System of sanitary in question, among others, galvanized steel pipes, pumping capacity, pipeline, pipeline installation and pipeline maintenance. The selected ship is MV. Sinar Sabang. MV. Sinar Sabang is a container ship belonging to Samudera Indonesia. MV. Sinar Sabang has Singapore-Surabaya shipping routes. This ship is chosen as the object of the thesis because it has a complete ship data. Thus the data needed to support the thesis will be easy to obtain.

3.2.4. Collecting Data

Collecting some data is very essential for every thesis. In this thesis, data that will be collected is sanitary pipe system data on MV. Sinar Sabang. Sanitary system data will be collected from MV. Sinar Sabang. The sanitary data is taken from MV. Sinar Sabang because it is the main object in this thesis. These include sanitary pipe system, and PVC specification of galvanized pipe.

In addition, general data on ships such as general arrangement is also required as supporting data. Sanitary discharge system is needed to know where the sanitary pipe is connected. From sanitary data discharge system there is also data of pipe. The collected pipe data is in the form of pipe type, pipe material, pipe diameter, and pipe thickness.

Sanitary pipe on MV. Sinar Sabang this will be analyzed to be replaced with PVC pipe material. In addition to pipes, pump data will also be taken on sanitary systems. The discharge pump will be the benchmark of the PVC pipe diameter selection. After the sanitary system data on MV. Sinar Sabang has been collected, the next is collecting PVC pipe data.

PVC pipe to be used is PVC pipe for fresh water needs. Where this pipe is usually used for sanitary systems landed. PVC pipe data is taken from brochure and manual book. The data comes from manufacturing provided on the internet. PVC pipe data will be collected for the calculation of diameter and thickness in galvanized steel and PVC pipes .. Thereafter data will be collected for cost analysis on galvanized steel pipes and PVC pipes. Cost analysis data include material costs, installation, and maintenance.

3.2.5. Analyzing Sanitary pipe system

After collecting data, the data of sanitary pipe system will be analyzed to determine the galvanized and PVC material, which will used for sanitary system. In data analysis, will be calculated pvc pipe and galvanized steel pipe diameter for sanitary system. Pipe diameter calculation is use formula, $dH = (Q \times 4/ \pi \times v)^{1/2}$. In order, calculation will be calculated first galvanized pipe diameter requirements on ships. The calculation results will be compared with the existing pipeline. If the diameter of the calculation result is the same as the existing pipe, then the calculation is appropriate. After that, selecting diameter galvanized pipe in the market.

Next, searched pvc pipe diameter requirements on sanitary system. Pipe diameter calculation is use same formula as galvanized steel pipe. In the calculation of pvc pipe diameter will require adjustments to the class rules. Also performed a calculation of wall thickness pvc pipe required. Wall thickness calculation is intended to find the minimum wall thickness required on PVC pipe. As for the galvanized steel pipe is sufficient, Wall thickness simply choose from the results of DNVGL calculation. For Wall thickness calculations use the formula $S = So + c + t + b$. On the analysis of this data, it will be found that the final result pvc pipe specifications that can be used in the ship sanitary system.

3.2.6. Selecting PVC Material

From the analyzing sanitary pipe system, next is selecting pvc pipe in accordance with the data analysis calculation. How the selection of PVC pipe that is by choosing the pvc pipe products in the market. The selected pipes must be in accordance with the provisions of the class rules. It should also be in accordance with the calculation of the diameter and thickness of the pipe. Where the diameter and thickness

must be in accordance with existing pipe in MV. Sinar Sabang brands that will be used is Wavin.

3.2.7. Economical Analyzing

On this stage, will find the price of each type of pipe, and will do a price comparison. Cost analysis is performed after collecting data on installation, material, and maintenance costs. Cost data is taken from market price. With this cost data, it can be done cost comparison between PVC pipe and galvanized steel pipe. Thus, it will be determined which pipe type material is more economical to apply to the ship.

3.2.8. Make a Conclusion

Conclusion will be made after all the analysis has been done. And will be able to conclude the pipe where better technically and economically.

CHAPTER 4
DATA ANALYSIS

4.1. Data of Sanitary Pipe System

To analyze the pipe in the sanitary system, it would require an analysis on the data existing sanitary systems on ships. The selected ship is MV. Sinar Sabang as object. Galvanized pipes for sanitary system is used outside diameter 42 mm, 48 mm, 60, 76 mm, 89 mm, and 114 mm. The wall thickness of the pipe used in the sanitary system is 3 mm and 4,5 mm.

Table 4.I. Sanitary Sewage Treating[1]

SANITARY SEWAGE TREATMENT PIPING DIAGRAM SYSTEM 生活污水管系原理图						GW424-532-02 1700TEU.T1 CONTAINER VESSEL			PAGE
NO. 序号	APPLICATIION OF PIPES 管子用途	NOM. DIA. 公称通径	O.D. 外径 mm	THK. 壁厚 mm	'MATERIAL 材料	TYPE 型号	ABOUT LENGTH 近似长度 m	WEIGHT 重量 kg	REMARKS 备注
01	SOIL PIPE	40	48	4.5	seamless steel, galvanized	20#			N
02	SOIL PIPE	50	60	4.5	seamless steel, galvanized	20#			N
03	SOIL PIPE	65	76	4.5	seamless steel, galvanized	20#			N
04	SOIL PIPE	50	60	4.5	seamless steel, galvanized	20#			N
05	SOIL PIPE	40	48	4.5	seamless steel, galvanized	20#			N
06	SOIL PIPE	40	48	4.5	seamless steel, galvanized	20#			N
07	SOIL PIPE	40	48	4.5	seamless steel, galvanized	20#			N
08	SOIL PIPE	65	76	4.5	seamless steel, galvanized	20#			N
09	SOIL PIPE	50	60	4.5	seamless steel, galvanized	20#			N
10	SOIL PIPE	40	48	4.5	seamless steel, galvanized	20#			N
11	SOIL PIPE	40	48	4.5	seamless steel, galvanized	20#			N
12	SOIL PIPE	40	48	4.5	seamless steel, galvanized	20#			N
13	SOIL PIPE	65	76	4.5	seamless steel, galvanized	20#			N
14	SOIL PIPE	50	60	4.5	seamless steel, galvanized	20#			N
15	SOIL PIPE	40	48	4.5	seamless steel, galvanized	20#			N
16	SOIL PIPE	40	48	4.5	seamless steel, galvanized	20#			N
17	SOIL PIPE	40	48	4.5	seamless steel, galvanized	20#			N
18	SOIL PIPE	40	48	4.5	seamless steel, galvanized	20#			N
19	SOIL PIPE	65	76	4.5	seamless steel, galvanized	20#			N
20	SOIL PIPE	50	60	4.5	seamless steel, galvanized	20#			N
21	SOIL PIPE	40	48	4.5	seamless steel, galvanized	20#			N
22	SOIL PIPE	40	48	4.5	seamless steel, galvanized	20#			N
23	SOIL PIPE	40	48	4.5	seamless steel, galvanized	20#			N
24	SOIL PIPE	65	76	4.5	seamless steel, galvanized	20#			N
25	SOIL PIPE	50	60	4.5	seamless steel, galvanized	20#			N
26	SOIL PIPE	40	48	4.5	seamless steel, galvanized	20#			N
27	SOIL PIPE	40	48	4.5	seamless steel, galvanized	20#			N

Sanitary system on the MV. Sinar Sabang, is using the 3 main pipe line. The first main pipe, as the main line of the sanitary, flows around the shower, sinks, and scupper. Two other major pipelines used to connect water closet and connected to hospital.

[1] *MV. Sinar Sabang*

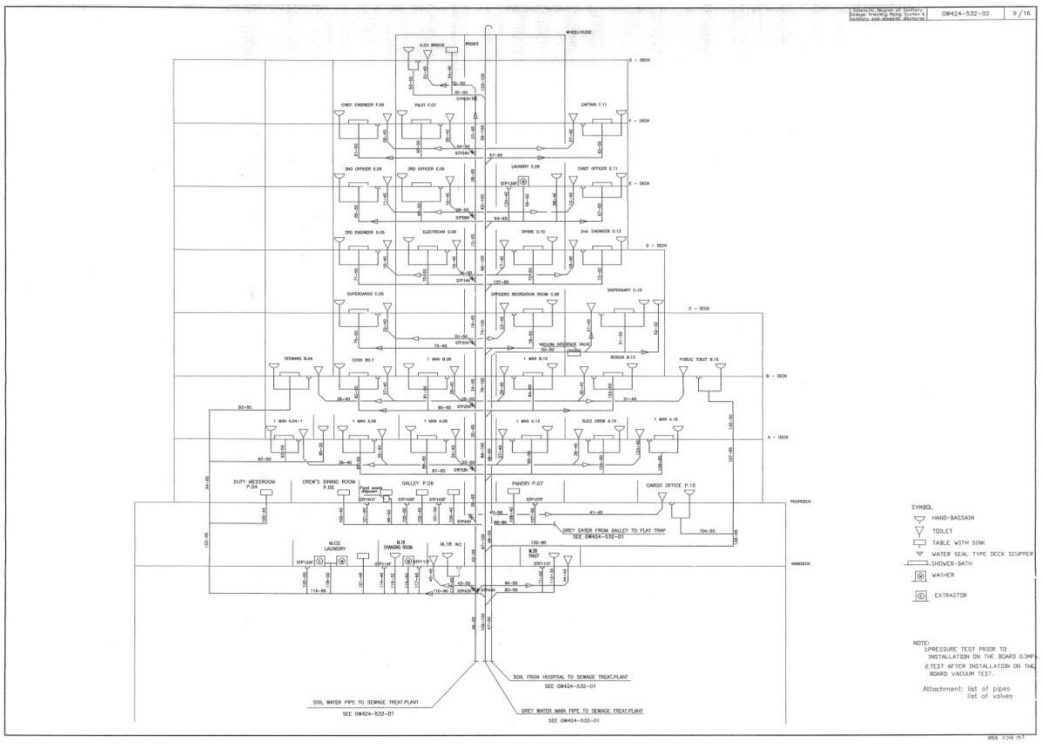


Figure 4.1. Domestic & FW Supply System[2]

4.2. Data of PVC Pipe

PVC pipe data is required for calculation on PVC pipe. The Calculation is to find the pipe diameter value, and the thickness of the pipe. To find the pipe diameter value, some data needed are ballast pump capacity (Q) and flow velocity (2-4) (v).

While to find the value of pipe thickness, data from the properties of the pipes are required, allowance for corrosion (C) [mm], allowance for manufacturing tolerance (t) [mm], allowance for bending (b) [mm], weld efficiency factor (v), design pressure (Pc) [bar], max permissible design stress (σ) [N/mm2], and tensile strength.

Table 4.2. PVC Pipe Properties[3]

PVC Pipe Properties		
Properties	Value	Unit
allowance for corrosion (C)		mm

[2] *MV. Sinar Sabang*

[3] PVC Wavin

Table 4.2. PVC Pipe Properties[3]

PVC Pipe Properties		
Properties	Value	Unit
allowance for manufacturing tolerance (t)		mm
allowance for bending (b)		mm
weld efficiency factor (v)		
design pressure (Pc)		bar
max permissible design stress (σ)		N/mm2
tensile strength (σ_t) (20°C)	40	MPa
Specific Gravity	1,4	g/cm
Elongation (%) (20°)	80	%
Longitudinal Reversion % (150°)	5	%
Dichloromethane Resistance Test (16°C/20 menit)	No attack	
Vicat Softening Temperature (° C)	79°	
Hydrostatic Pressure Test, (AW) Pressure resistance 1 min, 2,0 Mpa	No Failure	
Coefficient of linier expansion	8x10-2	mm/m.°K
Thermal conductivity	0,15	W/m.°K
Modulus of elasticity	3000	N/mm2
Surface resistance	>1012	ohm

In addition to the value of properties obtained from manufacturing. Also tested the material in the form of tensile test on PVC material, so the results obtained the following comparison:

Table 4.3. Comparison of PVC properties with tensile test results

Properties	Value		Unit
	Manufacture		
tensile strength (σ_t)	40	50	MPa
Strain (ε)		0.1482	mm
Modulus of elasticity	3000	343	MPa

4.3. Data Calculation

4.3.1. Pipe Diameter Calculation

Analysis results of the calculation, the diameter required in the sanitary system is 42.20mm, 60.30mm, 73mm (attachment 1.1). The results of these calculations have been compared with the original pipe on the ship. Where the comparison shows that the original pipe diameter and pipe selected is same.

The calculation of pipe diameter is for the first pipe (P1), second branch (P2) and main pipe (P3). Where the first pipe of branch is a pipe for hand-bassain, scuppers, and shower-bath. This pipe will be intended for water discharge of 5 m3 / h. The water debit is obtained from the discharge capacity of the freshwater pump. Where the calculation as follows (see attachment 1 for detail calculation):

Table 4.4. Pipe diameter calculation

P1		
Calculation	Unit	Result
dH = inside diameter	mm	32
Q = pump capacity.	m^3/h	5
	m^3/s	0.001389
v = flow velocity.	m/s	2.5
π		3.14

Thus, hand-bassain, scupper, and shower-bath pipes use pipe with inside diameter of 32.00 mm and outside diameter 42.20 mm. Next, calculate the diameter of the second branch pipe (P2). Where the second branch pipe is a meeting between the first pipe of branch (P1). This pipe will be intended for water discharge of 15 m3 / h. The water debit is obtained from the total amount of discharge of all the first branch pipes (P1). Where the calculation as table:

Table 4.5. Pipe diameter calculation

P2		
Calculation	Unit	Result
dH = inside diameter	mm	50
Q = pump capacity.	m^3/h	15
	m^3/s	0.004167
v = flow velocity.	m/s	2.5
π		3.14

Thus, the second branch pipe (P2) uses inside diameter 50.00 mm and outside diameter 60.30 mm. For the main pipe (P3), this pipe will be intended for the connecting channel of the entire second pipeline (P2). This pipe is able to pass water discharge of 30 m3 / h. The water debit is obtained from the total amount of debit of all second branch pipes (P2). Where the calculation as table:

Table 4.6. Pipe diameter calculation

P3		
Calculation	Unit	Result
dH = inside diameter	mm	65
Q = pump capacity.	m^3/h	30
	m^3/s	0.008333
v = flow velocity.	m/s	2.5
π		3.14

Thus, the main pipe (P3) uses inside diameter 65.00 mm and outside diameter 73. 0 mm.

4.3.2. Wall Thickness Calculation

Analysis results of the calculation, the wall thickness is needed on pvc pipe is 0.83759 mm to 42.2mm OD pipe, 1.88mm to 60mm OD pipe, and 2.39mm to 73mm OD pipe. This calculation is the result of the formula:

$$\mathbf{S = So + c + t + b}$$

The thickness of pipe diameter 42.2mm obtained from the calculation as follows:

Table 4.7. Pipe thickness calculation

OD 42 mm		
Calculation	Unit	Result
S = minimum thickness required	mm	0.83759
So = calculated thickness	mm	0.83759
da = outside diameter [mm]	mm	42.2
Pc = design pressure [bar]	bar	6
σ = max permissible design stress	N/mm2	14.8148
v = weld efficiency factor		1
t = allowance for mnufacturing tolerance [mm]	mm	0
b = allowance for beding [mm]	mm	0

The thickness of pipe diameter 60 mm obtained from the calculation as follows:

Table 4.8. Pipe thickness calculation

OD 60 mm		
Calculation	Unit	Result
S = minimum thickness required	mm	1.19088
So = calculated thickness	mm	1.19088
da = outside diameter [mm]	mm	60
Pc = design pressure [bar]	bar	6
σ = max permissible design stress	N/mm2	14.8148
v = weld efficiency factor		
c = allowance for corrosion [mm]	mm	1
t = allowance for manufacturing tolerance [mm]	mm	0
b = allowance for beding [mm]	mm	0
	mm	0
	mm	0

The thickness of pipe diameter 76 mm obtained from the calculation as follows:

Table 4.9. Pipe thickness calculation

OD 76 mm		
Calculation	Unit	Result
S = minimum thickness required	mm	1.5085
So = calculated thickness	mm	1.5085
da = outside diameter [mm]	mm	76
Pc = design pressure [bar]	bar	6
σ = max permissible design stress	N/mm2	14.8148
v = weld efficiency factor		
c = allowance for corrosion [mm]	mm	1
t = allowance for manufacturing tolerance [mm]	mm	0
b = allowance for beding [mm]	mm	0
	mm	0
	mm	0

4.4. Pipe Material Selected

With the calculation results of pipe diameter and thickness, it can be selected the size of galvanized steel pipe and PVC pipe.

4.4.1. Galvanized Steel Pipe Selected

Selection of galvanized steel pipes In accordance with the pipe diameter calculation and pipe thickness conditions set in DNVGL. Where the selected pipe is as follows:

Table 4.10. Galvanized Steel Pipe Selected

Pipe Selected	
OD	**Unit**
42	mm
60	mm
76	mm
89	mm
114	mm

4.4.2. PVC Pipe Selected

The selection of pipes based on the calculation of diameter, thickness, and suitability of existing pipes. Where selected is Wavin PVC pipe with a thickness of 2 mm and diameter:

Table 4.11. PVC Pipe Selected

Pipe Selected	
OD	**Unit**
42	mm
60	mm
76	mm
89	mm
114	mm

Figure 4.2. PVC Pipe Wavin

4.5. Economic Analysis

4.5.1. Material Cost Analysis

Material cost analysis is done to find out the cost of sanitary pipe material procurement. Material cost analysis is done by calculating for each of the total length of pipe required. The length of the calculated pipe is the total length of pipe diameter of, 42mm, 60mm, 76mm, 89mm, and 114mm. The length of pipe to be analyzed is freshwater pipe supply, seawater pipe supply and discharge. The total length of the pipe is measured in the figure (see attachment 4.1).

In sanitary systems, water supply to be supplied to toilets, toilets, laundry and other washing channels through supply pipes. Water supply pipes deliver two types of water, fresh water and seawater, where fresh water is for toileting, washing, eating and other purposes, while sea water is used as water to clean the toilet. The total length of pipe is get from domestic pipe schematic drawing. The total length of fresh water and sea water pipe supply is as follows (see attachment 2 for pipe schematic drawing) :

Table 4.12. Fresh Water Pipe Supply for Deck G

Deck G	
Size Diameter Mm	**Length m**
32	0.8
42	2.5
76	-

In Deck G, the total length of the pipe OD 32 mm pipe is 0.8 m, for the length of the OD 42 mm pipe is 2.5 m, and the length of the OD 76 m pipe is 0 m.

Table 4.13. Fresh Water Pipe Supply for Deck F

Deck F	
Size Diameter Mm	**Length M**
32	2.2
42	5
76	8.9

In Deck F, the total length of the pipe OD 32 mm is 2.2 m, for the length of the OD 42 mm pipe is 5 m, and the length of the OD 76 mm pipe is 8.9 m.

Table 4.14. Fresh Water Pipe Supply for Deck E

Deck E	
Size Diameter mm	**Length m**
32	2.6
42	6.5
76	9,3

In Deck E, the total length of the pipe OD 32 mm is 2.6 m, for the length of the OD 42 mm pipe is 6.5 m, and the length of the OD 76 mm pipe is 9.3 m.

Table 4.15. Fresh Water Pipe Supply for Deck D

Deck D	
Size Diameter mm	**Length m**
32	2.9
42	6.7
76	9.3

In Deck D, the total length of the pipe OD 32 mm is 2.9 m, for the length of the OD 42 mm pipe is 6.7 m, and the length of the OD 76 mm pipe is 9.3 m.

Table 4.16. Fresh Water Pipe Supply for Deck C

Deck C	
Size Diameter mm	**Length m**
32	5
42	4.6
76	9.3

In Deck C, the total length of the pipe OD 32 mm is 5 m, for the length of the OD 42 mm pipe is 4.6 m, and the length of the OD 76 mm pipe is 9.3 m.

Table 4.17. Fresh Water Pipe Supply for Deck B

Deck B	
Size Diameter Mm	**Length m**
32	7.5
42	8.5
76	1.4

In Deck B, the total length of the pipe OD 32 mm is 7.5 m, for the length of the OD 42 mm pipe is 8.5 m, and the length of the OD 76 mm pipe is 1.4 m.

Table 4.18. Fresh Water Pipe Supply for Deck A

Deck A	
Size Diameter Mm	**Length m**
32	4
42	8.3
76	15.2

In Deck A, the total length of the pipe OD 32 mm is 4 m, for the length of the OD 42 mm pipe is 8.3 m, and the length of the OD 76 mm pipe is 15.2 m.

Table 4.19. Fresh Water Pipe Supply for Poop Deck

Poop Deck	
Size Diameter Mm	**Length m**
32	16
42	5.8
76	5.4

In Poop Deck, the total length of the pipe OD 32 mm is 16 m, for the length of the OD 42 mm pipe is 5.8 m, and the length of the OD 76 mm pipe is 5.4 m.

Table 4.20. Fresh Water Pipe Supply for Main Deck

Main Deck	
Size Diameter mm	**Length m**
32	16
42	20.3
76	-

In Poop Deck, the total length of the pipe OD 32 mm is 16 m, for the length of the OD 42 mm pipe is 20.3 m, and the length of the OD 76 mm pipe is 0 m.

Table 4.21. Fresh Water Pipe Supply for 2nd Deck

2nd Deck	
Size Diameter mm	**Length m**
32	-
42	-
76	23.9

In Poop Deck, the total length of the pipe OD 32 mm is 0 m, for the length of the OD 42 mm pipe is 0 m, and the length of the OD 76 mm pipe is 23.9 m.

Table 4.22. Sea Water Pipe Supply for Deck G

Deck G	
Size Diameter mm	**Length m**
32	1.4
42	-
76	-

In Deck G, the total length of the pipe OD 32 mm pipe is 1.4 m, for the length of the OD 42 mm pipe is 0 m, and the length of the OD 76 m pipe is 0 m.

Table 4.23. Sea Water Pipe Supply for Deck F

Deck F	
Size Diameter Mm	**Length m**
32	2.5
42	7.3
76	1.2

In Deck F, the total length of the pipe OD 32 mm is 2.5 m, for the length of the OD 42 mm pipe is 7.3 m, and the length of the OD 76 mm pipe is 1.2 m.

Table 4.24. Sea Water Pipe Supply for Deck E

Deck E	
Size Diameter Mm	**Length m**
32	2.6
42	8.6
76	1.1

In Deck E, the total length of the pipe OD 32 mm is 2.6 m, for the length of the OD 42 mm pipe is 8.6 m, and the length of the OD 76 mm pipe is 1.1 m.

Table 4.25. Sea Water Pipe Supply for Deck D

Deck D	
Size Diameter Mm	**Length m**
32	2
42	2.3
76	8.6

In Deck D, the total length of the pipe OD 32 mm is 2 m, for the length of the OD 42 mm pipe is 2.3 m, and the length of the OD 76 mm pipe is 8.6 m.

Table 4.26. Sea Water Pipe Supply for Deck C

Deck C	
Size Diameter Mm	**Length m**
32	3.3

Table 4.26. Sea Water Pipe Supply for Deck C

Deck C	
Size Diameter Mm	**Length m**
42	7.5
76	1.1

In Deck C, the total length of the pipe OD 32 mm is 3.3 m, for the length of the OD 42 mm pipe is 7.5 m, and the length of the OD 76 mm pipe is 1.1 m.

Table 4.27. Sea Water Pipe Supply for Deck B

Deck B	
Size Diameter mm	**Length m**
32	11.7
42	9.8
76	8.6

In Deck B, the total length of the pipe OD 32 mm is 11.7 m, for the length of the OD 42 mm pipe is 9.8 m, and the length of the OD 76 mm pipe is 8.6 m.

Table 4.28. Sea Water Pipe Supply for Deck A

Deck A	
Size Diameter mm	**Length m**
32	12
42	2.3
76	8.6

In Deck A, the total length of the pipe OD 32 mm is 12 m, for the length of the OD 42 mm pipe is 2.3 m, and the length of the OD 76 mm pipe is 8.6 m.

Table 4.29. Sea Water Pipe Supply for Poop Deck

Poop Deck	
Size Diameter mm	**Length m**
32	10.7
42	1.2

Table 4.29. Sea Water Pipe Supply for Poop Deck

Poop Deck	
Size Diameter mm	**Length m**
76	-

In Poop Deck, the total length of the pipe OD 32 mm is 10.7 m, for the length of the OD 42 mm pipe is 1.2 m, and the length of the OD 76 mm pipe is 0 m.

Table 4.30. Sea Water Pipe Supply for Main Deck

Main Deck	
Size Diameter Mm	**Length m**
32	14.1
42	3
76	-

In Poop Deck, the total length of the pipe OD 32 mm is 14.1 m, for the length of the OD 42 mm pipe is 3 m, and the length of the OD 76 mm pipe is 0 m.

Table 4.31. Sea Water Pipe Supply for 2nd Deck

2nd Deck	
Size Diameter Mm	**Length m**
32	-
42	-
76	3

In Poop Deck, the total length of the pipe OD 32 mm is 0 m, for the length of the OD 42 mm pipe is 0 m, and the length of the OD 76 mm pipe is 3 m.

Thus, the total length of the water pipe supply is:

Table 4.32. Total Length Water Pipe Supply

Deck	Length of Pipe		
	OD 42 mm	**OD 48 mm**	**OD 76 mm**
Deck G	22 m	2.5 m	0

Table 4.32. Total Length Water Pipe Supply

Deck	Length of Pipe		
	OD 42 mm	OD 48 mm	OD 76 mm
Deck F	4.7 m	12.3 m	10.1 m
Deck E	5.2 m	15.1 m	10.4 m
Deck D	4.9 m	9 m	17.9 m
Deck C	8.3 m	12.1 m	10.4 m
Deck B	19.2 m	18.3 m	10 m
Deck A	16 m	10.6 m	23.8 m
Poop Deck	26.7 m	7 m	5.4 m
Main Deck	30.1 m	23.3 m	-
2nd Deck	-	-	26.9 m
Total	**137 m**	**110 m**	**115 m**

After getting the total length of the supply pipe, the other pipe need is discharge pipe. Where the discharge pipes are pipes for sewer. This sewer pipe is for discharging dirty water from shower, toilet, washbasin, laundry, and other wastewater. In the total length requirements of the discharge pipe the length of the pipe is as follows:

Table 4.33. Total length of domestic discharge

Deck	Length of Pipe					
	42 (mm)	48 (mm)	60 (mm)	76 (mm)	89 (mm)	114 (mm)
Deck G	8	5.4	7.9	-	-	-
Deck F	7.7	6.6	69	16.5	-	7.20
Deck E	8.5	6.2	22.5	17.1	-	7.20
Deck D	9	6.8	21.5	17.1	-	7.20
Deck C	7.5	6.8	28.5	17.1	-	7.20
Deck B	15.4	6.3	45.8	17.1	-	7.20
Deck A	12.5	6.6	39.8	18.3	-	7.20
Poop Deck	7.6	6.5	19.6	-	14.4	7.20
Main Deck	8.7	11.6	12.2	17.5	16.4	-
2nd Deck			11.6	11.9	-	7.2
Total	**39.9**	**27.8**	**183.4**	**92.6**	**20.8**	**22.6**

Thus, there is a need for total length of pipe on all decks. For 42 mm diameter pipe it takes a total length of 58.32 m, 48 mm diameter pipe required total length 53,825, 60 mm diameter pipe required total length of 7,436 m, 76 mm diameter pipe required total length 66.3349 m, and 114 mm diameter tube required total length 15.40 m.

From the total length of the domestic discharge and supply pipes, we get the total length of pipe needed in the sanitary system on the vessel. The overall length of the pipe is:

Table 4.34. Total length of sanitary pipe

Deck	Length of Pipe					
	42 (mm)	48 (mm)	60 (mm)	76 (mm)	89 (mm)	114 (mm)
Deck G	25	2.9	2.9	-	-	-
Deck F	7.4	13.9	19	21.6	-	3.2
Deck E	8.7	16.3	17.5	22.5	-	3.2
Deck D	8.9	10.8	16.5	30	-	3.2
Deck C	10.8	13.9	23.5	22.5	-	3.2
Deck B	29.6	21.6	40.8	22.1	-	3.2
Deck A	23.5	16.2	34.8	37.1	-	3.2
Poop Deck	29.3	12.5	14.6	5.4	9.4	3.2
Main Deck	33.8	29.9	7.2	12.5	11.4	-
2nd Deck	0	0	6.6	33.8	-	7.2
Total	**177**	**138**	**14.31**	**173.7**	**20.8**	**29.6**

4.5.1.1. Galvanized Steel Pipe Material Cost

Prices of galvanized steel pipes based on market prices. Galvanized steel pipes have varying prices based on the diameter or thickness of the pipe. The greater the thickness of the pipe or the diameter of the pipe, will make the price of the pipe more expensive. The price of the pipe is valid every 6 meters. On the purchase of this pipe material the price includes tax. The price of galvanized steel pipe is as follows:

Table 4.35. Price list of galvanized steel pipe[4]

Size	Thickness	Length	Cost (Rp)
½″	2,60 mm	6 m	155.000,-
¾″	2,60 mm	6 m	200.000,-
1″	3,20 mm	6 m	300.000,-
1¼ ″	3,20 mm	6 m	400.000,-
1½″	3,20 mm	6 m	455.000,-
2″	3,60 mm	6 m	620.000,-
2½″	3,60 mm	6 m	790.000,-
3″	4,00 mm	6 m	1.020.000,-
4″	4,50 mm	6 m	1.470.000,-
5″	4,85 mm	6 m	2.020.000,-
6″	4,85 mm	6 m	2.400.000,-
8″	5,00 mm	6 m	3.400.000,-

From the above cost data, we get the total cost of galvanize steel pipe material per piece is as follows:

Table 4.36. Total Cost of galvanized steel pipe material

Galvanized Steel Pipe Material			
Size (mm)	**Piece (per 6 m)**	**Cost per piece**	**Total Cost**
42	57	Rp. 400.000,-	Rp. 22,800,000
48	49	Rp. 455.000,-	Rp. 22,295,000
60	67	Rp. 620.000,-	Rp. 41,540,000
76	62	Rp. 790.000,-	Rp. 48,980,000
89	26	Rp. 1.020.000,-	Rp. 26,520,000
114	30	Rp. 1.470.000,-	Rp. 44,100,000
		Total	**Rp. 206,235,000**

So the total cost of galvanized steel pipe material is Rp. **206,235,000**

4.5.1.2. PVC Pipe Material Cost

Cost of PVC pipe based on market price. PVC pipe has different price based on the diameter or thickness of pipe. The greater the thickness of the pipe or the diameter of the pipe, will make the price of the pipe

[4] *http://www.hargamaterial.xyz/harga-pipa-pvc-galvanis-terbaru/*

more expensive. The price of the pipe is also valid every 4 meters. On the purchase of this pipe material the price includes tax. Where PVC pipe prices are as follows:

Table 4.37. Price list PVC pipe

Size		Type	
inch	**Mm**	**AW**	**D**
½″	22	Rp. 21,100	Rp. -
¾″	26	Rp. 28,800	Rp. -
1″	32	Rp. 39,300	Rp. -
1¼″	42	Rp. 58,900	Rp. 37,000
1½″	48	Rp. 67,600	Rp. 41,800
2″	60	Rp. 86,500	Rp. 53,600
2½″	76	Rp. 126,200	Rp. 72,400
3″	89	Rp. 177,800	Rp. 96,100
4″	114	Rp. 294,600	Rp. 151,200
5″	140	Rp. 466,800	Rp. 233,000
6″	165	Rp. 654,700	Rp. 307,300
8″	216	Rp. 1,098,700	Rp. 540,500
10″	267	Rp. 1,698,900	Rp. 890,300
12″	318	Rp. 2,394,400	Rp. 1,249,800

From the above price data, we get the total cost of PVC pipe material is as follows:

Table 4.38 Total Cost of PVC pipe material

PVC Pipe Material Cost			
Size (mm)	**Piece (per 4 m)**	**Cost per piece**	**Total Cost**
42	76	Rp. 58,900	Rp. 4,476,400
48	64	Rp. 67,600	Rp. 4,326,400
60	90	Rp. 86,500	Rp. 7,785,000
76	82	Rp. 126,200	Rp. 10,348,400
89	28	Rp. 177,800	Rp. 4,978,400
114	35	Rp. 294,600	Rp. 10,311,000
		Total	**Rp. 42225600**

The total cost of PVC pipe material is Rp. **42,225,600**

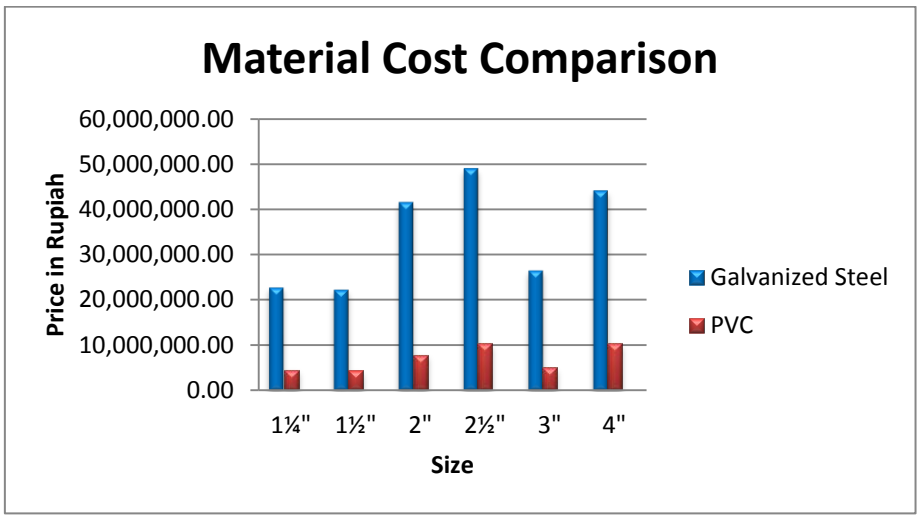
4.5.1.3 Material Cost Comparison Analysis

Galvanized steel pipes and PVC pipes have very different prices. From that difference can be compared the price difference of each pipe. Where price comparison can be seen in table:

Table 4.39. Galvanized steel pipe and PVC pipe price comparison

Cost Comparison Analysis					
Size		**Type of Material**		**Saving Cost**	
inch	**mm**	**Galvanized Steel**	**PVC**	**Rp**	**(%)**
1¼"	42	Rp. 22,800,000	Rp. 4,476,400	Rp. 18,323,600	80.4%
1½"	48	Rp. 22,295,000	Rp. 4,326,400	Rp. 17,968,600	80.6%
2"	60	Rp. 41,540,000	Rp. 7,785,000	Rp. 33,755,000	81.3%
2½"	76	Rp. 48,980,000	Rp. 10,348,400	Rp. 38,631,600	78.9%
3"	89	Rp. 26,520,000	Rp. 4,978,400	Rp. 21,541,600	81.2%
4"	114	Rp. 44,100,000	Rp. 10,311,000	Rp. 33,789,000	76.6%

In the table above shows that galvanized steel pipes have a price much more expensive than PVC pipe. Where the price different between galvanized steel pipe and PVC with size 1¼" is 85.3%. For pipe with size 1½" have price different equal to 85.1%%. For pipe with size 2 "have price difference equal to 86%. Pipes with size 2½ have price difference of 84%. Pipe with size 3" has a price difference of 82.6%, while the pipe with size 4" has a price different of 80%. The price different between galvanized steel pipe and PVC pipe can also be seen in graph form as follows:



4.5.2. Installation and Maintenance Cost Analysis

The cost of installation is the cost of services of workers in the installation of pipes. The amount of installation and maintenance costs in accordance with the material pipe. In galvanize steel pipes, the installation requires welding services. While PVC pipe does not require welding services.

Maintenance cost is the service cost of the workers in dismantling and plumbing, as well as material cost. The material difference between PVC and galvanized steel affects the treatment method of the pipe. Thus it will affect the amount of maintenance costs that will be issued.

4.5.2.1. Galvanized Steel Pipe Installation and Maintenance Analysis

Installation of galvanize steel pipe must use welding, Where welding is done by a person who has a certificate or an expert in welding. This affects the amount of service costs to be incurred. Cost analysis of galvanized steel pipe installation as follows:

Table 4.40 Installation cost of galvanized steel pipes

Size		Unit	Salary
inch	Mm	m	
1¼″	42	1	Rp. 200,000
1½″	48	1	Rp. 250,000
2″	60	1	Rp. 282,600
2½″	76	1	Rp. 340,000
3″	89	1	Rp. 444,000
4″	114	1	Rp. 599,500
		Total	**Rp. 146,000**

From the installation cost data, the total installation cost of the pipe is as follows:

Table 4.41 Installation cost of galvanized steel pipes

Size		Unit	Salary
inch	Mm	m	
1¼″	42	222	Rp. 44,400,000
1½″	48	173	Rp. 43,250,000
2″	60	278.4	Rp. 78,675,840
2½″	76	247.5	Rp. 84,150,000
3″	89	20.8	Rp. 9,235,200
4″	114	57.6	Rp. 34,531,200

Table 4.41 Installation cost of galvanized steel pipes

Size		Unit	Salary
inch	Mm	m	
		Total	**Rp. 294,242,240**

As for the maintenance cost, the cost is taken from 4% investment value. In this case, investment is taken from the cost of pipe materials and installation. Then the calculation of maintenance costs as follows:

Table 4.42 Maintenance cost of galvanized steel pipes

Size		Unit	Investment	Maintenance Cost
inch	mm	m		
1¼″	42	222	Rp. 67,200,000	Rp. 2,688,000
1½″	48	173	Rp. 65,545,000	Rp. 2,621,800
2″	60	278.4	Rp. 120,215,840	Rp. 4,808,634
2½″	76	247.5	Rp. 133,130,000	Rp. 5,325,200
3″	89	20.8	Rp. 35,755,200	Rp. 1,430,208
4″	114	57.6	Rp. 78,631,200	Rp. 3,145,248
			Total	**Rp 20,019,089**

Thus, the cost of galvanized steel pipe installation is Rp. **294,242,240**, and galvanized steel pipe maintenance cost is Rp. **20,019,089**.

4.5.2.2. PVC Pipe Installation and Maintenance Analysis

Installation of PVC pipe is different from galvanized steel pipe. PVC pipe cannot be welded. Connection is using adhesive or glue. Thus it does not require welding services. This affects the amount of service costs to be incurred. Cost analysis of PVC pipe installation as follows:

Table 4.43. Installation cost of PVC pipe

Size		Unit	Salary
inch	mm	M	
1¼″	42	1	Rp. 20,000
1½″	48	1	Rp. 21,000
2″	60	1	Rp. 22,000
2½″	76	1	Rp. 25,000
3″	89	1	Rp. 28,000
4″	114	1	Rp. 30,000
		Total	**Rp. 146,000**

From the installation cost data, the total installation cost of the pipe is as follows:

Table 4.44. Installation cost of PVC pipe

Size		Unit	Salary
inch	Mm	m	
1¼″	42	222	Rp. 4,440,000
1½″	48	173	Rp. 3,633,000
2″	60	278.4	Rp. 6,124,800
2½″	76	247.5	Rp. 6,187,500
3″	89	20.8	Rp. 582,400
4″	114	57.6	Rp. 1,728,000
		Total	**Rp. 22,695,700**

As for the maintenance cost, the cost is taken from 4% investment value. In this case, investment is taken from the cost of pipe materials and installation. Then the calculation of maintenance costs as follows:

Table 4.45 Maintenance cost of PVC pipe

Size		Unit	Investment	Maintenance
inch	mm	m		Cost
1¼″	42	222	Rp. 8,916,400	Rp. 356,656
1½″	48	173	Rp. 7,959,400	Rp. 318,376
2″	60	278.4	Rp. 13,909,800	Rp. 556,392
2½″	76	247.5	Rp. 16,535,900	Rp. 661,436
3″	89	20.8	Rp. 5,560,800	Rp. 222,432
4″	114	57.6	Rp. 12,039,000	Rp. 481,560
			Total	**Rp. 2,596,852**

Thus, the cost of PVC pipe installation is Rp. **22,695,700**, and PVC pipe maintenance cost is Rp. **2,596,852.**

4.5.2.3. Installation and Maintenance Cost Comparison Analysis

From the analysis result of installation cost and maintenance of galvanized steel pipe and PVC pipe, then can be done comparative analysis as follows:

Table 4.46. Installation cost comparison analysis

Installation Cost Comparison Analysis				
Size		**Type of Material**		
inch	**mm**	**Galvanized Steel**	**PVC**	**Price Gap (%)**
1¼″	42	Rp. 44,400,000	Rp. 4,440,000	90.0%
1½″	48	Rp. 43,250,000	Rp. 3,633,000	91.6%
2″	60	Rp. 78,675,840	Rp. 6,124,800	92.2%
2½″	76	Rp. 84,150,000	Rp. 6,187,500	92.6%
3″	89	Rp. 9,235,200	Rp. 582,400	93.7%
4″	114	Rp. 34,531,200	Rp. 1,728,000	95.0%

From the results of comparison analysis above, it can be concluded that balvanized steel pipes have a installation cost is much more expensive than PVC pipe. Where the average price comparison reaches 86%

For comparison analysis of maintenance cost, the analysis was done by comparing the results of PVC and galvanized steel pipe maintenance cost. The analysis can be done as follows:

Table 4.47 Maintenance cost comparison analysis

Maintenance Cost Comparison Analysis				
Size		**Type of Material**		
inch	**mm**	**Galvanized Steel**	**PVC**	**Price Gap (%)**
1¼″	42	Rp. 2,688,000	Rp. 356,656	86.7%
1½″	48	Rp. 2,621,800	Rp. 318,376	87.9%
2″	60	Rp. 4,808,634	Rp. 556,392	88.4%
2½″	76	Rp. 5,325,200	Rp. 661,436	87.6%
3″	89	Rp. 1,430,208	Rp. 222,432	84.4%
4″	114	Rp. 3,145,248	Rp. 481,560	84.7%

From the results of comparison analysis above, it can be concluded that galvanized steel pipe have a maintenance cost is much more expensive than PVC pipe, where the average price comparison reaches 88.4%.

4.5.3. Total Cost Comparison Analysis

From all result of cost analysis, hence can do comparison between installation cost, material, and maintenance of galvanized steel pipe and PVC as follows

Table 4.48 Galvinized Steel Pipe Total Cost

Galvanized Steel				
Size		**Cost**		
inch	**mm**	**Material**	**Installation**	**Maintenance**
1¼"	42	Rp. 22,800,000	Rp. 44,400,000	Rp. 2,688,000
1½"	48	Rp. 22,295,000	Rp. 43,250,000	Rp. 2,621,800
2"	60	Rp. 41,540,000	Rp. 78,675,840	Rp. 4,808,634
2½"	76	Rp. 48,980,000	Rp. 84,150,000	Rp. 5,325,200
3"	89	Rp. 26,520,000	Rp. 9,235,200	Rp. 1,430,208
4"	114	Rp. 44,100,000	Rp. 34,531,200	Rp. 3,145,248
	TOTAL	**Rp. 206,235,000**	**Rp. 294,242,240**	**Rp. 20,019,090**

Table 4.49 PVC Pipe Total Cost

PVC				
Size		**Cost**		
inch	**mm**	**Material**	**Installation**	**Maintenance**
1¼"	42	Rp. 4,476,400	Rp. 4,440,000	Rp. 356,656
1½"	48	Rp. 4,326,400	Rp. 3,633,000	Rp. 318,376
2"	60	Rp. 7,785,000	Rp. 6,124,800	Rp. 556,392
2½"	76	Rp. 10,348,400	Rp. 6,187,500	Rp. 661,436
3"	89	Rp. 4,978,400	Rp. 582,400	Rp. 222,432
4"	114	Rp. 10,311,000	Rp. 1,728,000	Rp. 481,560
	TOTAL	**Rp. 42,225,600**	**Rp. 22,695,700**	**Rp. 2,596,852**

In the table above can be seen the total comparison of material costs, installation and maintenance between galvanized pipe and PVC pipe.

CHAPTER 5
CONCLUSION & SUGGESTION

5.1 Conclusion

Based on the results and analysis data obtained from the previous chapter, it can be concluded:

1. There is a big difference between the price of galvanized steel pipe material with PVC pipe, ie 80% -86%
2. There is a difference in the installation of galvanized steel pipe with PVC pipe, where the galvanized pipe must be connected with the welding method, while the PVC pipe uses adhesive / weld.
3. In the installation of PVC pipe, still have to use galvanized steel pipe material for connection with plate.
4. There is a difference in price of galvanized steel pipe installation with PVC pipe, which is about 80-86%.

5.2 Suggestion

1. In the installation that must be penetrated on the plate, the pipe material used still use galvanized steel pipe, after that galvanized steel pipe will be connected with PVC pipe

REFERENCE

[1] DNV, "*RULES FOR CLASSIFICATION OF SHIPS NEWBUILDINGS, MACHINERY AND SYSTEMS, DNV PART 4 CHAPTER 6*"

[2] Charles Tailor Consulting. (2012). *A Master Guide To: Ships' Piping 2nd edition*

[3] Berens, Alan R., *"Prediction of Organic Chemical Permeation Through PVC Pipe," Journal American Waterworks Association, Denver, CO (Nov. 1985) pp. 57-65.*.

[4] Vonk, Martin W., *"Permeation of Organic Soil Contaminants Through Polyethylene, Polyvinylchloride, Asbestos Cement and Concrete Water Pipes," Some Phenomena*
Affecting Water Quality During Distribution: Permeation, Lead Release, Regrowth of Bacteria, KIWA Ltd., Neuwegen, The Netherlands (Nov. 1985) pp. 1-14.

[5] Vinidex. *PVC Pressure Pipe & Fittings Technical Manual*

[6] Pipe and Foundry Company, CHARLOTTE. "*Galvanized, Technical and Installation Manual*"

[7] George Fischer Piping System, "*Plastic Piping System*".

ATTACHMENT 1

Pipe Diameter Calculation

a. Calculation of Pipes in Deck G

Room : Man A.06, Man A.08, Man A.13, Man A.15, Man A.15

1) Calculation Of Hand-Bassain, Scupper, & Table with sink Pipe (P1)

Q pump	=	5.00	m^3/h
	=	0.001389	m^3/s
v flow	=	2.5	m/s

Specification of pipe diameter =

Q	=	A x V	
	=	$1/4 \times \pi \times D^2 \times v$	
D	=	$Q / (1/4 \times \pi \times v)$	
	=	0.0007	m
D	=	26.60	mm
	=	1.047	inches

So, the selected types of galvanized steel pipe =

Nom. Dia/ N.B	**=**	**32.00**	mm
Outside diameter	**=**	**42.20**	mm

2) Calculation Of Hand-Bassain + Scupper + Table with sink Pipe (P2)

Q pump	=	15.00	m^3/h
	=	0.004166667	m^3/s
v flow	=	2.5	m/s

Specification of pipe diameter =

Q	=	A x V	
	=	$1/4 \times \pi \times D^2 \times v$	
D	=	$Q / (1/4 \times \pi \times v)$	
	=	0.0021	m
D	=	46.08	mm
	=	1.814	inches

So, the selected types of galvanized steel pipe =

Nom. Dia/ N.B	**=**	**50.00**	mm
Outside diameter	**=**	**60.30**	mm

b. Calculation of Pipes in Deck F

Room : Man A.06, Man A.08, Man A.13, Man A.15, Man A.15

1) Calculation Of Hand-Bassain, Scupper, & Shower-Bath Pipe (P1)

Q pump	=	5.00	m^3/h

	=	0.001389	m^3/s
v flow	=	2.5	m/s

Specification of pipe diameter =

Q	=	A x V	
	=	1/4 x π x D^2 x v	
D	=	Q / (1/4 x π x v)	
	=	0.0007	m
D	=	26.60	mm
	=	1.047	inches

So, the selected types of galvanized steel pipe =

Nom. Dia/ N.B	**=**	**32.00**	mm
Outside diameter	**=**	**42.20**	mm

2) Calculation Of Hand-Bassain + Scupper + Shower-Bath Pipe (P2)

Q pump	=	15.00	m^3/h
	=	0.004166667	m^3/s
v flow	=	2.5	m/s

Specification of pipe diameter =

Q	=	A x V	
	=	1/4 x π x D^2 x v	
D	=	Q / (1/4 x π x v)	
	=	0.0021	m
D	=	46.08	mm
	=	1.814	inches

So, the selected types of galvanized steel pipe =

Nom. Dia/ N.B	**=**	**50.00**	mm
Outside diameter	**=**	**60.30**	mm

3) Calculation Of Q3 Pipe

Q pump	=	30.00	m^3/h
	=	0.008333333	m^3/s
v flow	=	2.5	m/s

Specification of pipe diameter =

Q	=	A x V	
	=	1/4 x π x D^2 x v	
D	=	Q / (1/4 x π x v)	
	=	0.0042	m
D	=	65.16	mm

= 1.814 inches

So, the selected types of galvanized steel pipe =

Nom. Dia/ N.B = **65.00** mm

Outside diameter = **73.00** mm

c. Calculation of Pipes in Deck E

Room : Man A.06, Man A.08, Man A.13, Man A.15, Man A.15

1) Calculation Of Hand-Bassain, Scupper, & Shower-Bath Pipe (P1)

Q pump = 5.00 m^3/h

= 0.001389 m^3/s

v flow = 2.5 m/s

Specification of pipe diameter =

Q = A x V

= 1/4 x π x D^2 x v

D = Q / (1/4 x π x v)

= 0.0007 m

D = 26.60 mm

= 1.047 inches

So, the selected types of galvanized steel pipe =

Nom. Dia/ N.B = **32.00** mm

Outside diameter = **42.20** mm

2) Calculation Of Hand-Bassain + Scupper + Shower-Bath Pipe (P2)

Q pump = 15.00 m^3/h

= 0.004166667 m^3/s

v flow = 2.5 m/s

Specification of pipe diameter =

Q = A x V

= 1/4 x π x D^2 x v

D = Q / (1/4 x π x v)

= 0.0021 m

D = 46.08 mm

= 1.814 inches

So, the selected types of galvanized steel pipe =

Nom. Dia/ N.B = **50.00** mm

Outside diameter = **60.30** mm

3) Calculation Of Q3 Pipe

Q pump	=	30.00	m^3/h
	=	0.008333333	m^3/s
v flow	=	2.5	m/s

Specification of pipe diameter =

Q	=	A x V	
	=	$1/4 \times \pi \times D^2 \times v$	
D	=	$Q / (1/4 \times \pi \times v)$	
	=	0.0042	m
D	=	65.16	mm
	=	1.814	inches

So, the selected types of galvanized steel pipe =

Nom. Dia/ N.B	**=**	**65.00**	mm
Outside diameter	**=**	**73.00**	mm

d. Calculation of Pipes in Deck D

Room : Man A.06, Man A.08, Man A.13, Man A.15, Man A.15

1) Calculation Of Hand-Bassain, Scupper, & Shower-Bath Pipe (P1)

Q pump	=	5.00	m^3/h
	=	0.001389	m^3/s
v flow	=	2.5	m/s

Specification of pipe diameter =

Q	=	A x V	
	=	$1/4 \times \pi \times D^2 \times v$	
D	=	$Q / (1/4 \times \pi \times v)$	
	=	0.0007	m
D	=	26.60	mm
	=	1.047	inches

So, the selected types of galvanized steel pipe =

Nom. Dia/ N.B	**=**	**32.00**	mm
Outside diameter	**=**	**42.20**	mm

2) Calculation Of Hand-Bassain + Scupper + Shower-Bath Pipe (P2)

Q pump	=	15.00	m^3/h
	=	0.004166667	m^3/s
v flow	=	2.5	m/s

Specification of pipe diameter =

Q	=	A x V	
	=	1/4 x π x D^2 x v	
D	=	Q / (1/4 x π x v)	
	=	0.0021	m
D	=	46.08	mm
	=	1.814	inches

So, the selected types of galvanized steel pipe =

Nom. Dia/ N.B	=	**50.00**	mm
Outside diameter	=	**60.30**	mm

3) Calculation Of Q3 Pipe

Q pump	=	30.00	m^3/h
	=	0.008333333	m^3/s
v flow	=	2.5	m/s

Specification of pipe diameter =

Q	=	A x V	
	=	1/4 x π x D^2 x v	
D	=	Q / (1/4 x π x v)	
	=	0.0042	m
D	=	65.16	mm
	=	1.814	inches

So, the selected types of galvanized steel pipe =

Nom. Dia/ N.B	=	**65.00**	mm
Outside diameter	=	**73.00**	mm

e. Calculation of Pipes in Deck C

Room : Man A.06, Man A.08, Man A.13, Man A.15, Man A.15

1) Calculation Of Hand-Bassain, Scupper, & Shower-Bath Pipe (P1)

Q pump	=	5.00	m^3/h
	=	0.001389	m^3/s
v flow	=	2.5	m/s

Specification of pipe diameter =

Q	=	A x V	
	=	1/4 x π x D^2 x v	
D	=	Q / (1/4 x π x v)	
	=	0.0007	m
D	=	26.60	mm

= 1.047 inches

So, the selected types of galvanized steel pipe =

Nom. Dia/ N.B **= 32.00** mm

Outside diameter **= 42.20** mm

2) Calculation Of Hand-Bassain + Scupper + Shower-Bath Pipe (P2)

Q pump = 15.00 m^3/h

= 0.004166667 m^3/s

v flow = 2.5 m/s

Specification of pipe diameter =

Q = A x V

= 1/4 x π x D^2 x v

D = Q / (1/4 x π x v)

= 0.0021 m

D = 46.08 mm

= 1.814 inches

So, the selected types of galvanized steel pipe =

Nom. Dia/ N.B **= 50.00** mm

Outside diameter **= 60.30** mm

3) Calculation Of Q3 Pipe

Q pump = 30.00 m^3/h

= 0.008333333 m^3/s

v flow = 2.5 m/s

Specification of pipe diameter =

Q = A x V

= 1/4 x π x D^2 x v

D = Q / (1/4 x π x v)

= 0.0042 m

D = 65.16 mm

= 1.814 inches

So, the selected types of galvanized steel pipe =

Nom. Dia/ N.B **= 65.00** mm

Outside diameter **= 73.00** mm

f. Calculation of Pipes in Deck B

Room : Man A.06, Man A.08, Man A.13, Man A.15, Man A.15

1) Calculation Of Hand-Bassain, Scupper, & Shower-Bath Pipe (P1)

Q pump	=	5.00	m^3/h
	=	0.001389	m^3/s
v flow	=	2.5	m/s

Specification of pipe diameter =

Q	=	A x V	
	=	$1/4 \times \pi \times D^2 \times v$	
D	=	$Q / (1/4 \times \pi \times v)$	
	=	0.0007	m
D	=	26.60	mm
	=	1.047	inches

So, the selected types of galvanized steel pipe =

Nom. Dia/ N.B	**=**	**32.00**	mm
Outside diameter	**=**	**42.20**	mm

2) Calculation Of Hand-Bassain + Scupper + Shower-Bath Pipe (P2)

Q pump	=	15.00	m^3/h
	=	0.004166667	m^3/s
v flow	=	2.5	m/s

Specification of pipe diameter =

Q	=	A x V	
	=	$1/4 \times \pi \times D^2 \times v$	
D	=	$Q / (1/4 \times \pi \times v)$	
	=	0.0021	m
D	=	46.08	mm
	=	1.814	inches

So, the selected types of galvanized steel pipe =

Nom. Dia/ N.B	**=**	**50.00**	mm
Outside diameter	**=**	**60.30**	mm

3) Calculation Of Q3 Pipe

Q pump	=	30.00	m^3/h
	=	0.008333333	m^3/s
v flow	=	2.5	m/s

Specification of pipe diameter =

Q	=	A x V	
	=	1/4 x π x D^2 x v	
D	=	Q / (1/4 x π x v)	
	=	0.0042	m
D	=	65.16	mm
	=	1.814	inches

So, the selected types of galvanized steel pipe =

Nom. Dia/ N.B	=	**65.00**	mm
Outside diameter	=	**73.00**	mm

g. Calculation of Pipes in Deck A

Room : Man A.06, Man A.08, Man A.13, Man A.15, Man A.15

1) Calculation Of Hand-Bassain, Scupper, & Shower-Bath Pipe (P1)

Q pump	=	5.00	m^3/h
	=	0.001389	m^3/s
v flow	=	2.5	m/s

Specification of pipe diameter =

Q	=	A x V	
	=	1/4 x π x D^2 x v	
D	=	Q / (1/4 x π x v)	
	=	0.0007	m
D	=	26.60	mm
	=	1.047	inches

So, the selected types of galvanized steel pipe =

Nom. Dia/ N.B	=	**32.00**	mm
Outside diameter	=	**42.20**	mm

2) Calculation Of Hand-Bassain + Scupper + Shower-Bath Pipe (P2)

Q pump	=	15.00	m^3/h
	=	0.004166667	m^3/s
v flow	=	2.5	m/s

Specification of pipe diameter =

Q	=	A x V	
	=	1/4 x π x D^2 x v	
D	=	Q / (1/4 x π x v)	
	=	0.0021	m
D	=	46.08	mm

= 1.814 inches

So, the selected types of galvanized steel pipe =

Nom. Dia/ N.B **= 50.00** mm

Outside diameter **= 60.30** mm

3) Calculation Of Q3 Pipe

Q pump = 30.00 m^3/h

= 0.008333333 m^3/s

v flow = 2.5 m/s

Specification of pipe diameter =

Q = A x V

= 1/4 x π x D^2 x v

D = Q / (1/4 x π x v)

= 0.0042 m

D = 65.16 mm

= 1.814 inches

So, the selected types of galvanized steel pipe =

Nom. Dia/ N.B **= 65.00** mm

Outside diameter **= 73.00** mm

h. Calculation of Pipes in Poop Deck

Room : Man A.06, Man A.08, Man A.13, Man A.15, Man A.15

1) Calculation Of Food Waste Disposer, Scupper, & Table with sink Pipe (P1)

Q pump = 5.00 m^3/h

= 0.001389 m^3/s

v flow = 2.5 m/s

Specification of pipe diameter =

Q = A x V

= 1/4 x π x D^2 x v

D = Q / (1/4 x π x v)

= 0.0007 m

D = 26.60 mm

= 1.047 inches

So, the selected types of galvanized steel pipe =

Nom. Dia/ N.B **= 32.00** mm

Outside diameter **= 42.20** mm

2) Calculation Of Hand-Bassain + Scupper + Shower-Bath Pipe (P2)

Q pump	=	45.00	m^3/h
	=	0.0125	m^3/s
v flow	=	2.5	m/s

Specification of pipe diameter =

Q	=	A x V	
	=	$1/4 \times \pi \times D^2 \times v$	
D	=	$Q / (1/4 \times \pi \times v)$	
	=	0.0064	m
D	=	79.81	mm
	=	3.142	inches

So, the selected types of galvanized steel pipe =

Nom. Dia/ N.B	**=**	**80.00**	mm
Outside diameter	**=**	**89.00**	mm

i. Calculation of Pipes in Main Deck

Room : Man A.06, Man A.08, Man A.13, Man A.15, Man A.15

1) Calculation Of Hand-Bassain, Scupper, Table with sink, Washer, & Exstrastor Pipe (P1)

Q pump	=	5.00	m^3/h
	=	0.001389	m^3/s
v flow	=	2.5	m/s

Specification of pipe diameter =

Q	=	A x V	
	=	$1/4 \times \pi \times D^2 \times v$	
D	=	$Q / (1/4 \times \pi \times v)$	
	=	0.0007	m
D	=	26.60	mm
	=	1.047	inches

So, the selected types of galvanized steel pipe =

Nom. Dia/ N.B	**=**	**32.00**	mm
Outside diameter	**=**	**42.20**	mm

2) Calculation Of Hand-Bassain + Scupper Pipe (P2)

Q pump	=	10.00	m^3/h
	=	0.002777778	m^3/s
v flow	=	2.5	m/s

Specification of pipe diameter =

Q	=	A x V	
	=	1/4 x π x D^2 x v	
D	=	Q / (1/4 x π x v)	
	=	0.0014	m
D	=	37.62	mm
	=	1.481	inches

So, the selected types of galvanized steel pipe =

Nom. Dia/ N.B	**=**	**42.00**	mm
Outside diameter			mm

3) Calculation Of Hand-Bassain + Scupper + Table with sink + Washer + Exstrastor Pipe (Q3)

Q pump	=	45.00	m^3/h
	=	0.0125	m^3/s
v flow	=	2.5	m/s

Specification of pipe diameter =

Q	=	A x V	
	=	1/4 x π x D^2 x v	
D	=	Q / (1/4 x π x v)	
	=	0.0064	m
D	=	79.81	mm
	=	3.142	inches

So, the selected types of galvanized steel pipe =

Nom. Dia/ N.B	**=**	**80.00**	mm
Outside diameter	**=**	**89.00**	mm

ATTACHMENT 2

Biography

Angya Prambiksono, Born in Balikpapan, East Kalimantan, on Friday, November 3, 1995. The author began his education in 2001 until 2007 at the elementary school at the Elementary School National KPS Balikpapan, East Kalimantan. In that same year the author continued his education at the National Junior High School of KPS Balikpapan East Kalimantan until 2010. After graduating from the First High School, the author continued his education at Senior High School 2 Balikpapan East Kalimantan until 2013. Currently the author continues his education tiered Which is higher in Sepuluh Nopember Institute of Technology Surabaya by taking the major Marine Engineering Department.