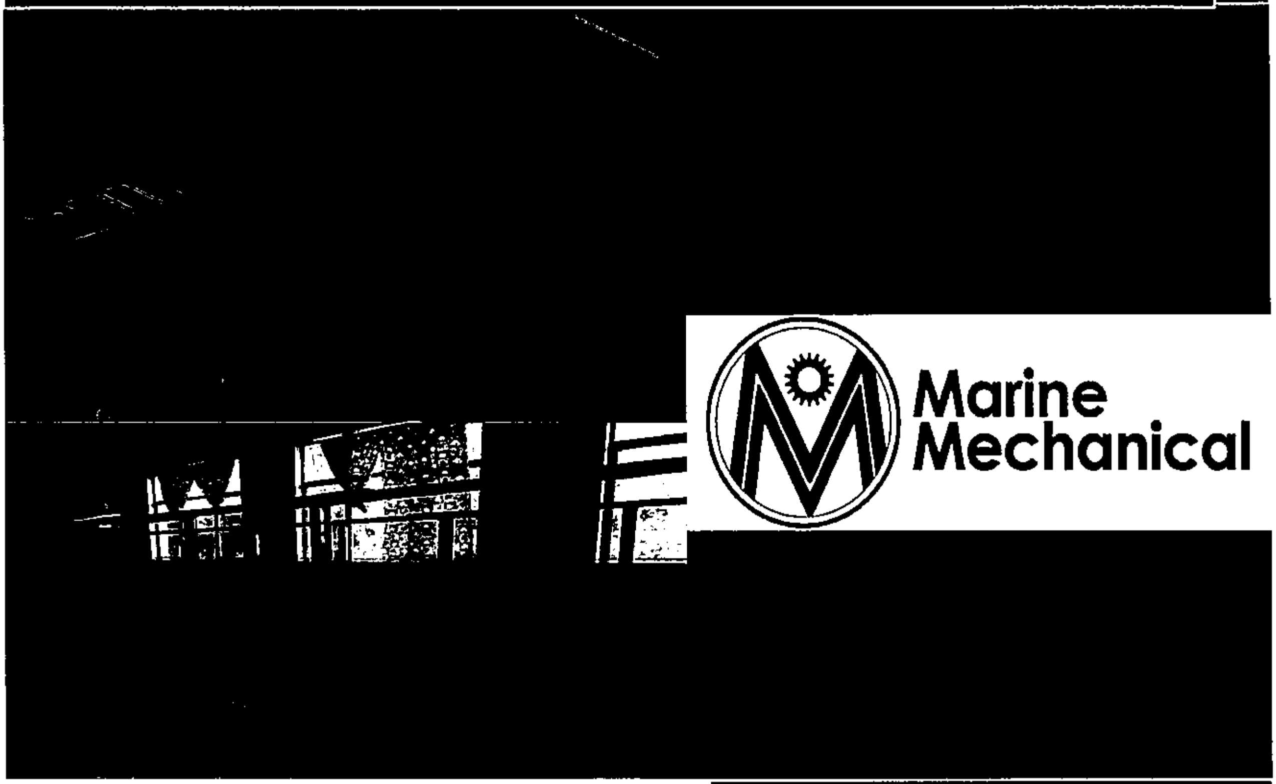
Myanmar Maritime University

Marine Mechanical Engineering Department

2017-2018

Study of renewable energy from wave by physical simulation



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Supported by WNI WxBunka Foundation

2017-2018

Introduction

Being located to the east of Indian Ocean, Myanmar possesses a very long coastline of 1930 km. But renewable energy cannot still be generated from tidal wave. The Department of Port and Harbour Engineering from our university has now been doing a research on generating renewable energy from tidal wave.

As the Department of Marine Mechanical Engineering, production of renewable energy from water waves will be studied by using a physical simulation.

Since the current wave generating machine (1989), donated to MMU by Japan, can only generate paddle motion for deep water, a new wave generator is needed to be designed and constructed to conduct this physical simulation which is capable of performing the following functions:

i. deep water wave
ii. shallow water wave and
iii. complex wave

This project is planned to generate the renewable energy from the waves described above.

Objectives

The primary objectives of this project are to generate verified water waves with required wave length and amplitude, and to produce electricity from water waves.

This project is to produce deep water waves from which electricity will be generated as a form of renewable energy, being different from other power plants in that it is not very harmful to the environment.

Besides, students can study the nature of wave as a part of their hydrodynamic studies and how it is converted to electricity by means of dynamics of mechanisms and control systems. Being a maritime university, this project is also aimed to test ship stability and maneuverability experiments as well as port and harbour field.

Types of Wave Generator

There are various types of wave generators around the world which can produce shallow water wave, deep water wave and transition wave with desired wave length, wave height and wave period.

i. Rigid Flap Type
ii. Single articulation
iii. Double articulation
iv. Pneumatic
v. Plunger, etc

Our wave generator is based on double articulation type. In this type, the lower end of the paddle can be adjusted to travel a longitudinal distance different to that transverse by the top end.

To produce deep water waves, the bottom end of the paddle is adjusted at zero travel distance, operating as the flap type with single articulation as shown in Fig 1.

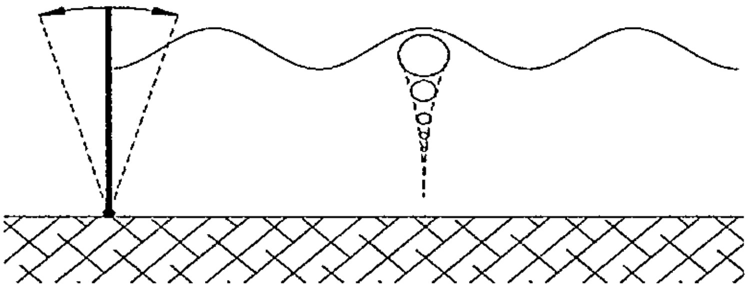


Fig 1. Flap paddle motion for deep water waves

Fig 2 shows how to produce shallow water waves, the top and bottom ends are adjusted to travel the same distance, acting as piston type wave generator.

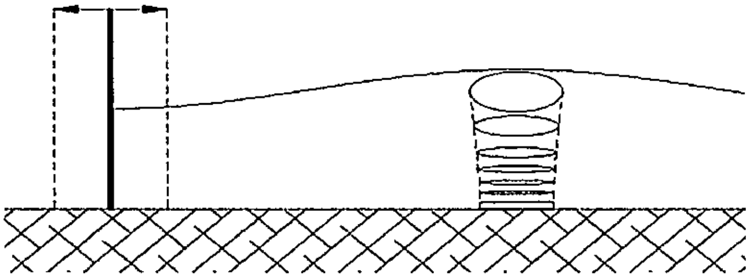


Fig 2. Piston paddle motion for shallow water waves

To produce transition waves, the bottom end of the paddle is adjusted between zero and the distance travelled by the top end in Fig 3.

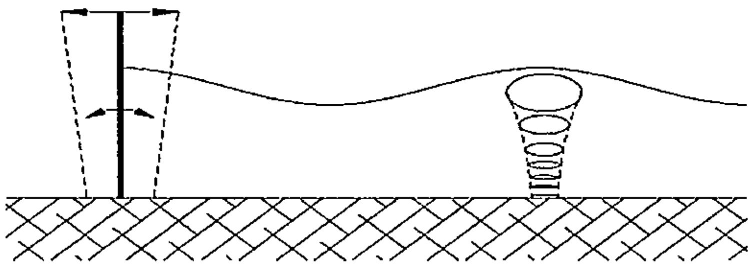


Fig 3. Complex motion for transition waves

Wave Tank Specifications

The wave tank is made of stainless steel and glass as shown in Fig 4. The tank was built in panels and assembled using fasteners. Silicone and rubber seals are used for sealing of water.

For the motion of the paddle, two 1.8kW electric servos, ball screws and linear bearings are used. Force calculations and side panel stress simulation for the wave generator are present in Appendix-A. The specifications of the tank and paddle are shown below and the detail drawings in Appendix-B.

Tank length	5 meters
Tank width	1 meter
Tank height	1 meter
Maximum water level	0.8 meter
Maximum flap stroke	140 mm
Maximum flap frequency	4 Hz

Fig 4. CAD rendering of the wave generator

Applications of the wave generator

Using our wave generator, various experiments such as ship motion in 3DOF (roll, pitch and heave), anchor test, port and harbour application, resistance test with wave and power generation from waves. Study of velocity and wake field of propellers can be made with additional instruments.

Generation of renewable energy from waves

Energy from ocean waves can be extracted and converted to electricity as a mean of sustainable power source. Several methods can be used for the conversion of wave energy to electricity such as buoy, overtopping device or oscillating water column as shown in Fig 5.

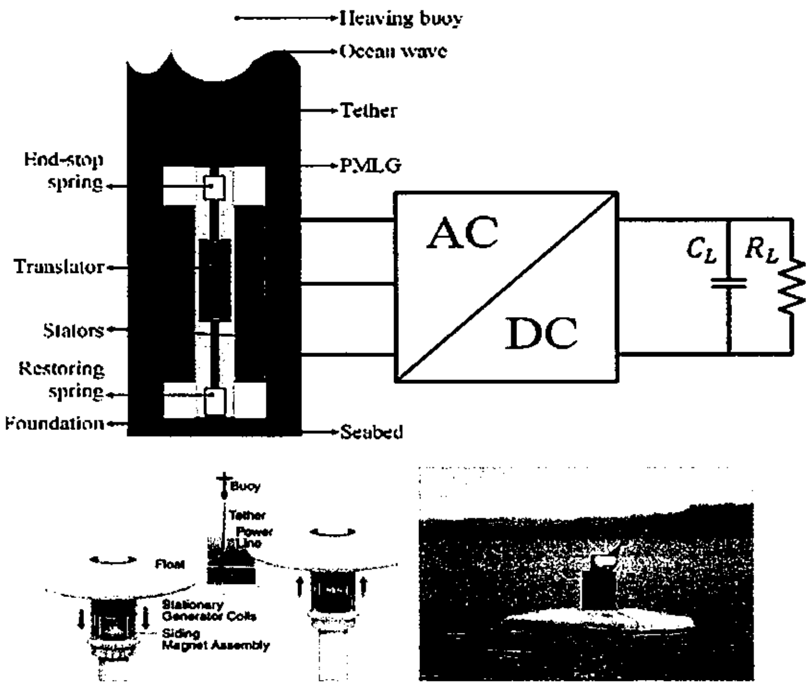


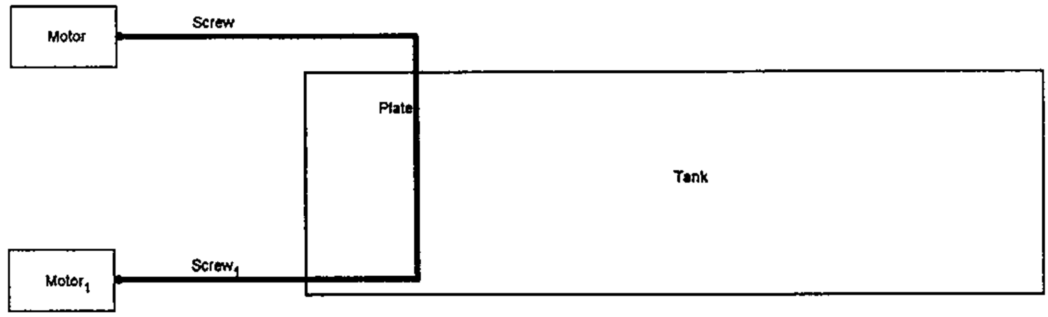
Fig 5. Float and magnet assembly

Our method is similar to buoy type. An array of magnets is linked via a string to a floating object. The float and magnet assembly is placed inside stationary coils. The float oscillates in waves which in turn oscillate the magnet. Hence the device acts as a linear generator and uses principles of electromagnetism to produce an electromotive force inside the coil. The movement of the magnets produces a changing magnetic field which induces EMF inside the coil. The generated EMF or voltage can be measured by a voltmeter.

Results

The amount of electricity generated depends on the frequency and amplitude of water waves. We observed that usual wave heights used in model tests are too low to excite the magnets. EMF is highest when the wave frequency is near the natural frequency of the float-magnet assembly. The typical EMF produced during our experiment was 0.5-1 V. Higher voltages can be achieved by connecting multiple devices in parallel.

Force calculations for the wave generator in MMU



Tank dimensions

Width = 1m, Height = 0.6m, Length = 5m, Water depth = 0.45m

V_{max} = 30 mm/s = 0.03 m/s

ρ = 1000 kg/m^3

A = 1 × 0.45 = 0.45 m^2

Pressure force

P_0 = 0

P_h = $\rho \times g \times h$

= 1000 × 9.81 × 0.45

= 4415 N/m^2

F_P = $0.5 \times P_h \times h \times w$

= 0.5 × 4415 × 0.45 × 1

= 993 N

Resistance

F_R = $0.5 \times \rho \times V^2 \times A$

= 0.5 × 1000 × 0.03^2 × 0.45

= 0.203 N

Nomenclature

V_{max} = maximum velocity of the plate

A = cross sectional area of water

h = depth of water

P_0 = Pressure at depth 0 m

P_h = Pressure at depth h m

F_P = Force due to pressure

F_R = Force due to resistance

$V_{displaced}$ = displaced volume of water

$m_{displaced}$ = displaced mass of water

a_{max} = maximum acceleration

F_I = inertial force

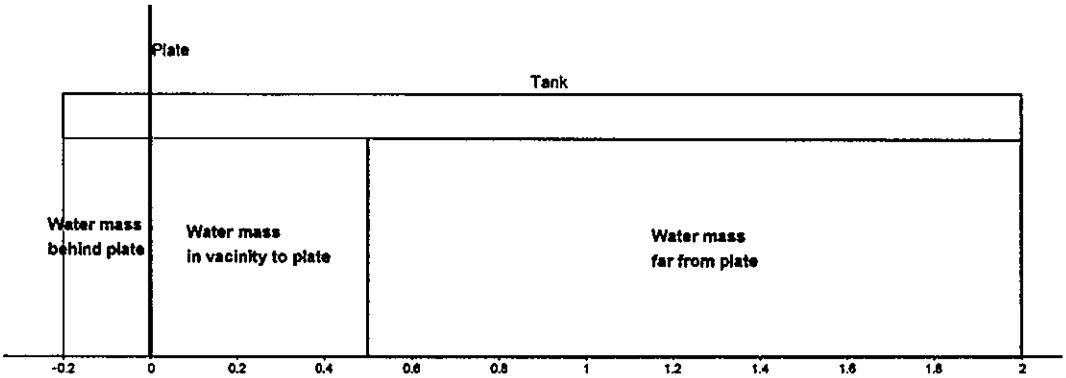
F_D = maximum driving force

Inertial force

Mass of flap plate ~ 9kg (Aluminum)/ 26kg (Steel)

Mass of control rods ~ 4kg

Mass of moving water body



$V_{displaced}$ $= 0.5 \times 1 \times 1 = 0.5\ m^3$

$m_{displaced}$ $= 0.5 \times 1000 = 500\ kg$

a_{max} $= 1\ m/s^2$

F_I $= m \times a$

$= (26+4+500) \times 1$

$= 530\ N$

Inertial force while reversing direction = $2F_I$ = 1060 N

Total Force

F_T $= F_P + F_R + 2F_I$

$= 596 + 0.203 + 1060$

$= 1656\ N$

Note: Force due to pressure may be neglected if there is water at the back side of the plate.

Driving force calculation

Torque of the motor = 6 Nm (Per motor)

Diameter of lead screw = 20 mm

Pitch of lead screw = 4 mm/rev

$$\text{work done by the motor} = \text{work done by the plate}$$

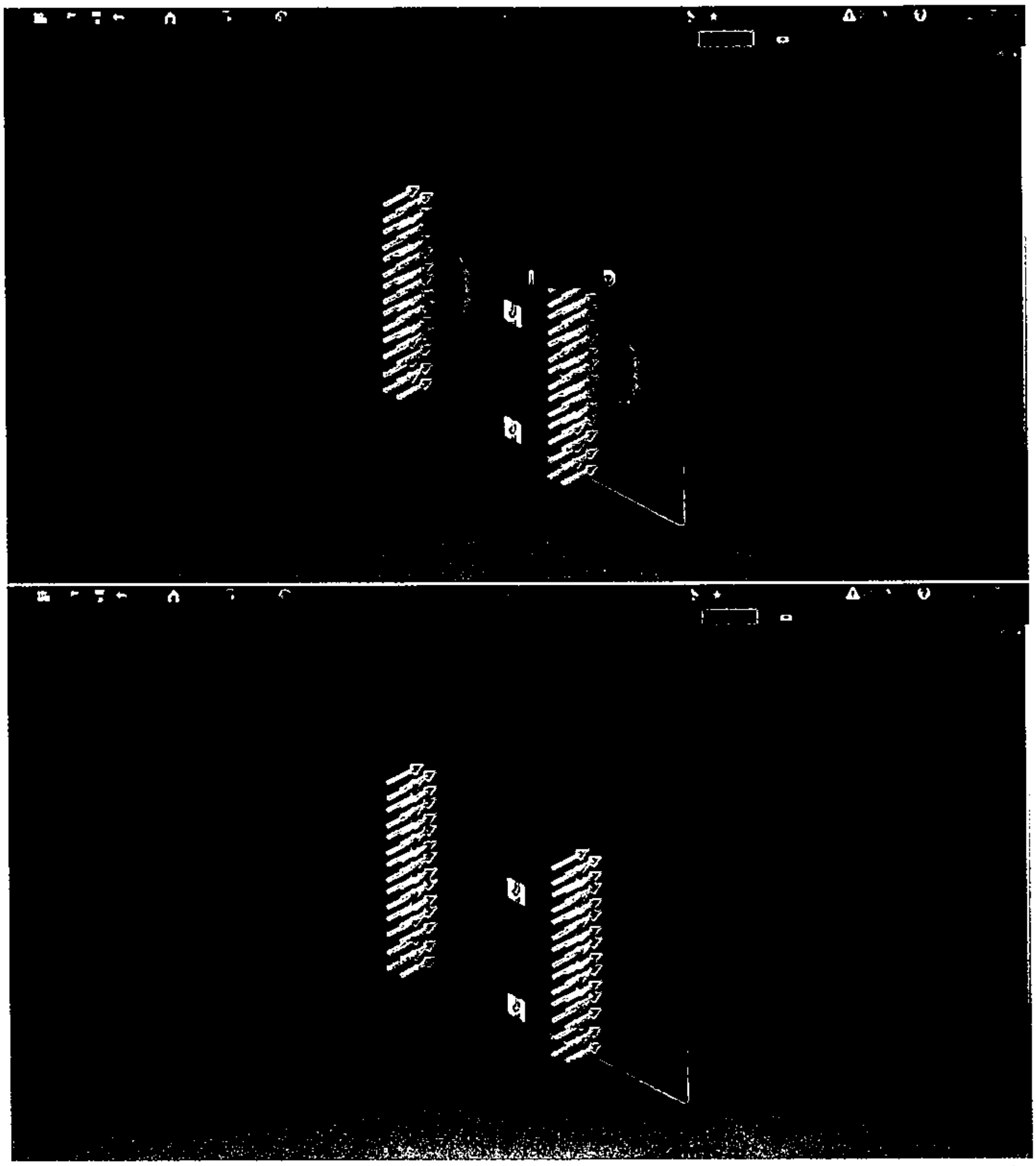
$$6 \times 2\pi = F_D \times 0.004$$

$$F_D = 9425\ N$$

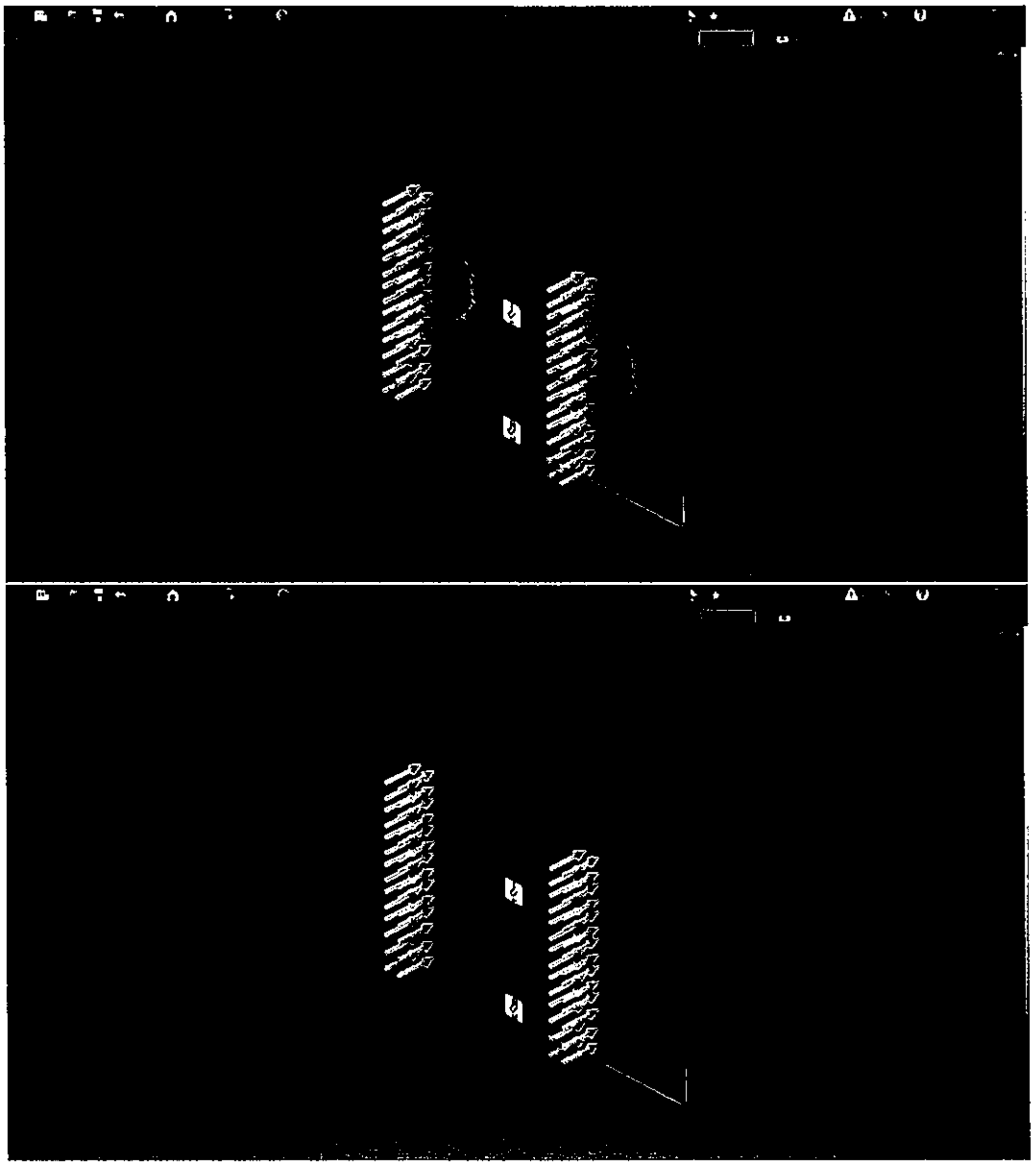
Side panel stress simulation (Water level = 800 mm)

Panel size = 1500 x 900 mm (Boarder frame and verticle middle frame)

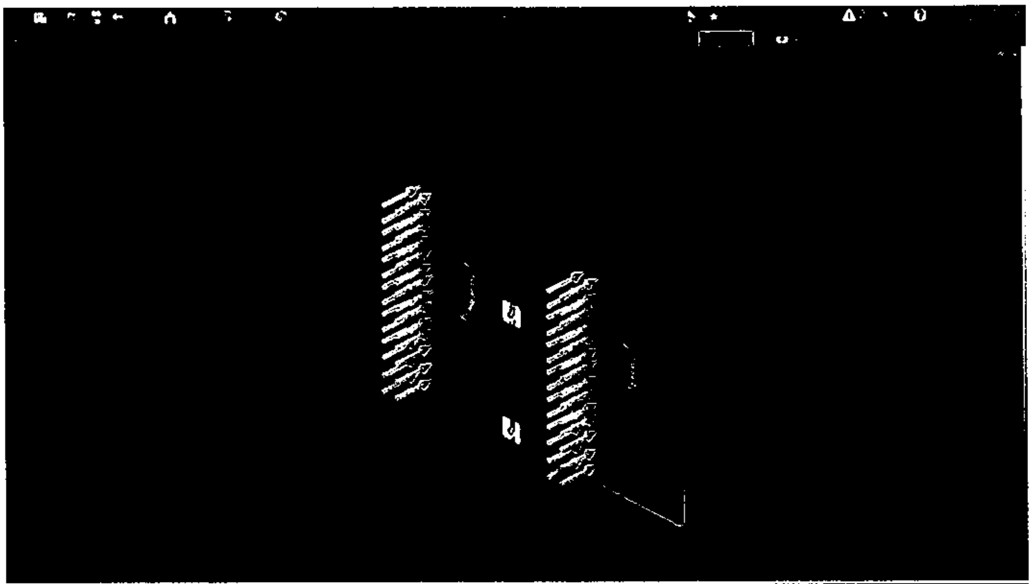
Acrylic - 6 mm

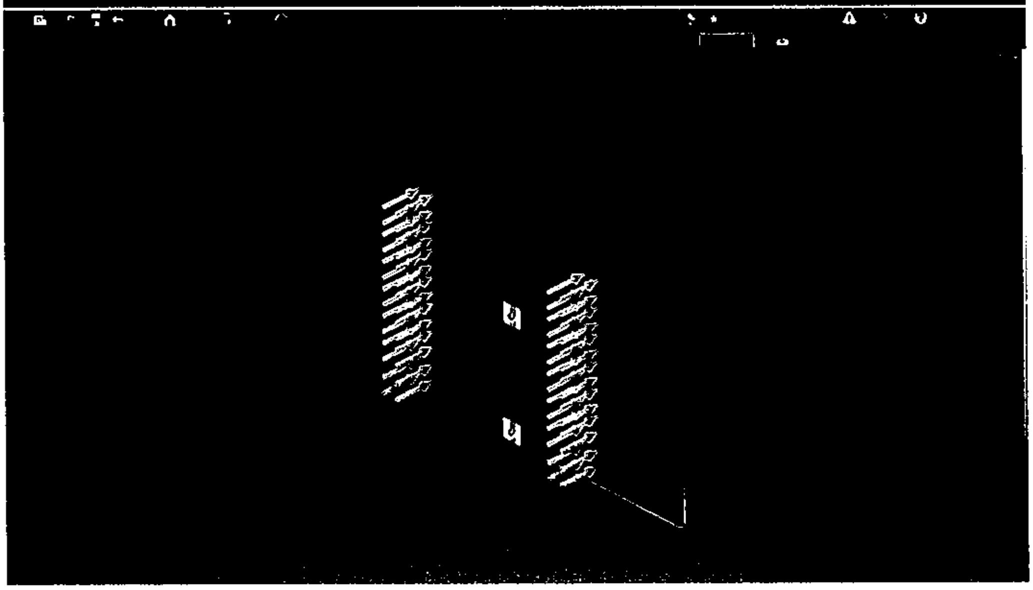


Acrylic – 8 mm

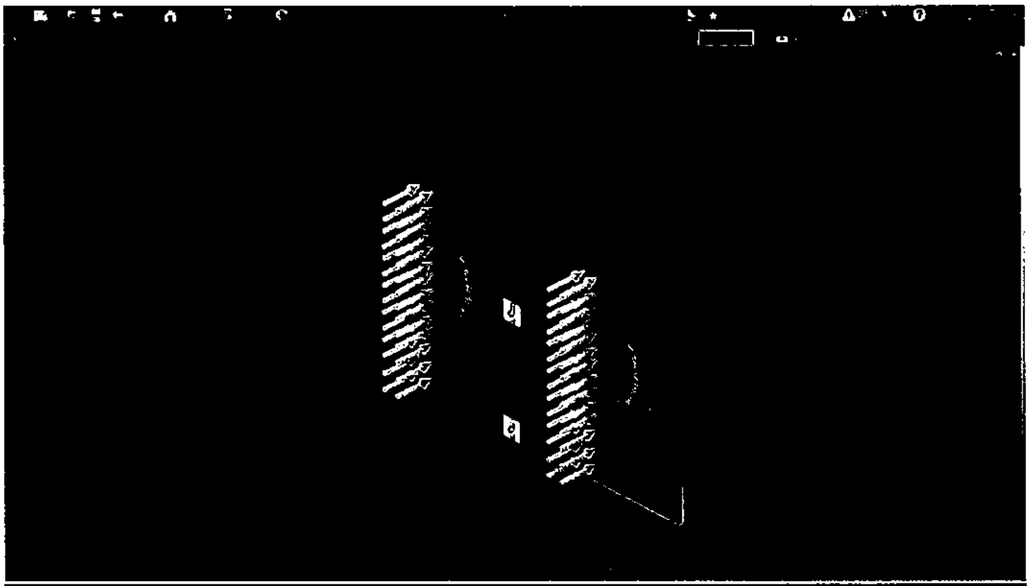


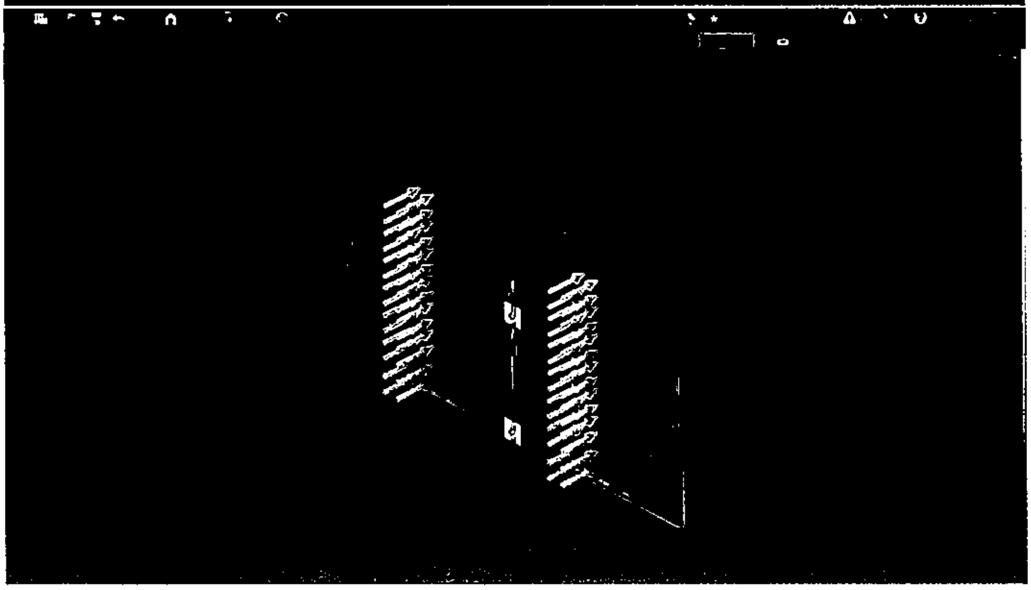
Acrylics – 10 mm





Glass – 6 mm

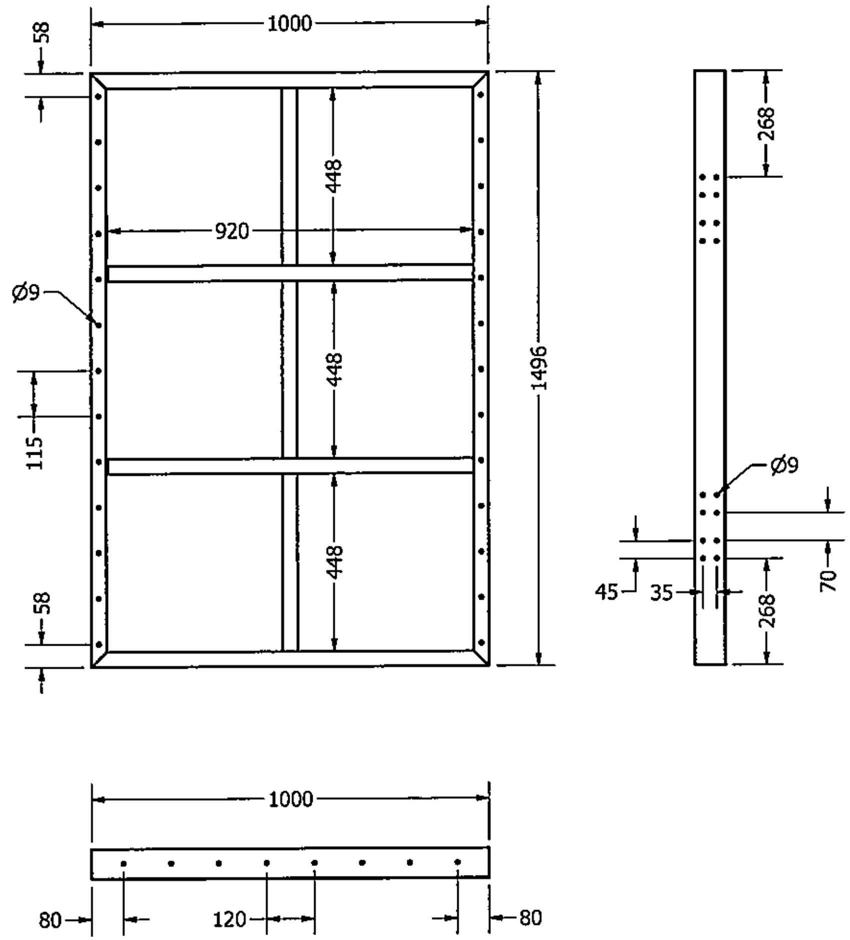


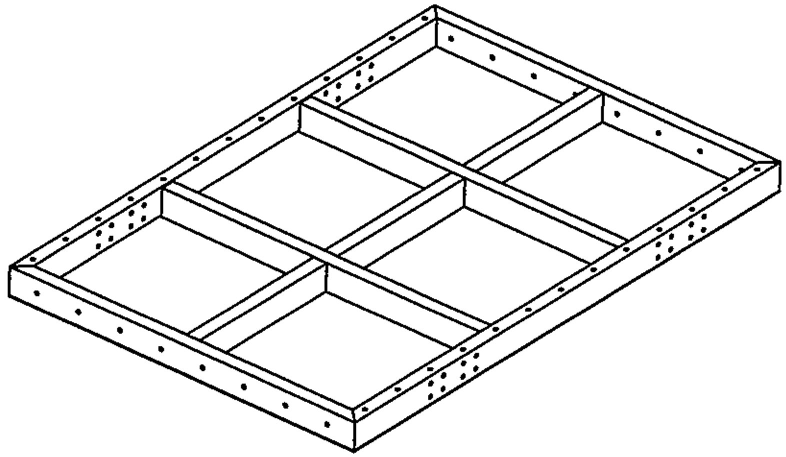


Acrylic		
Thickness	Deflection	Safety factor
6 mm	20.43 mm	3.13 - 15
8 mm	10.41mm	7.08 - 15
10 mm	5.41 mm	11.53 - 15
GLASS		
6 mm	0.96 mm	1.45 - 15

Appendix - B

PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	Bottom Plate	
2	9	75x38x1 Steel Hollow Channel	3"x1.5"

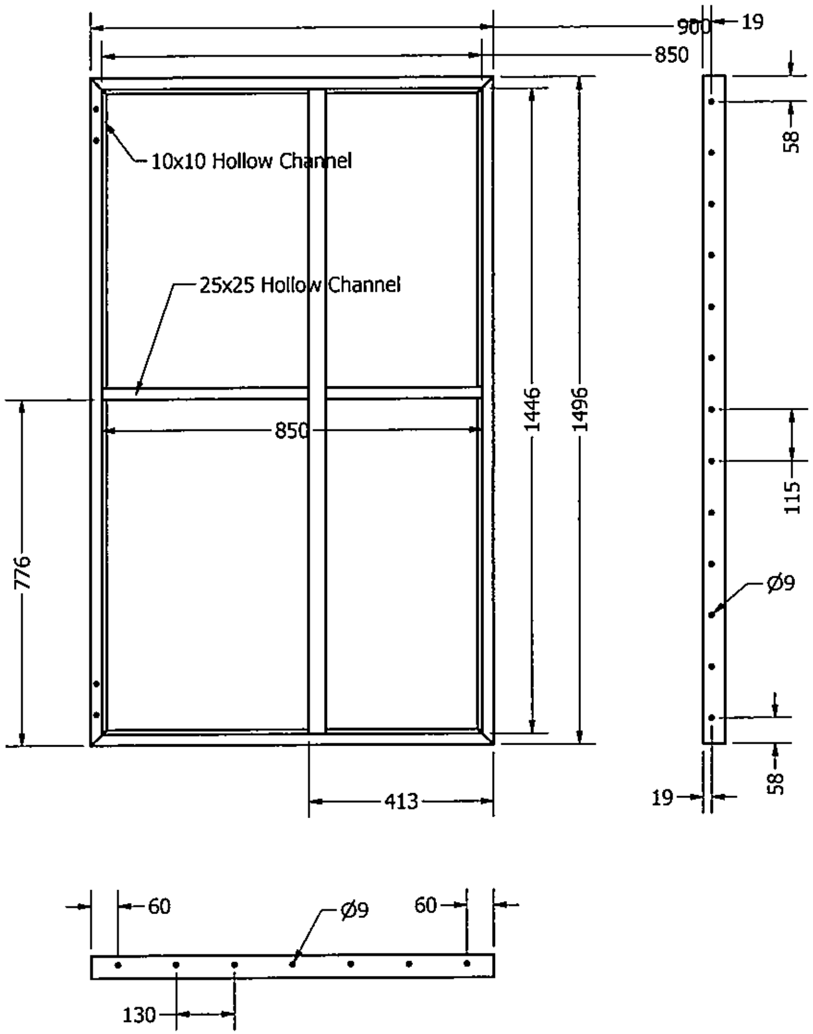


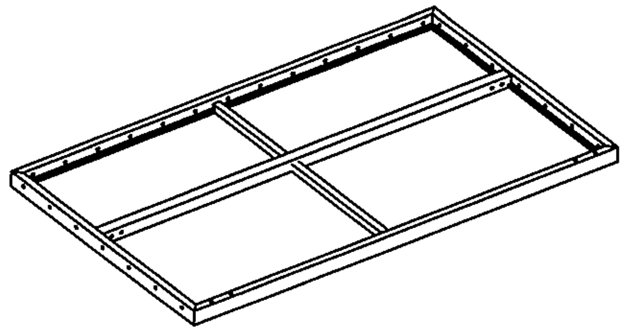


BOTTOM PANEL

DRAWN Thein Lin Aung	2/27/2018		
CHECKED Dr. Thu Han Tun			
QA		TITLE	
MFG			
APPROVED		Tank Panels	
		SIZE A3	DWG NO Panel Subassembly	REV
		SCALE 0.09	SHEET 1 OF 5

PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	3	50x25x0.8 Steel Hollow Channel	2"x1"
2	1	Side Acrylic Plate	6mm Glass Plate
3	4	10x10x0.5mm Steel Hollow Channel-01	
4	1	25x25x0.8mm Steel Hollow Channel-01	1"x1"
5	1		
6	1	38x38x0.8mm Steel Hollow Channel-01	





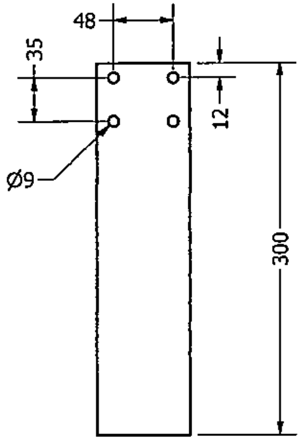
Glass Plate
Thickness >6 mm
Size = 1446 x 850 mm

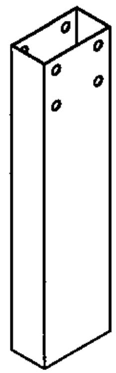
SIDE PANEL

DRAWN Thein Lin Aung	2/27/2018	
CHECKED Dr. Thu Han Tun		
QA		TITLE
MFG		
APPROVED		Tank Panels
		SIZE A3 — DWG NO Panel Subassembly — REV
		SCALE 0.07 — SHEET 2 OF 5

Appendix - B

PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	75x38x1 Steel Hollow Channel	



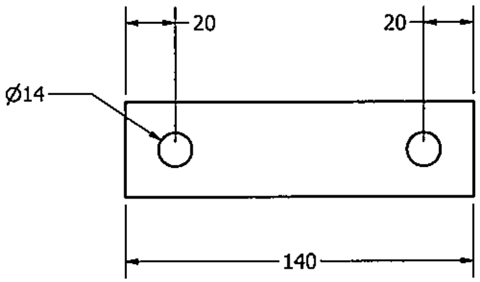


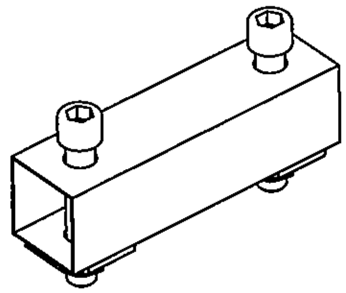
LEG

DRAWN Thein Lin Aung	2/27/2018		
CHECKED Dr. Thu Han Tun			
QA		TITLE	
MFG		Tank Panels	
APPROVED			
		SIZE A3	DWG NO Panel Subassembly	REV
		SCALE 1 / 4	SHEET 3 OF 5

Appendix - B

PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	38x38x0.8mm Steel Hollow Channel-01	
2	2	ANSI B 18.2.4.1 M - M12 x 1.75	Hex Nut
3	2	ANSI B18.3.1M - M12x1.75 x 70	Broached Socket Head Cap Screw - Metric
4	2	Foot interface plate	

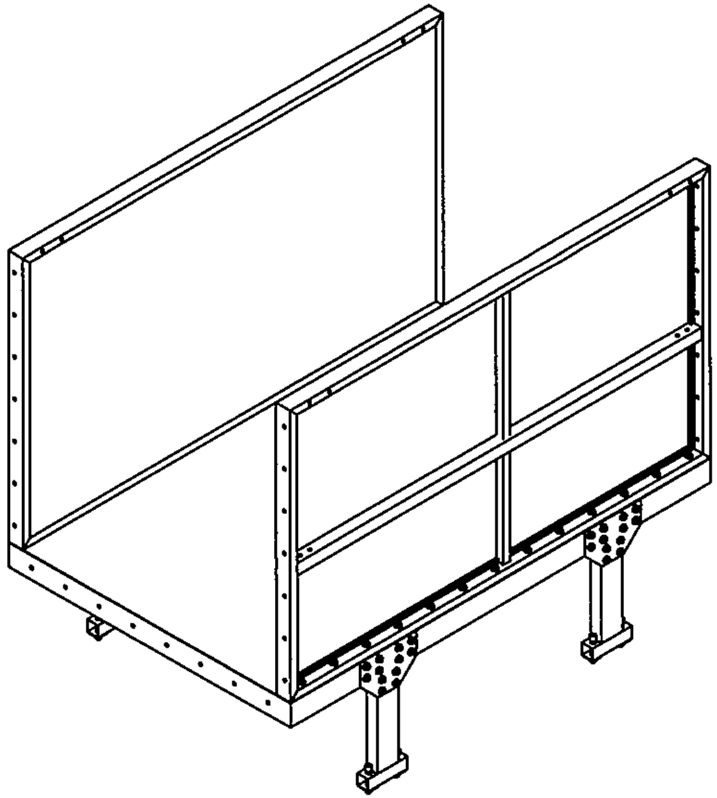




LEVELLER

DRAWN Thein Lin Aung	2/27/2018	
CHECKED Dr. Thu Han Tun		
QA		TITLE Tank Panels
MFG		
APPROVED		SIZE A3 · DWG NO Panel Subassembly · REV
		SCALE 1 / 2 · SHEET 4 OF 5

PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	Bottom Panel Subassembly	
2	8	Symmetrical Bracket 1	
3	148	ANSI B18.22M - 8 N	Metric Plain Washers
4	48	ANSI B18.2.3.5M - M8 x 1.25 x 60	Hex Bolt
5	74	ANSI B 18.2.4.1 M - M8 x 1.25	Hex Nut
6	2	Side Panel Subassembly	
7	4	75x38x1 Steel Hollow Channel	
8	4	Leveling Foot Subassembly	
9	26	ANSI B18.3.1M - M8x1.25 x 120	Broached Socket Head Cap Screw - Metric
11	1	38x38x0.8mm Steel Hollow Channel-01	



TANK SEGMENT

DRAWN Thein Lin Aung	2/27/2018	
CHECKED Dr. Thu Han Tun		
QA		TITLE Tank Panels
MFG		
APPROVED		
		SIZE A3 · DWG NO Panel Subassembly · REV
		SCALE 0.08 · SHEET 5 OF 5

"Simple can be harder than complex: You have to work hard to get your thinking clean to make it simple"

Steve Jobs