TENDON BIOREACTOR

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KXGL6305

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Table of Contents

Abstract

The drawbacks of surgery and grafts pertaining to the chronic tendon ailments or aging factor have led to the emergence of promising alternative, engineered tendon tissues. The engineered tissue is capable to mimic the physiological function of the native tissue. The dynamic tendon bioreactor system with appropriate mechanical stimulation is also able to mimic the dynamics of the in vivo environment for tendon maturation. Thus, in designing tendon bioreactor, the cyclic stretch and tensile strains are vital when considering the choice of mechanical stimulation to promote efficient cell differentiation. The parameters such as frequency, the duration and the strain applied can further fine tune to meet the design requirement. Nevertheless, the optimum function of the bioreactor also relies on the mass transport of the nutrients or the medium circulation. In this prototype design of the tendon bioreactor, the mechanical stimulation such as stretch are considered to provide uniform distribution of the medium throughout the construct. The gear principle is used to generate the stretch motion. The media intake and discharge will be controlled automatically. The temperature, carbon dioxide level and oxygen level are also controlled, hence no incubator is required in the design. The temperature inside the bioreactor will be maintained through the heat exchanger. The temperature and pH of the media in this prototype bioreactor will be monitored by their respective sensors.

Keywords: Tissue engineering, bioreactor, mechanical stimulation, cyclic stretch, tensile strains, mass transport.

Introduction

Tendon is a tough, inelastic and dense cord or band of fibrous connective tissue. Thus, it is able to withstand the tension. The main function of tendon is to connect or attach bone and muscles. It transmits force from muscle to bone. Besides, tendon is able to bend at the joints and also acts as a shock absorber to avoid the muscle damage. Tendon is comprised mostly of collagen type I fibrils along with small amounts of other proteins that provide support, elasticity, and hydration. By referring to Figure 1, from the macroscopic view, the tendon unit is composed of tertiary fibre bundle (fascicle), followed by secondary fibre bundle and primary fibre bundle. The primary fibre bundle is composed of collagen fibre. The collagen fibre consists of smaller subunit of collagen fibril. Finally, at the microscopic view, the fibril consists of the smallest subunit which is a triple-helix polypeptide chain, also known as tropocollagen. By referring to Figure 2, the collagen fibres are observed to be oriented longitudinally.

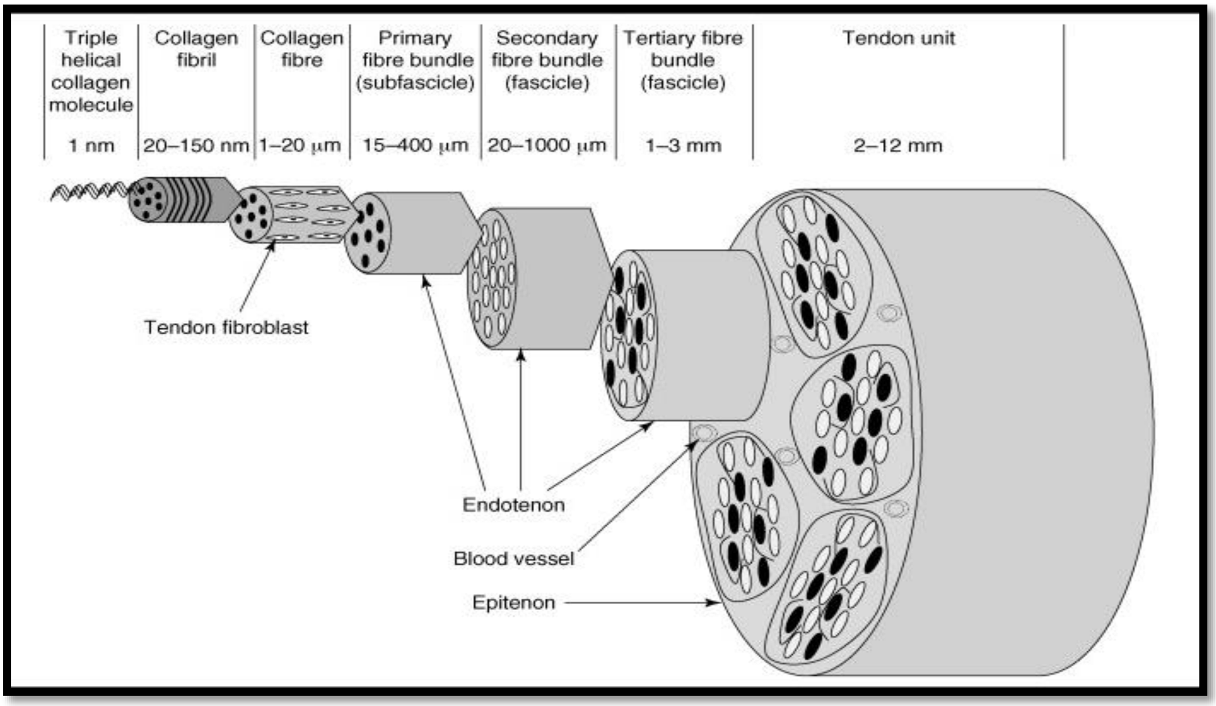

Figure 1: From macroscopic to microscopic view of tendon. Adapted from "Tendon Injury and Tendinopathy: Healing and Repair" by Sharma, P & Maffulli, N., 2005. *The Journal of Bone and Joint Surgery (American), 87*, p.188.

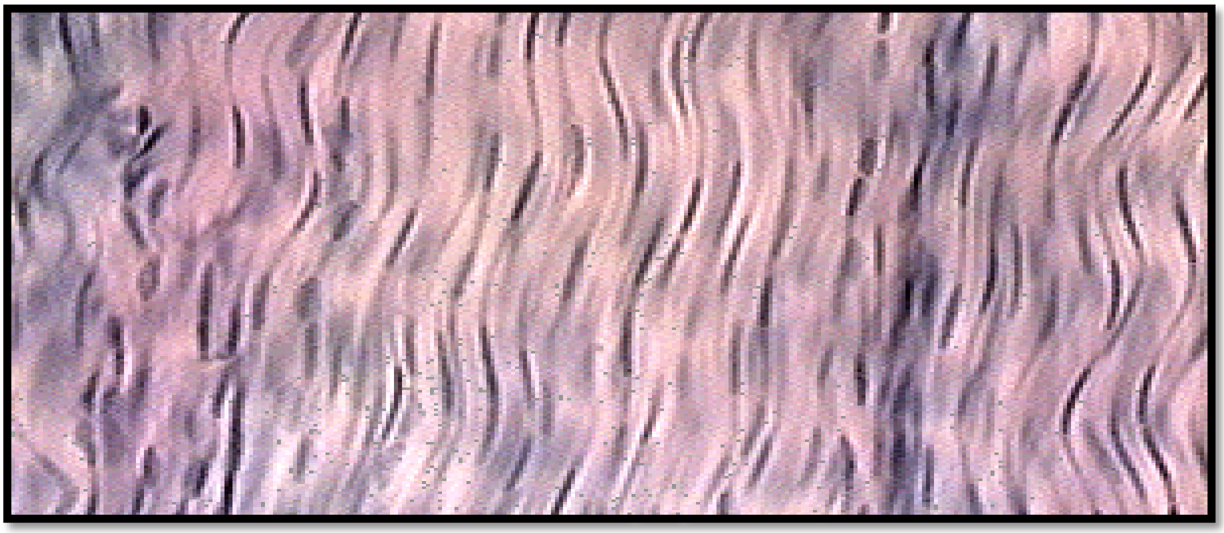

Figure 2: Tendon Tissue. Retrieved from: http://faculty.une.edu/com/abell/histo/histolab2.htm

Tendons are prone to injuries as they are made up of connective tissues which are poorly vascularised (Archambault, Wiley, & Bray, 1995). They also have low cellularity and low cell metabolism (Maffulli & Benazzo, 2000). Chronic tendon ailments such as tendinosis (microtears) and tendinitis (inflammation) can lead to severe tendon injury or even rupture when high tensile load are applied (Sharma & Maffulli, 2005). Tendons have low healing capacity (Sharma, 2005). For severe cases mentioned above, surgery is the main option. Surgeries always imposes the risk of infection and requires long intensive care. On the other hand, the grafts for example allograft may induce immune rejection or trigger immune responses in one’s body. Apart from that, the replacement using prosthetic too fail to generate satisfactory result in the long term. Thus, the tissue engineered tendon is gaining a new momentum and have been opted to overcome and address the challenges as well as the concern. By using the tissue engineering technique, autologous cells may be used to produce different types of tissues. Nevertheless, in tissue engineering, there are also a few challenges for example to grow three dimensional (3D) tissue structures of relevant clinical sizes as well as to induce the growth and 3D assembly of various cell types for meeting complex functional tissue. To overcome those challenges, a bioreactor system is designed and developed. The bioreactor is vital for the application of the cell-based tissue engineering approach. The tissue engineering bioreactor is defined as a device which provides the environment which mimics the cell in vivo. It is equipped or provided with relevant chemical and dynamic mechanical stimuli that could ultimately facilitate the conversion of the cells into specific functional tissue types.

According to Kearney, Prendergast, & Campbell (2008), proliferation rate increased when 2D stretching with strains between 2-8% were carried out on stem cells. Mesenchymal stem cells can align and elongate following the direction of stretching according to characteristics of tenocytes within a tendon (Zhang, Kahn, Chen, Tran, & Wang, 2008). The process starts with cell isolation from the patients themselves. The cells are then expanded. These cells are then conditioned in a dynamic environment in bioreactor which mimics the native environment of the cells. The bioreactors provide tendon cells with the appropriate biochemical and biomechanical stimulus to ensure the tissue is robust and is able to withstand continuous loading when implanted in humans. The common biomechanical stimulus required for tendons is stretching. In a study carried out by Chen et al., (2008), collagen type I and III gene expression increased together with an increment in production of collagen when mesenchymal stem cell were exposed to cyclic stretching. The biochemical stimuli required for tendon growth are insulin-like growth factor-I (IGF-I), transforming growth factor beta (TGFbeta), vascular endothelial growth factor (VEGF), platelet-derived growth factor (PDGF), and basic fibroblast growth factor (bFGF) (Molloy, Wang, & Murrell, 2003). These growth factors aid proliferation, migration of fibroblast and increase collagen production.

Mechanical Properties of Tendon

The tendon force and displacement at maximum isometric load were 530 N and 4·1 mm, and the corresponding stress and strain values were 25 MPa and 2·5 %, respectively. The tendon stiffness and Young's modulus at maximum isometric load were 161 N mm^{-1} and 1·2 GPa respectively (Maganaris, & Paul, 1999). Experiments on several tendons indicate that the Young's modulus reaches the level of 1 to 2 GPa at stresses exceeding 30 Mpa (Bennett, Ker, Imery, & Alexander, 1986; Shadwick, 1990; Pollock, & Shadwick, 1994). Ultimate tendon stress (i.e., stress at failure) values in the range of 50 to 100Mpa are generally reported (Shadwick, 1990; Pollock, & Shadwick, 1994; Elliott, 1965).Ultimate tendon strain (i.e., strain at failure) values of 4% to 10% have been reported (Elliott, 1965).The tendon toughness (i.e., work done on the tendon until failure) values reported are in the range of 1000 to 4500 J/kg. Shadwick (1990) demonstrated that the tensile strength of tendons is related to collagen content as well as thickness. A tendon with an area of 1 cm2 is able to sustain the load of 500-1,000 kg. Zernicke, Garhammer, & Jobe (1977) reported that very high loads are placed on tendons during strenuous physical activities for examples weight lifting and jumping. According to (Komi, Fukashiro, & Järvinen, 1992), during running, forces of 9 kN which is approximately 12.5 times body weight, have been recorded in the human Achilles tendon. In tendon rupture, the rate of loading also plays a vital role. (Fyfe & Stanish, 1992) has observed the highest forces during eccentric muscle contraction.

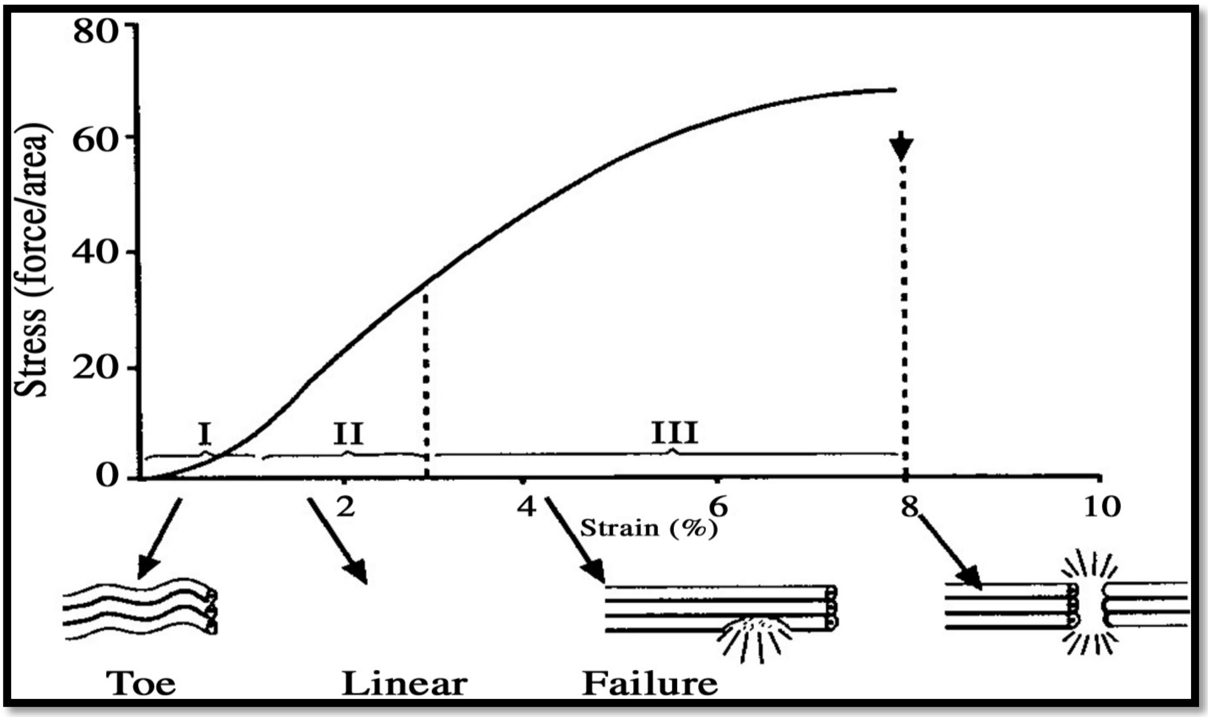

Figure 3: Tendon stress and strain curve Adapted from "Tendon Injury and Tendinopathy: Healing and Repair" by Sharma, P & Maffulli, N., 2005. *The Journal of Bone and Joint Surgery (American), 87,* p.188.

The physiological behaviour of tendon can be shown through a stress-strain curve (Fig. 3). Based on figure 3, the crimped configuration is exhibited by collagen fibres and fibrils at rest. When the strain of the tendon is increased to 2%, the crimp configuration flatten. This is represented by the toe region or the initial concave portion of the curve. Tendons then deform in a linear form beyond this point. The elasticity fashion of the tendon will be demonstrated if the strain is below 4%. When the strain is above 4%, microscopic failure occurs while macroscopic failure occurs when the strain is beyond 8% to 10%.

Design Description

There are many factors that are needs to be taken into consideration when creating a bioreactor where its biochemical and biomechanical conditions are fulfilled. A bioreactor should be designed in such a way that it imitates the physiological specifications of tendon in vivo. Bioreactor has a significant role in providing a space for cells to proliferate, differentiate and allow for matrix production in a mechanical based surrounding. It is essential that proper biomechanical and biochemical environment which are crucial for the formation of healthy tendon tissues. For tendon, the force required for its mechanical stimulations is stretching. A culture chamber is also required to have a controlled culture environment. A medium circulation system is essential to have fresh medium circulated in a controlled flow. A medium analysis system is vital as it affects the growth of the cells. Any minute changes in the medium in terms of pH and nutrient concentration should be monitored through appropriate sensors. The temperature of the bioreactor should be 37˚C, humidity level of 99% and 5% carbon dioxide concentration to allow optimal growth of the cells.

Design criteria for Tendon Bioreactor

i. Mechanical loading – Stretching

Load applied should be between 0N to 30N. The frequency of the stretching should be 1Hz. Sensors are needed to monitor the load in real time. The strain rate should be between 2% and 8%. The displacement range should be between 0mm to 6mm.

ii. Biological chamber

The material containing the cells should be able withstand the continuous cyclic stretching. The biological chamber should be transparent to allow complete visual of the conditions inside. The biological chamber should not be complicated in design as components in the chamber requires cleaning. The components should be easily sterilised or easily replaced. It should be easily dismantled and put together. The biological chamber should also be sealed properly to avoid contamination.

iii. Medium flow

The flow of the medium should be continuous. The flowrate of the medium should be between 0.05ml/min – 5ml/min. The flowrate should be optimal for the cell growth.

iv. Materials

The materials used in constructing the bioreactor should be of medical grade. The materials are exposed to humid conditions for a long period of time. Hence, corrosive materials for example could cause contamination causing cell deaths. The materials should be biocompatible. They should also be easily cleaned and sterilised.

Final Design

The bioreactor designed is for research purpose. The initial concept was actually to incorporate compression and rotation into the bioreactor. Several sketches were produced to integrate the compression and rotation. Finally, a design including the compression and rotation was decided upon. The initial design (Generation 1) is attached in the Appendix. After further research, exploration and discussion, the consensus was reached that tendon requires stretching instead of compression for the cell growth, differentiation and proliferation. Tendon does go through compression but at a very small scale. Thus, the entire initial design was scraped. The design was then changed to another design (Generation 2) which incorporates stretching. Apart from that, the bioreactor is designed to be an independent bioreactor. The temperature and the carbon dioxide in this particular bioreactor can be controlled and monitored. However, there were many issues with the design 2. The second design was produced with the silicone tubing. Initially the 3D stretching was planned for this design as the cells were initially to be seeded on the scaffold. In terms of stretching motion, it was provided using stepper motor, drive gear, driven gears and pulleys. Unfortunately, this design does not provide direct stretching by the means of gears on the cells. Instead of providing the stretching, the gear motion would provide compressive force onto the scaffolds. This design was revised again and ultimately 2D stretching was chosen instead. To accommodate the 2D stretching, the membrane is opted instead of a silicone tubing. This design was finalised. This final design (Generation 3) is attached at the Appendix alongside the dimensions.

Materials

The upper housing material is acrylic while the lower housing material is nylon. These materials are compatible and are resistant to corrosion. The acrylic is clear which allows complete view of the bioreactor. The upper housing is machined into two parts to ease the membrane change without having to dismantle the stepper motor. The dimension of the bioreactor is 188.5mm (length) x 145.9mm (width) x 113.5mm (height). The cells are seeded on the membrane. The length of the membrane is approximately 6cm. This membrane is extremely flexible, non-toxic and resistant to moisture. The growth media labelled medium reservoir travels through PE tubing towards the heater. This heater is in charge of heating the growth media to 37°C. The heater is interlocked with the temperature sensor (TC-01). The pH and temperature sensors are mounted directly onto the upper housing to detect any changes in the medium. The pH sensor is interlocked with the solenoid valves. Solenoid valves functions electromechanically. Hence, if there are any major changes in the pH of the medium, it would automatically redirect the medium away from the scaffolds. PLC or programmable logic controller are used. PLC are extremely robust as they can undergo heat and moisture, hence PLC is an excellent choice for a bioreactor.

The stretching motion is created using the stepper motor which directly rotates the input gear (drive gear) which in turn rotates the output gears (driven gear). The gears are made from nylon which are non-toxic and corrosion resistant. The first driven gear (left) in turn rotates the second driven gear (right) with the aid of pulleys. Three sets of drive and driven gears are placed in the chamber to allow more membrane to be stretched. These pulleys are placed outside the housing so that the medium would not constrict the movement of the pulleys. The movement of the gears causes a cyclic stretching of the membrane. Cyclic stretching as mentioned earlier aids the production of collagen types I and III gene expression along with increased collagen production (Chen et al., 2008). Apart from that, cyclic stretching could increase mechanical properties of the tendon cells (Su, Chen, & Luo, 2008). The rotation (degree) of the gear, the corresponding strain and the displacement is shown in the Appendix. Option B was chosen – the placement of the ends of membrane is much more suitable compared to Option A. For option B, the corresponding strain and the displacement range is within the limit of 10% and 6mm respectively. The strain rate and displacement can be manipulated by adjusting the stepper motor and the gears. This allows research to be carried out in proper conditions suitable for the tendon cells.

Table 1 shows the materials used and the estimated cost. The cost is excluding the cost required for environmental chamber.

Table 1: Materials used and estimated cost

Item	Description	Reference Drawing #	Quantity	Unit Price (RM)	Total Price (RM)
1	Upper Housing Material Acrylic & Machining	21650104A	1	150.00	150.00
2	Lower Housing Material & Machining nylon	21650105A	1	150.00	150.00
3	Gears	21650106A	3	10.00	30.00
4	Stepper Motor	21650107A	1	300.00	300.00
5	M4 Counter Sunk Screw	21650106A	4	1.50	6.00
6	M4 Hexagon Bolt	21650106A	6	1.50	9.00
7	Rubber Belt	21650106A	1	1.00	1.00
8	Pulleys	21650106A	2	20.00	40.00
9	EPDM O-Ring Seals	21650106A	5	0.80	4.00
10	Silicone Tube	21650108A	1	10.00	10.00
11	Peristaltic Pump	21650109A	1	180.00	180.00
12	PTFE Solenoid Valve	21650109A	3	180.00	540.00
13	Temperature Sensor	21650109A	1	70.00	70.00
14	Push In Fittings-Ball Valve	21650109A	7	3.50	24.50
15	Push In Fittings-Check Valve	21650109A	2	3.00	6.00
16	Mini Heating Elements	21650109A	1	30.00	30.00
17	PLC, Temperature Controller, Digital Panel Meter for pH Controller	-	1	4,000.00	4,000.00
18	Tubing & Consumables	-	1	100.00	100.00
	GRAND TOTAL COST (RM)				**5,650.50**

Advantages of the design

The major advantage of this bioreactor system is its independency towards the incubator. This bioreactor does not need to be put in an incubator. It has its own heater where the medium is heated to 37°C. The carbon dioxide level and the oxygen level can be controlled. Placing the entire bioreactor in an incubator can directly affect the stepper motor and also the wiring. The corrosion resistant stepper motor is available. However, the size and weight are not suitable for the bioreactor design. It weighs approximately 2.5kg. The stepper motor with the size and weight mentioned is too heavy for the bioreactor design. Moreover, the study which was conducted on a corrosion resistant stepper motor was only carried out for 140 hours or 5 days (Design World Staff, 2010). This study is not convincing as bioreactors should be able to operate continuously for more than 2000 hours. This was the only study carried out on corrosion resistant stepper motor. Apart from that, wiring with PVC and Teflon insulation could still undergo corrosion at the exposed area of the copper wire. With the high humidity level, corrosion can be accelerated. Placing stepper motor in an incubator requires DC power supply. Stepper motors draw in power even when not moving. Using DC power supply would not be suitable as it would diminish quickly as this bioreactor would be operating for at least 8 hours per day stimulating the number of active hours. This would affect the entire system and could cause failure to the system. In addition, the high humidity would affect a DC power supply if it is placed in an incubator and could corrosion. Hence, an independent bioreactor is opted for the design.

Limitations of the design

The upper housing of this bioreactor is made from acrylic. This material is hard to machine as it is brittle. Other than that, for the mechanical stimulation, only stretching (uniaxial) is provided and rotation was not included in this design. Rotation of the scaffolds are essential for the homogenous distribution of the cells. Static culture conditions would result in fewer cells in the centre of the scaffolds (Cartmell, Porter, García, & Guldberg, 2003). Cell seeding in this bioreactor design is done manually. This could be solved with automated cell seeding which would increase the precision.

Conclusion

Tendon is a dynamic tissue of which proper mechanical stimulation is needed in the bioreactor to ensure proper cell growth, proliferation and differentiation. This bioreactor is designed to be independent. Independent bioreactor has its own advantages and disadvantages. The limitations can however be overcome. The actual efficiency of this designed bioreactor can only be observed with a prototype. The design of a bioreactor should be simple but effective. The quality of a bioreactor should also be given greater emphasis as it is going to be used for long term.

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Appendix

PART LIST			
ITEM	QTY	DESCRIPTION	PART NUMBER
1	1	HOUSING A	21650100
2	1	HOUSING B	21650101

DESIGN GENERATION # 1

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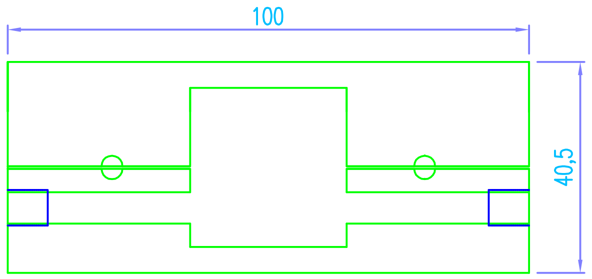
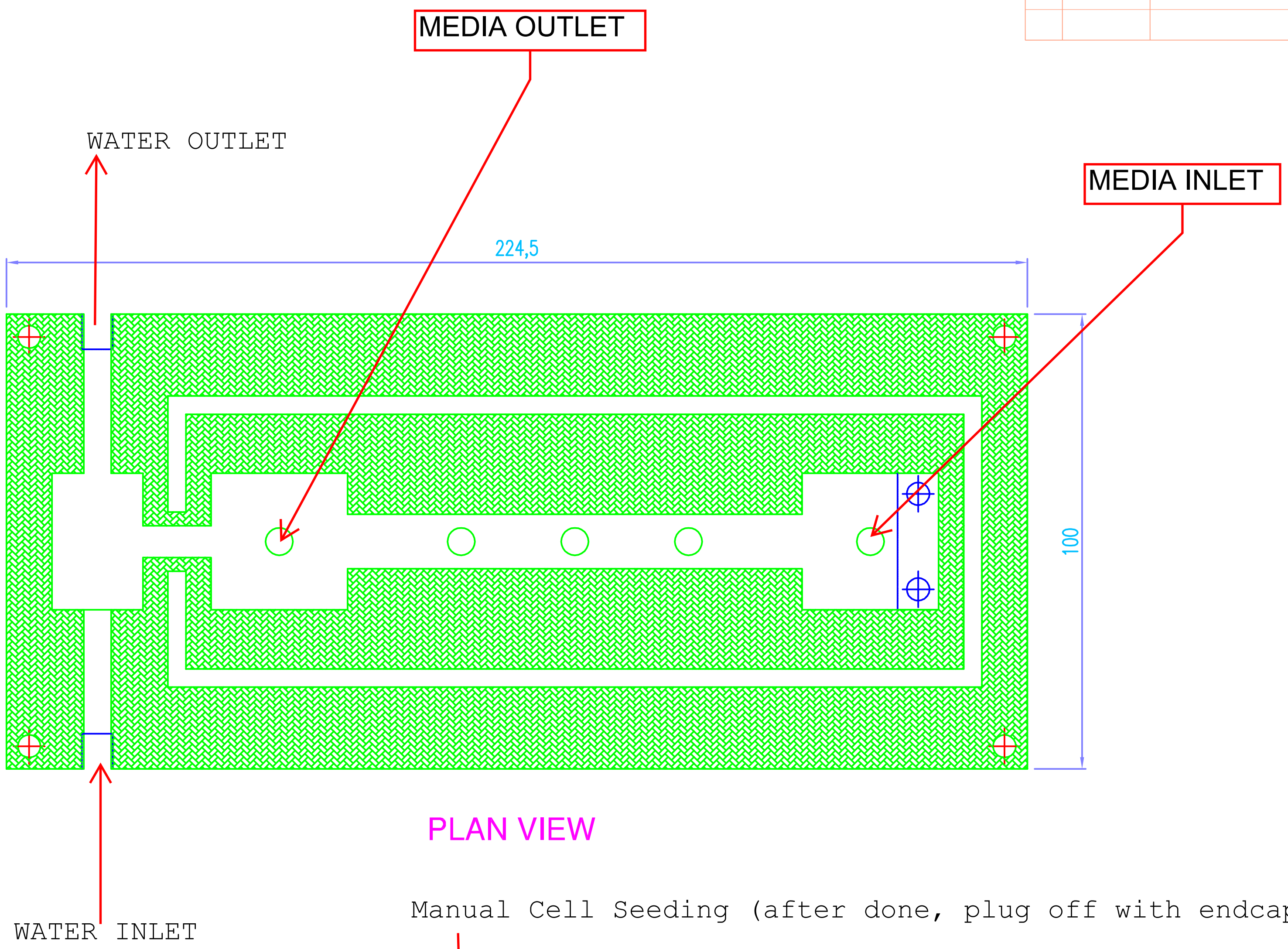
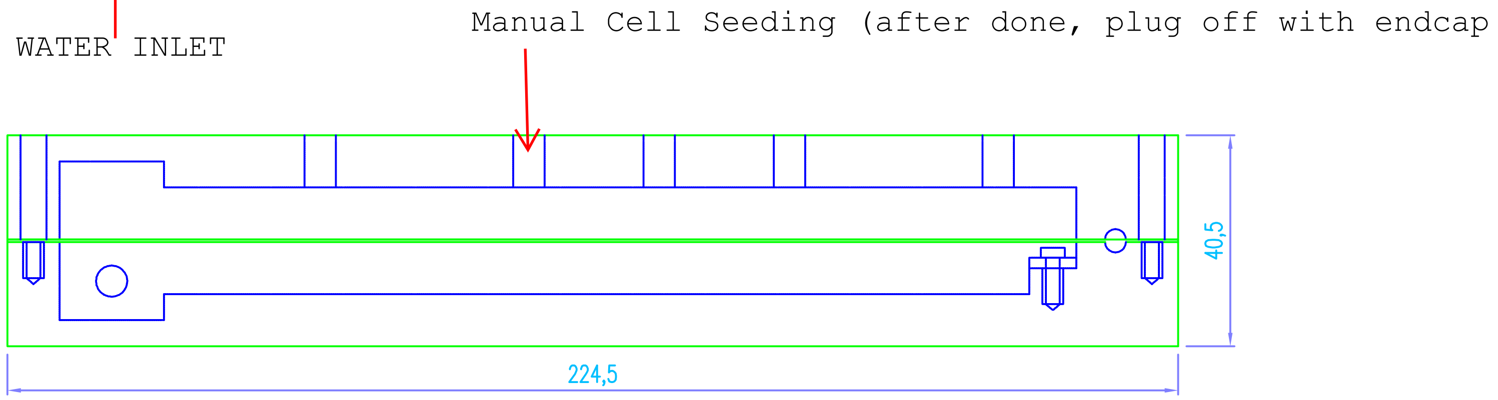


FRONT VIEW



PLAN VIEW



ELEVATION VIEW

DESIGN CRITERIA:

1. Compression & Torsion
2. Using Water inlet to turn the wheel, which will rotate the scaffold
3. One (1) end of scaffold bolted
4. Manual seeding of cells on scaffold
5. Construction to be lightweight, easy to dismantle, small, compact, parts replacement easily available and cost factored in.
6. Water injection will be by pump (small pump).

MATERIAL: ACRYLIC BLOCK MACHINED TO SIZE
QUANTITY: 1 UNIT

MATCH TOLERANCE UNLESS OTHERWISE STATED			
OVER TO	TOLERANCE	OVER TO	TOLERANCE
0–6mm	± 0.1mm	300–1000mm	± 3mm
6–30mm	± 0.2mm	1000–3000mm	± 5mm
30–100mm	± 0.3mm	3000 PLUS	± 8mm
100–300mm	± 0.5mm	ANGLES	± 1°

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DRAWING NO : 11650100		MODUL : 01
UNIT : MM	SCALE: 1:1.5 A3	SHEET : 1/1
DRAWN BY:		
Nina		
APPROVED BY:		
Kala/Nazira		

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A	22.4.2016	INITIAL ISSUED	NINA

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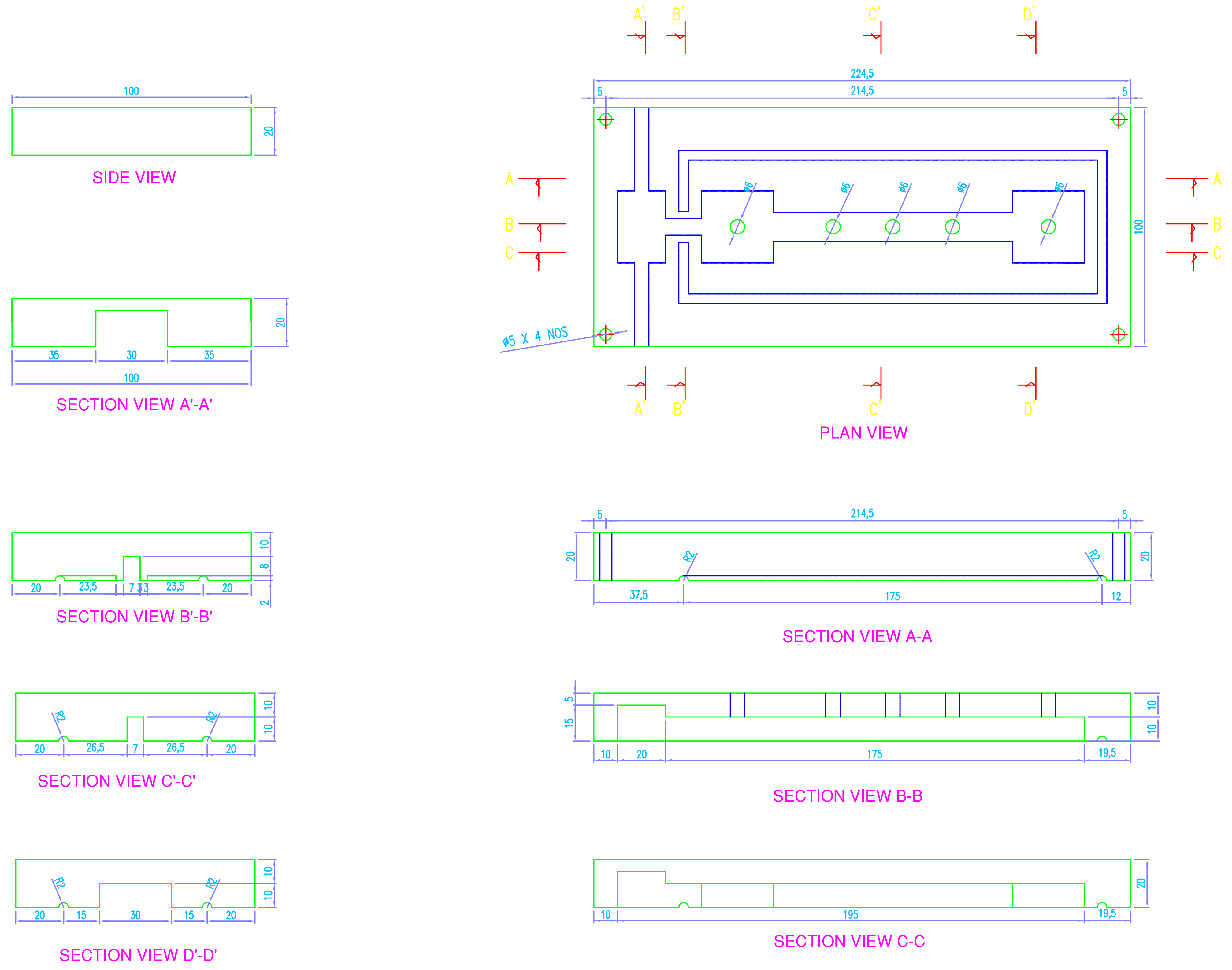

MATERIAL: ACRYLIC BLOCK MACHINED TO SIZE 20MM THICKNESS
QUANTITY: 1 UNIT

MATCH TOLERANCE UNLESS OTHERWISE STATED			
OVER TO	TOLERANCE	OVER TO	TOLERANCE
0–6mm	± 0.1mm	300–1000mm	± 3mm
6–30mm	± 0.2mm	1000–3000mm	± 5mm
30–100mm	± 0.3mm	3000 PLUS	± 8mm
100–300mm	± 0.5mm	ANGLES	± 1°

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DRAWN BY:		
Nina		
APPROVED BY:		
Kala/Nazira		

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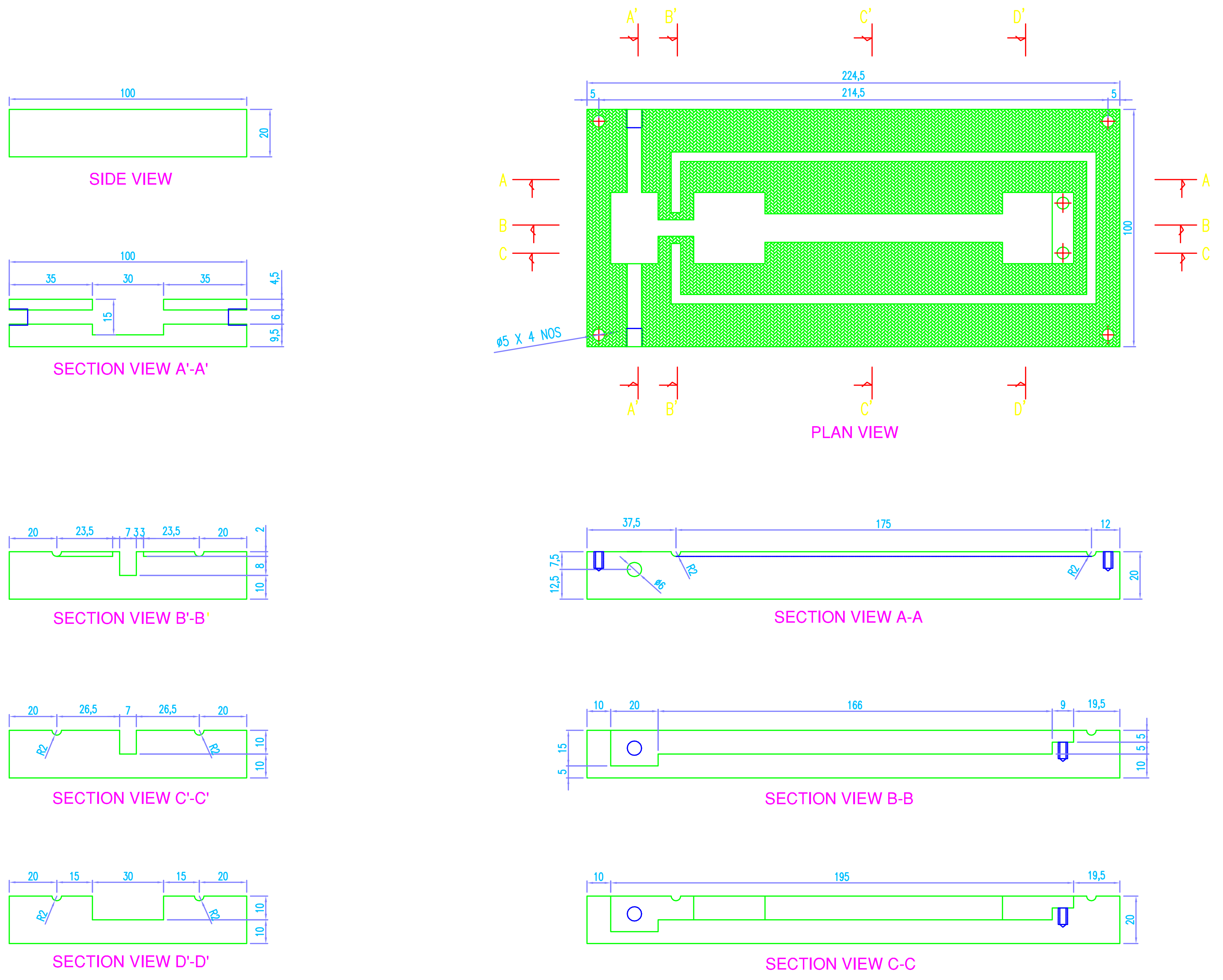

MATERIAL: ACRYLIC BLOCK MACHINED TO SIZE 20MM THICKNESS
QUANTITY: 1 UNIT

MATCH TOLERANCE UNLESS OTHERWISE STATED			
OVER TO	TOLERANCE	OVER TO	TOLERANCE
0–6mm	± 0.1mm	300–1000mm	± 3mm
6–30mm	± 0.2mm	1000–3000mm	± 5mm
30–100mm	± 0.3mm	3000 PLUS	± 8mm
100–300mm	± 0.5mm	ANGLES	± 1°

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DRAWING TITLE :	HOUSING B	
DRAWING NO :	21650101	MODUL : 01
UNIT : MM	SCALE: 1:2 A3	SHEET : 1/1
DRAWN BY:	Nina	
APPROVED BY:	Kala/Nazira	

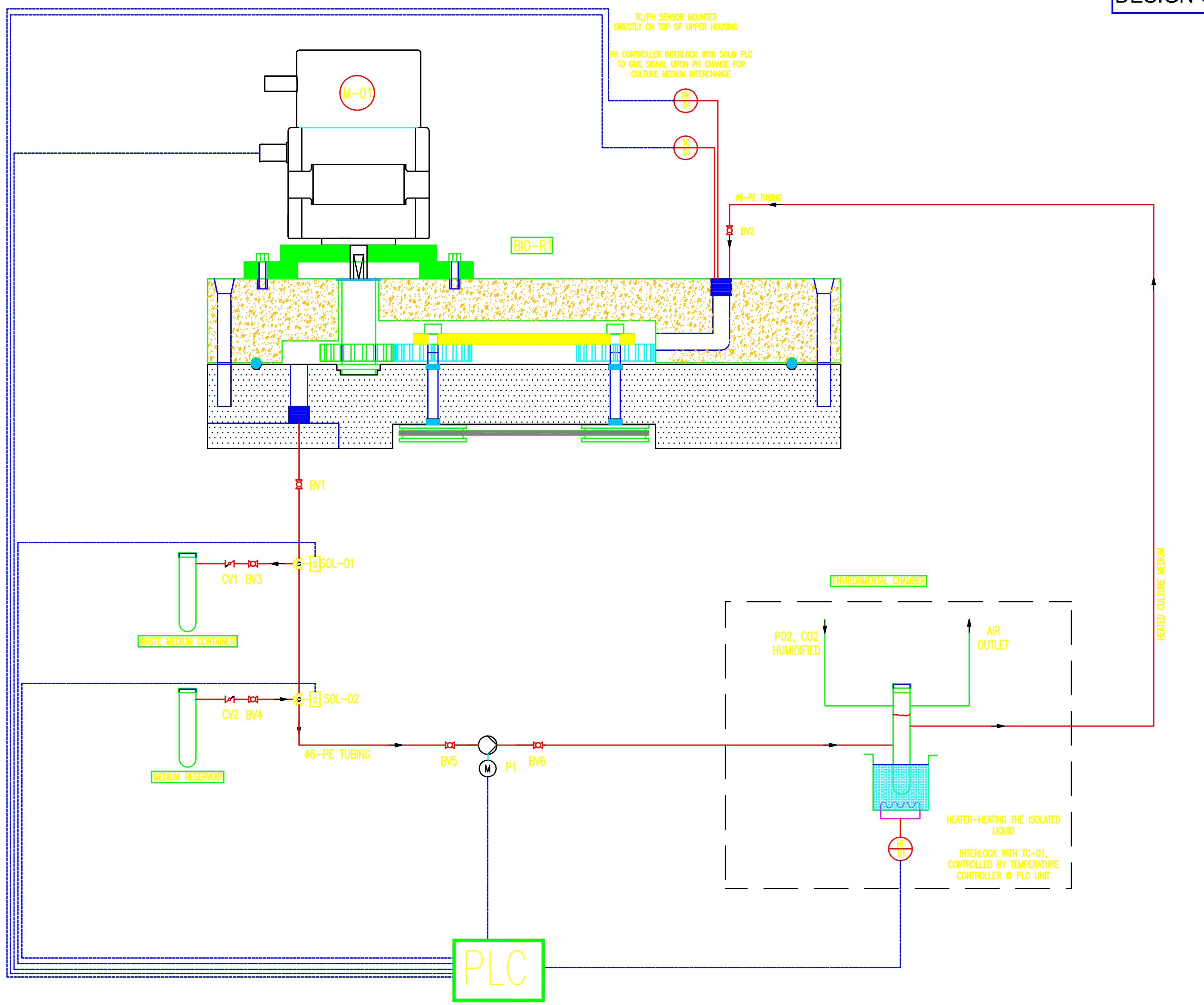
UNIVERSITY OF MALAYA
KUALA LUMPUR
2015/2016

KXGL6305 TISSUE ENGINEERING

LEGEND			
ITEM	TAG	DESCRIPTION	REMARKS
1	M01	DRIVE MOTOR	PLC
2	P1	PERISTALTIC PUMP 5.2–90ML/MIN	PLC
3	SOL–01	SOLENOID VALVE	PLC
4	SOL–02	SOLENOID VALVE	PLC
5	TC–01	TEMPERATURE SENSOR	PLC
6	BV1–6	BALL VALVE	MANUAL VALVE
7	CV1,2	CHECK VALVE (1 WAY VALVE)	AUTO–MECHANICAL
8	BIO–R1	BIOREACTOR	11650101
9	PH/CRTL–01	PH SENSOR & CONTROLLER	PLC
10	HT–01	HEATING ELEMENTS	PLC

REV.	DATE	DESCRIPTION	UPDATED BY:
A	5.5.2016	INITIAL ISSUED	NINA

DESIGN GENERATION # 2



Note:

1. Cells are seeded into scaffold manual outside bioreactor
2. Any Intake/Discharge Port not being in used, will be plug off
3. Tubing Connection will be using Standard Push In Fittings inclusive Manual Valves
4. Components for Auto System–Refer # 21650109
5. Heated culture medium will be circulated into bioreactor, until pH changes, at the same time, new cold medium will be channelled into the circulation line

MATCH TOLERANCE UNLESS OTHERWISE STATED			
OVER TO	TOLERANCE	OVER TO	TOLERANCE
0–6mm	± 0.1mm	300–1000mm	± 3mm
6–30mm	± 0.2mm	1000–3000mm	± 5mm
30–100mm	± 0.3mm	3000 PLUS	± 8mm
100–300mm	± 0.5mm	ANGLES	± 1°

DRAWING TITLE : PROCESS FLOW DIAGRAM FOR TENDON BIOREACTOR

DRAWING NO : 31650100 | MODUL : 01

UNIT : MM | SCALE: 1:1 A3 | SHEET : 1/1

DRAWN BY:

Nina

APPROVED BY:

Kala/Nazira

UNIVERSITY OF MALAYA

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2015/2016

KXGL6305 TISSUE ENGINEERING

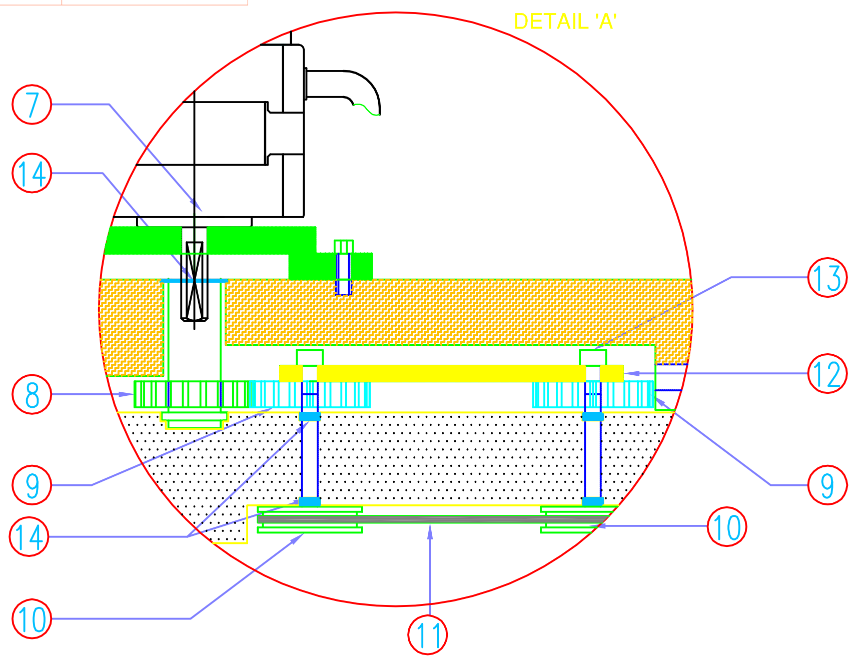
PART LIST			
ITEM	QTY	DESCRIPTION	PART NUMBER
1	3	INTAKE PORT 6MM	21650104
2	4	M4 COUNTER SUNK SCREW	21650106
3	1	UPPER HOUSING	21650104
4	1	SILICONE SEAL	NIL
5	1	LOWER HOUSING	21650105
6	3	DISCHARGE PORT 6MM	21650105
7	1	STEPPER MOTOR C/W BRACKET	21650107
8	1	DRIVE GEAR	21650106
9	2	DRIVEN GEAR	21650106
10	2	PULLEY	21650106
11	1	BELT	21650106
12	1	SILICONE TUBE 6MM	21650108
13	2	M4 HEX BOLT	21650106
14	5	O-RING SEALS	21650106

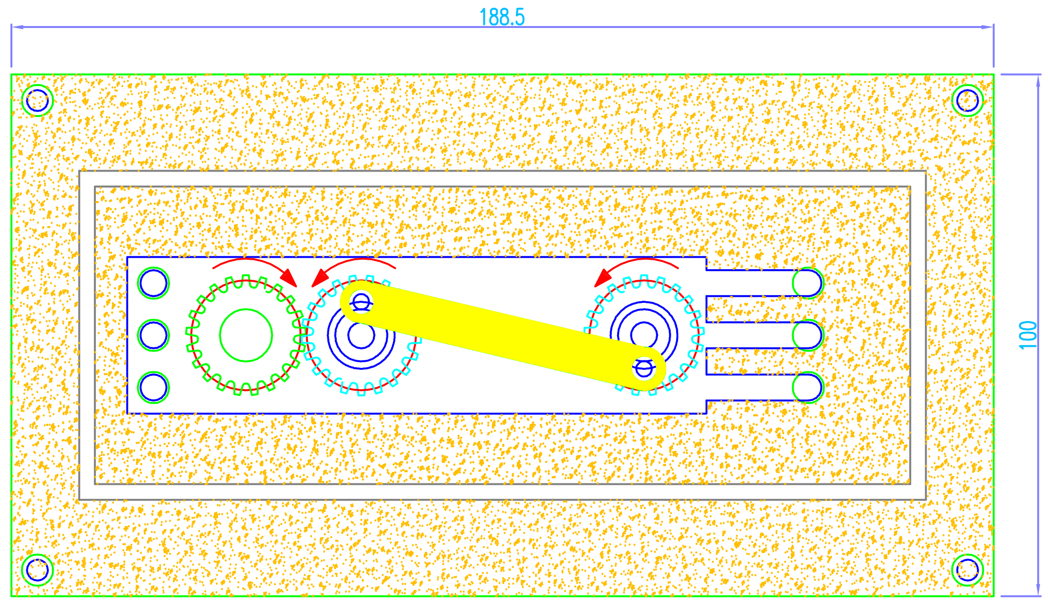
Note:

1. Scaffold inserted into tube outside.
2. Any Intake/Discharge Port not being in used, will be plug off
3. Tubing Connection will be using Standard Push In Fittings inclusive Manual Valves

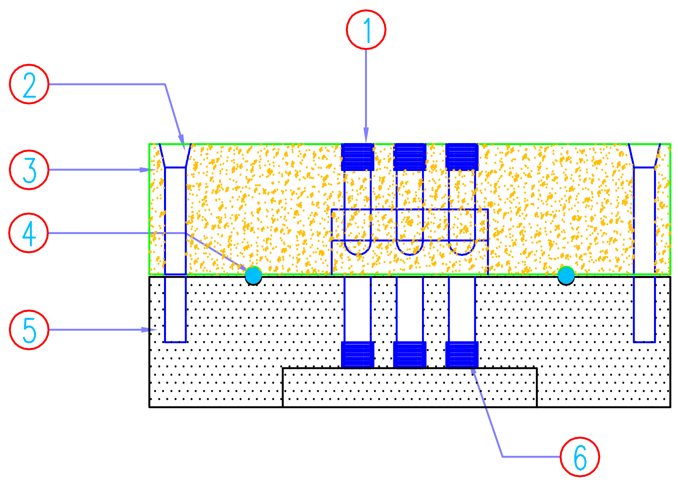
REV.	DATE	DESCRIPTION	UPDATED BY:
A	22.4.2016	INITIAL ISSUED	NINA

DESIGN GENERATION # 2

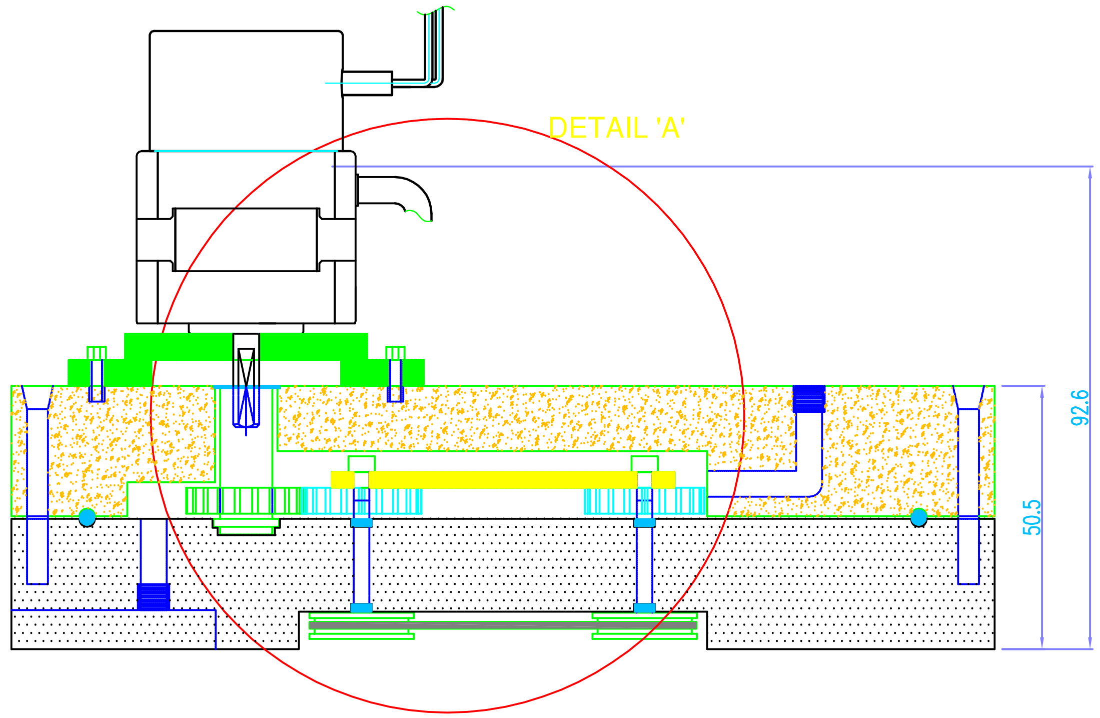




PLAN VIEW



SIDE VIEW



ELEVATION VIEW

QUANTITY: 1 SET

MATCH TOLERANCE UNLESS OTHERWISE STATED			
OVER TO	TOLERANCE	OVER TO	TOLERANCE
0-6mm	± 0.1mm	300-1000mm	± 3mm
6-30mm	± 0.2mm	1000-3000mm	± 5mm
30-100mm	± 0.3mm	3000 PLUS	± 8mm
100-300mm	± 0.5mm	ANGLES	± 1°

DRAWING TITLE : BIOREACTOR BIO-R1		
DRAWING NO : 11650101		MODUL : 01
UNIT : MM	SCALE: 1:1.5 A3	SHEET : 1/1
DRAWN BY:		
Nina		
APPROVED BY:		
Kala/Nazira		

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KUALA LUMPUR

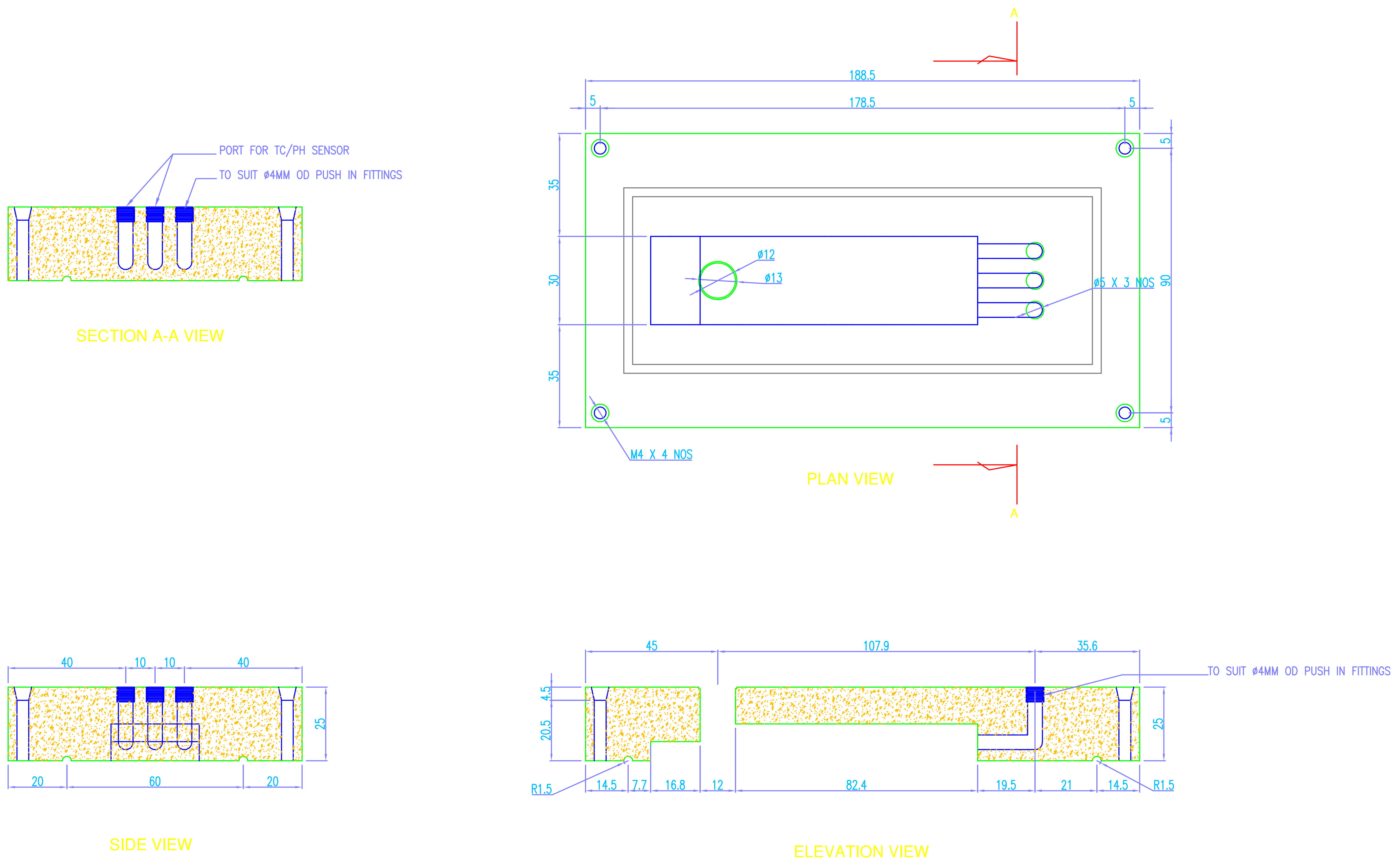
2015/2016

KXGL6305 TISSUE ENGINEERING

NOTE:	
MATERIAL	ACRYLIC SHEET
QUANTITY	1 UNIT

REV.	DATE	DESCRIPTION	UPDATED BY:
A	3.5.2016	INITIAL ISSUED	NINA

DESIGN GENERATION # 2



MATCH TOLERANCE UNLESS OTHERWISE STATED			
OVER TO	TOLERANCE	OVER TO	TOLERANCE
0–6mm	± 0.1mm	300–1000mm	± 3mm
6–30mm	± 0.2mm	1000–3000mm	± 5mm
30–100mm	± 0.3mm	3000 PLUS	± 8mm
100–300mm	± 0.5mm	ANGLES	± 1°

DRAWING TITLE : UPPER HOUSING		
DRAWING NO : 21650104		MODUL : 01
UNIT : MM	SCALE: 1:1.5 A3	SHEET : 1/1
DRAWN BY:		
Nina		
APPROVED BY:		
Kala/Nazira		

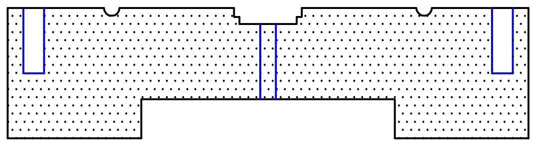
UNIVERSITY OF MALAYA
KUALA LUMPUR
2015/2016

KXGL6305 TISSUE ENGINEERING

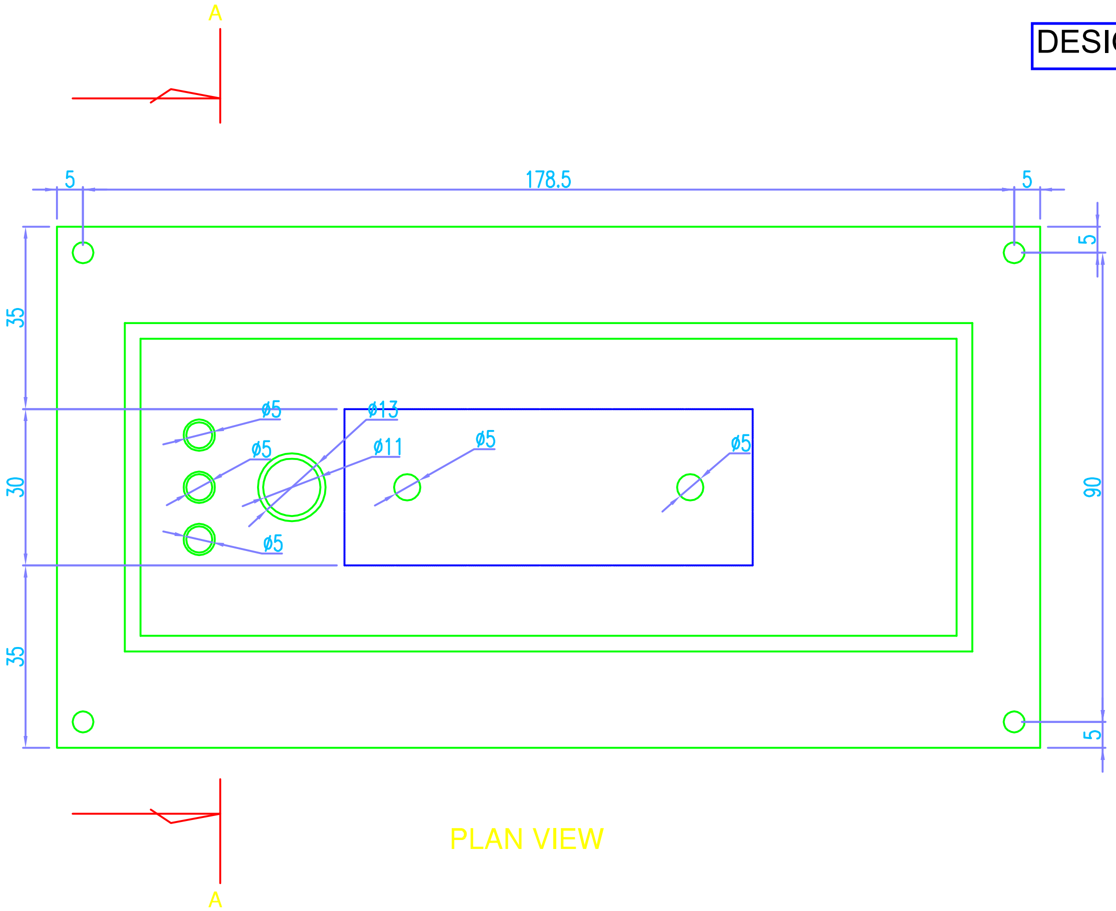
NOTE:	
MATERIAL	ACRYLIC SHEET
QUANTITY	1 UNIT

REV.	DATE	DESCRIPTION	UPDATED BY:
A	3.5.2016	INITIAL ISSUED	NINA

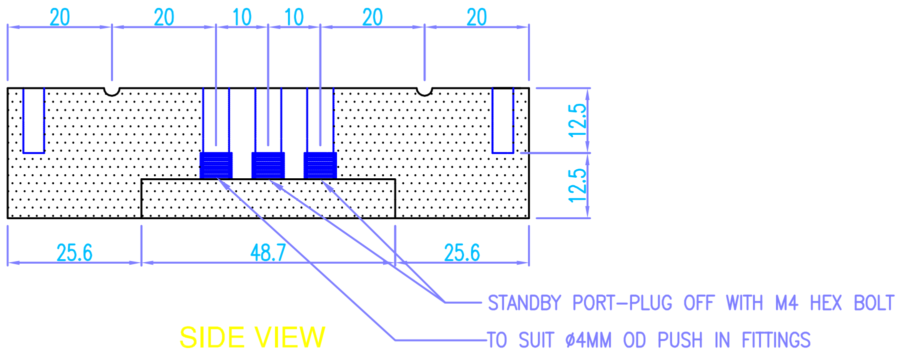
DESIGN GENERATION # 2



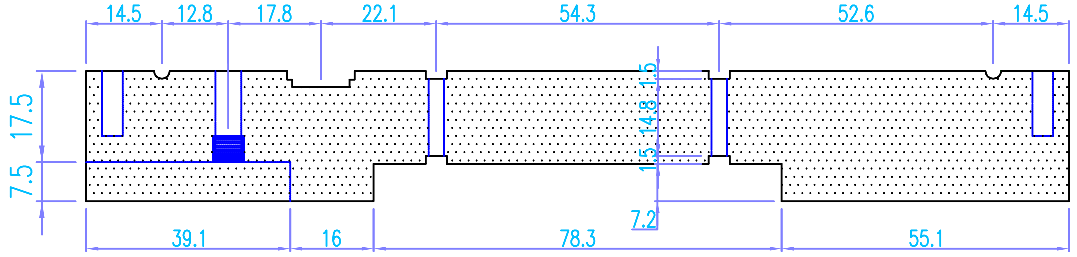
SECTION A-A VIEW



PLAN VIEW



SIDE VIEW



ELEVATION VIEW

MATCH TOLERANCE UNLESS OTHERWISE STATED			
OVER TO	TOLERANCE	OVER TO	TOLERANCE
0–6mm	± 0.1mm	300–1000mm	± 3mm
6–30mm	± 0.2mm	1000–3000mm	± 5mm
30–100mm	± 0.3mm	3000 PLUS	± 8mm
100–300mm	± 0.5mm	ANGLES	± 1°

DRAWING TITLE : LOWER HOUSING

DRAWING NO : 21650105 | MODUL : 01

UNIT : MM | SCALE: 1:1.5 A3 | SHEET : 1/1

DRAWN BY:

Nina

APPROVED BY:

Kala/Nazira

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KXGL6305 TISSUE ENGINEERING

REV.	DATE	DESCRIPTION	UPDATED BY:
A	3.5.2016	INITIAL ISSUED	NINA

DESIGN GENERATION # 2

GEARS

MATERIAL	NYLON
QUANTITY	3 UNITS
MODEL	Z=21T, MODULE: 1

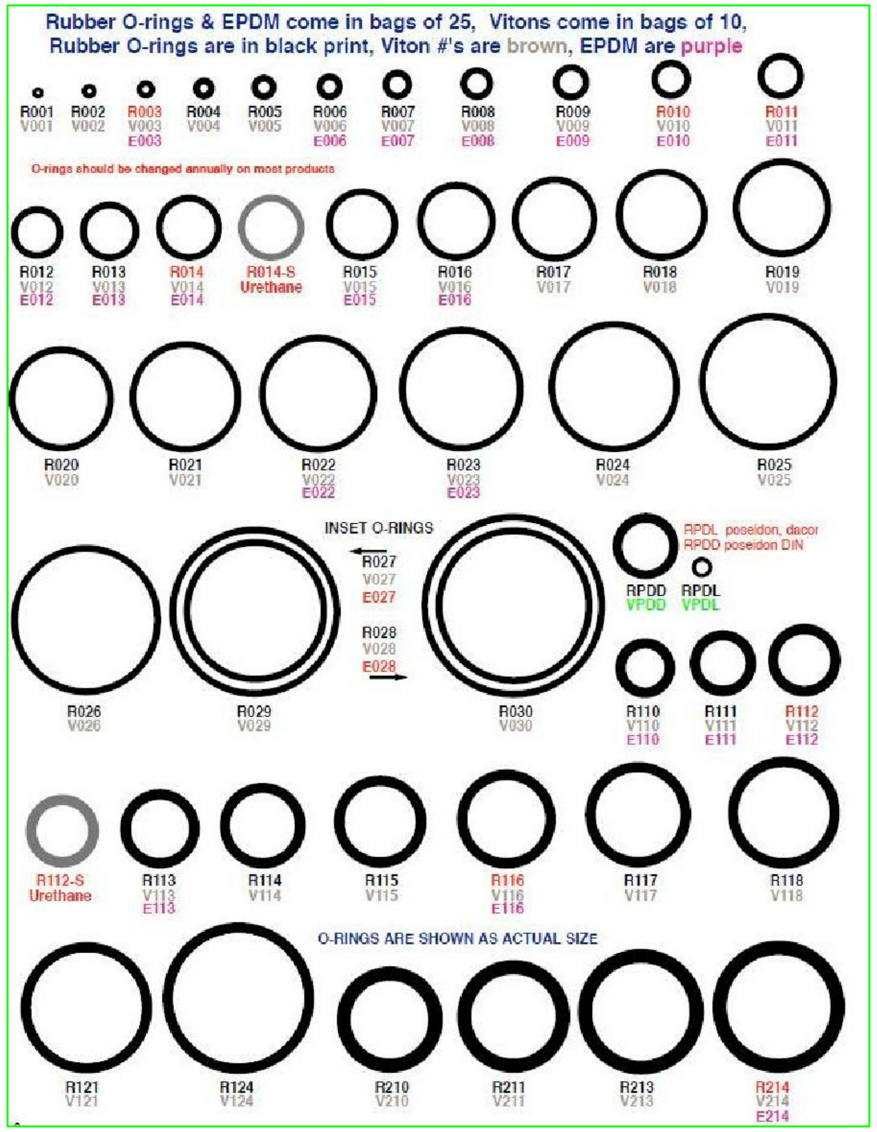
PULLEYS

MATERIAL	NYLON
QUANTITY	2 UNITS
DIAMETER	ø 18MM X 1 GROOVE

HEX BOLT

MATERIAL	NYLON/PLASTIC CLEAR
QUANTITY	6 UNITS (ALSO AS PLUG)
SIZE	M4

RUBBER O-RINGS



COUNTERSUNK BOLT

MATERIAL	NYLON/PLASTIC CLEAR
QUANTITY	4 UNITS
SIZE	M4

MATERIAL	RUBBER
QUANTITY	1 UNIT
CENTER DISTANCE	ø 3MM X 54.3MM CD

MATCH TOLERANCE UNLESS OTHERWISE STATED			
OVER TO	TOLERANCE	OVER TO	TOLERANCE
0-6mm	± 0.1mm	300-1000mm	± 3mm
6-30mm	± 0.2mm	1000-3000mm	± 5mm
30-100mm	± 0.3mm	3000 PLUS	± 8mm
100-300mm	± 0.5mm	ANGLES	± 1°

DRAWING TITLE : STANDARD PARTS		
DRAWING NO : 21650106		MODUL : 01
UNIT : MM	SCALE: 1:1.5 A3	SHEET : 1/1
DRAWN BY:		
Nina		
APPROVED BY:		
Kala/Nazira		

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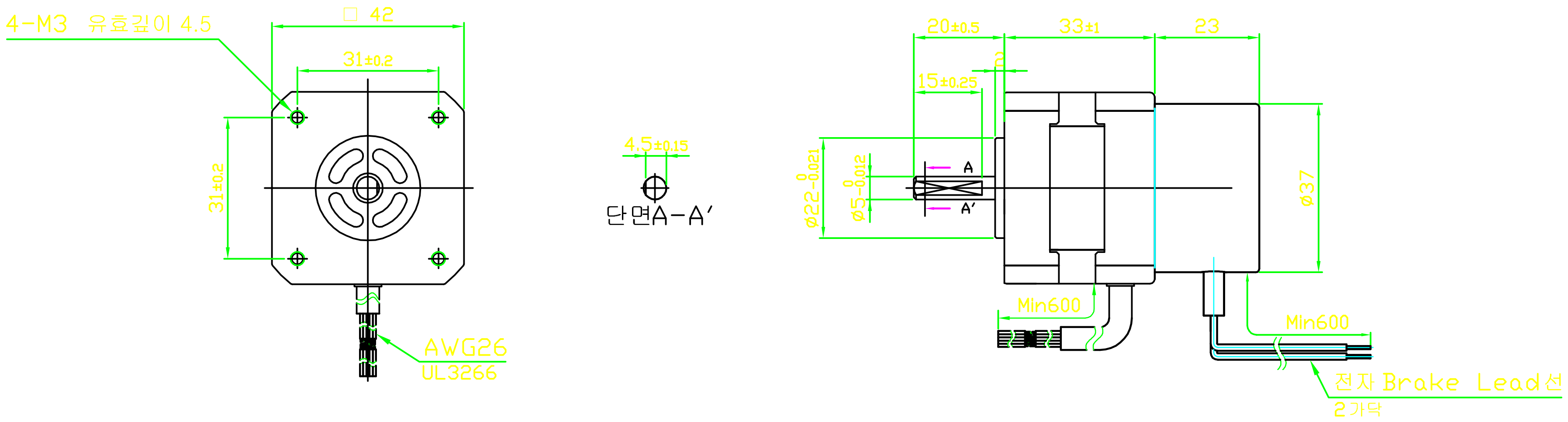
2015/2016

KXGL6305 TISSUE ENGINEERING

REV.	DATE	DESCRIPTION	UPDATED BY:
A	22.4.2016	INITIAL ISSUED	NINA

DESIGN GENERATION # 2

MODEL : A1K-S543



• 42-square

Model	Shaft type	A1K-S543(W)	A2K-S544(W)	A2K-M544(W)	A3K-S545(W)
Max. allowable torque		-	-	-	-
Max. holding torque		1.3kgf·cm (0.13 N·m)	1.8kgf·cm (0.18 N·m)		2.4kgf·cm (0.24 N·m)
Moment of rotor inertia		35g·cm^2 ($35x10^{-7}$ kg·m^2)	54g·cm^2 ($54x10^{-7}$ kg·m^2)		68g·cm^2 ($68x10^{-7}$ kg·m^2)
Rated current		0.75A/Phase		1.4A/Phase	0.75A/Phase
Basic step angle		0.72° / 0.36°(Full/Half step)			
Gear ratio		-			
Allowable speed range		-			
Backlash[min]		-			
Electormagnetic	Rated excitation voltage	24VDC ±10%			
	Rated excitation current	0.2A			
	Static friction torque	1.8kgf·cm			
	Rotation part inertia	3.0×10^{-7} kg.cm^2			
	Operating time	Max. 24ms			
	Releasing time	Max. 15ms			
Insulation class		B type(130°C)			
Insulation resistance		Min. 100MΩ(at 500VDC megger) between motor coil-case			
Dielectric strength		1Min. at 1 kVAC(0.5kVAC for 0.75A/Phase) 50/60Hz between Motor coil-case			
Environ -ment	Ambient temperature	-10 to 50°C, storage: -25 to 85°C			
	Ambient humidity	35 to 85%RH, storage: 35 to 85%RH			
Protection		IP30(IEC34-5 standard)			
Unit weight		Standard type / Geared type: Approx. 0.25kg	Standard type / Geared type: Approx. 0.3kg		Standard type / Geared type:

MATCH TOLERANCE UNLESS OTHERWISE STATED

OVER TO	TOLERANCE	OVER TO	TOLERANCE
0–6mm	± 0.1mm	300–1000mm	± 3mm
6–30mm	± 0.2mm	1000–3000mm	± 5mm
30–100mm	± 0.3mm	3000 PLUS	± 8mm
100–300mm	± 0.5mm	ANGLES	± 1°

DRAWING TITLE : STEPPER MOTOR

DRAWING NO : 21650107 | MODUL : 01

UNIT : MM | SCALE: 1:1.5 A3 | SHEET : 1/1

DRAWN BY:

Nina

APPROVED BY:

Kala/Nazira

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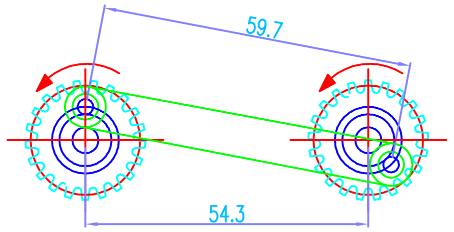
2015/2016

KXGL6305 TISSUE ENGINEERING

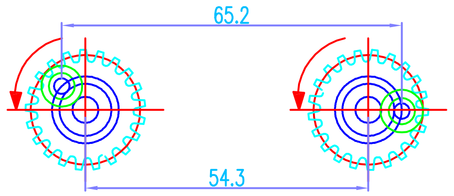
DESIGN GENERATION # 2

REV.	DATE	DESCRIPTION	UPDATED BY:
A	3.5.2016	INITIAL ISSUED	NINA

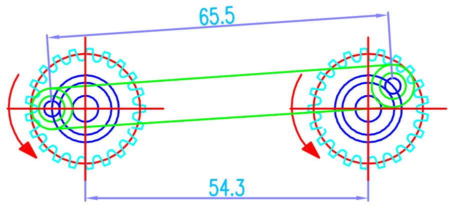
POSITION OPTION A



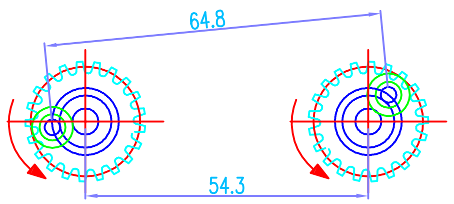
POSITION	INITIAL POSITION (0 DEG)
LENGTH (MM)	60 MM
% STRAIN	0



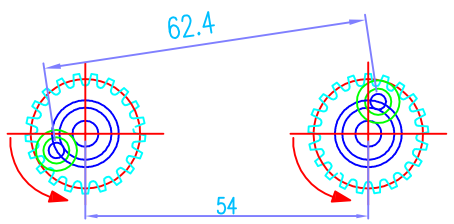
POSITION	45 DEG ROTATION, CCW
LENGTH (MM)	65.2
% STRAIN	9.2



POSITION	90 DEG ROTATION, CCW
LENGTH (MM)	65.5
% STRAIN	9.72

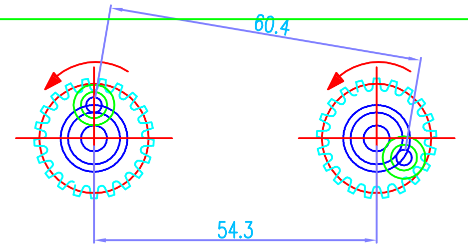


POSITION	100 DEG ROTATION, CCW
LENGTH (MM)	64.8
% STRAIN	8.5

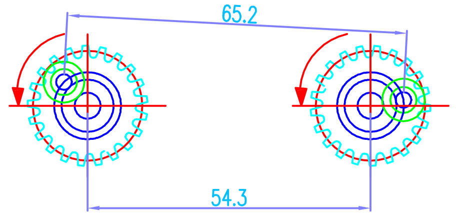


POSITION	120 DEG ROTATION, CCW
LENGTH (MM)	62.4
% STRAIN	4.5

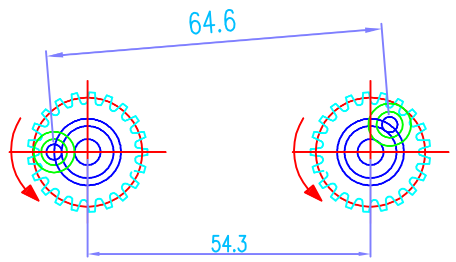
POSITION OPTION B



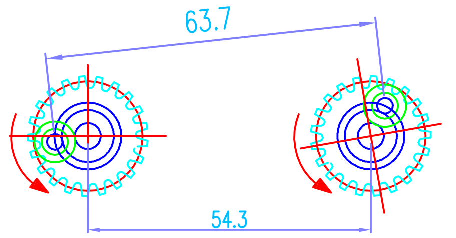
POSITION	INITIAL POSITION (0 DEG)
LENGTH (MM)	60 MM
% STRAIN	0



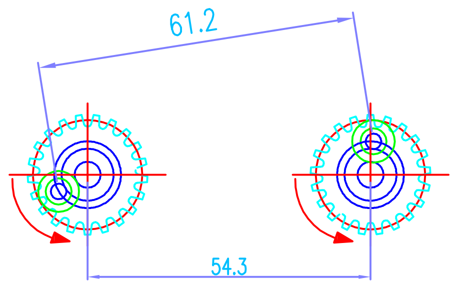
POSITION	45 DEG ROTATION, CCW
LENGTH (MM)	65.2
% STRAIN	7.95



POSITION	90 DEG ROTATION, CCW
LENGTH (MM)	64.6
% STRAIN	6.95



POSITION	100 DEG ROTATION, CCW
LENGTH (MM)	63.7
% STRAIN	5.46



POSITION	120 DEG ROTATION, CCW
LENGTH (MM)	61.2
% STRAIN	1.32

MATERIAL FOR HOUSING

SIZE	ø 6MM (OD) TUBING
MATERIAL	SOFT SILICONE TUBE

* CENTER DISTANCE TUBING: 60.4MM POSITIONING
* MAKE HOLE BOTH END TO BE FIXED TO THE GEAR
* TUBING ARE PUNCTURED WITH PIN TO CREATE PIN HOLES TO ALLOW GROWTH MEDIA ABSORPTION INTO SCAFFOLD

MATCH TOLERANCE UNLESS OTHERWISE STATED			
OVER TO	TOLERANCE	OVER TO	TOLERANCE
0–6mm	± 0.1mm	300–1000mm	± 3mm
6–30mm	± 0.2mm	1000–3000mm	± 5mm
30–100mm	± 0.3mm	3000 PLUS	± 8mm
100–300mm	± 0.5mm	ANGLES	± 1°

DRAWING TITLE :	SCAFFOLDING HOUSING & POSITIONING	
DRAWING NO :	21650108	MODUL : 01
UNIT : MM	SCALE: 1:2 A3	SHEET : 1/1
DRAWN BY:	Nina	
APPROVED BY:	Kala/Nazira	

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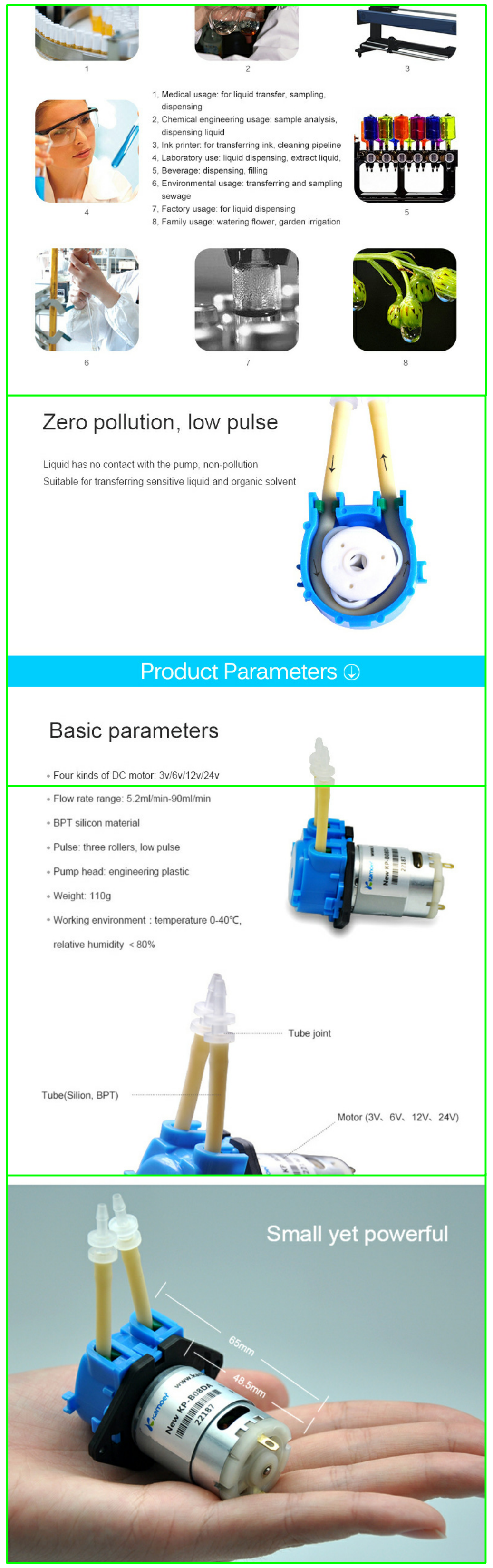
KUALA LUMPUR
2015/2016
KXGL6305 TISSUE ENGINEERING

DESIGN GENERATION # 2

REV.	DATE	DESCRIPTION	UPDATED BY:
A	3.5.2016	INITIAL ISSUED	NINA

PERISTALTIC PUMP



MODEL	KP
QUANTITY	1 UNIT
FLOW RATE	5.2 ml/min–90 ml/min

SOLENOID VALVE

Series 1 & 2 Miniature Inert PTFE Isolation Valves

2-Way and 3-Way Solenoid Valves

The 2-Way & 3-Way inert Series 1 & 2 valves have been designed for systems where chemical compatibility is most important. The wetted path is isolated from the solenoid and only PTFE and borosilicate glass are in contact with the media passing through the valve. Low internal volume and fast response time ensure repeatable, accurate volumes. Valves will actuate without any pressure or vacuum applied.

Features

- Provides unsurpassed chemical compatibility for a wide range of media with PTFE and borosilicate glass as the only wetted parts
- 100% continuous duty rating in ambient temperatures up to 66°C
- Low power for reduced heat generation and power consumption
- Fast response times for accurate repeatable results
- Direct acting: does not require pressure or vacuum to operate
- 100% tested leak rate provides assurance of a quality seal
- Provides reliable operation for the life of your instrument
- RoHS compliant

Typical Applications

- Reagent Control
- Solvent Management
- Aggressive Liquid Control

Product Specifications

Physical Properties

Valve Type:
Diaphragm Isolation Valve
Valve Configuration:
3-Way (Series 1)
2-Way, Normally Closed (Series 2)
Media:
Liquids
Operating Environment:
40 to 150°F (4 to 66°C)
Dimensions:
Width: 1.0" (25.4 mm)
Height: 2.1" (53.34 mm)
Length: 1.0"(25.4 mm)
Porting:
1/4-28 Threaded Ports
Weight:
2.7 oz (76.5 g)
Internal Volume (µL):
96 (3-Way)
49 (2-Way)

Electrical

Voltage (VDC):	12	24
Power (Watts):	2.5	4.2
Current (mA):	211	173
Resistance (Ohm):	57	139
(Ω±5% @ 70°F, 21.1°C)		
Connections:		
12" Lead Wire Standard		
26 AWG, PTFE Insulated		

Wetted Materials*

Seals:
PTFE
Body Options:
PTFE
All Others:
Borosilicate Glass (3 - Way only)

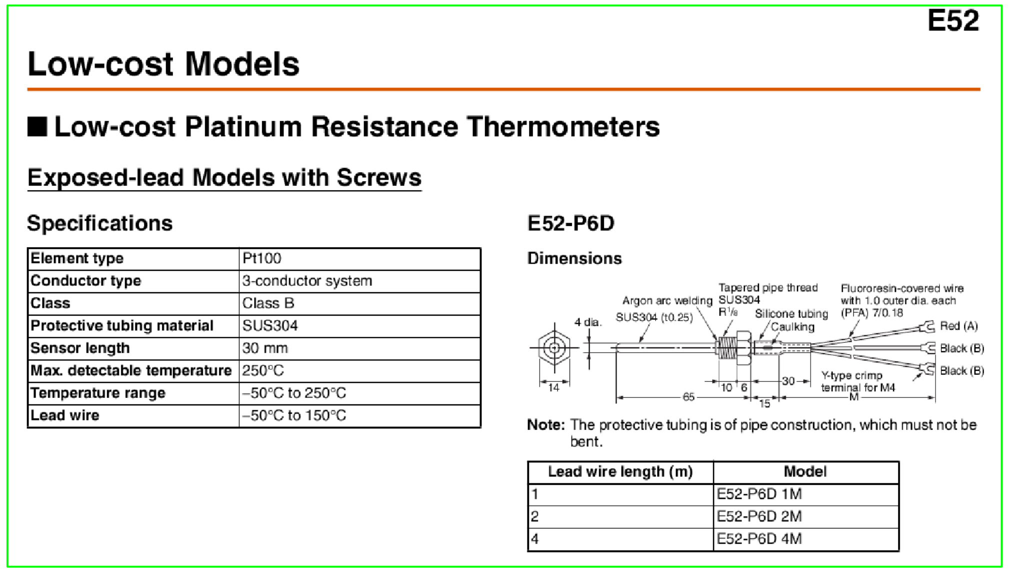
* See Chemical Compatibility Page
Consult factory for other options

Performance Characteristics

Operating Pressure/ Orifice Diameters:
Vacuum - 20 psig (1.4 bar) / 0.060" (1.52 mm)
Proof Pressure:
1.5X rated pressure
Leak Rate:
Bubble Tight
Response Time:
3-Way: <12 ms cycling
2-Way: <20 ms cycling
Recommended Filtration:
10 µm min
Reliability:
Life Cycle Rating of 10 million (Application dependent)

Parker

TEMPERATURE SENSOR



E52

Low-cost Models

Low-cost Platinum Resistance Thermometers

Exposed-lead Models with Screws

Specifications

Element type	Pt100
Conductor type	3-conductor system
Class	Class B
Protective tubing material	SUS304
Sensor length	30 mm
Max. detectable temperature	250°C
Temperature range	–50°C to 250°C
Lead wire	–50°C to 150°C

E52-P6D

Dimensions

Tapered pipe thread SUS304 R1/8; Argon arc welding; SUS304 (t0.25); 4 dia.; Silicone tubing; Caulking; Fluororesin-covered wire with 1.0 outer dia. each (PFA) 7/0.18; Red (A); Black (B); Black (B); Y-type crimp terminal for M4; 14; 65; 10; 6; 15; 30; M

Note: The protective tubing is of pipe construction, which must not be bent.

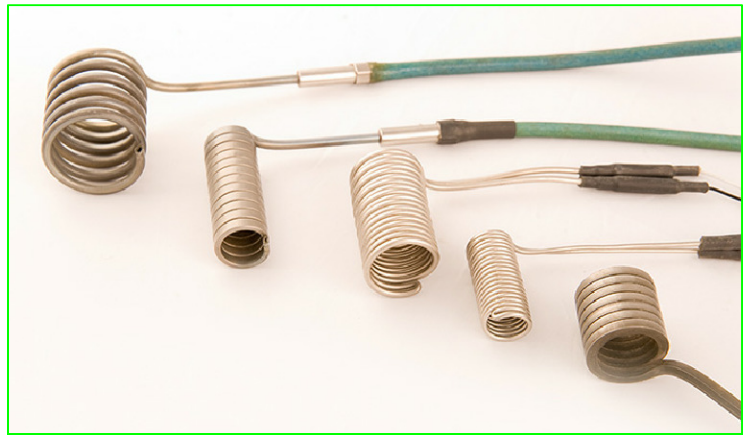
Lead wire length (m)	Model
1	E52-P6D 1M
2	E52-P6D 2M
4	E52-P6D 4M

MODEL	PT100
QUANTITY	1 UNIT

BALL VALVES-PUSH IN FITTINGS TYPE

SIZE	ø 6MM (OD) TUBING
QUANTITY	7 UNITS

HEATING ELEMENTS



CHECK VALVE-PUSH IN FITTINGS TYPE

SIZE	ø 6MM (OD) TUBING
QUANTITY	2 UNITS

MATCH TOLERANCE UNLESS OTHERWISE STATED			
OVER TO	TOLERANCE	OVER TO	TOLERANCE
0–6mm	± 0.1mm	300–1000mm	± 3mm
6–30mm	± 0.2mm	1000–3000mm	± 5mm
30–100mm	± 0.3mm	3000 PLUS	± 8mm
100–300mm	± 0.5mm	ANGLES	± 1°

DRAWING TITLE : COMPONENT OF AUTO SYSTEM		
DRAWING NO : 21650109		MODUL : 01
UNIT : MM	SCALE: 1:2 A3	SHEET : 1/1
DRAWN BY:		
Nina		
APPROVED BY:		
Kala/Nazira		

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KUALA LUMPUR
2015/2016

KXGL6305 TISSUE ENGINEERING

LEGEND

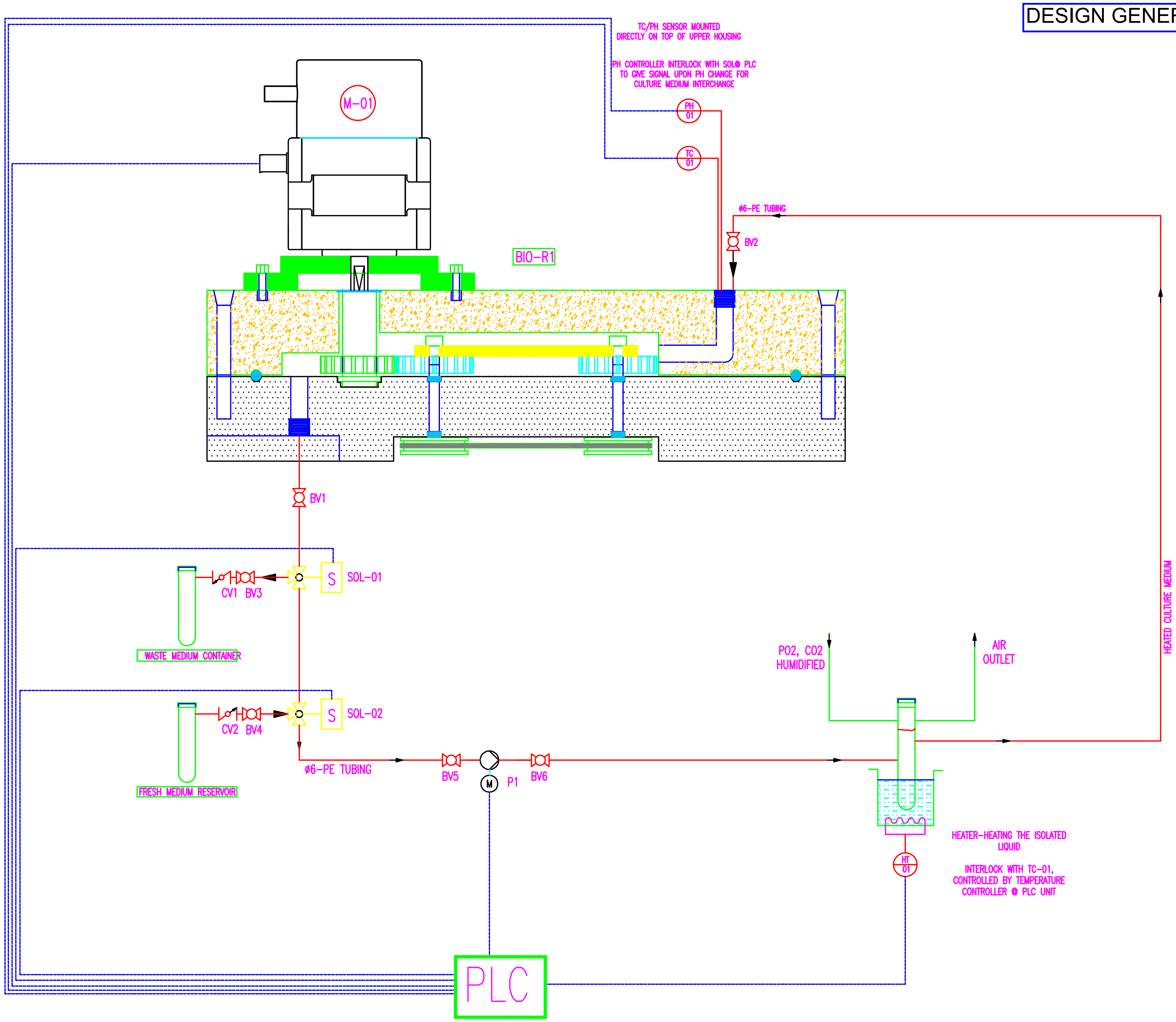
ITEM	TAG	DESCRIPTION	REMARKS
1	M01	DRIVE MOTOR	PLC
2	P1	PERISTALTIC PUMP 5.2–90ML/MIN	PLC
3	SOL–01	SOLENOID VALVE	PLC
4	SOL–02	SOLENOID VALVE	PLC
5	TC–01	TEMPERATURE SENSOR	PLC
6	BV1–6	BALL VALVE	MANUAL VALVE
7	CV1,2	CHECK VALVE (1 WAY VALVE)	AUTO–MECHANICAL
8	BIO–R1	BIOREACTOR	11650101
9	PH/CRTL–01	PH SENSOR & CONTROLLER	PLC
10	HT–01	HEATING ELEMENTS	PLC

DESIGN CRITERIA

1	STRETCHING MECHANISM, WITH STRAIN RANGE 2%–8%
2	MEDIUM FLOWRATE SUPPLY @ RANGE 0.5ml/min – 5ml/min
3	AUTO SUPPLY OF FRESH MEDIUM & AUTO DISCHARGE OF WASTE MEDIUM
4	COMPACT, LIGHTWEIGHT
5	COST FACTOR
6	AVAILABILITY OF PARTS REPLACEMENT
7	MATERIAL BIOCOMPATIBILITY
8	SENSOR & FEEDBACK
9	CHAMBER TEMPERATURE MAINTAIN @ 37 DEG C

REV.	DATE	DESCRIPTION	UPDATED BY:
A	5.5.2016	INITIAL ISSUED	NINA

DESIGN GENERATION # 3



Note:

1. Any Intake/Discharge Port not being in used, will be plug off
2. Tubing Connection will be using Standard Push In Fittings inclusive Manual Valves
3. Components for Auto System–Refer # 21650109
4. Heated culture medium will be circulated into bioreactor, until pH changes, at the same time, new cold medium will be channelled into the circulation line

MATCH TOLERANCE UNLESS OTHERWISE STATED			
OVER TO	TOLERANCE	OVER TO	TOLERANCE
0–6mm	± 0.1mm	300–1000mm	± 3mm
6–30mm	± 0.2mm	1000–3000mm	± 5mm
30–100mm	± 0.3mm	3000 PLUS	± 8mm
100–300mm	± 0.5mm	ANGLES	± 1°

DRAWING TITLE : PROCESS FLOW DIAGRAM FOR TENDON BIOREACTOR		
DRAWING NO : 31650100		MODUL : 01
UNIT : MM	SCALE: 1:1 A3	SHEET : 1/1
DRAWN BY:		
Nina		
APPROVED BY:		
Kala/Nazira		

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KUALA LUMPUR

2015/2016

KXGL6305 TISSUE ENGINEERING

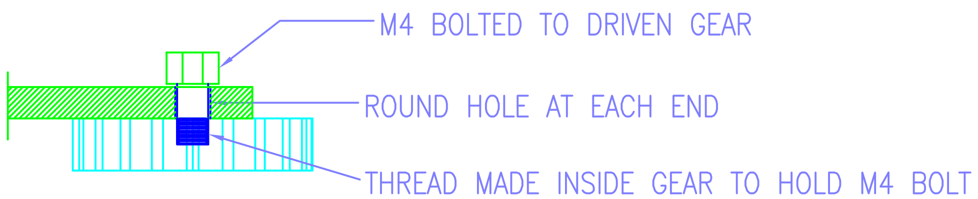
PART LIST			
ITEM	QTY	DESCRIPTION	PART NUMBER
1	3	INTAKE PORT 6MM	21650104
2	4	M4 COUNTER SUNK SCREW	21650106
3	1	UPPER HOUSING	21650104
4	1	SILICONE SEAL	NIL
5	1	LOWER HOUSING	21650105
6	3	DISCHARGE PORT 6MM	21650105
7	1	STEPPER MOTOR C/W BRACKET	21650107
8	1	DRIVE GEAR	21650106
9	2	DRIVEN GEAR	21650106
10	2	PULLEY	21650106
11	1	BELT	21650106
12	1	MEMBRANE FITTED TO DRIVEN GEAR	21650108
13	2	M4 HEX BOLT	21650106
14	5	O-RING SEALS	21650106

Note:

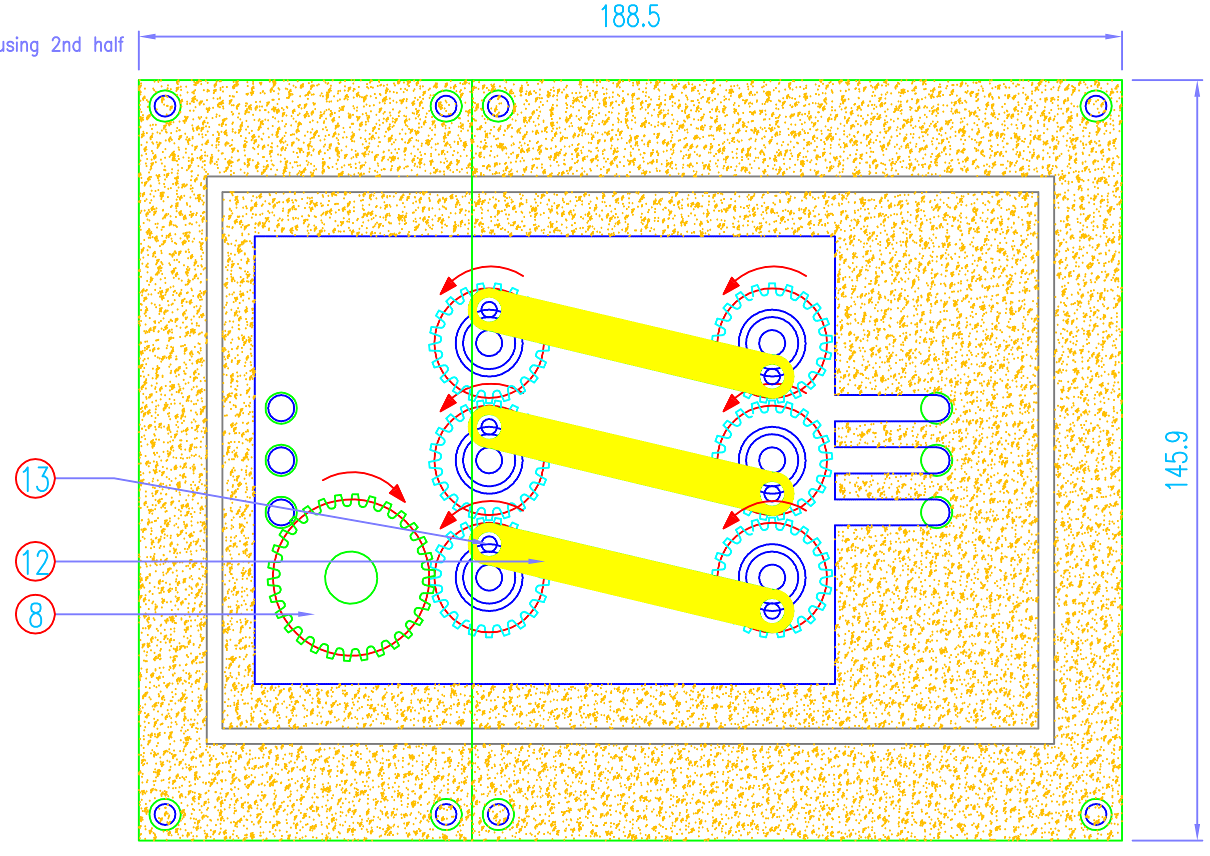
1. Tubing Connection will be using Standard Push In Fittings inclusive Manual Valves
2. Cell is seeded on top of membrane.
3. A hole is made at each end of membrane, fitted to each driven gear and held by the M4 Hex bolt that screwed to the gear.
4. Cell is seeded on top of membrane before fitted the upper housing 2nd half to completed the overall assembly and run the bioreactor

REV.	DATE	DESCRIPTION	UPDATED BY:
A	22.4.2016	INITIAL ISSUED	NINA

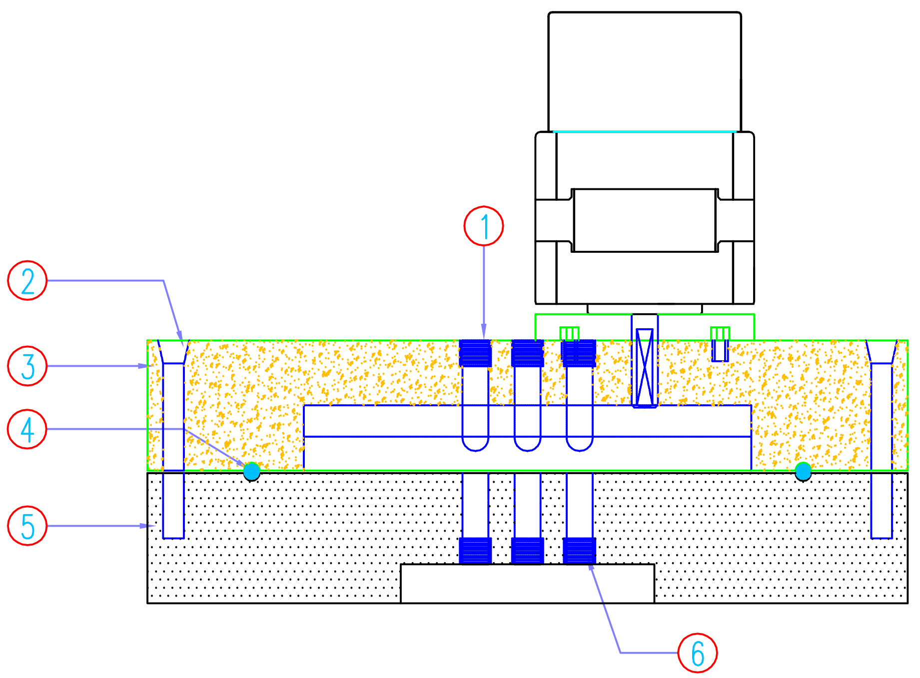
DESIGN GENERATION # 3



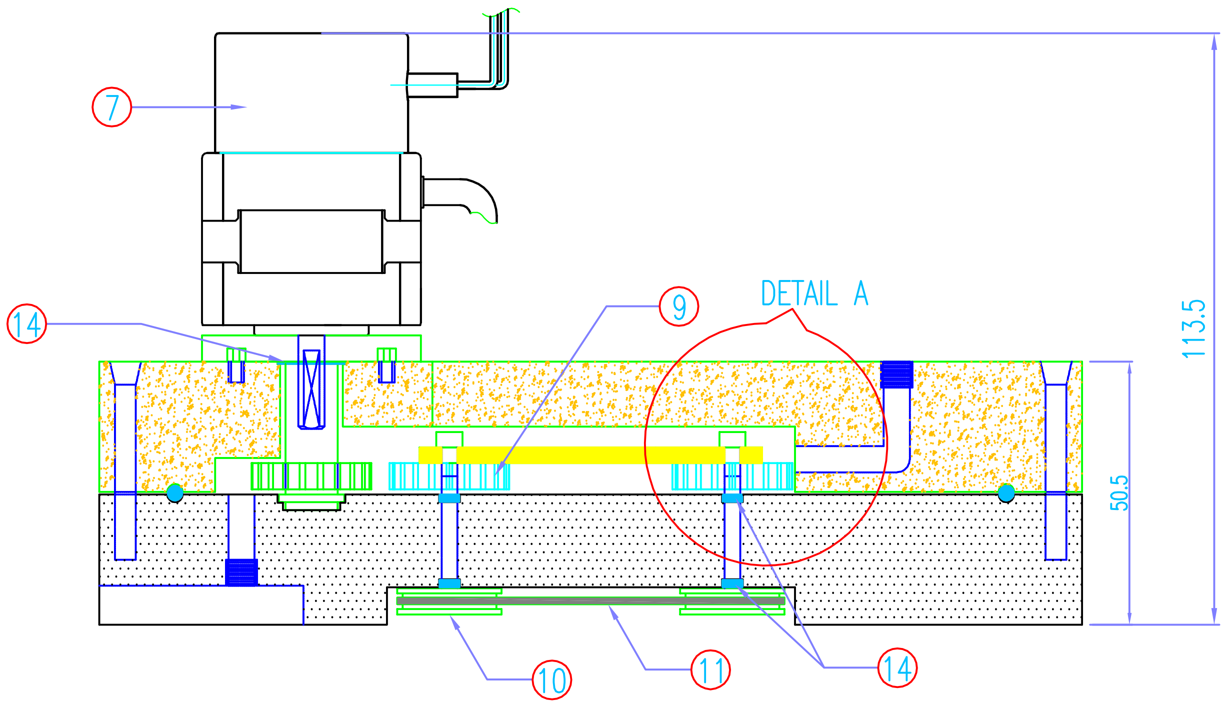
DETAIL A



PLAN VIEW



SIDE VIEW



ELEVATION VIEW

QUANTITY: 1 SET

MATCH TOLERANCE UNLESS OTHERWISE STATED			
OVER TO	TOLERANCE	OVER TO	TOLERANCE
0–6mm	± 0.1mm	300–1000mm	± 3mm
6–30mm	± 0.2mm	1000–3000mm	± 5mm
30–100mm	± 0.3mm	3000 PLUS	± 8mm
100–300mm	± 0.5mm	ANGLES	± 1°

DRAWING TITLE : BIOREACTOR BIO-R1		
DRAWING NO : 11650101		MODUL : 01
UNIT : MM	SCALE: 1:1.5 A3	SHEET : 1/1
DRAWN BY:		
Nina		
APPROVED BY:		
Kala/Nazira		

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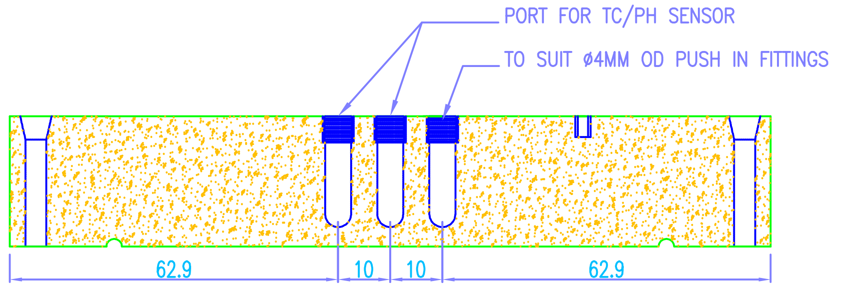
KXGL6305 TISSUE ENGINEERING

NOTE:	
MATERIAL	ACRYLIC SHEET
QUANTITY	1 UNIT

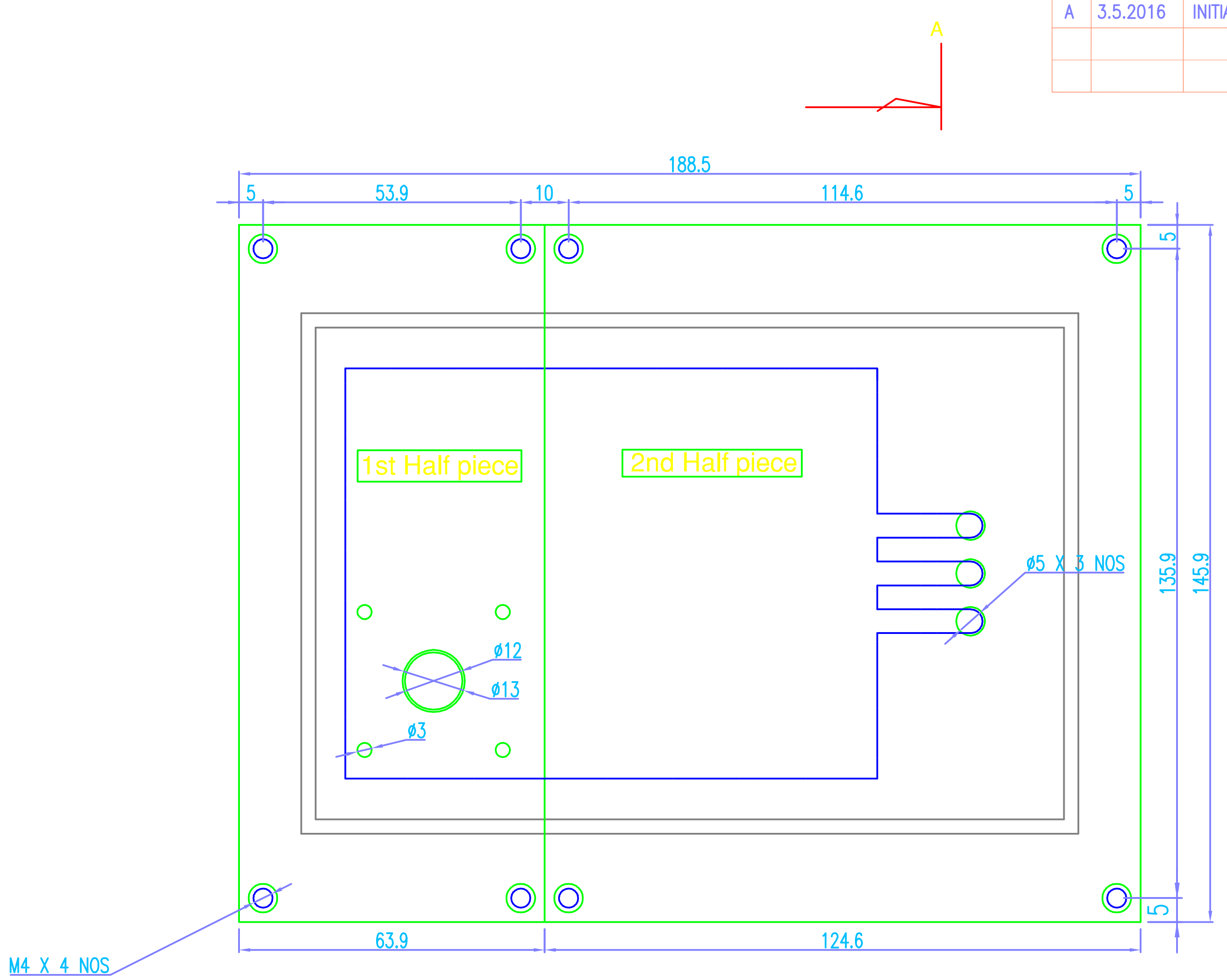
1. UPPER CASING MADE INTO 2 SPLIT UNIT-TO ALLOW CHANGING SAMPEL WITHOUT DISMANTLING THE MOTOR
2. MATERIAL SELECTION CRITERIA:
   * TRANSPARENT, FLEXIBLE AND EXHIBIT GREAT RESISTANCE TO BREAKAGE
   * OPERATING TEMPERATURE -40 DEG C TO 80 DEG C
   * FABRICATION MUST BE DONE WITH FINE TOOTH BLADES & CEMENTED WITH ACRYLIC CEMENT
   * FDA APPROVED
   * NOT MEANT FOR AUTOCLAVE STERILIZATION
3. STEPPER MOTOR, SHAFT & DRIVER GEAR MUST BE FITTED TO THIS UPPER HOUSING BEFORE ASSEMBLED TO THE LOWER HOUSING

REV.	DATE	DESCRIPTION	UPDATED BY:
A	3.5.2016	INITIAL ISSUED	NINA

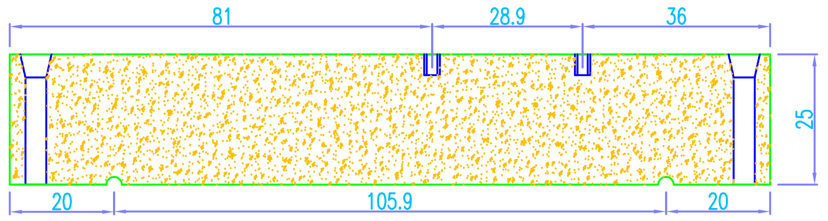
DESIGN GENERATION # 3



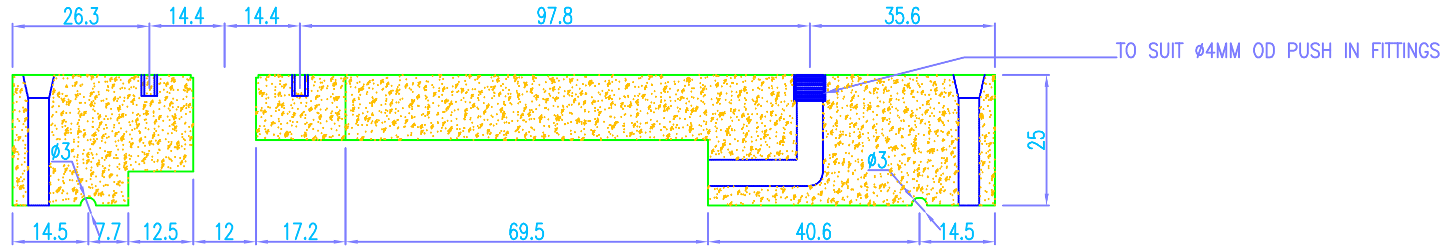
SECTION A-A



PLAN VIEW



SIDE VIEW



ELEVATION VIEW

MATCH TOLERANCE UNLESS OTHERWISE STATED			
OVER TO	TOLERANCE	OVER TO	TOLERANCE
0-6mm	± 0.1mm	300-1000mm	± 3mm
6-30mm	± 0.2mm	1000-3000mm	± 5mm
30-100mm	± 0.3mm	3000 PLUS	± 8mm
100-300mm	± 0.5mm	ANGLES	± 1°

DRAWING TITLE :	UPPER HOUSING	
DRAWING NO :	21650104	MODUL : 01
UNIT : MM	SCALE: 1:1.5 A3	SHEET : 1/1
DRAWN BY:		
Nina		
APPROVED BY:		
Kala/Nazira		

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2015/2016

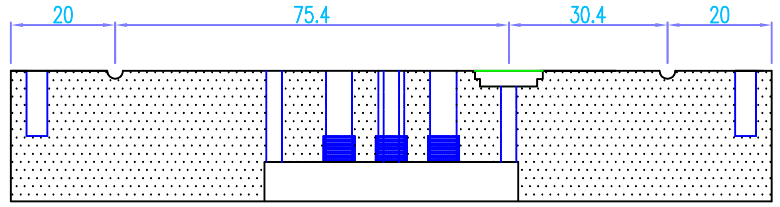
KXGL6305 TISSUE ENGINEERING

NOTE:	
MATERIAL	ACRYLIC SHEET
QUANTITY	1 UNIT

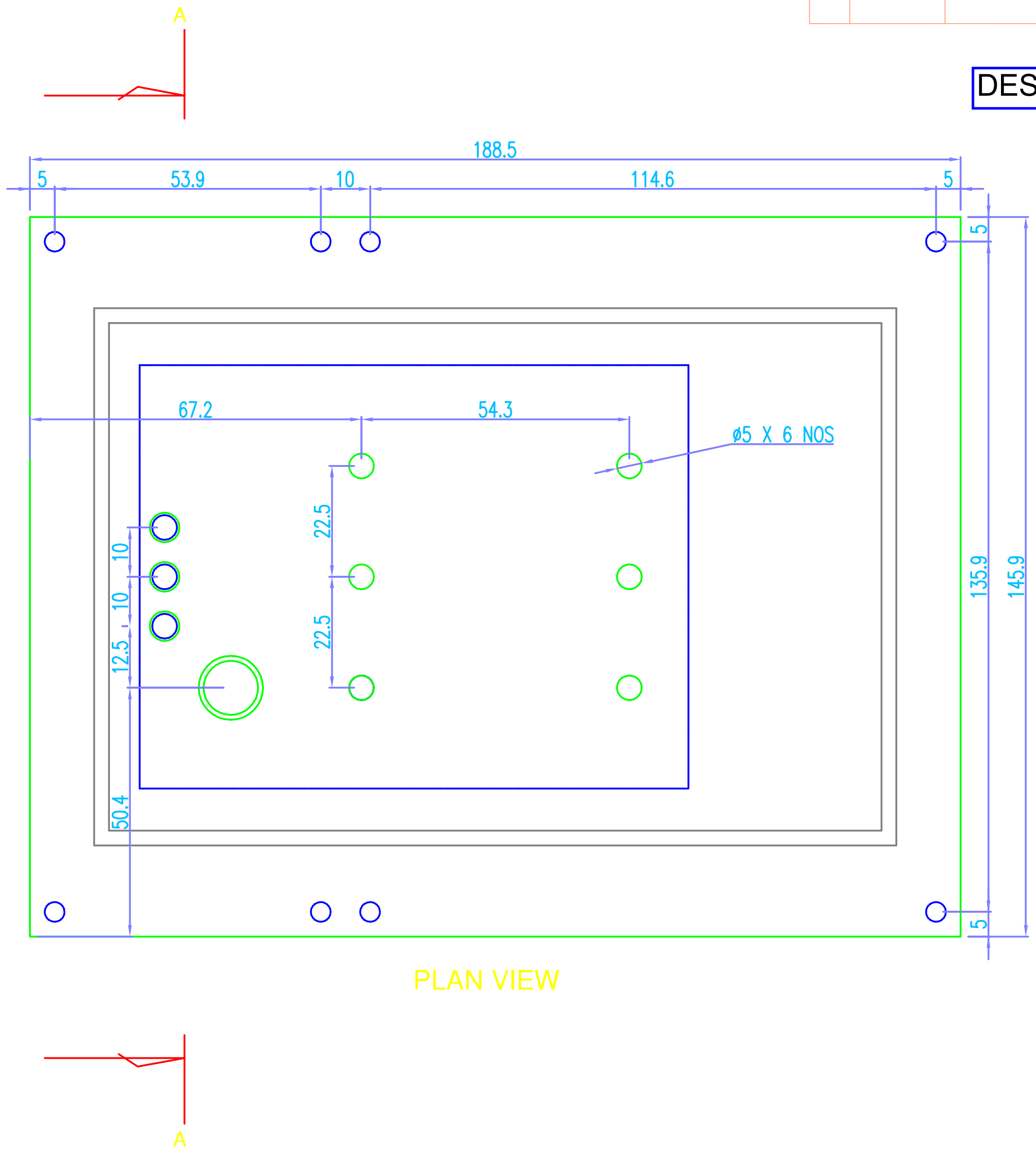
1. BOTH DRIVER GEAR MUST BE FITTED INTO POSITION, FOLLOWED BY THE PULLEYS AND BELT UNDERNEATH.
2. MATERIAL SELECTION CRITERIA:
   * TRANSPARENT, FLEXIBLE AND EXHIBIT GREAT RESISTANCE TO BREAKAGE
   * OPERATING TEMPERATURE -40 DEG C TO 80 DEG C
   * FABRICATION MUST BE DONE WITH FINE TOOTH BLADES & CEMENTED WITH ACRYLIC CEMENT
   * FDA APPROVED
   * NOT MEANT FOR AUTOCLAVE STERILIZATION
3. MEMBRANE TO BE FITTED ONTO DRIVEN GEAR AT FINAL STAGE OF ASSEMBLY.

REV.	DATE	DESCRIPTION	UPDATED BY:
A	3.5.2016	INITIAL ISSUED	NINA

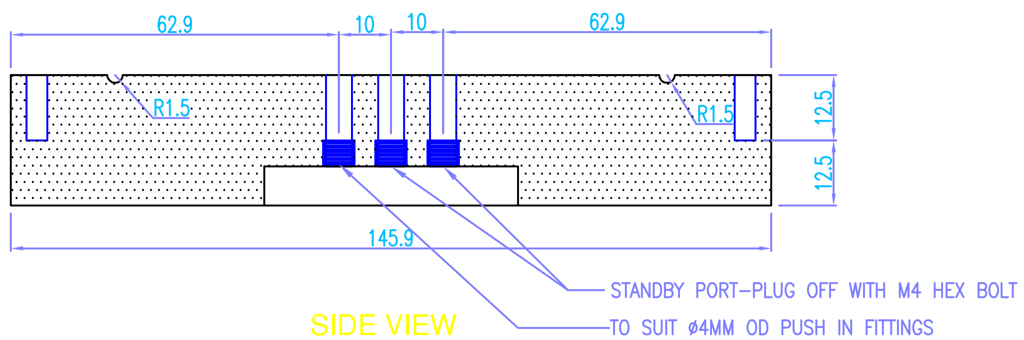
DESIGN GENERATION # 3



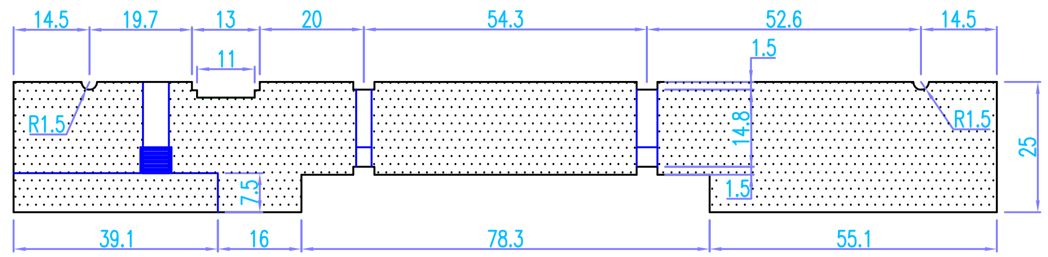
SECTION A-A



PLAN VIEW



SIDE VIEW



ELEVATION VIEW

MATCH TOLERANCE UNLESS OTHERWISE STATED			
OVER TO	TOLERANCE	OVER TO	TOLERANCE
0-6mm	± 0.1mm	300-1000mm	± 3mm
6-30mm	± 0.2mm	1000-3000mm	± 5mm
30-100mm	± 0.3mm	3000 PLUS	± 8mm
100-300mm	± 0.5mm	ANGLES	± 1°

DRAWING TITLE : LOWER HOUSING		
DRAWING NO : 21650105		MODUL : 01
UNIT : MM	SCALE: 1:1.5 A3	SHEET : 1/1
DRAWN BY:		
Nina		
APPROVED BY:		
Kala/Nazira		

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KXGL6305 TISSUE ENGINEERING

REV.	DATE	DESCRIPTION	UPDATED BY:
A	3.5.2016	INITIAL ISSUED	NINA

DESIGN GENERATION # 3

GEARS

MATERIAL	NYLON
QUANTITY	7 UNITS
MODEL	Z=21T, MODULE: 1

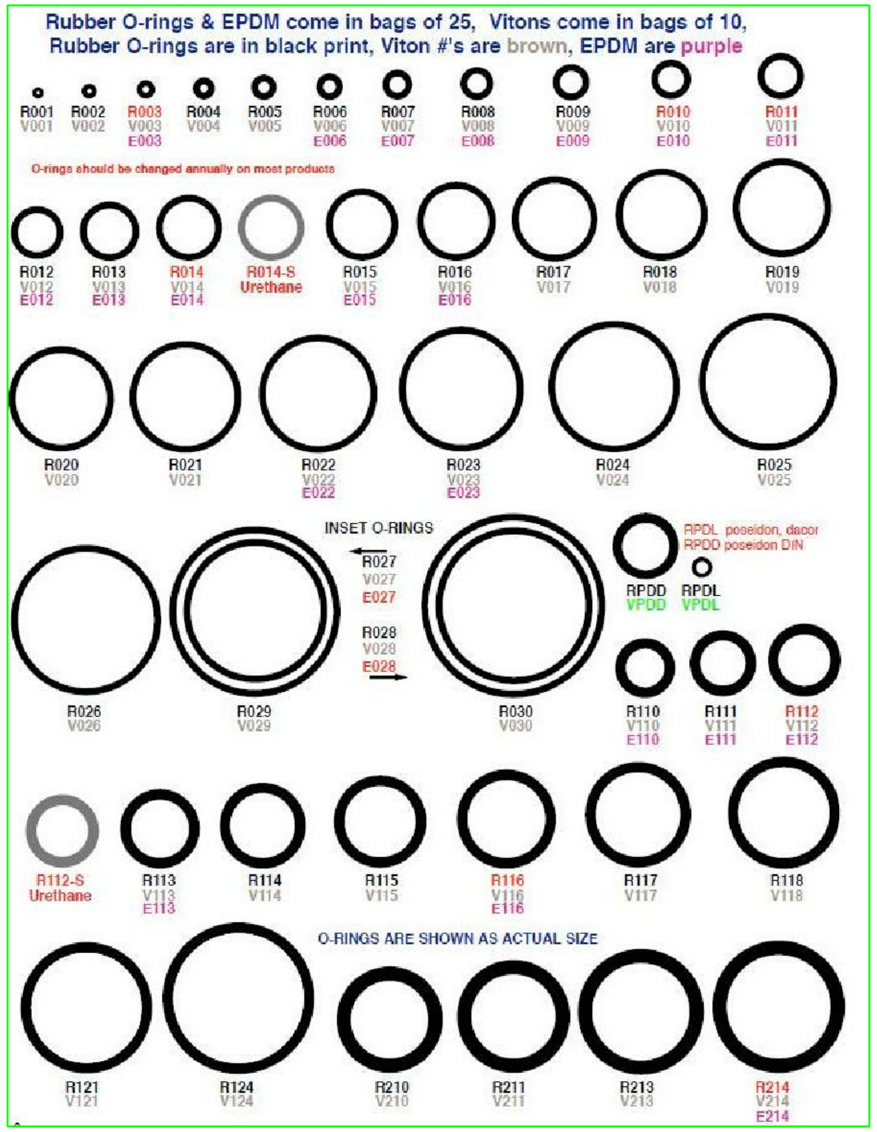
PULLEYS

MATERIAL	NYLON
QUANTITY	2 UNITS
DIAMETER	ø 18MM X 1 GROOVE

HEX BOLT

MATERIAL	NYLON/PLASTIC CLEAR
QUANTITY	6 UNITS (ALSO AS PLUG)
SIZE	M4

RUBBER O-RINGS



COUNTERSUNK BOLT

MATERIAL	NYLON/PLASTIC CLEAR
QUANTITY	4 UNITS
SIZE	M4

MATERIAL	RUBBER
QUANTITY	1 UNIT
CENTER DISTANCE	ø 3MM X 54.3MM CD

MATCH TOLERANCE UNLESS OTHERWISE STATED			
OVER TO	TOLERANCE	OVER TO	TOLERANCE
0–6mm	± 0.1mm	300–1000mm	± 3mm
6–30mm	± 0.2mm	1000–3000mm	± 5mm
30–100mm	± 0.3mm	3000 PLUS	± 8mm
100–300mm	± 0.5mm	ANGLES	± 1°

DRAWING TITLE : STANDARD PARTS		
DRAWING NO : 21650106		MODUL : 01
UNIT : MM	SCALE: 1:1.5 A3	SHEET : 1/1
DRAWN BY:		
Nina		
APPROVED BY:		
Kala/Nazira		

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2015/2016

KXGL6305 TISSUE ENGINEERING

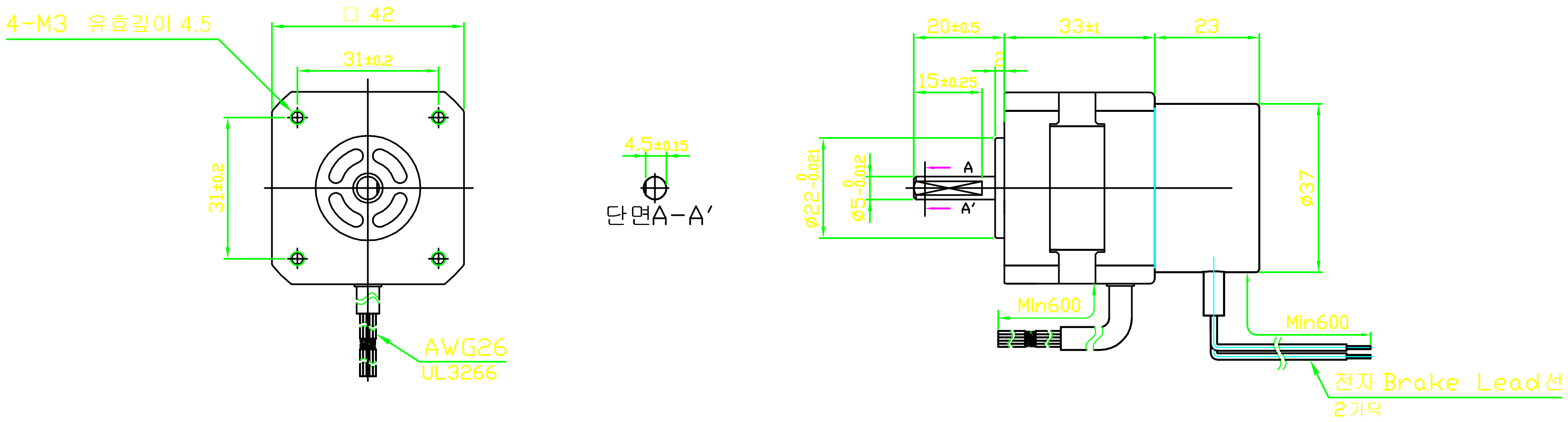
REV.	DATE	DESCRIPTION	UPDATED BY:
A	22.4.2016	INITIAL ISSUED	NINA

DESIGN GENERATION # 3

• 42-square

Model	Shaft type	A1K-S543(W)	A2K-S544(W)	A2K-M544(W)	A3K-S545(W)
Max. allowable torque		-	-	-	-
Max. holding torque		1.3kgf·cm (0.13 N·m)	1.8kgf·cm (0.18 N·m)		2.4kgf·cm (0.24 N·m)
Moment of rotor inertia		$35g\cdot cm^2$ ($35x10^{-7}$ $kg\cdot m^2$)	$54g\cdot cm^2$ ($54x10^{-7}$ $kg\cdot m^2$)		$68g\cdot cm^2$ ($68x10^{-7}$ $kg\cdot m^2$)
Rated current		0.75A/Phase		1.4A/Phase	0.75A/Phase
Basic step angle		0.72° / 0.36°(Full/Half step)			
Gear ratio		-			
Allowable speed range		-			
Backlash[min]		-			
Electormagnetic	Rated excitation voltage	24VDC ±10%			
	Rated excitation current	0.2A			
	Static friction torque	1.8kgf·cm			
	Rotation part inertia	3.0×10^{-7} $kg.cm^2$			
	Operating time	Max. 24ms			
	Releasing time	Max. 15ms			
Insulation class		B type(130°C)			
Insulation resistance		Min. 100MΩ(at 500VDC megger) between motor coil-case			
Dielectric strength		1Min. at 1 kVAC(0.5kVAC for 0.75A/Phase) 50/60Hz between Motor coil-case			
Environ -ment	Ambient temperature	-10 to 50°C, storage: -25 to 85°C			
	Ambient humidity	35 to 85%RH, storage: 35 to 85%RH			
Protection		IP30(IEC34-5 standard)			
Unit weight		Standard type / Geared type: Approx. 0.25kg	Standard type / Geared type: Approx. 0.3kg		Standard type / Geared type:

MODEL : A1K-S543



MATCH TOLERANCE UNLESS OTHERWISE STATED

OVER TO	TOLERANCE	OVER TO	TOLERANCE
0–6mm	± 0.1mm	300–1000mm	± 3mm
6–30mm	± 0.2mm	1000–3000mm	± 5mm
30–100mm	± 0.3mm	3000 PLUS	± 8mm
100–300mm	± 0.5mm	ANGLES	± 1°

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DRAWING TITLE :	STEPPER MOTOR	
DRAWING NO : 21650107		MODUL : 01
UNIT : MM	SCALE: 1:1.5 A3	SHEET : 1/1
DRAWN BY:		
Nina		
APPROVED BY:		
Kala/Nazira		

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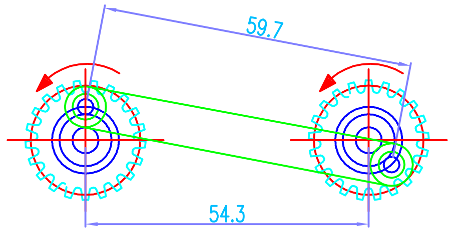
KXGL6305 TISSUE ENGINEERING

REV.	DATE	DESCRIPTION	UPDATED BY:
A	3.5.2016	INITIAL ISSUED	NINA

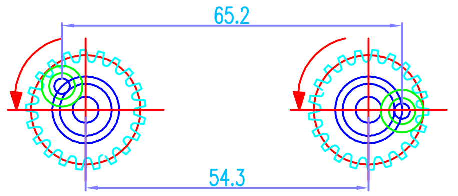
DESIGN GENERATION # 3

* CENTER DISTANCE MEMBRANE: 60.4MM POSITIONING
* MAKE HOLE BOTH END TO BE FIXED TO THE GEAR

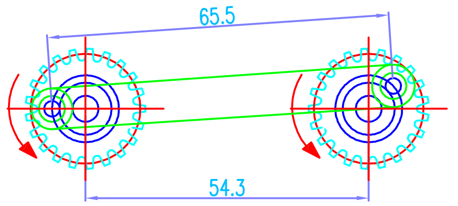
POSITION OPTION A



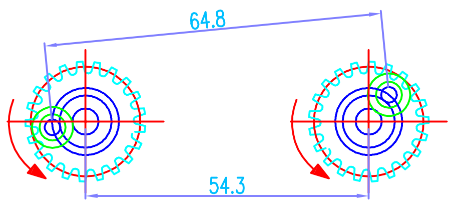
POSITION	INITIAL POSITION (0 DEG)
LENGTH (MM)	60 MM
% STRAIN	0



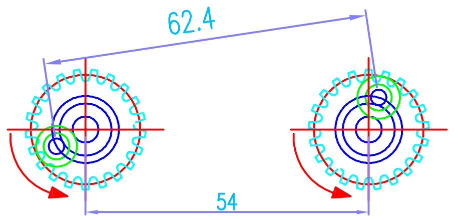
POSITION	45 DEG ROTATION, CCW
LENGTH (MM)	65.2
% STRAIN	9.2



POSITION	90 DEG ROTATION, CCW
LENGTH (MM)	65.5
% STRAIN	9.72

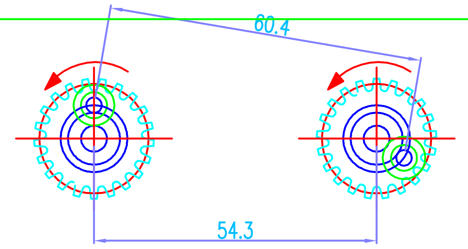


POSITION	100 DEG ROTATION, CCW
LENGTH (MM)	64.8
% STRAIN	8.5

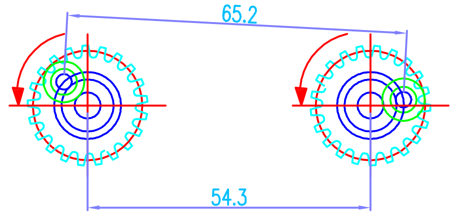


POSITION	120 DEG ROTATION, CCW
LENGTH (MM)	62.4
% STRAIN	4.5

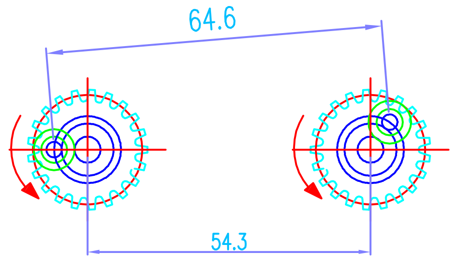
POSITION OPTION B



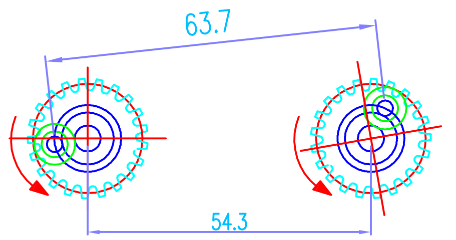
POSITION	INITIAL POSITION (0 DEG)
LENGTH (MM)	60 MM
% STRAIN	0



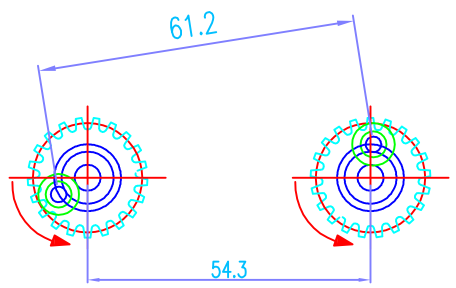
POSITION	45 DEG ROTATION, CCW
LENGTH (MM)	65.2
% STRAIN	7.95



POSITION	90 DEG ROTATION, CCW
LENGTH (MM)	64.6
% STRAIN	6.95



POSITION	100 DEG ROTATION, CCW
LENGTH (MM)	63.7
% STRAIN	5.46



POSITION	120 DEG ROTATION, CCW
LENGTH (MM)	61.2
% STRAIN	1.32

MATCH TOLERANCE UNLESS OTHERWISE STATED			
OVER TO	TOLERANCE	OVER TO	TOLERANCE
0–6mm	± 0.1mm	300–1000mm	± 3mm
6–30mm	± 0.2mm	1000–3000mm	± 5mm
30–100mm	± 0.3mm	3000 PLUS	± 8mm
100–300mm	± 0.5mm	ANGLES	± 1°

DRAWING TITLE :	SCAFFOLDING HOUSING & POSITIONING	
DRAWING NO :	21650108	MODUL : 01
UNIT : MM	SCALE: 1:2 A3	SHEET : 1/1
DRAWN BY:	Nina	
APPROVED BY:	Kala/Nazira	

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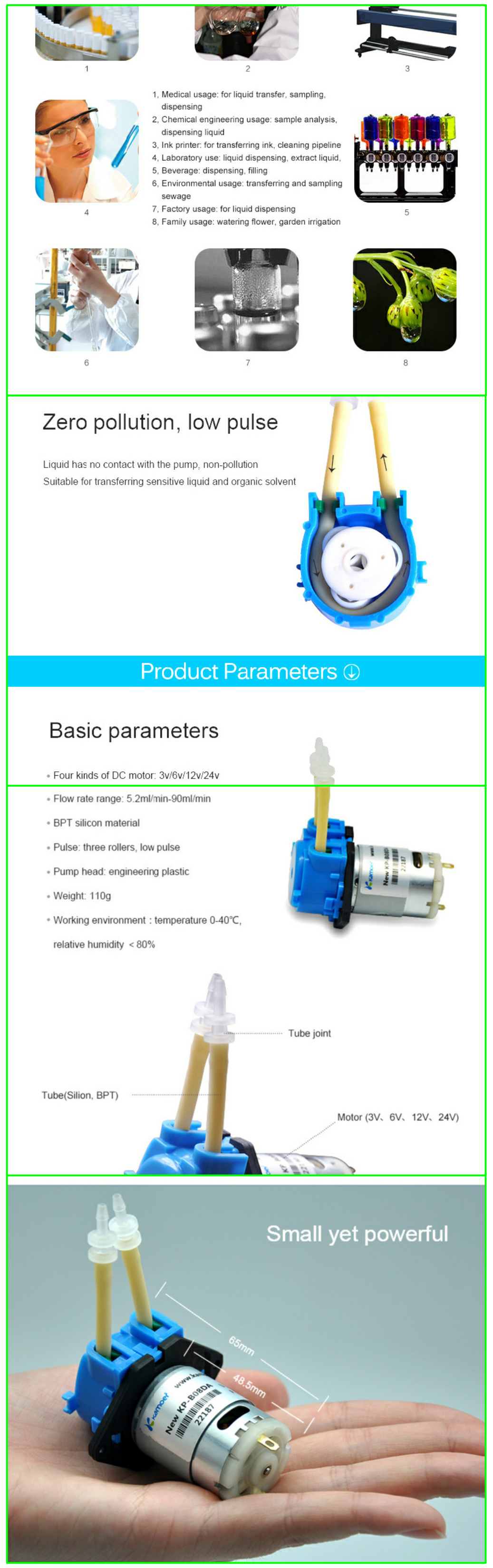
KXGL6305 TISSUE ENGINEERING

REV.	DATE	DESCRIPTION	UPDATED BY:
A	3.5.2016	INITIAL ISSUED	NINA

DESIGN GENERATION # 3

PERISTALTIC PUMP



MODEL	KP
QUANTITY	1 UNIT
FLOW RATE	5.2 ml/min–90 ml/min

SOLENOID VALVE

Series 1 & 2 Miniature Inert PTFE Isolation Valves

2-Way and 3-Way Solenoid Valves

The 2-Way & 3-Way inert Series 1 & 2 valves have been designed for systems where chemical compatibility is most important. The wetted path is isolated from the solenoid and only PTFE and borosilicate glass are in contact with the media passing through the valve. Low internal volume and fast response time ensure repeatable, accurate volumes. Valves will actuate without any pressure or vacuum applied.

Features

- Provides unsurpassed chemical compatibility for a wide range of media with PTFE and borosilicate glass as the only wetted parts
- 100% continuous duty rating in ambient temperatures up to 66°C
- Low power for reduced heat generation and power consumption
- Fast response times for accurate repeatable results
- Direct acting: does not require pressure or vacuum to operate
- 100% tested leak rate provides assurance of a quality seal
- Provides reliable operation for the life of your instrument
- RoHS compliant

Typical Applications

- Reagent Control
- Solvent Management
- Aggressive Liquid Control

Product Specifications

Physical Properties

Valve Type:	
Diaphragm Isolation Valve	
Valve Configuration:	
3-Way (Series 1)	
2-Way, Normally Closed (Series 2)	
Media:	
Liquids	
Operating Environment:	
40 to 150°F (4 to 66°C)	
Dimensions:	
Width: 1.0" (25.4 mm)	
Height: 2.1" (53.34 mm)	
Length: 1.0"(25.4 mm)	
Porting:	
1/4-28 Threaded Ports	
Weight:	
2.7 oz (76.5 g)	
Internal Volume (µL):	
96 (3-Way)	
49 (2-Way)	

Electrical

Voltage (VDC):	12	24
Power (Watts):	2.5	4.2
Current (mA):	211	173
Resistance (Ohm):	57	139
(Ω±5% @ 70°F, 21.1°C)		
Connections:		
12" Lead Wire Standard		
26 AWG, PTFE Insulated		

Wetted Materials*

Seals:	
PTFE	
Body Options:	
PTFE	
All Others:	
Borosilicate Glass (3 - Way only)	

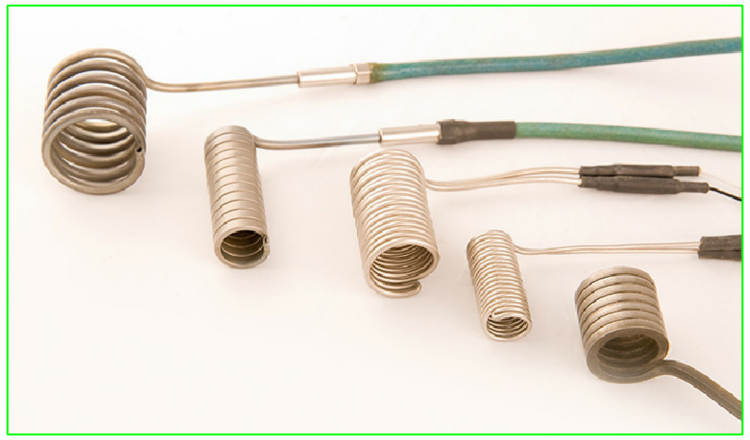
* See Chemical Compatibility Page
Consult factory for other options

Performance Characteristics

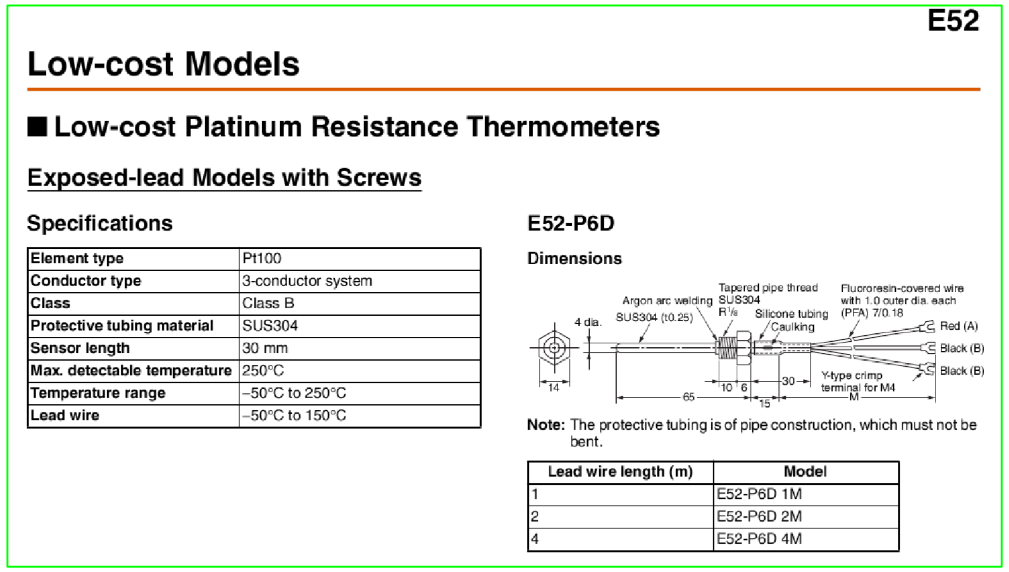
Operating Pressure/ Orifice Diameters:	
Vacuum - 20 psig (1.4 bar) / 0.060" (1.52 mm)	
Proof Pressure:	
1.5X rated pressure	
Leak Rate:	
Bubble Tight	
Response Time:	
3-Way: <12 ms cycling	
2-Way: <20 ms cycling	
Recommended Filtration:	
10 µm min	
Reliability:	
Life Cycle Rating of 10 million (Application dependent)	

Parker

HEATING ELEMENTS



TEMPERATURE SENSOR



E52

Low-cost Models

■ Low-cost Platinum Resistance Thermometers

Exposed-lead Models with Screws

Specifications

Element type	Pt100
Conductor type	3-conductor system
Class	Class B
Protective tubing material	SUS304
Sensor length	30 mm
Max. detectable temperature	250°C
Temperature range	–50°C to 250°C
Lead wire	–50°C to 150°C

E52-P6D

Dimensions

Note: The protective tubing is of pipe construction, which must not be bent.

Lead wire length (m)	Model
1	E52-P6D 1M
2	E52-P6D 2M
4	E52-P6D 4M

MODEL	PT100
QUANTITY	1 UNIT

BALL VALVES-PUSH IN FITTINGS TYPE

SIZE	ø 6MM (OD) TUBING
QUANTITY	7 UNITS

CHECK VALVE-PUSH IN FITTINGS TYPE

SIZE	ø 6MM (OD) TUBING
QUANTITY	2 UNITS

MATCH TOLERANCE UNLESS OTHERWISE STATED			
OVER TO	TOLERANCE	OVER TO	TOLERANCE
0–6mm	± 0.1mm	300–1000mm	± 3mm
6–30mm	± 0.2mm	1000–3000mm	± 5mm
30–100mm	± 0.3mm	3000 PLUS	± 8mm
100–300mm	± 0.5mm	ANGLES	± 1°

DRAWING TITLE : COMPONENT OF AUTO SYSTEM		
DRAWING NO : 21650109		MODUL : 01
UNIT : MM	SCALE: 1:2 A3	SHEET : 1/1
DRAWN BY:		
Nina		
APPROVED BY:		
Kala/Nazira		

UNIVERSITY OF MALAYA
KUALA LUMPUR
2015/2016

KXGL6305 TISSUE ENGINEERING