Atomiser Project Summary (Personal)

1. The Objective

An efficient and quick method of humidifying air was sought, and ultrasonic actuators were one of the designs considered. To test out the use and efficacy of ultrasonic piezoelectric actuators, I endeavoured to create a home-made atomiser. To create a continuous supply, I utilised a wick's capillary action dipped within a water container. Due to surface tension forces and the capillary effect, the siphoning of the water would ensure a steady flow rate to the disk/mesh for atomisation. A system diagram is shown in Figure 1.

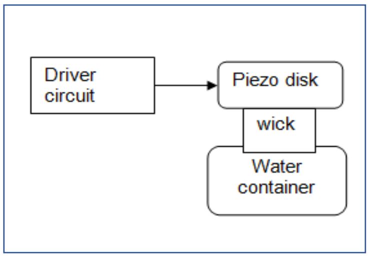


Figure 1: The system architecture summary of the project.

2. The Theory

When a liquid film contacts a smooth surface that is set into vibrating motion that is perpendicular to the surface, the liquid absorbs some of the vibrational energy, which is transformed into standing waves. These capillary waves form a grid pattern on the surface with regularly alternating crests and troughs extending in both directions.

When the amplitude of the vibration is increased, the amplitude of the waves increases correspondingly. A critical amplitude is ultimately reached at which the height of the capillary waves exceeds a stable height. The result is that the waves collapse, and droplets of liquid are ejected from the tops of the degenerating waves normal to the atomizing surface.

An analogy found in nature is wave action on a shoreline. Ocean waves coming in go through a transition from stability on the open water to instability as they approach shore. The instability is evident as the waves form foamy breakers.

The reason for instability in this type of wave is that as it approaches shore, the bottom of the wave contacts the ocean floor and is slowed down by frictional forces. The wave top, on the other hand, continues to move ahead unimpeded. The net result is that the wave topples over. In this process of breaking up, a spray of tiny drops is ejected from the wave surface. Although the mechanisms governing the creation of a spray from capillary and ocean waves differ, the results are similar.

3. Components

3.1 Reservoir

The reservoir was a small bottle with a common thread type for the cap. Figure 2 shows the bottle to be used and the cap with the thread type. The water container for this specific design was a bottle of 350 mL capacity. Its lip had a standard 415 “Glass Packaging Institute” (GPI) threaded finish which required a 415 GPI threaded cap. Information on this is found within appendix B. The nominal diameter from the chart within the appendix was 28mm for the desired cap.

Figure 2: The bottle used as the reservoir and the corresponding cap.

3.2 Driving Circuit

The driver circuit for the transducer is shown in Figures 3 and 4. It consisted of three main stages: the boost stage, the oscillation stage, and the feedback stage. The principle behind the design was to generate an oscillatory electrical wave which, with a piezoelectric transducer, would create mechanical waves with an equivalent frequency. For efficient functionality, the frequency must be at or close to the resonant frequency of the disc. Although the circuit was bought with the disk, a small modification was made to increase the output voltage amplitude.

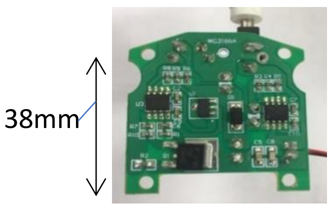


Figure 3: The lower layer of the driving circuit PCB.

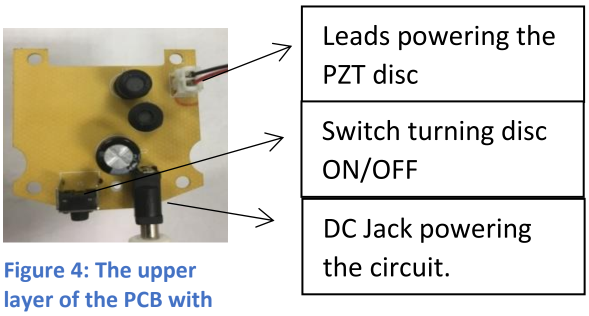


Figure 4: The upper layer of the PCB with key components labelled.

The current implemented driver circuit generates sinusoidal electrical waves which operate close to a natural harmonic of the disc. To change the resonant frequency, either the thickness of the disk may be increased to change the fundamental frequency, or the power output may be increased.

3.3 Piezoelectric Disk

The transducer consisted of a piezoelectric disc made of lead zirconate titanate (PZT). The disc was encased within rubber to ensure isolation as shown in Figure 5. The disc has been perforated to form a vibrating mesh.

The effective diameter of the transducer was 20mm. As mentioned, for effective functionality a frequency of 113 kHz ± 3 kHz is suitable.

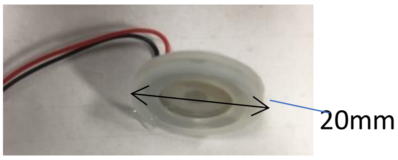


Figure 5: The ultrasonic PZT disk with a perforated centre.

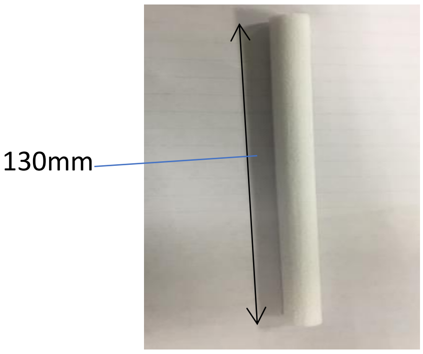


Figure 6: The wick which will siphon water via capillary action.

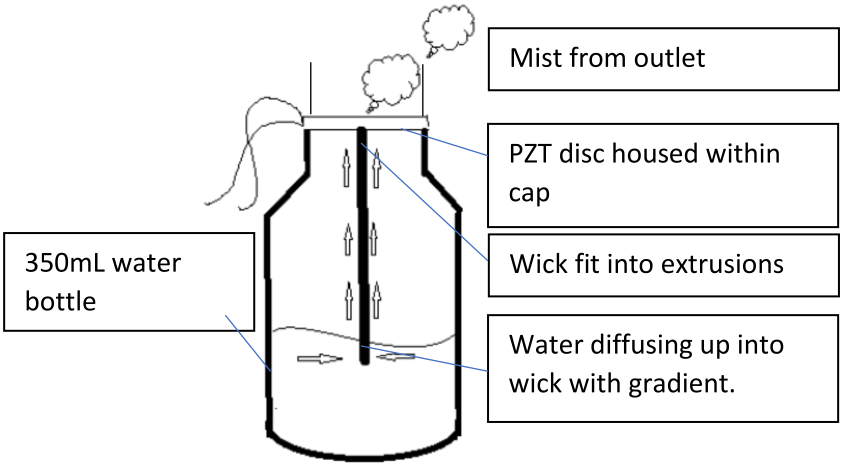


Figure 7 A simplified diagram showing the set-up.

The wick's cross-sectional diameter was approximately 7.5mm without compression and is shown within Figure 6. Its primary purpose was to siphon water from the reservoir and provide it to the atomising disk. This was achieved via surface tension forces and the capillary effect present within the wick which caused diffusion of water as demonstrated within Figure 7.

2.3 Cap Design

The design of the cap was done by the measuring of key component dimensions and the dimensions of male pipe fittings for interfacing with the outlet. Consideration was made for the placement of a wick and housing of the PZT disc. The wick would slot into the bottom while the disc would slot in from the top into their respective casings. The wick was held in place by the four extrusions within the orifice and the disc had both a tight fit as well as an enclosure from a pipe fitting and the cap housing. The final model is as shown in Figures 8 and 9 with the extrusions shown more clearly in the latter. All dimensions and cross-sectional views are shown within appendix A. The cap was printed on a Projet machine and is made of VisiJet EX200 material. The material properties are found within appendix C.

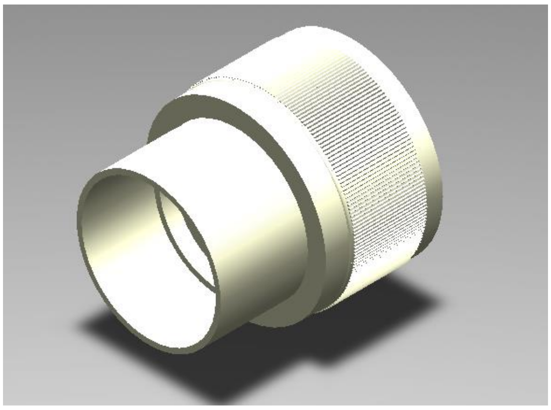


Figure 8: An isometric view of the cap showing the grip.

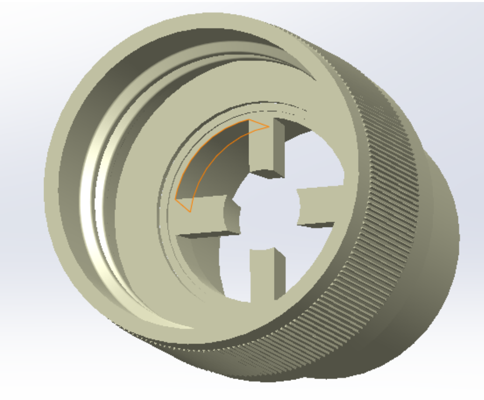


Figure 9: A front view showing the orifice of the cap and the slot for the disk.

4. Results

Shown within Figure 10 is the atomising unit without the water reservoir. the cap holding the wick and PZT disc, and the pipe fitted on top.

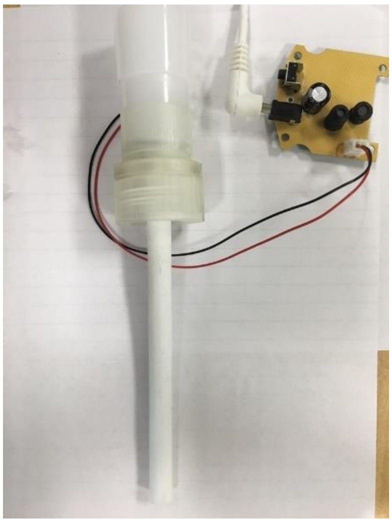


Figure 10: The interface cap, wick, piping, and ultrasonic transducer.

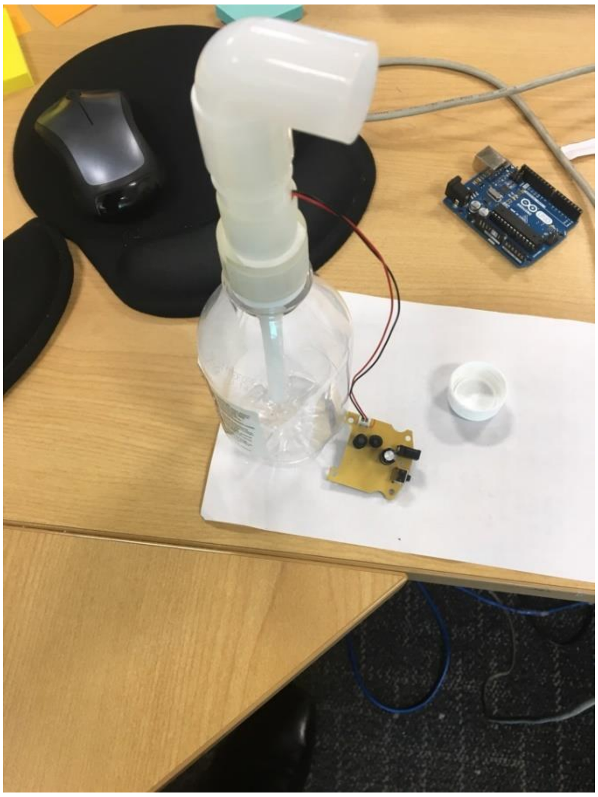


Figure 11: The final set-up of the atomiser project.

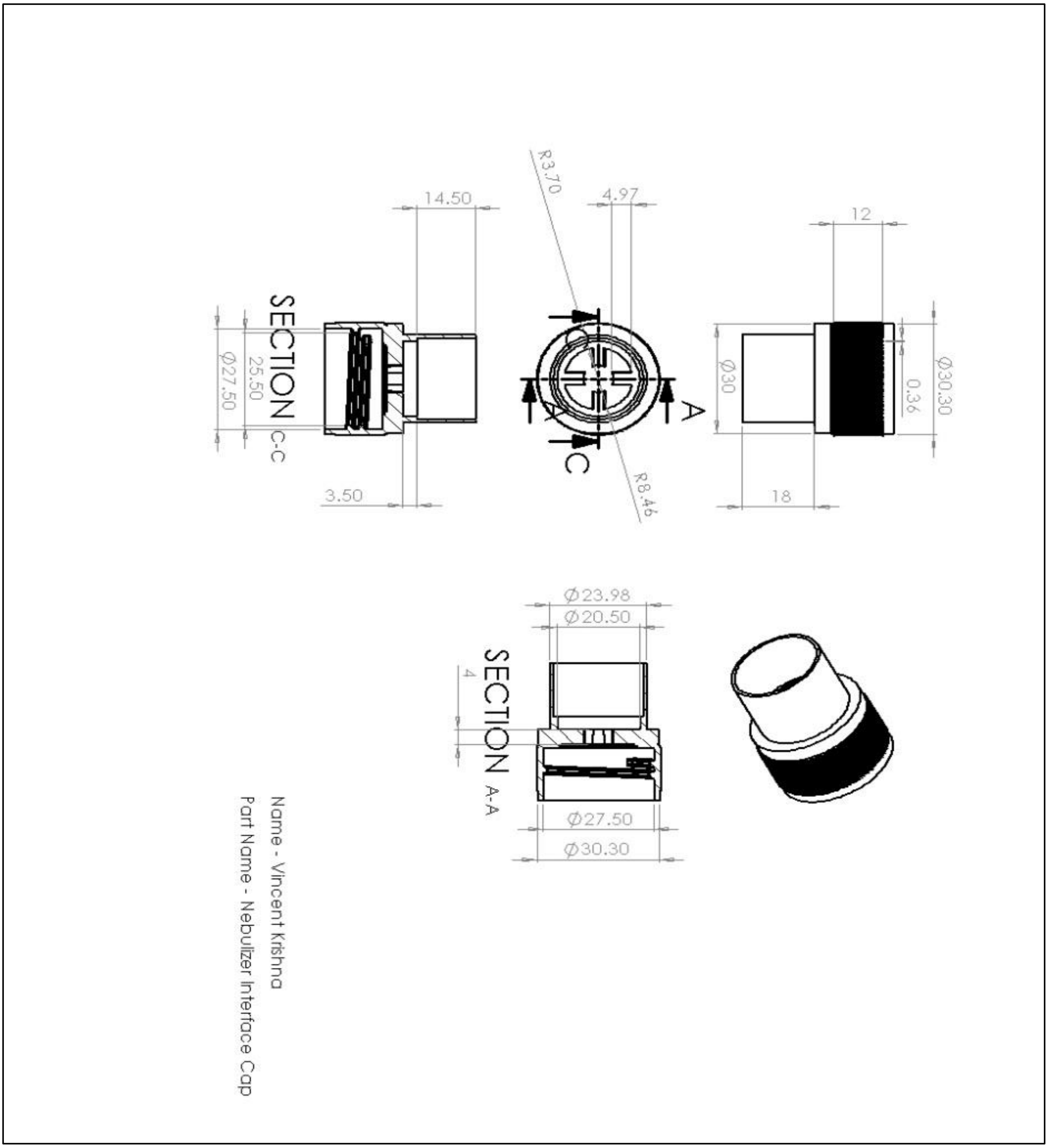
The atomising unit needed a certain output rate to deliver adequate amount of humidity to the patient. A quick experiment to calculate the mass flow was conducted. The mass of the water reservoir was weighed at the start and the nebuliser left to run for a measured amount of time. The mass was then reweighed, and the mass flow calculated. Results are shown in table 1 and an average of 13.23g/hour was calculated.

Table 1 Results of nebulising rate experiment

Trial	Mass at start (g)	Mass at end (g)	Time (hours)	Mass flow (g/hour)
1	343	249	8	11.75
2	355	240	9	12.78
3	240	149	6	15.17

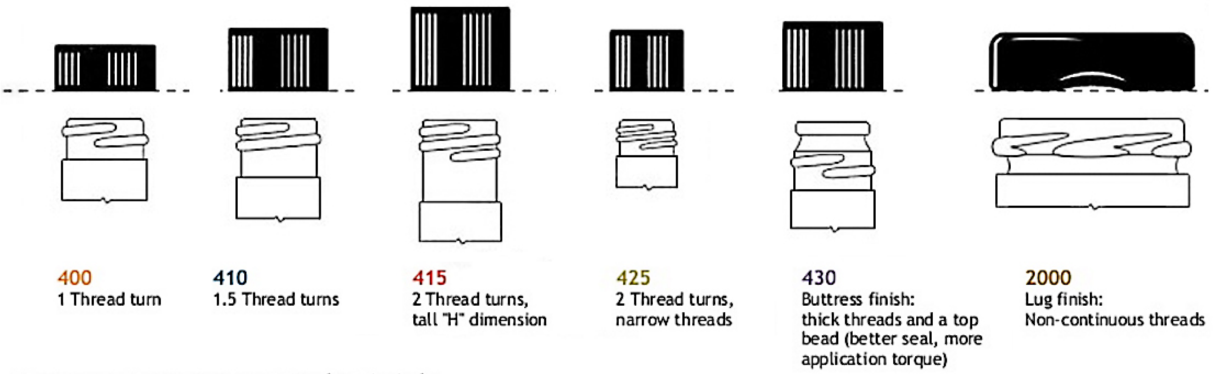
The mass output of the nebuliser was observed to be an average of 13.23 g / hour.

Appendix A: Drawings for the cap solid part



Appendix B: Bottle cap design guides

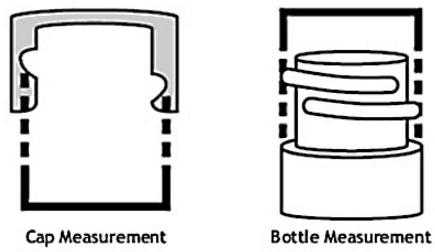
Common GPI / SPI Neck Finishes



How to Measure a Neck Finish

To find a cap's diameter, measure from one side of the inner wall to the opposite side. Calculate a bottle's neck finish by measuring the diameter of the outermost threads. The resulting millimeter measurement will be the "T" dimension.

Then, see how many times the threads pass one another to determine the finish. (ex. 24 mm "T" dimension with 1.5 thread turns = 24/410 neck finish)



Nominal Dia. (mm)	400		410		415		425		430	
	"T"	"H"	"T"	"H"	"T"	"H"	"T"	"H"	"T"	"H"
8	-	-	-	-	-	-	0.360 (3/8)	0.245 (1/4)	-	-
10	-	-	-	-	-	-	0.415 (13/32)	0.255 (1/4)	-	-
13	-	-	-	-	0.520 (17/32)	0.430 (7/16)	0.520 (17/32)	0.280 (9/32)	-	-
15	-	-	-	-	0.585 (19/32)	0.535 (17/32)	0.585 (19/32)	0.280 (9/32)	-	-
18	0.710 (23/32)	0.360 (3/8)	0.710 (23/32)	0.500 (1/2)	0.710 (23/32)	0.595 (19/32)	-	-	0.710 (23/32)	0.605 (19/32)
20	0.790 (25/32)	0.360 (3/8)	0.790 (25/32)	0.530 (17/32)	0.790 (25/32)	0.720 (23/32)	-	-	0.790 (25/32)	0.605 (19/32)
22	0.870 (7/8)	0.360 (3/8)	0.870 (7/8)	0.560 (9/16)	0.870 (7/8)	0.815 (13/16)	-	-	0.870 (7/8)	0.605 (19/32)
24	0.945 (15/16)	0.390 (3/8)	0.945 (15/16)	0.620 (5/8)	0.945 (15/16)	0.935 (15/16)	-	-	0.945 (15/16)	0.650 (21/32)
28	1.095 (1 3/32)	0.390 (3/8)	1.095 (1 3/32)	0.685 (11/16)	1.095 (1 3/32)	1.060 (1 1/16)	-	-	1.095 (1 3/32)	0.725 (23/32)
30	1.130 (1 1/8)	0.390 (3/8)	-	-	-	-	-	-	1.130 (1 1/8)	0.760 (3/4)
33	1.270 (1 9/32)	0.390 (3/8)	-	-	-	-	-	-	1.270 (1 9/32)	0.775 (25/32)
38	1.480 (1 1/2)	0.390 (3/8)	-	-	-	-	-	-	1.480 (1 1/2)	0.940 (15/16)
43	1.660 (1 21/32)	0.390 (3/8)	-	-	-	-	-	-	-	-
45	1.750 (1 3/4)	0.390 (3/8)	-		-		-		-	
48	1.875 (1 7/8)	0.390 (3/8)	-	-	-	-	-	-	-	-
53	2.075 (2 1/16)	0.390 (3/8)	-		-		-		-	
58	2.230 (2 7/32)	0.390 (3/8)	-	-	-	-	-	-	-	-
63	2.470 (2 15/32)	0.390 (3/8)	-		-		-		-	
70	2.745 (2 3/4)	0.390 (3/8)	-	-	-	-	-	-	-	-
83	3.275 (3 9/32)	0.470 (15/32)	-		-		-		-	
89	3.520 (3 17/32)	0.515 (1/2)	-	-	-	-	-	-	-	-
100	3.945 (3 15/16)	0.580 (19/32)	-	-	-	-	-	-	-	-

Appendix C: Material Properties

Build Envelope (xyz) 203 x 178 x 152mm
Resolution (xyz) 750x750x890 DPI; 29µ layers

- ProJet part **accuracy** is around **±0.05mm.**

Specifications for ProJet HD3000 materials used in-house						
Name	**Tensile Strength**	**Modulus**	**Elongation at break**	**Deflection Temp (DTUL)**	**Colour**	**Special features**
VisiJet EX200/M3 Visijet Crystal	42.4MPa	Tensile; 1293MPa	6.8%	*56°C	Translucent	#Biocompatible; Has 5 approvals to ISO 10993-1