

1. Introduction

Last year we were invited to a number of schools to let the kids have a go at making and launching water rockets. For the uninitiated this is where you take a 1.5 - 2L plastic soft drink bottle (commonly referred to as [PET](#) bottles) and launch it 50+ metres into the air using nothing more than water and compressed air. Essentially it's the best fun you'll ever have with your recycling, and kids absolutely love it.

The rig shown on the drawings attached was originally based on one described in an article from [The Shed magazine](#). Ours has a modified release system, and a supporting frame. This was because it was soon found that excited kids are a lot stronger than the look!

Water rockets can be as simple or as complex as you want to make them. A simple one for young children may just be a bottle covered in stickers. To go higher you need to start looking at the aerodynamics involved by adding stabilising fins, shifting the centre of gravity, and lengthening the body.

2. Materials

Apart from the high pressure plastic piping, the materials and dimensions given in the attached drawing are all nominal. You should utilise and adapt to what you can find in your own garage or shed, adjusting the given design to suit. In fact a quick [search on the internet](#) will present you with a multitude of alternative options.

In addition to the water rocket launcher you will need the following:

- **Soft drink bottle** (obviously). Initially you can start just with a plain bottle, then progress to more aerodynamic designs (a simple example of one is included with the drawings).
- **Hand pump**. It is recommend you use a [floor pump](#) type to minimise your pumping time. Whatever pump you use it must include a pressure gauge, so you know when you have got your rocket up to pressure.
- **Water**. Simple tap water is all you should need, however you may like to experiment with more exotic fuel mixes such as food colouring, salt water, and dish washing liquid to name a few.



2.1. Pipework

The piping used for the launcher is half inch (15NB) PVC pressure pipe. This pipe size has an OD of around 21.4mm, which makes for a good sliding fit on the opening of a plastic soft drink bottle.

A union coupling provides a shoulder where an o-ring can be fitted, providing a seal to the bottle opening. As this is not an ideal seal face for an o-ring you will likely find you need to build up the contact area by wrapping some teflon tape (PTFE, also known as plumbing thread tape) over the o-ring.

PVC pressure pipe is commonly referred to as high pressure pipe and is readily available from most hardware or plumbing merchants. High pressure pipes and fittings should be labelled as conforming to AS/NZS 1477, and have a minimum pressure rating of 15Bar (look for PN15 on the labelling). If you are in doubt ask.

Also note that pressure piping has specific gluing requirements, with solvent cements particular to that material type. Again look for reference to AS/NZS 1477, and ask if you are in doubt.

2.2. Frame

The frame performs a number of functions:

- It provides protection and support to the plastic pipework and connections.
- Provides a mounting point for the trigger mechanism, along with guides and limits on the pull rope.
- Has peg holes allowing the launcher to be pegged the ground.

In our frame we have used offcuts of timber decking and plywood. The stand is held in place with a coach bolt and wing nut, allowing it to be broken down to fit more easily into the boot of car, or for storage.

2.3. Trigger Mechanism

The trigger mechanism sits either side of the bottle. One half has two angle fingers that slide over the neck of the bottle, and then the other half clamps down on top of it. This provides a balanced arrangement to the force coming from the centrally mounted bottle. Only a little force is necessary to release.

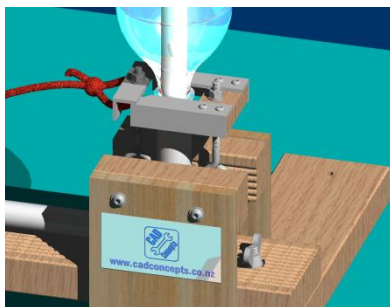


Figure 1. Trigger Mechanism Closed



Figure 2. Trigger Mechanism Open

Both sides have double nuts allowing the trigger to be adjusted to the right clamping pressure. Once adjusted you should find this arrangement will work without further adjustment for hundreds of rocket launches.

The pull rope ties to one end of the trigger and then runs through a guide hole in the frame. Knots tied either side of the guide hole will keep the rope captive and prevent over pulling of the trigger.



There are lots of other examples of trigger mechanisms on the internet. If you look at alternatives try to find one that won't interfere with any fins that extend down from the rocket.

3. Launching

So on to the fun bit. Half fill hour bottle with water, slide over the end of the open pipe of your launcher onto the o-ring seal, and then clamp it in place with the trigger mechanism. Making sure everyone is standing well clear, pump air into the bottle until the pressure reaches 60 – 80 PSI (400 – 550 kPa). Then after a suitable countdown sequence pull the rope attached to the trigger.

4. Safety

A water rocket launcher will and can inflict damage if misused. The following safety steps are recommended:

- Don't let young children use without adult supervision.
- Always use in an open space, such as a park or beach. And position yourself well away from other people.
- Maintain a clear area of at least 5 m around the launcher. Use soccer cones to mark out the space.
- Extend the hose on your pump (you can use vacuum hose to do this), and use a long enough pull rope to allow you to position yourself away from the launcher.
- If you use a compressor instead of a hand pump it must be fitted with a regulator or relief valve.

I prefer to use a hand pump rather than compressor as most kids don't have the strength or the body weight to get the pressure much above 60 PSI (400 kPa).

Soft drink bottles can reliably sustain pressures of over 120 PSI (830 kPa), and won't tend to fail until the pressure exceeds 140 PSI (965 kPa). Most modern bottles are one piece with a formed base, which is where they tend to fail due to the stress raiser of the formed shape. So bottles that fail tend to burst at the end, as long as you're not standing over the top of it you shouldn't come to harm.

If you have any doubts with a bottle it's probably best to get rid of it. Otherwise you can hydraulically test them (and the launcher at the same time). To do this fill the bottle and rig completely with water, then pressurise it to 140 PSI (965 kPa) in the launch position to test it.

Don't store your rocket launcher outside. PVC is susceptible to UV and will degrade rapidly in New Zealand's harsh summer sun. Keep your launcher somewhere that it will not be exposed to direct sunlight.



5. Design Principals

The design principals of a water rocket can be every bit as technical as a real rocket. Newton's Third Law states that for every action there is an equal and opposite reaction. In the case of our water rocket this means that the water forcibly ejected from the bottle creates an equal and opposite force on it, causing it to move in the opposite direction.

So what can you change to achieve more height? You need to consider the following with your rocket design:

- **Opening (orifice) size.** The rate that the water leaves the bottle is governed by the opening. Adjusting this opening (orifice) size will have an effect on the height you achieve. Some alternative rocket designs use Gardena style hose fittings to provide a smaller opening.
- **Water volume, density and viscosity.** The more water you fill your rocket with the more energy it will take to launch it, as the rocket becomes heavier. Increasing the density (by dissolving salt) of the water will increase its mass without increasing its volume. Changing the viscosity (by using dishwashing liquid or jelly crystals) has a similar effect to changing the opening size, as it also affects the rate that water leaves the bottle.
- **Aerodynamics.** For water rockets to fly stably the centre of gravity (COG) needs to be in front of the centre of pressure (COP). This can be achieved in a number of ways (refer to our advanced rocket example):
 - Add fins to the bottom of your rocket. This will create some drag shifting the COP back towards the fins.
 - Add mass to the front of your rocket. This pulls the COG forward.
 - Increase the length of the rocket. Increasing the body length will increase stability by creating better separation of the COG and COP.

Enough theory, go and experiment!





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Water Rocket Launcher

Appendix A. Drawings

1.5 – 2.0L PLASTIC (PET)
CARBONATED BEVERAGE BOTTLE.
SEE DWG CCL001–WR020
FOR AN ADVANCED
ROCKET EXAMPLE.

TRIGGER ARRANGEMENT
REFER DWG CCL001–WR015
FOR DETAILS.

USE STOPPER KNOTS IN TRIGGER LINE
TO PREVENT OVER EXTENSION
OF TRIGGER MECHANISM.

CONNECT TO HAND PUMP.
PUMP TO 60 – 80 PSI
(4 – 5.5 Bar).

ADJUST NUTS ON EITHER SIDE
TO HOLD BOTTLE AGAINST
O–RING SEAL.

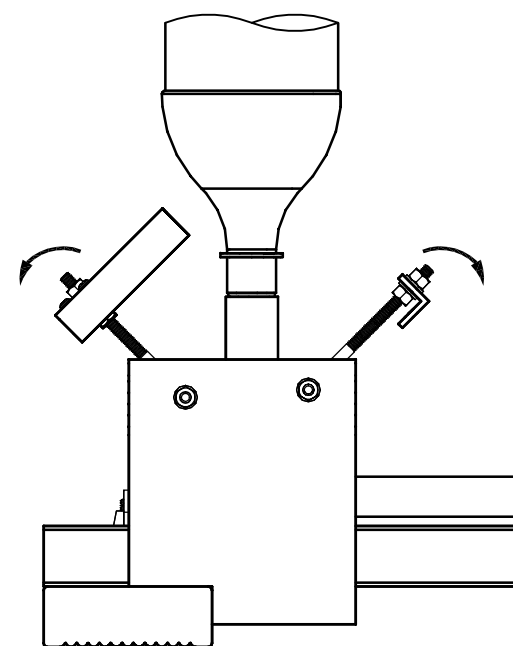
LATCH CLOSED POSITION
BOTTLE CAPTIVE

PULL
HERE!!

PIPEWORK ARRANGEMENT
REFER DWG CCL001–WR005
FOR DETAILS.

WOODEN FRAME
REFER DWG CCL001–WR010
FOR DETAILS.

USE TENT PEGS TO HOLD
LAUNCHER IN PLACE



LATCH OPEN POSITION
BOTTLE RELEASED

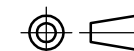
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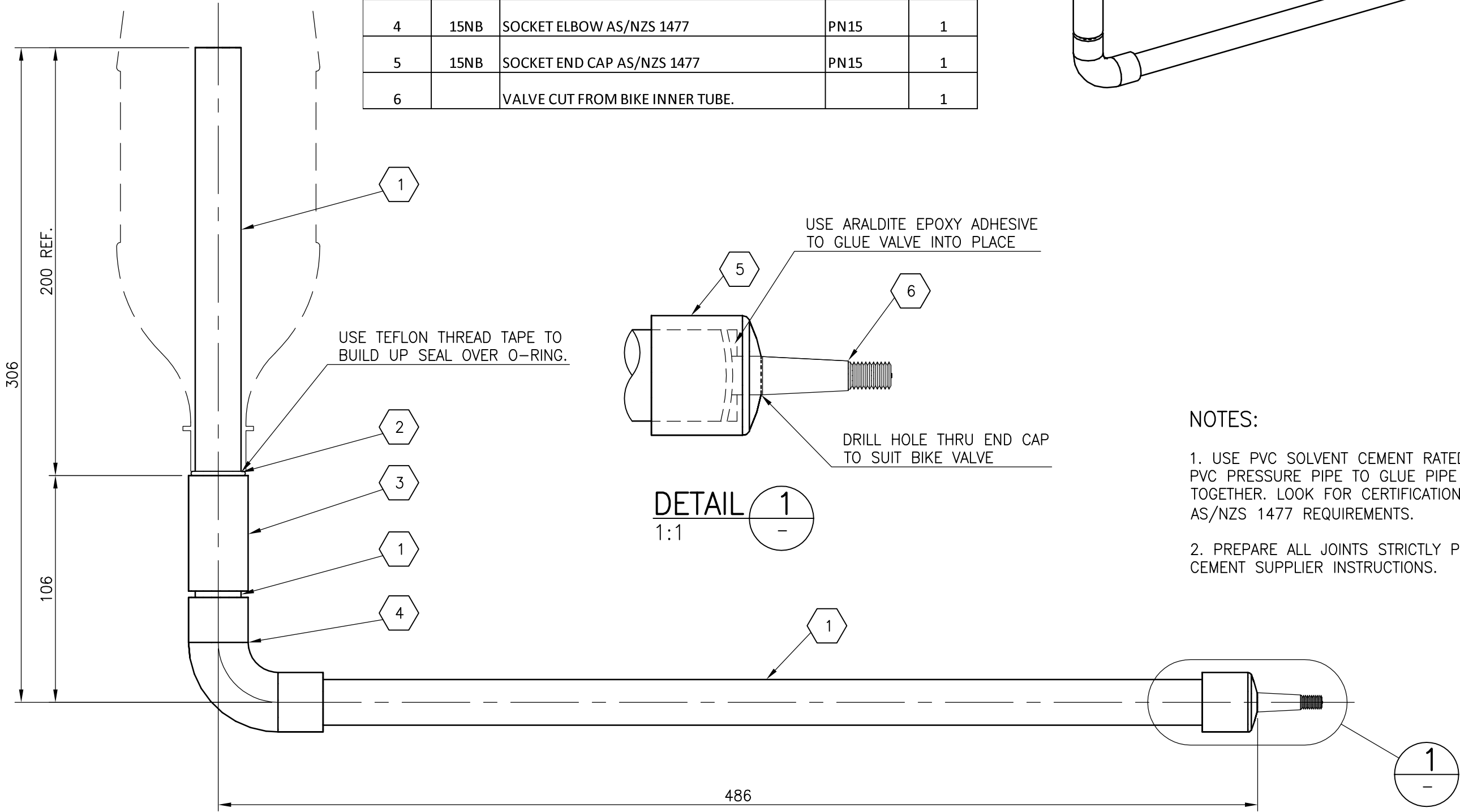
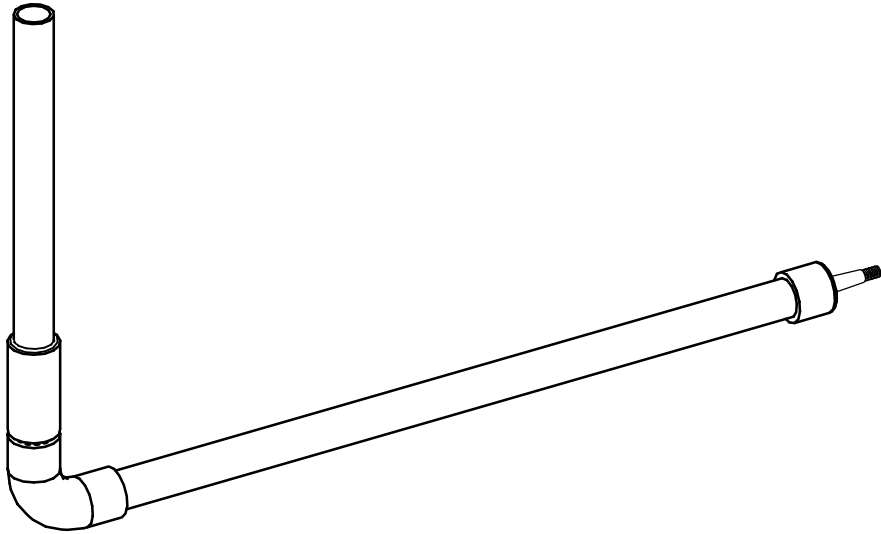
ALL DIMENSIONS IN mm
UNLESS OTHERWISE STATED.
DO NOT SCALE FROM DRAWING.
IF IN ANY DOUBT ASK.



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CAD CONCEPTS LTD		10/03/11	CCL001
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DRAWING NUMBER			SHEET
CCL001–WR001			1 of 1
REV.			SIZE
A			A3

BILL OF MATERIALS

ITEM	SIZE	DESCRIPTION	RATING	QTY
1	15NB	PVC PRESSURE PIPE AS/NZS 1477	PN15	1m
2		O-RING TO SUIT 21.4mm PIPE OD		1
3	15NB	SOCKET UNION AS/NZS 1477	PN15	1
4	15NB	SOCKET ELBOW AS/NZS 1477	PN15	1
5	15NB	SOCKET END CAP AS/NZS 1477	PN15	1
6		VALVE CUT FROM BIKE INNER TUBE.		1



NOTES:

1. USE PVC SOLVENT CEMENT RATED FOR USE ON PVC PRESSURE PIPE TO GLUE PIPE & FITTINGS TOGETHER. LOOK FOR CERTIFICATION THAT IT MEETS AS/NZS 1477 REQUIREMENTS.
2. PREPARE ALL JOINTS STRICTLY PER PVC SOLVENT CEMENT SUPPLIER INSTRUCTIONS.

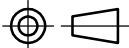
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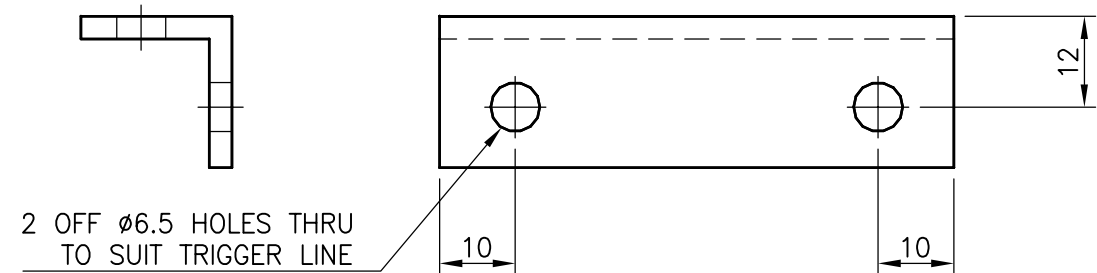
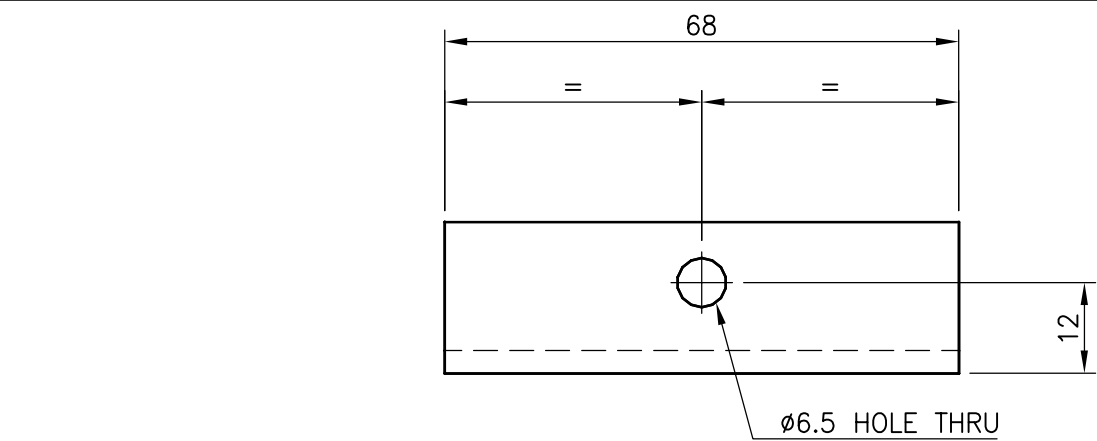
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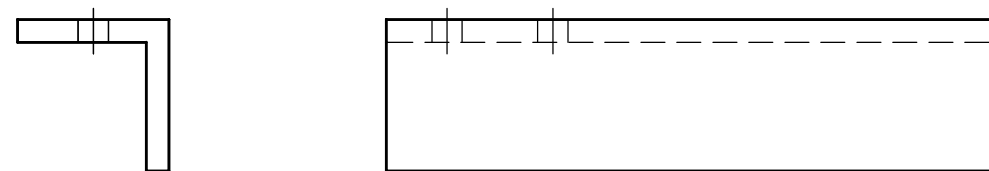
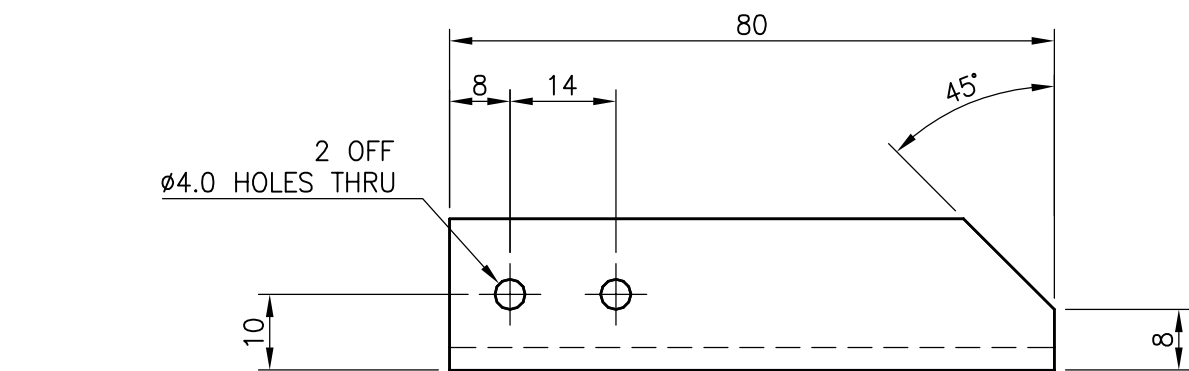


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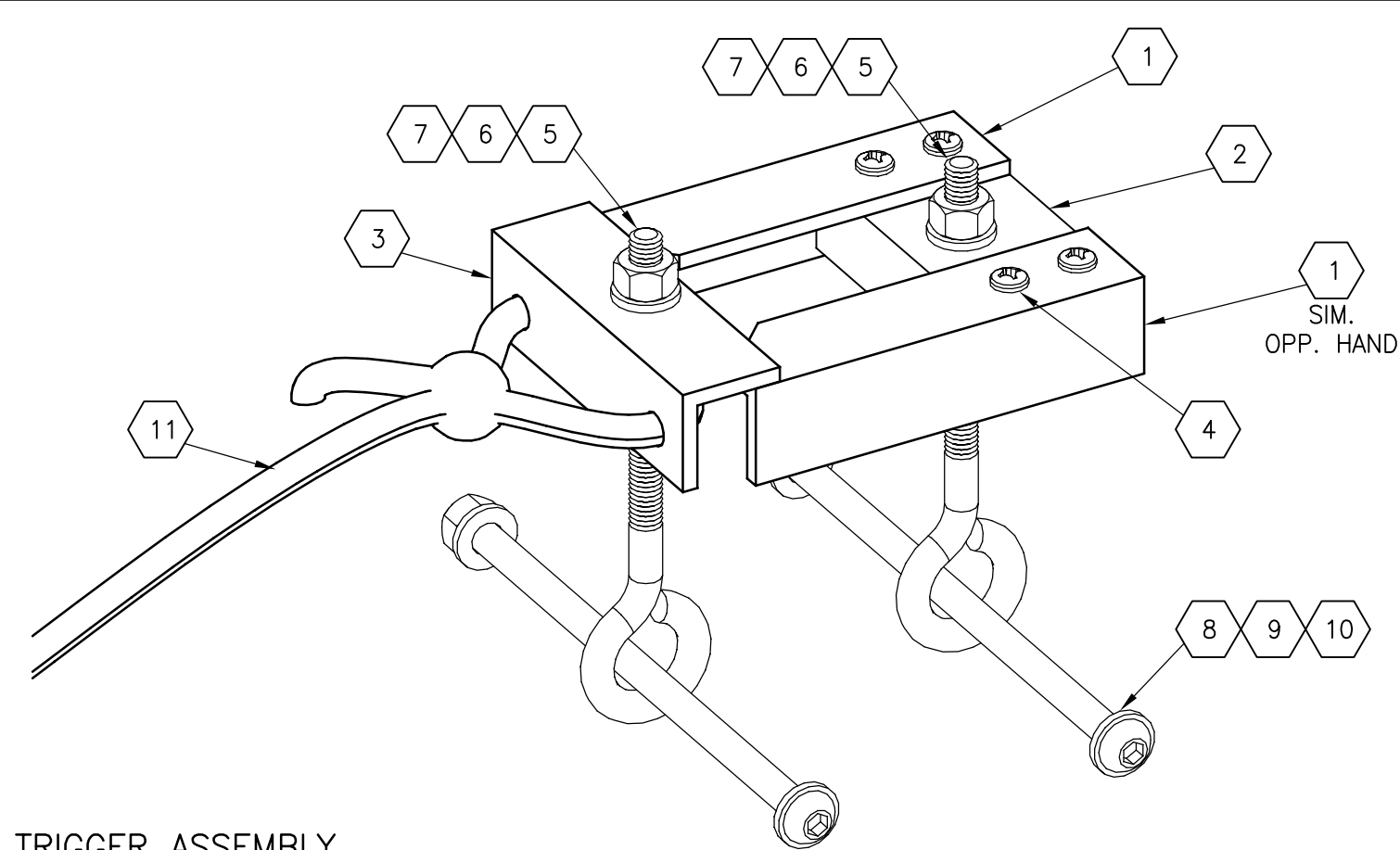
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PIPEWORK DETAILS		SCALE	
		1:2	
DRAWING NUMBER	SHEET	REV.	SIZE
CCL001-WR005	1 of 1	A	A3



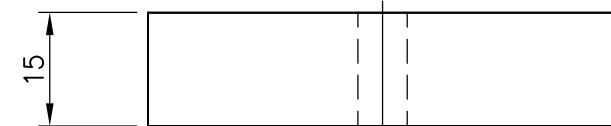
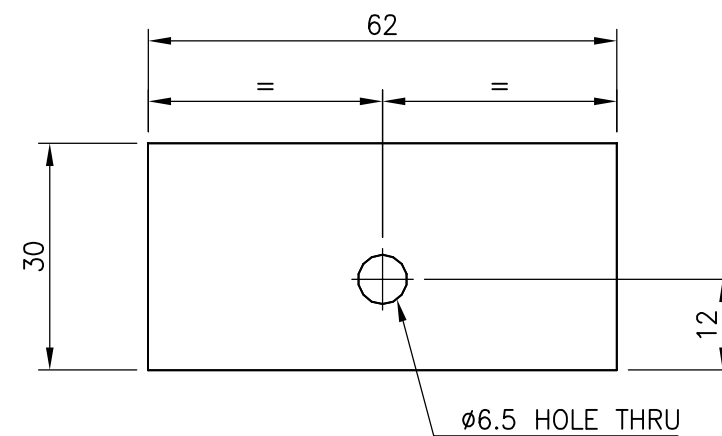
3 TRIGGER LATCH



1 BOTTLE CATCH



TRIGGER ASSEMBLY



2 CATCH MOUNTING BLOCK

BILL OF MATERIALS

ITEM	SIZE	DESCRIPTION	MATERIAL	QTY
1	20x20x3	BOTTLE CATCH	ALUMINIUM ANGLE	180mm
2		CATCH MOUNTING BLOCK	HARD WOOD	1
3	20x20x3	TRIGGER LATCH	ALUMINIUM ANGLE	80mm
4	6G X 1/2"	SELF TAPPING SCREW PAN POZI	ZP STEEL	4
5	M6x100	EYE BOLT	ZP STEEL	2
6	M6	SPRING WASHER	ZP STEEL	4
7	M6	NUT	ZP STEEL	4
8	M6 x 130	COACH BOLT	ZP STEEL	2
9	M6	SPRING WASHER	ZP STEEL	2
10	M6	NUT	ZP STEEL	2
11	6mm	TRIGGER LINE	BRAIDED ROPE	3-5m

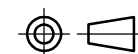
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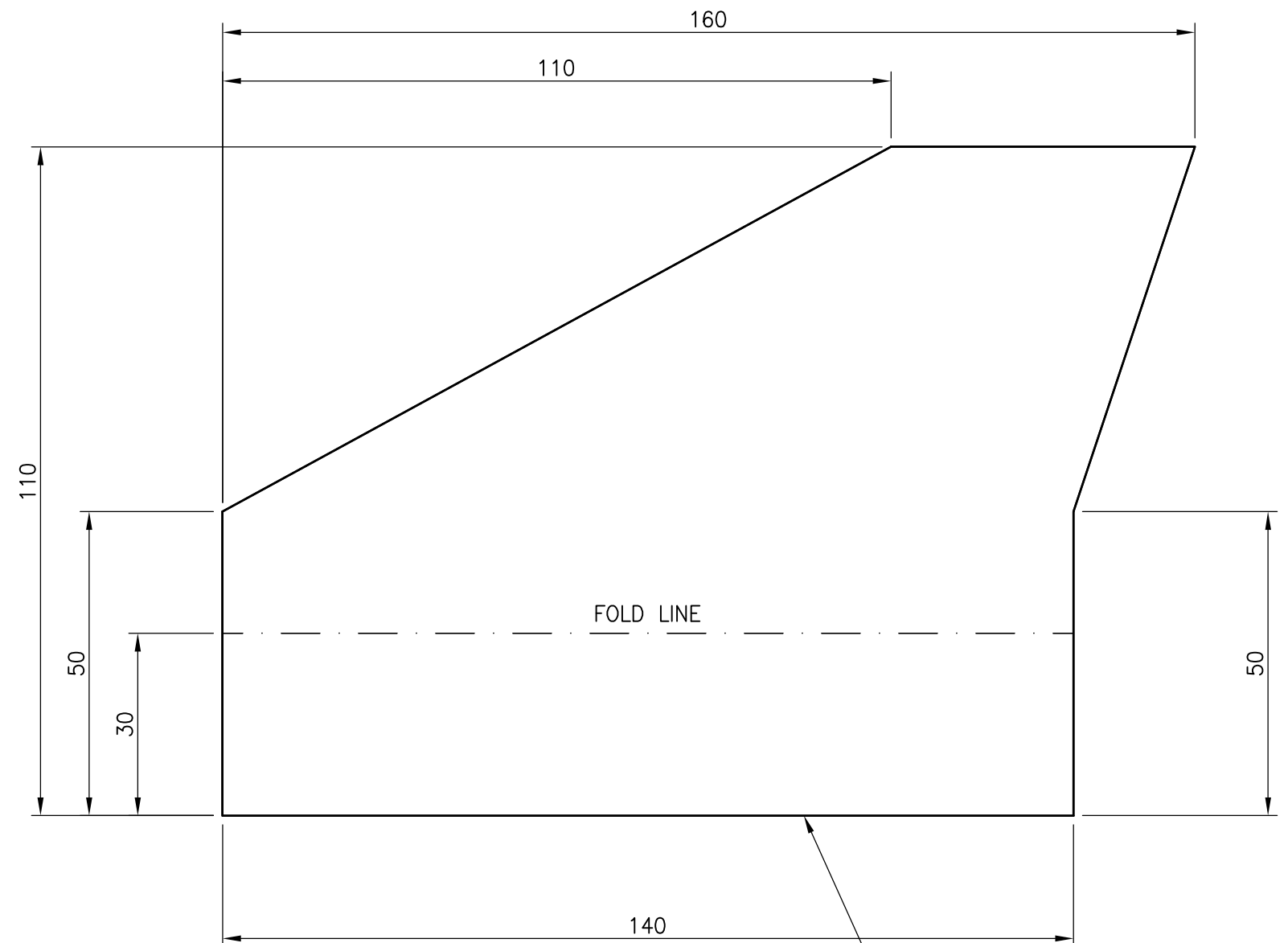
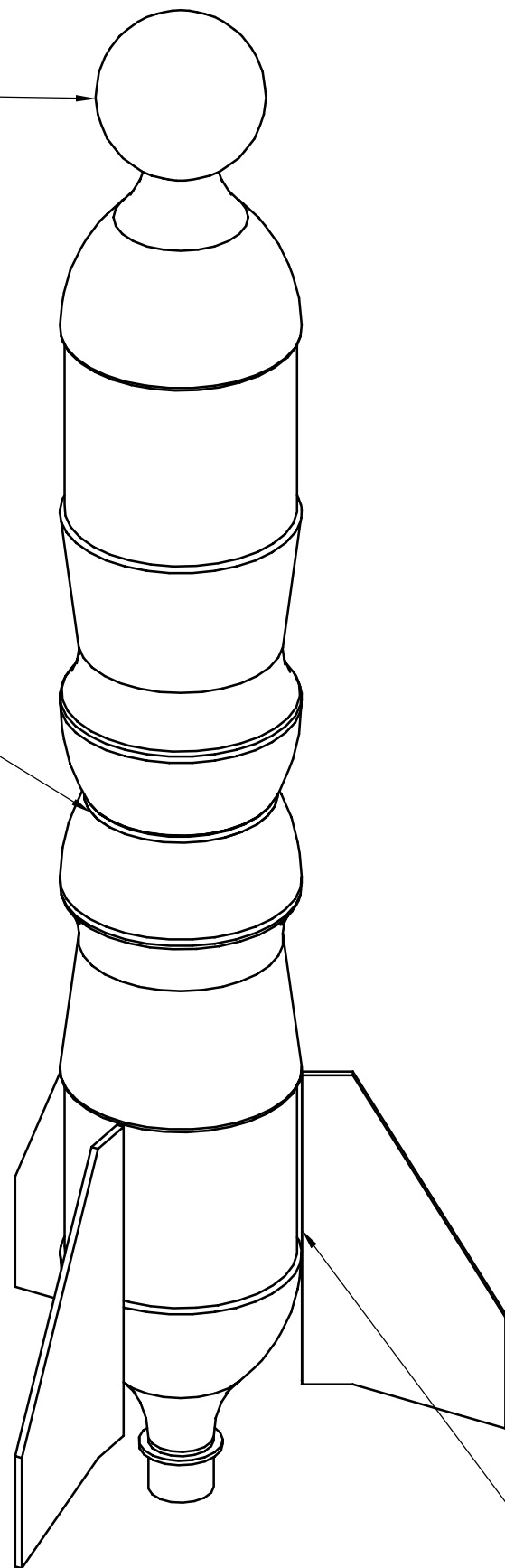


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CAD CONCEPTS LTD. WATER ROCKET LAUNCHER				JOB No CCL01
TRIGGER DETAILS				SCALE 1:1
DRAWING NUMBER CCL001-WR015	SHEET 1 of 1	REV. A	SIZE A3	

FIT OLD TENNIS BALL TO TOP
PROVIDES SOME PROTECTION
AND PULLS THE CENTRE OF
GRAVITY FORWARD.

CONNECT TO BOTTLES TOGETHER
USING WIDE TAPE.



ROCKET FIN
3 OFF REQUIRED
USE THICK CARD OR FLUTE BOARD

IF FLUTE BOARD IS USED,
SPLIT IN THE MIDDLE TO
THE FOLD LINE. THIS ALLOWS
THE FIN TO BE GLUED ON
BOTH SIDES TO THE BOTTLE.

FIT ROCKET FIN'S TO BOTTLE USING
HOT GLUE GUN. PLACE AS FAR DOWN
AS POSSIBLE WITHOUT INTERFERING
WITH TRIGGER MECHANISM.

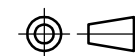
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WATER ROCKET LAUNCHER
SIMPLE ADVANCED ROCKET

DRAWING NUMBER
CCL001-WR020

SHEET
1 of 1

REV.
A

SIZE
A3

JOB No
CCL01
SCALE
1:1