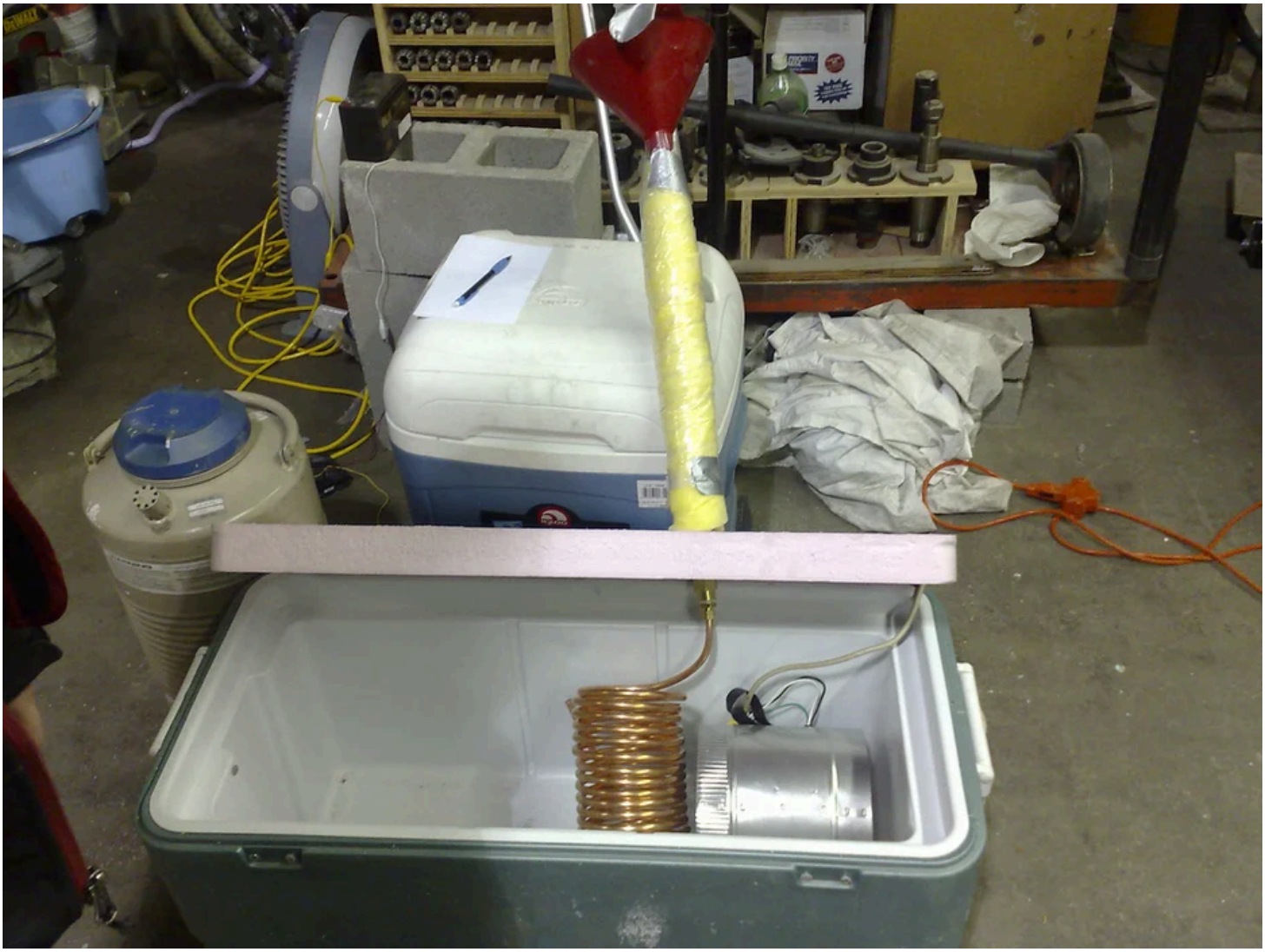
AUTODESK Instructables

Thermal Test Chamber for Edge of Space Testing.

By 3ricj in WorkshopScience

(cc) BY-NC-SA

Introduction: Thermal Test Chamber for Edge of Space Testing.



Getting stuff *really* cold is difficult, dangerous, and lots of fun. Our group is preparing to send an autonomous glider up to about 100,000 feet, so we needed a way to chill our electronics to -70c to test their use before these edge-of-space flights.

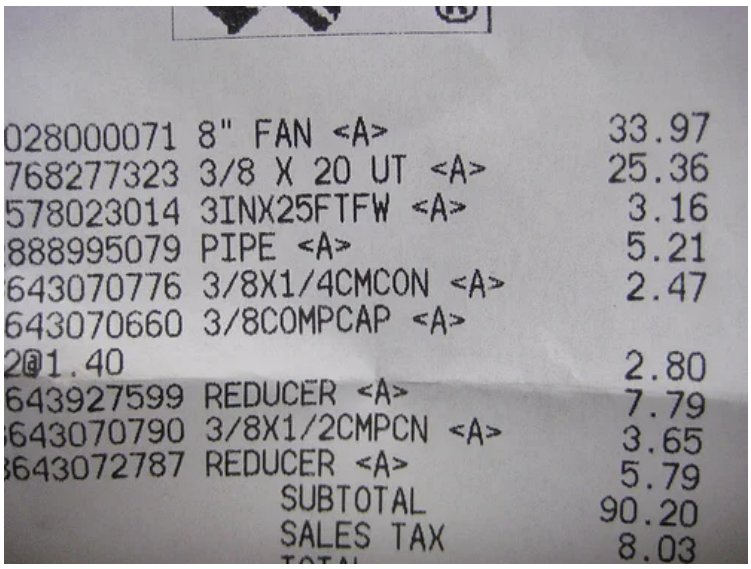
Basic concept:

Just using dry ice in a cooler will result in about 0c air. In order to chill air much colder, a fan is used to circulate the air to reach -42c. In order to hit -70c or colder, liquid nitrogen and a heat exchange (coil) is used.

This test chamber uses dry ice and liquid nitrogen to cool the air.

This instructable is part of our edge-of-space project. Watch for updates over on Hackerbot Labs

Step 1: Acquire Parts for Building



You'll need a bunch of parts to build a test chamber, along with some supplies. Here's what we used:

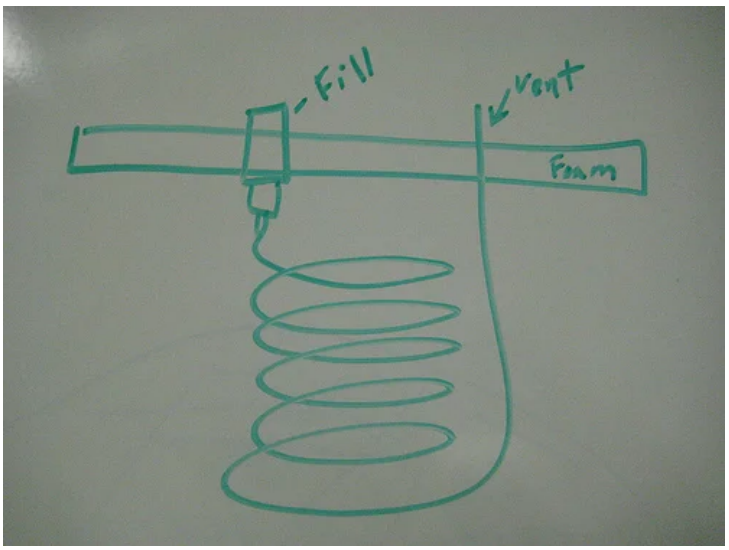
- 25' of 3/8" copper pipe (hardware store)
- Fittings to adapt up to 1/2" ID pipe (hardware store)
- 2' of 1/2" pipe to use as a reservoir
- Fiberglass wrap insulation for reservoir
- Teflon tape for the threads (hardware store)
- 4" diameter PVC pipe (just for forming the coil, about 2' will do)
- A large ice cooler which you can remove the lid from.
- 2" thick pink insulation foam. a full sheet is handy, but it needs to be the size of your cooler
- A powerful fan which can fit in the ice cooler for air circulation
- One or more thermal probes for monitoring the temp (K type thermocouples work best here)
- A large cooler/ice chest with a lid which can be completely removed.
- "ice" packs. The sealed kind you reuse. A bunch of them
- A funnel
- Some stiff plastic tubing

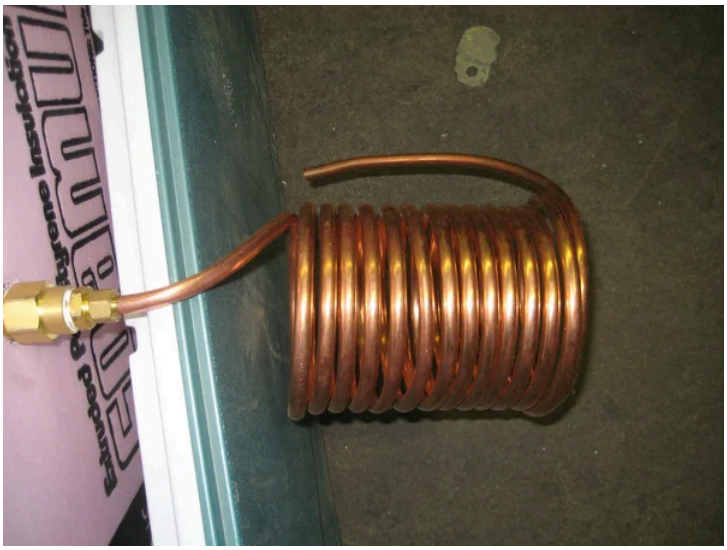
For operation of your test chamber, you will need the following consumables:

WARNING: This stuff is cold - so cold that it will burn you. Seriously. It can blind you. It can freeze off a finger or a limb, and I'm not even going to get into what would happen to your insides if you drink it. Use proper care while handling. Eye protection is very important while interacting with liquid nitrogen. Ventilation is extremely important as well. USE AT YOUR OWN RISK.

- Several blocks of dry ice. 10 lbs will do, 20 is better. This can be sourced at most grocery stores. Some states require you to be 18 or older to purchase and consume Dry Ice.
- a large dewar of liquid nitrogen. This can be sourced at most welding supply shops. Dewars can be rented or borrowed.

Step 2: Turn Your Coil..





Start by dry-fitting all of the fittings, ensuring all the threads line up and have the correct gender and size so you can get up to the diameter of the small end of the funnel.

Next, it's time to make the coil. Copper pipe is stiff and can kink very easily. Kinks are not desired. Using a large cylindrical object of some kind (I used 4" diameter PVC pipe), 'turn' the copper pipe around the object to get a nearly perfect coil without any kinks. This requires much hand/arm/upper body strength, and may require a helper or two, depending on the wall thickness of your copper coil. It's important to leave extra at each end of the coil for connecting adapters and allowing for venting from the other end of the coil. You should end up with something that looks like the below photo.

Next, install all of the fittings on the end of the copper pipe to adapt it up to a larger size. Caution, the press fittings on the copper pipe are a pain to install, and it can be tricky to get a good fit. Don't over tighten the press fittings, or the threads will fail. It will still be somewhat 'loose' on the fitting, but should be water and air tight. Compression fittings are not designed to be load bearing, so don't stress the system too much or it will break or kink.

We created a reservoir by using a 2 foot length of 1/2" pipe; this extends the after the fittings. don't install this section of pipe until you've completed your lid..

Step 3: Prep the Cooler

We found this rather large budwiser compliant cooler at a local grocery store. It claims to keep 10 cases of beer cold for 10 days. It was selected due to the ease at which the lid was removed, and the size of the internal volume. Due to the size of the coil and circulation fan, much space is needed. Make sure your cooler is dry and clean. Having water or moisture in the cooler is bad.

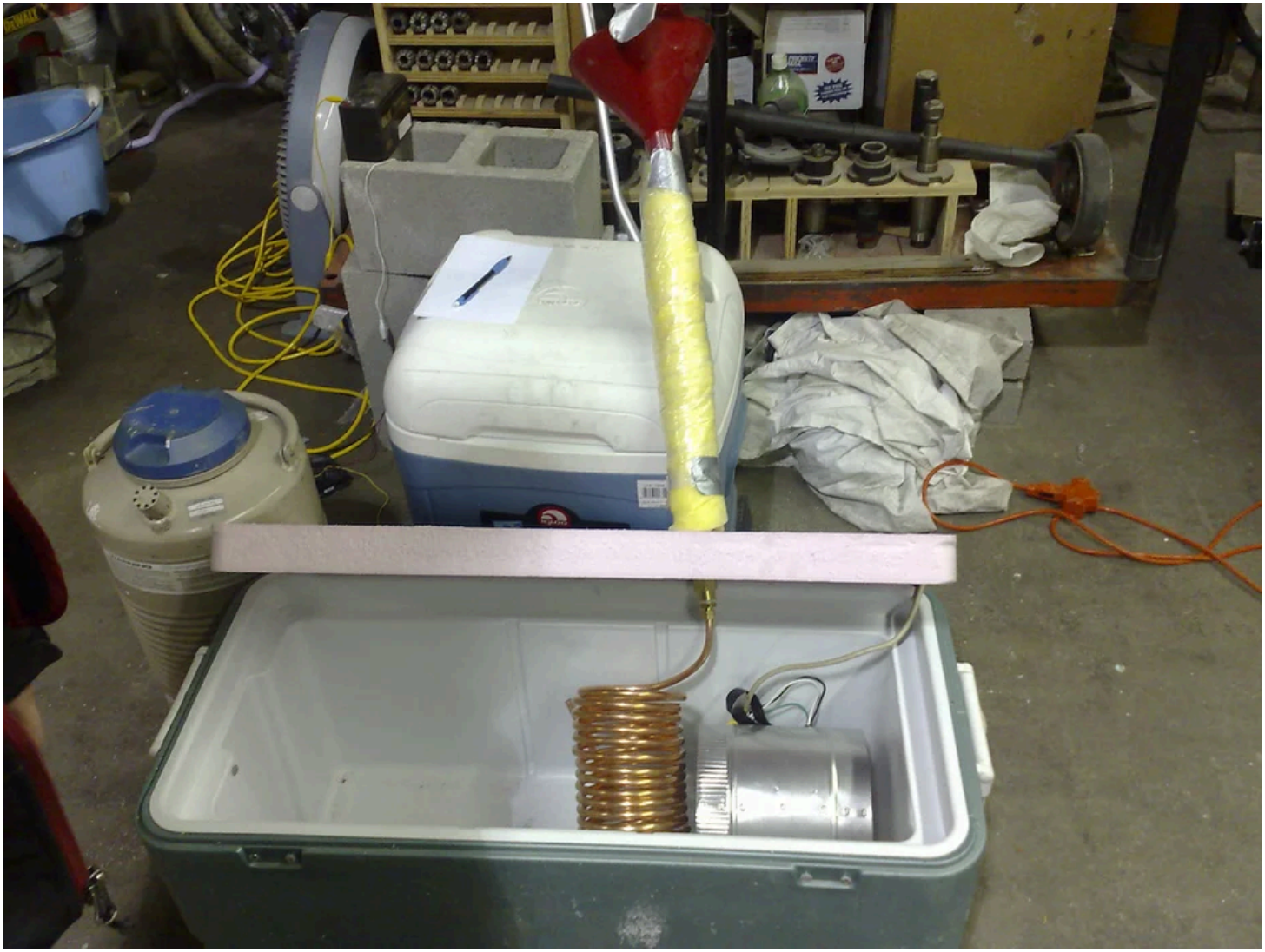
Start by removing the lid on your ice chest/cooler by whatever means required. In our case, it was 5 screws. We will be building a replacement lid for the cooler, which we can then drill holes into. You could, in theory, use the stock lid and drill holes in it. This reduces it's effectiveness for cooling beer later, unless you like your beer at -70c.

Next, cut and form your pink insulative foam to fit the recess left by the removed lid. Cutting and shaping foam is messy prospect; the chips get stuck everywhere, have a shopvac handy. Cutting foam can be done with a skillsaw, handsaw, or even a table saw. If you happen to have a hotknife made out of nichrome wire, it cuts foam rather effectively. For final shaping, simple 100 grit sandpaper works best. The goal is to create a new lid which needs to be 'press fit' into the cooler. It should compress slightly when it's properly installed on the top of the cooler. This will create a very effective seal.

Finally, install your circulation fan. We used a duct fan from a hardware store. It fit nicely inside of our cooler. Somehow, the specifications on the fan do not list the lowest temp it will operate at. There is some risk that the oil used on the fan will freeze; keeping the fan running should allow the heat from friction to keep the bearings at a happen temp. In practice, this has shown to be true.

When you are done, you should have something which looks like the below photos..

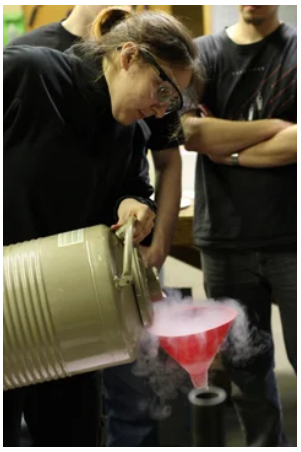
Step 4: Final Assembly



- Drill a 1/2" hole in the foam lid.
- install coil and reservoir pipe on the lid
- Insulate reservoir pipe

When you are done, you should have something which looks like the below photo.

Step 5: Using the Test Chamber



Make sure you are well stocked on liquid nitrogen and dry ice. SAFETY is very important here. You can really hurt yourself with these items; they WILL freeze you if you come in contact with them. Use strong insulative gloves, safety glasses, closed sealed boots, pants & long sleeved shirts. Also, getting moisture inside of the coil could cause it to clog and burst with very hazardous results. Don't do that. Ensure your coil is dry and empty of all moisture and fluids (best method is to make sure water doesn't get in there in the first place..) In addition, ventilation is very important. nitrogen can displace o2 in the air, which means you've got yourself a vapor version of iocaine powder. Odorless, tasteless, deadly. Make sure you've got lots of room and a source of fresh air.

Liquid nitrogen can splash, which sends -321F liquid all over the place. This is bad, don't let it happen. It will boil at room temperature. Seek the guidance of a professional on the safe handling of dry ice and liquid nitrogen.

Start off by staging your work area. Have cleanup devices handy, and plenty of room to work. Get out your supplies and objects you wish to freeze.

Load the cooler with the dry ice and reusable ice packs. Don't use normal ice; this will create moisture in your test chamber, which is a pain. It will freeze and condense on your coil, which reduces the effectiveness.

The reusable ice packs increase the thermal capacitance of the system. Pre-freezing them in your freezer is a good idea.

Place your thermal probes inside of the cooler, at positions you wish to measure the temperature. On your first run, you will likely discover that your thermal probe won't measure as low as required. Some testing will be needed.

The dry ice should be placed between the coil and fan, staged such that the fan blows air over them. Once the lid is sealed and the fan is turned on, you should start to see a rapid drop in temperature. This will not cool past -30c to -42c due to heat loss. Once the chamber has hit a stable temperature, it's time for the liquid nitrogen.

This is the hazardous part. Use due care.

The liquid nitrogen when it enters the reservoir will phase change almost instantly. This creates nitrogen vapor, which is of a much larger volume. So it will tend to spray and burp until it cools the reservoir down to a point where it is not boiling so rapidly. If you just 'dump' much liquid nitrogen into this reservoir, it will likely splash back into your face blinding you. Don't do that.

One trick to help with the out gassing is to vent the funnel. This can be done with a simple tube run down inside of the funnel. This allows the gaseous nitrogen to escape without it blasting up liquid nitrogen into your face. In addition, ensure that the other end of the coil is not blocked or clogged, or it could burst/explode.

Slowly pour the liquid nitrogen into the funnel. At first, the temp of the system will not change, as the liquid nitrogen needs a chance to pre-chill the external reservoir and coil. Closely monitor the temp to ensure that you don't get below your target temp. Do not overfill the reservoir.

As shown on the multimeters below, you can reach very cold temperatures very easily.

That is it! you've now built yourself a el-cheapo thermal test chamber!