Insulated Solar Electric Cookers
Preliminary Report and Construction Manual

Living Energy Farm, February 10, 2021
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In the United States, our kitchens consume more energy than our farms. All over the world, low-income people suffer from chronic health problems caused by smoky wood cooking fires. At Living Energy Farm (LEF), we have pioneered a DC Microgrid that allows us to use solar energy in a manner that is cheaper and more efficient than the norm. Now, partnering with a solar cooking project based at Cal Poly in California, we are finding technologies that dramatically reduce the amount of energy needed for cooking in ordinary American homes. And this same technology can be scaled to provide very cheap, effective solar cookers suitable for use in communities that have little money.

What Is In This Document

The first few pages of this document give an overview of ISECs, why they are important, what to expect in using them, and various options for building larger and smaller ISECs. **The reader should note that this document is not "the" manual for building ISECs.** There are other manuals (noted below) that outline the work being done by folks based at Cal Poly. The bulk of this document is made up of step-by-step instructions on how to build the ISECs and their component parts such as we have been building and using them at LEF. For the sake of clarity, we present each component part as a separate set of instructions.

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Introduction: Why Are ISECs Important, and What Are Your Choices?

Why Are These Solar Cookers Revolutionary?

"Normal" cooking involves using a lot of energy quickly, and very inefficiently. When you are cooking on a stove or in an oven, most of the heat is lost, not transferred to the food. The new cooking technology we are working with is called *Insulated* Solar Electric Cookers, or ISECs. These cookers are very efficient.

At LEF, we use solar power, and that makes us 100% energy self sufficient at the residential level. But unlike other off-grid projects, 90% of our electricity never goes through a battery. Rather, our solar electric panels send electricity straight to its useful destination. The Cal Poly team had the same idea, and ISECs use energy straight from solar panels. That makes the this way of using solar energy "radically inexpensive," to use the term coined by the Cal Poly research crew. At a practical level, *we have found ISECs to be more effective than any other solar cooking technology on the market.* There are many solar cookers available, but ISECs are the most convenient to use, and provide by far the most effective means of solar cooking in sub-optimal weather. And they are cheap to build!

What to Expect

This technology is new and changing quickly. We are releasing this document now in order to support and encourage other entities to engage with the ongoing research and development of ISECs. This document will tell you how to build ISECs. A materials source list is at the end of this document.

The smaller ISECs function like a crock pot. All ISECs cook slowly, though the larger ones can cook somewhat more quickly. A 100 watt ISEC will cook 2 - 3 kg of food in winter or in partly cloudy weather, and more in sunnier weather. Larger ISECs will naturally cook greater quantities of food. Slow cooking means less burned food, less carcinogenic substances in the food (which are created by very high temperatures), and more flavorful food. Slow cooking does involve changing the rhythm of cooking. Preparation is done ahead of time. ISECs could never replace all other cooking fuels in every climate, but they could do most of the cooking we need.

Safety

The reader should note that any device that can cook can also start a fire. At LEF, we build our cookers entirely out of non-flammable material, so the cooker itself cannot burn. But the reader should be aware that ISECs, like any cooking technology, carries some risk of fire and burns to the user. A more extensive discussion of fire risks is at the end of this document. We are pleased to share as much information as we have at our disposal, but if you build your own ISEC, you proceed at your own risk.

Community Scale Cooking

At LEF, we have built several biogas digesters, numerous solar cooking devices, as well as rocket stoves that use wood. Overall, a combination of biogas and ISECs seem to be the best approach to a cost effective, year-round, fully renewable approach to community scale cooking.The mix of biogas and ISECs is optimal because it allows cooking in any weather, is scalable to most any size, and can be adapted to most any climate. Biogas in a temperate climate is challenging because a biogas digester needs to stay very warm and cannot be indoors. And tending a biogas digester is like taking care of an animal -- you need to feed it every day, and pay some attention to it. That is easiest to do on a community scale.

ISECs Designs -- Your Options

There are many different ways to build ISECs. Construction details for each design will follow. Each ISEC design that has been built so far has been named. Those are:

1) **First ISEC** -- This is a direct cooking ISEC developed by Pete Schwartz at Cal Poly. This ISEC has a track record of how it performs. It is a 100 watt cooker with an aluminum one gallon pot that stays in the cooker. The heat source is a section of electric stovetop burner glued to the pot. Description and construction details can be found at https://docs.google.com/document/d/1Zb9pRqpO86WIrD2BxRaDKivvLIk_kYKkqb45jqxjJqI/edit?ts=5efa5ebb
Video at
https://www.youtube.com/watch?v=MEaCE7GpcNA&feature=youtu.be

2) **Phase Change ISEC** -- The is an experimental design being developed at Cal Poly using a thermal storage phase change material that allows the cook to use the ISEC in the evening. Description and construction details can be found at https://docs.google.com/document/d/1vRAD0hDm8jEF5-CPS8lX4dBaMNHyoVlymd5i4Oxn4_I/edit?ts=5efa5ef6

3) **Ashley** -- This ISEC (developed at LEF) is made with a 5 gallon bucket and wood ashes. It is very cheap to build. It uses a stainless pot that can be removed from the cooker and can be any size up to about 6 quarts. The heat source is a homemade burner. Instructions follow.

4) **Perl** -- This ISEC is made with a 5 gallon bucket and perlite. It was developed at LEF. **For a small cooker, this one is our favorite.** It is cheap and easy to build. It uses a stainless pot that can be removed from the cooker and can be any size up to about 6 quarts. The heat source is a homemade burner. Instructions follow.

5) **Roxy** -- This is way to build ISECs of many different sizes and insulation levels using rockwool sheets. Naturally, larger ISECs or ISECs with thicker insulation levels cost more. For larger, more powerful ISECs, this is the way to go. Roxies can use pots that you already have in your kitchen. The burner is homemade and not attached to the pot.

ISEC Burners -- Your Options

Any ISEC will need a burner. Perl, Ashley, the Roxies use either a brick burner or radiant a burner, either of which is homemade. Functionally, the two are the same. The brick burners need fewer parts. The radiant burners are necessary for building higher powered ISECs. We prefer the radiant burners, but if you don't have the beads you need to build radiant burners, then build brick burners. Refer to aforementioned documents for information about the burners used in First ISEC and PCM ISEC.

This is a brick burner, 18 volt PMAX, 100 watts or more.

This is a radiant burner, 18 volt PMAX, 100 watts or more.

This is a radiant burner, 48 volt, 330 (or more) watts. It has a metal support around it to hold up a large pot (so the pot does not sit right on top of the burner.) A burner this size (it has 64 inches of nichrome wire) could not be built as a brick burner.

I) Build Instructions -- Burner Wires

Get the Right Kind of Nichrome for Building Burners
There are different kinds of nichrome, and it comes in many different sizes of wire or ribbon. You want wire, not ribbon, and you want a twenty-something gauge. Make sure you know the ohms (resistance) per inch/ foot/ meter, because that is how you will figure out how much nichrome to use in your burner. The Cal Poly folks use a 100 watt, nominal 12 volt photovoltaic (PV) panel to set up their ISECs. Most 12 volt panels have a "maximum power point," denoted as PMAX on the back of the panel, at around 18 volts.

Calculating Nichrome Wire Length
For an 18 volt PMAX panel, you will need to cut a length of nichrome wire with 3 to 3.2 ohms resistance. The length of nichrome you need is easy to figure out if you know the resistance per length. We are using nichrome with 1.6 ohms per foot resistance. That means 2 feet gives us 3.2 ohms. Perfect. Alternately, you can use a electrical multimeter with a resistance scale. But beware, most cheap digital multimeters have inaccurate resistance scales. If you build a nichrome wire burner for 100 watts at 18 volts PMAX, you can use it for a 100 watt panel, or you can connect two panels (in parallel) and use the same burner at 200 watts. At LEF, we do exactly that. The voltage determines the length of the nichrome wire. The total wattage you use to power your burner does not matter as long as you are not using more than a few hundred watts. But beware, more wattage can create more of a fire hazard.

Nichrome Wire Length for Bigger ISECS
To set up different sized ISECs, figuring out how much nichrome to use is not difficult. To step up a burner for voltage higher than 18 PMAX, use the same ratio of resistance to the PMAX of the panel(s). At LEF, we have two panels with PMAX at 24 volts, and we put them in series to get 48 volts. We are using the same size nichrome wire (24 gauge) for bigger burners. The simplest way to find the length of wire for a higher voltage burner is a simple ratio. Thus 24 inches/ 18 volts = x inches/ 48 volts, and x solves to 64 inches. Or to use resistance to solve the equation, the math looks like 3.2 ohms / 18 volts = X ohms/ 48 volts, and X solves to 8.5 ohms. Then 8.5 ohms/ 1.6 ohms per foot = 5.3 feet, or about 64 inches. Beware that electricity above 48 volts starts to become a shock hazard.

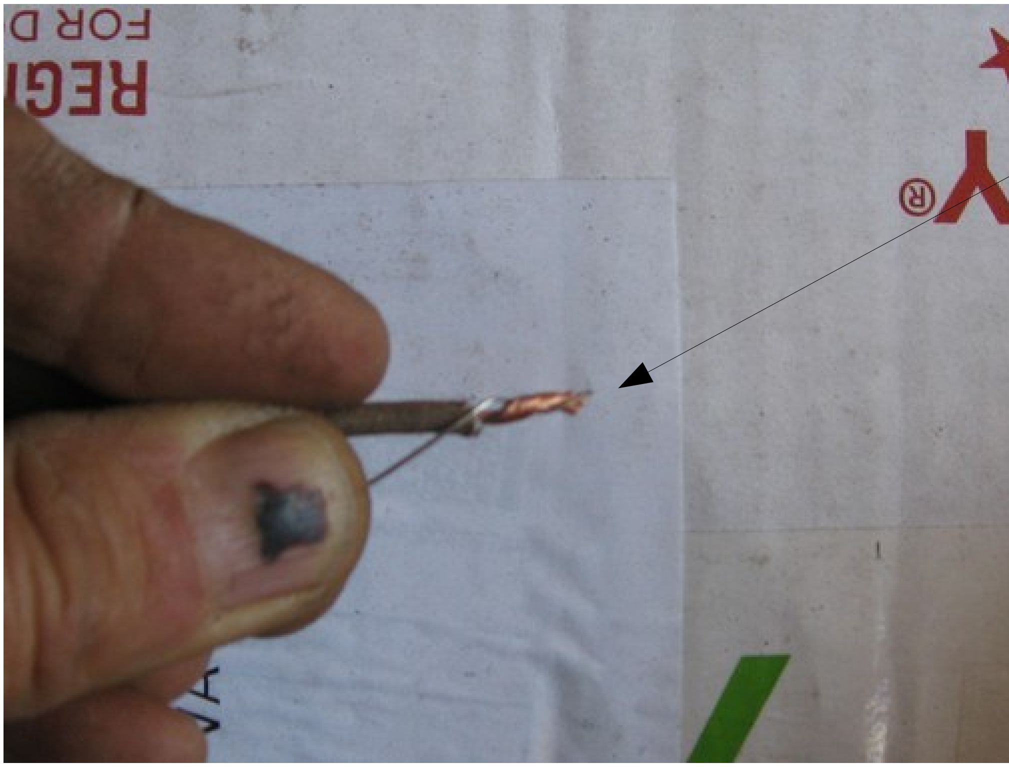
You will also need bare crimp connector couplings. These come in various sizes to accommodate different wire sizes. If you can't find bare connectors, you can take the insulated connectors (as in the image) that are available in hardware and auto parts stores and remove the plastic from the outside of the coupling.

Wire and Connections for Burners

You can use the nichrome wire to build burners of various kinds in various sizes. We are going to show you the steps for building a few different shapes and sizes of burners. You will need to connect the nichrome to some copper wire. High temperature wire, like the kind used inside ovens and toasters, is easiest to use. If you can't get that, you can use bare (or stripped) copper wire, but you will have to take a few extra steps to make it work. Braided (stranded, as opposed to solid) wire is easiest to use in crimp connectors. For most ISECs, you need 10, 12, 14 or 16 gauge wire. Using crimp connectors is easiest, but you can also solder. Soldering is best, but slower. We are assuming here you will be crimping your wires. You cannot use wire nuts because the connections are exposed to a lot of heat. Cut your length of nichrome, and two lengths of copper wire (a foot or so), and strip the ends of the copper wire about a half inch/ 1 cm. The image below shows 14 gauge wire and a bare crimp connector, being crimped with a very cheap wire crimper/ stripper (see resource list). If you are building a brick burner (see below), you can go ahead and crimp both ends. If you want a radiant burner, you will crimp one end now and one later.

Shove the copper wire through the crimp connector if you can. Shove the nichrome all the way through the connector so the copper and nichrome overlap. A connector large enough to handle the copper wire will not grip the nichrome if they are not overlapped. See the nichrome sticking out here.

If you don’t have a crimper, you can use a pair of pliers or vice grips to squeeze the connector, but squeeze hard. If you don’t have crimp connector or soldering tools, you can’t make connections Do not twist wires together and leave them. A lot of people do that as a quick fix (on various old cars and what not). It will not work for long.



Do ***NOT*** do it this way!

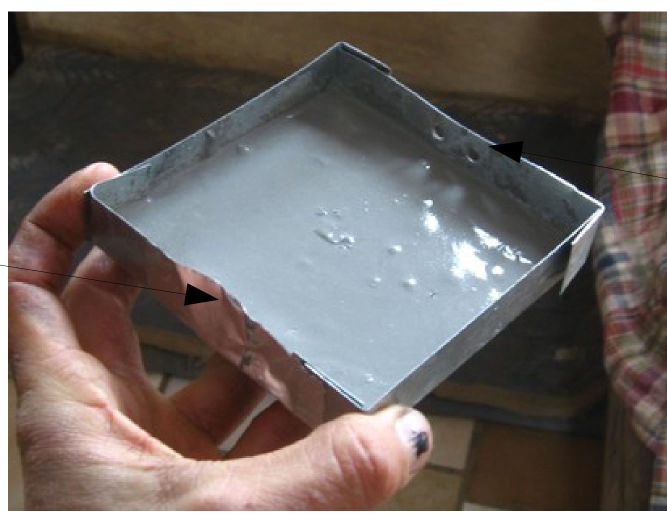
II) Build Instructions, Brick Burner, With Standard Low Temperature, Wire

To build a brick burner, you will need a small metal tray. A circular or rectangular tray is fine, or a piece of scrap metal that happens to be the approximate shape you need. Following are instructions for a quickly built tray. Cut a rectangle. Cut the corners too. Bend up the edges to form a small tray. Pliers will work. Don’t worry if it’s not pretty. Put a 1 inch/ 2 cm slot in one side of your tray. This is where the wires will go through.

Here is the slot where low temperature wires can exit the tray.

You will need to fill the bottom of the tray with some form of cement. Portland cement will work (mixed with a bit of sand, one to one ratio, or a bit more sand than cement). The portland will break down because of the heat. How quickly? We don’t know, but it will last a while if that’s what you have or you are only building one ISEC. A better solution is refractory cement (see resource list). It is made to stand up to heat. Whichever cement you use, just mix up a little and tap the tray so it settles in the bottom. Notice the holes in the picture where the wires come in.

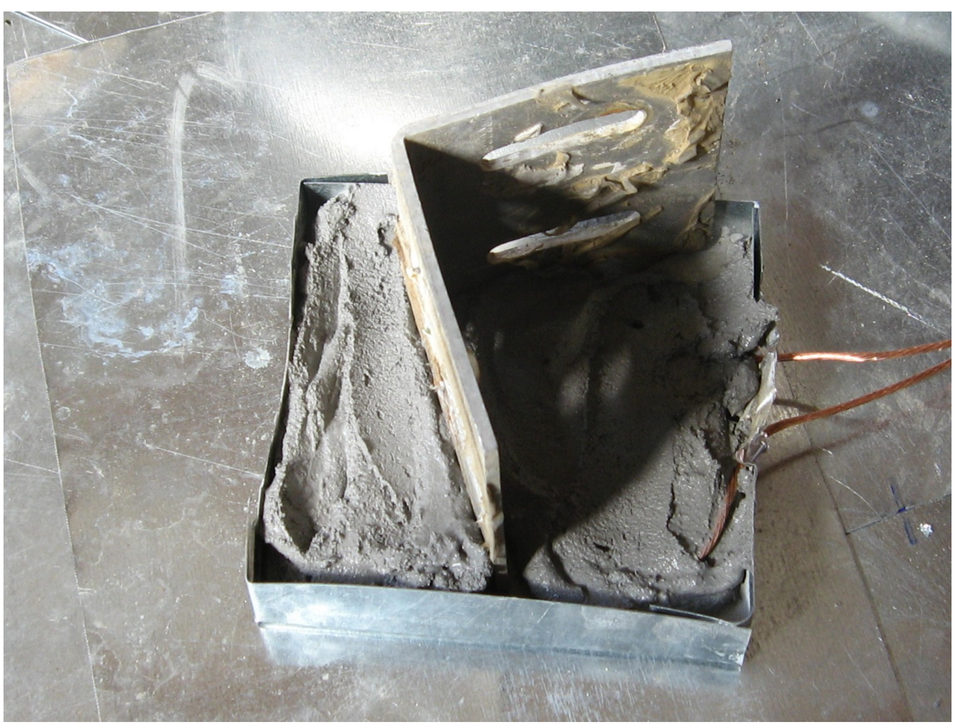
There is a cut here about and inch/ 2 cm wide to let the wires come through. It is covered with tape.



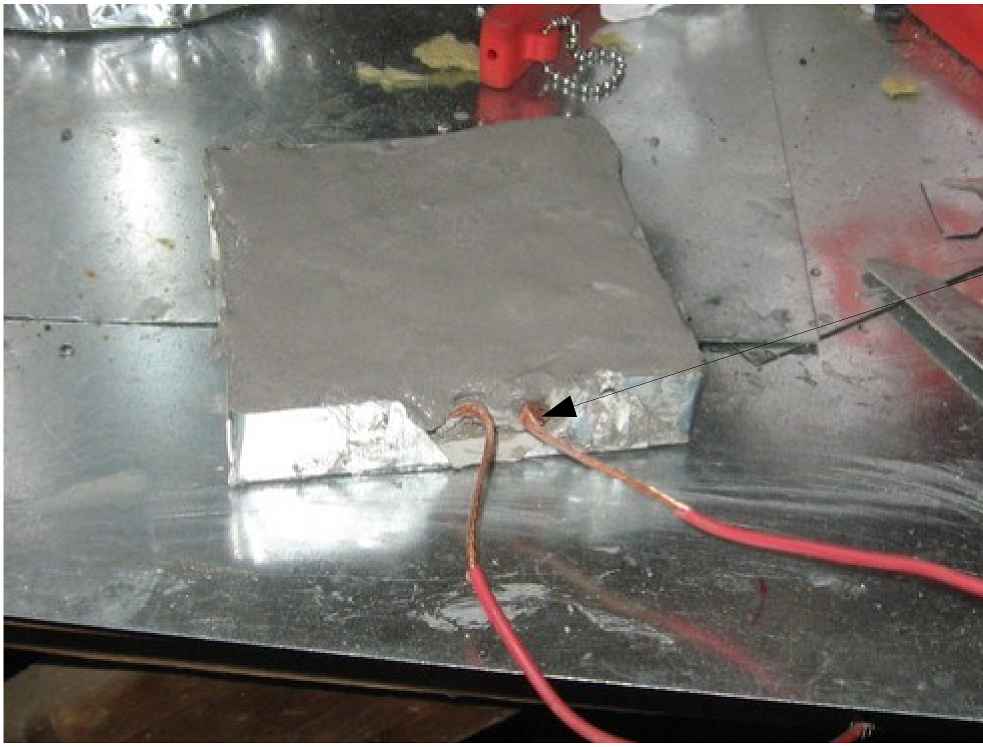
Ignore these holes.

Put the tray down overnight and let the cement harden. Then get the wires you have connected to the nichrome wire. Strip the wires back a few inches from the connections to the nichrome. (This is not necessary for high temperature wire.) Put the wire through holes in the tape. Bend the nichrome in U shapes so it fits in your tray. This part is annoying! *You will need to make sure the nichrome does not overlap itself or the copper wires.* You will need a piece of scrap metal or wood to hold the nichrome wires down. It takes some patience, but it’s not hard. The tape is removed later.

Put in enough stiff cement (portland or refractory) to over the wires. You are not filling the tray fully. Do not move the wires. Let the tray sit overnight so the cement will harden.



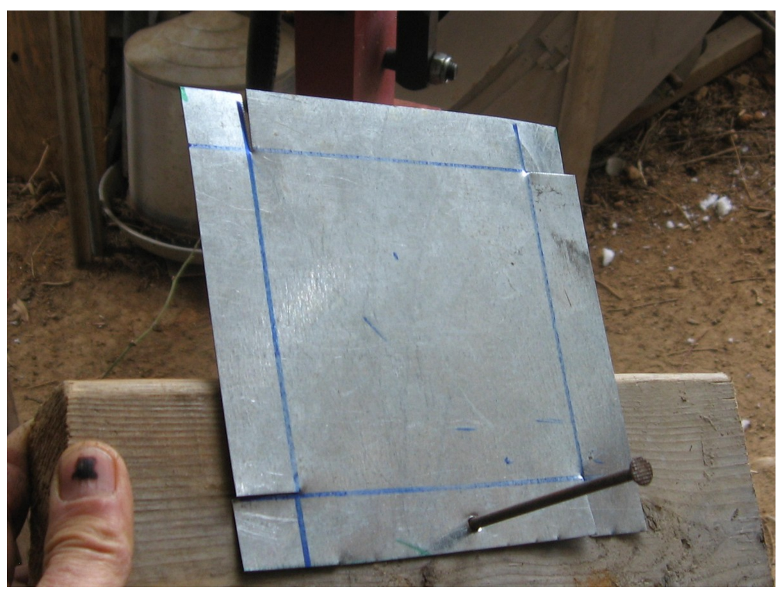
Fill the burner and level off the top with cement. Once the cement is hardened, remove the tape on the side where the stripped wires come out. Brick burner with normal low temperature wire complete.



The copper wires must not touch the metal tray. The cement insulates the wires

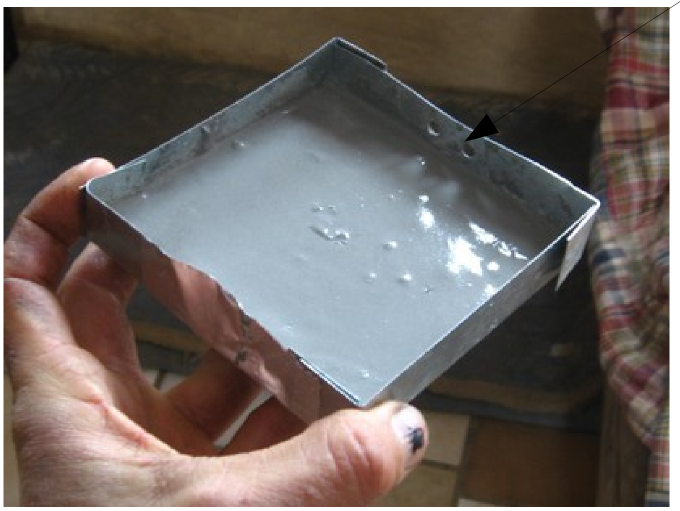
III) Build Instructions, Brick Burner, With High Temperature Wire

Building a brick burner with high temperature wire is easier than building one with normal (low temperature) wire. Cut a rectangular piece of metal, and cut corners, just like you would for a burner with low temperature wire. Punch 2 holes large enough for the high temperature wire. A metal punch is ideal (left photo), but a drill or a nail will work too (right photo). You can also make circular burners if you want.



Whitney no. 5 Jr hole punch, easily available used on ebay.

Put some cement in the bottom. Let it harden. These holes are where the wires pass through.



After the cement hardens, you will follow the same steps as in the previous instructions; put the nichrome wire in the bottom of the tray, hold it down while you put some cement on top of it, then when that cement is dry, you top it off with more cement and let it harden. The only difference is that you can take the high temperature wires through smaller holes on the side of the burner tray because they are electrically insulated.

The way these wires come right through the metal in this image is not ideal. See next page.

This material is high temperature wire sleeve. It helps protect wires. You can add it to high temperature wire to help protect the wires where they poke through the side of the burner and the side of the bucket. If you add this sleeve to low temperature wire, it will *not* protect the insulation on that wire from melting.

This is better – high temperature wire inside a high temperature sleeve to protect the wire from the edges of the metal. The sleeve should be continuous out the side of the cooker.

IV) Build Instructions, Radiant Burner

Radiant Burner
While the brick burner is the cheapest to build with easily available materials, you can build much larger burners if they are radiant burners. It's a matter of preference. Both work. For the radiant burner, build or find a metal tray. Fill the bottom with cement (portland is okay, refractory cement is better), the same as a brick burner. But *while the cement is still wet*, you are going to set heat resistant ceramic beads into the cement. These are made to protect and insulate wires inside toasters, ovens, etc. This image shows what the beads look like. They cost $.06 cents each if you buy $60 worth.

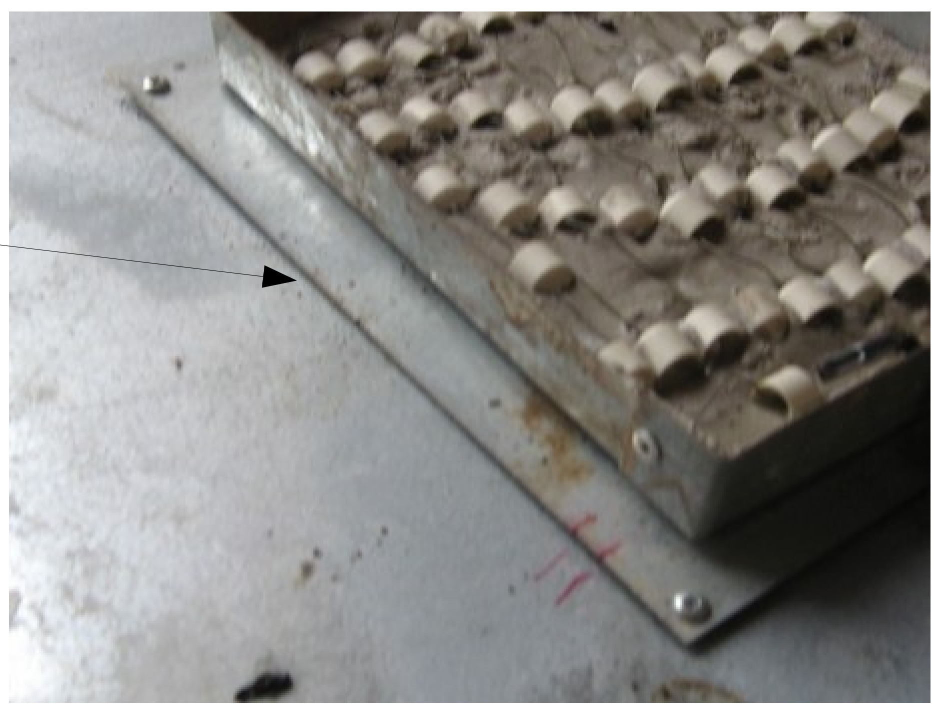
You will need to figure out how many turns you need in your nichrome wire. Cut a piece of string the length of your nichrome and bend it around to get an idea. It does not have to be precise. You can shortcut beads or put extra bends in the wire to make up for miscalculations. Wiggle the beads vigorously to get the cement to bond to the beads. Don't cover the holes in the beads. This image shows a circular burner -- shape doesn't matter much.

Bend a partial curl in one of your nichrome and sew it through the beads one at a time. Don't pull up hard on the beads or you will pop one loose. If you do, stick it back down with cement later.

Crimp the other end of the nichrome wire to the copper wire once you have sewn it through the beads, and your burner is done. Make sure neither the copper nor the nichrome are touching the metal burner tray.

The biggest advantage of radiant burners is that this approach allows you to build much larger burners if you want to. The image below is a 48 volt, 330 watt burner. Notice how close the wires are together. There is no way you could do that with a brick burner. This burner has a metal support around it so the pot does not sit on the burner. It is installed in a Roxy Jumbo ISEC. In Ahley and Perl, the pot is held up by a tube, so there is no need for an extra metal support.

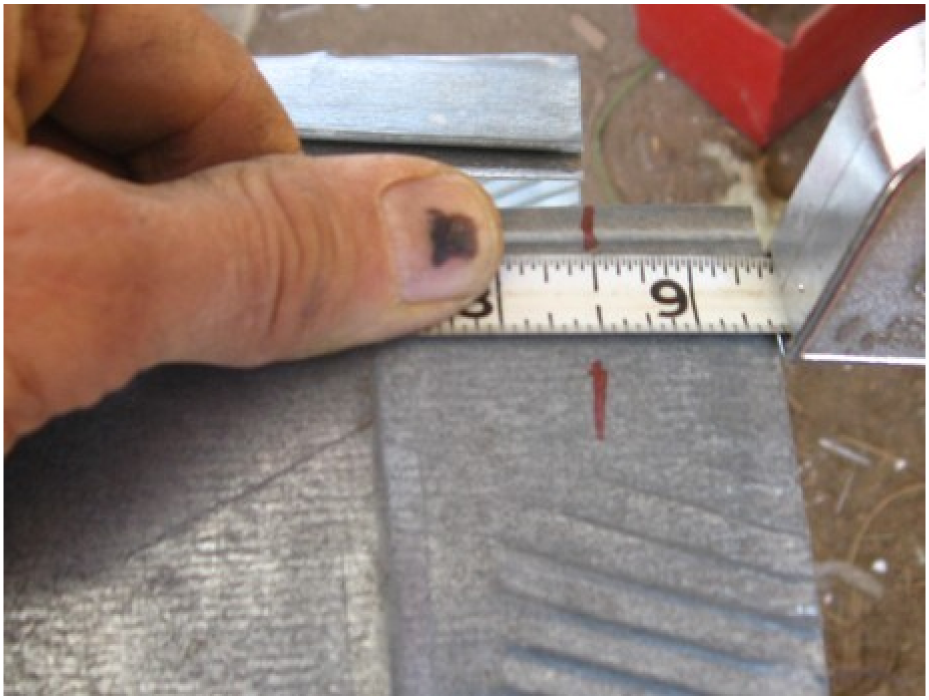
This is a closer shot of the same burner showing the stand-off plate under the burner. This is just a piece of metal with an air gap under it to keep the insulation under the burner from getting too hot. The gap is as thick as one number eight machine nut.



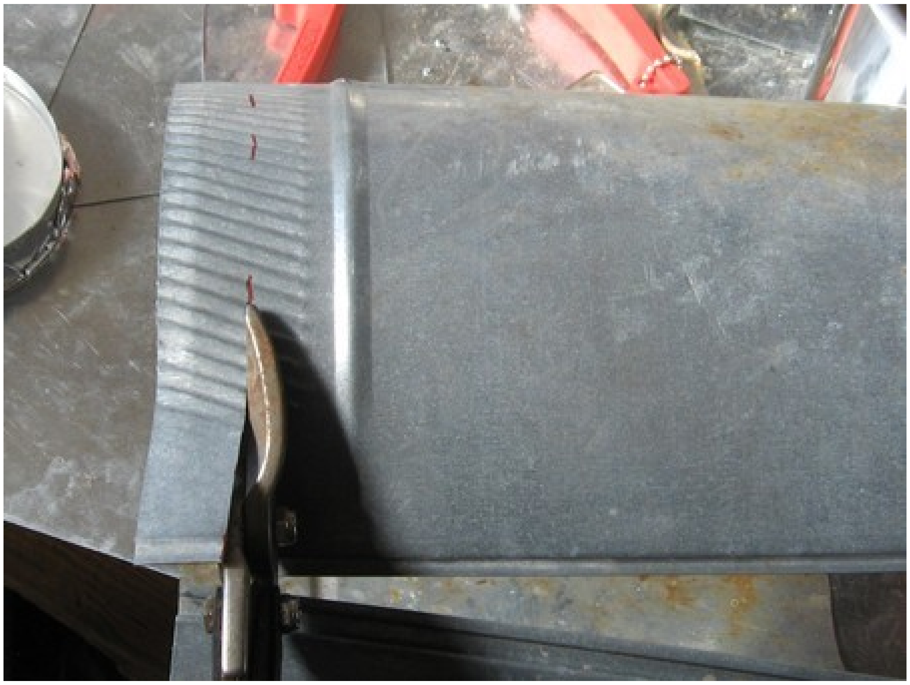
V) Build Instructions, Pot Tube For Perl or Ashley ISEC

Measure the height of your pot, which is a tall, narrow pot. We have been using 3.5, 4.25, and 6 quart Bain Marie pots. Those are steam table drop-in pots. You are going to use a piece of metal to make a tube into which the pot can drop. Metal duct pipe works great because it already has a curved shape. But any metal will do -- scrap, roofing metal, anything you can bend with your hands. The width of rectangular metal needs to be a bit more than three times the diameter of your pot, and about 1.5 inches taller than the pot. The metal in the picture is 8 inch diameter duct.

Take the metal and mark it about 1.5 inches longer than the height of the pot. In this case, my pot was about 7.25 inches, so I am marking at 8.5 inches.

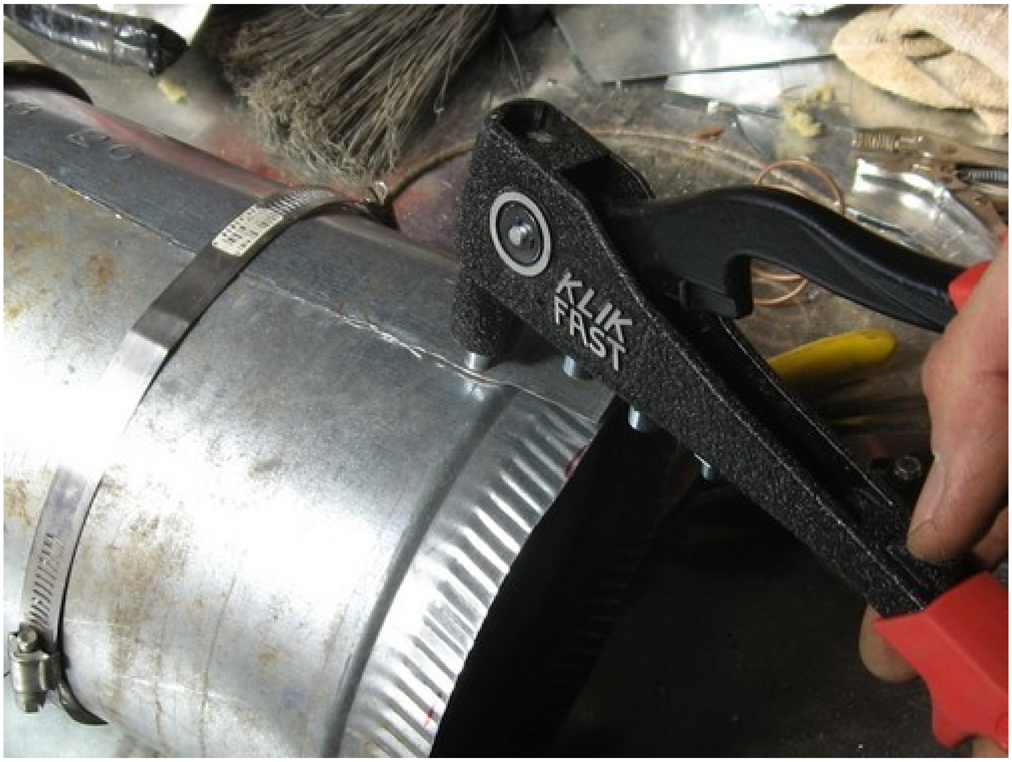


Cut the metal. A good pair of shears is desirable. With a hammer and a chisel, one can cut metal by placing it on a block of wood. That will give you a pretty rough cut though.



Wrap the metal around the pot to form a tube. You can hold the metal in place with a pipe clamp if you have a large one. A piece of wire will work too. You want the metal wrapped around the pot ***loosely***. The pot needs to slide in and out of the tube easily. You will be lifting the pot out often to cook (and pour out your soup!).

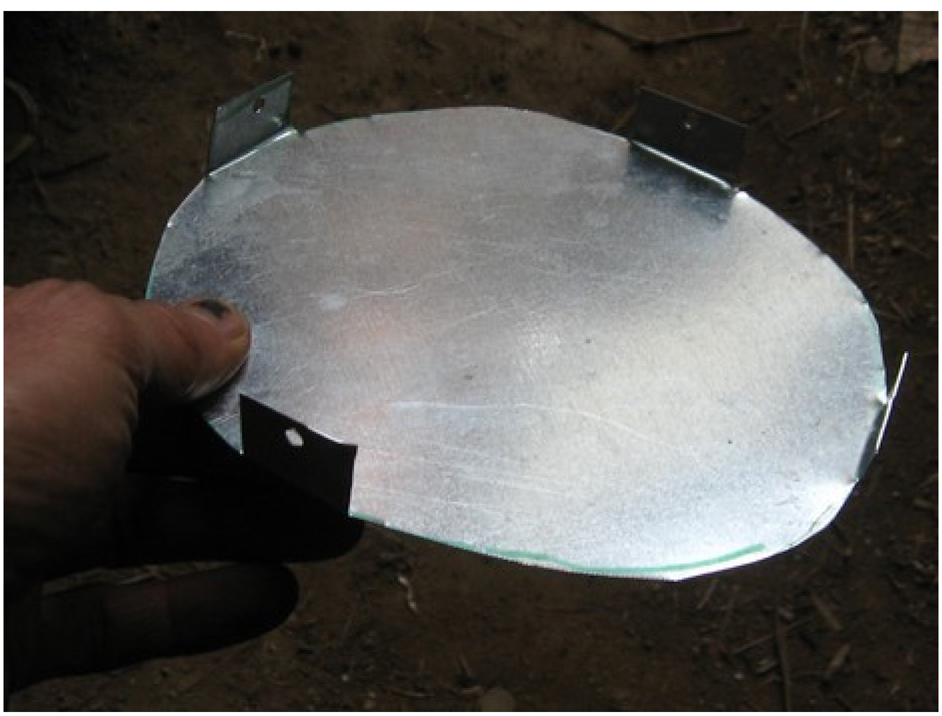
Fasten the metal at the bottom with a sheet metal screw or a pop rivet. Any shortish screw will do. (Drywall screws are not so good in metal.) For most screws, you would need to drill or punch a small hole to get the screw started. For pop rivets, you have to drill or punch a hole, and use a pop rivet tool. It does not matter much if the screw faces in or out, so long as it does not run into your pot.



Pull the pot out. Fasten the top end with a pop rivet or sheet metal screw. This screw or rivet MUST face outward or it will get in the way of your pot.

Poke some holes near the bottom of your tube. This is where the wires come out if you are using high temperature wires. If you are using low temperature wire, you will need to make a larger opening. (See next page.)

Mark and cut a circle of metal the same diameter as the tube, but with ears you can fold up. Minimum 4 ears, or bend up around the whole edge in sections if you want. You want to put holes in the ears for screws or pop rivets.



Set the bottom on the tube and fasten with screws or pop rivets. If you are going to use low temperature wire, you will need to cut a larger opening in the side of the tube.

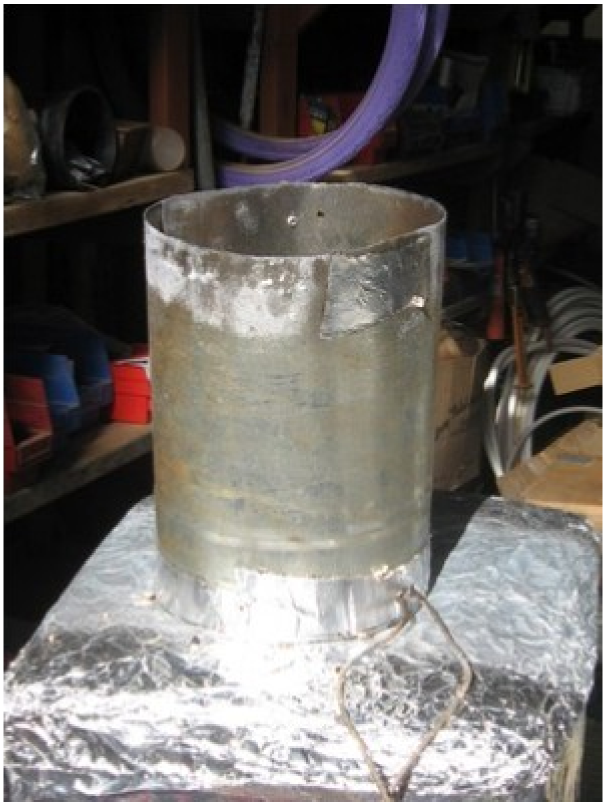
This is where the wires come out if you are using low temperature wire.

Tape up the bottom with aluminum tape if you want. If you are building Ashley, tape here will help keep ash out of the tube. If you are using high temperature wire, do not cover the small holes where the wire will come out. If you are using low temperature wire, cover the larger hole (temporarily). You will remove this tape later.

Put the thermal switch on the outside of the tube near the top, mark the holes, and attach with screws or rivets. Note, we are in the process of getting thermal switches that do not have pre-punched holes like this one does. You may need to wrap a small piece of metal over the switch and fasten it down (if it does not have holes like the one in the picture). Either way, make sure your screws or rivets point outward so they do not run into your pot.

Drop the burner into the tube, and feed the wires out the side of the tube.

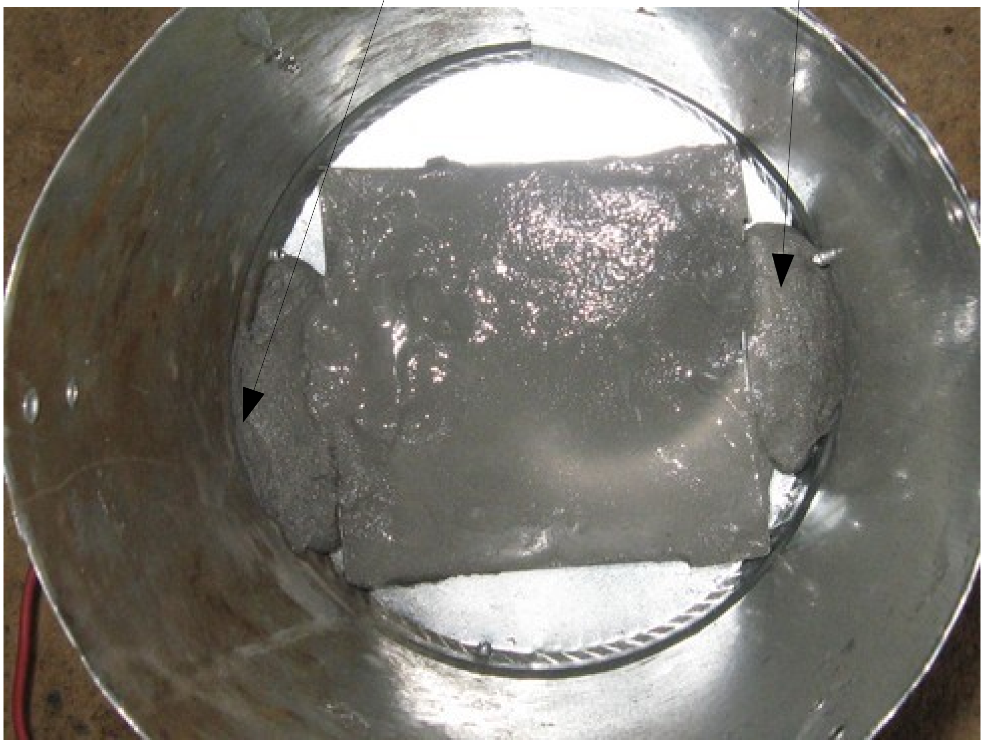
These image show a completed pot tube made with high temperature wire and a thermal switch. The thermal switch is probably a good idea, though these cookers are made of materials that do not burn. Notice the bottom of these tubes are taped with aluminum tape. That is not so important for Perl, but is needed for Ashley (to keep the ashes out of the tube).



This is a completed pot tube with low temperature wires coming out of the tube, and the thermal switch in place.

VI) Build Instructions, Installing Low Temperature Wire Brick Burner in ISEC Tube

This image shows the burner made with low temperature wire dropped into the tube of a Perl or Ashley ISEC. On the inside of the tube, put some cement around the bare wires to insulate and protect them. Here. Cement on the other side simply stabilizes the burner.



The stripped wires from the brick burner with low temperature wire come through temporary tape on the side of the ISEC tube.

Remove aluminum tape here and make sure the wires are not touching any metal. The cement should insulate them.

VII) Build Instructions, A Perlite Based ISEC

Perl -- A solar cooker made with a bucket and some perlite.
Materials:
Bucket, 5 gallon
Tall, narrow pot, Bain Marie Pot or similar, 3.5, 4.25, or 6 quart, with lid.
Some scrap metal to wrap around the pot, 8 inch duct pipe is a good size, but any metal will do.
Burner, homemade, see above.
5 gallons perlite
Aluminum foil and/ or high temperature cloth, aramid or fiberglass welding blanket.
Duct tape or similar.
Aluminum tape can be helpful but is not required.
Metal to make a 6 inch band slightly wider than the bucket, or a second bucket.
About one cubic foot of insulation, rockwool is best, fiberglass will work.
A few sheet metal screws or pop rivets.
Flatbar steel, 1 inch X 1 foot or so, and one bolt a few inches long, if you want to make a pot lifter.

Get your 5 gallon bucket and set the tube beside the bucket with the top of the tube at the top of the bucket to measure the distance down where the wires will come out. Drill two holes in your bucket so the wires can come out. While you are at it, drill a few holes in the bottom of bucket in case you get in any condensed water down there.

You can use foil or high temperature cloth at the top of the ISEC. Aluminum foil will form a thermal bridge and reduce efficiency somewhat. How much? At this time we have not done enough testing to answer that question definitively.

If you are going to use heat resistant cloth at the top of the ISEC, you will need to cut a doughnut shaped piece (a big ring with a hole in the middle). The outer ring of that doughnut will need to be about 2 inch wider in diameter than the top of the bucket. The inner hole of that doughnut shape will need to be 2 inches narrower than the tube.
Aramid is good for this purpose. Cut slits in the inner circle of the aramid so the material can fold down and the tube can fit through the hole in the middle of the aramid ring. If you are using foil, you will need to use multiple pieces. Tape the aramid or foil around the top of the outside of the tube. Aluminum tape is better here. Other tape will overheat and make bad smells. If you use duct tape, don’t use a lot. You only need to use enough tape to hold this top seal in place so the perlite can settle around it.

Aramid is a tightly woven fabric that will hold together when you cut slits in it. (It’s about $3.70 USD/ square foot if you buy a few hundred dollars worth.) Fiberglass welder’s blanket is a much more loosely woven material and will fall apart if you try cut slits in it, though it can be used in one large piece for the lid.

Fill the bucket with perlite up to the level of the holes in the side, or slightly higher. There are different particulate sizes for perlite. The smaller stuff is probably best, but any will do. Damp perlite will take time to dry and may slow down your cooking at first, but that’s okay.

Drop your tube for into the bucket, feeding the wires through the side of the bucket. Settle and pack the perlite some so the tube settles firmly and the top is the same level as the top of the bucket. Pull up the aramid or foil and cover the top of the tube with a bit of foil (to be removed shortly) so you can pour perlite to fill the rest of the bucket.

Remove the temporary foil over the top, then settle the perlite so it is a bit lower than the top of the bucket.

Pack some insulation around the top of the bucket. Rockwool (batt form, not board form) is best here, but fiberglass will do. Overfill it so it sticks up quite a bit. This needs to form a seal with the lid. Do NOT use flammable material.

Pull the aramid or foil down around the top of the bucket and tape it. It is okay to use duct tape here, as this area does not get so hot. Done! (Except for the lid....)

VIII) Build Instructions, Steam Venting

Steam Venting

LEF has only been building ISECs for a few weeks, and our work thus far has been in mid-winter with very few fully sunny days. Any cooking releases some steam, and one can expect moisture to accumulate in the insulation of an ISEC. Perlite will not degrade under wet conditions, and rockwool is more tolerate of moisture than fiberglass. If too much moisture builds up in the insulation, it will begin to defeat the insulation because you will have to heat up all that water while you are trying to cook your food. Particularly in the lid, there are likely to be moisture build-up issues. The Cal Poly crew has been working on this for a few years, working largely in southern California (where there is lots of sun). For First ISEC and PCM ISEC, they use a steam tube vent through the lid. Perl or Ashley could have a steam tube vent through the lid or immediately under it. The material that works for this purpose is high temperature silicon tubing. See resource list for what that is and where to get it.

IX) Build Instructions, An ISEC Built With Wood Ashes

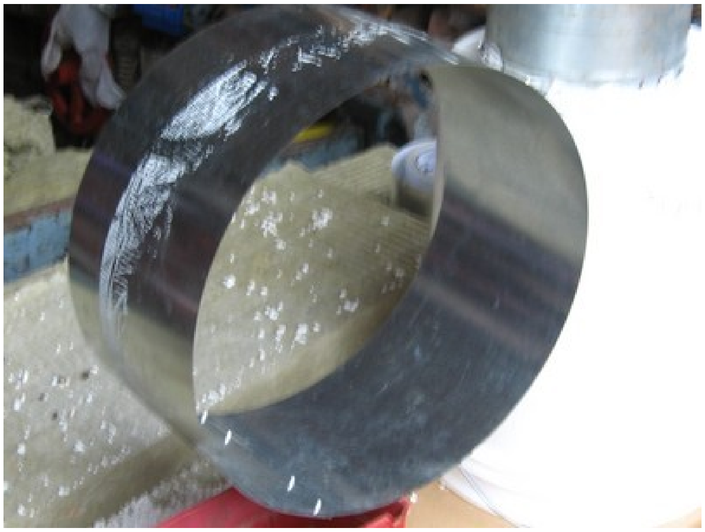
Ashley, The Cheapest ISEC

We have built a couple of ISECs using wood ashes. The build instructions are the same as Perl, with some minor differences. Ashes pack more than perlite. We suggest you pack the ashes lightly, but not vigorously. Ashes degrade quickly with moisture, so Ashley may need to be repacked/ remade from time to time. The photo here shows one Ashley on the left and three Perls. We have built these with only foil at the top, no aramid, and they work okay.

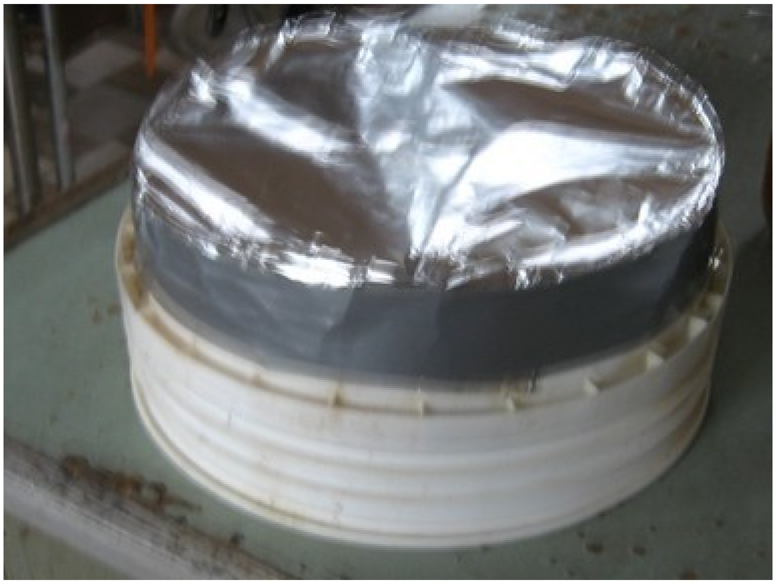
X) Build Instructions, Lid for Ashley or Perl

A Lid for Perl or Ashley

Perl ISEC or Ashley ISEC will need a lid. The lid is the same for either cooker, contingent on what you have available. You will need to make a ring as large or slightly larger than the top of the bucket. The ring needs to be about six inches tall. We use a metal strip. Alternately, you can cut the top six inches off of another bucket. If you have the metal, a strip is better because you can make a lid that is a little wider.



Cover one side of your lid with foil (cheap) or fiberglass welder's blanket (more expensive) or aramid (most expensive). Tape the outer edge of the foil or material around the lid ring.



If you are using fiberglass welder's blanket or aramid, put a layer of foil on the inside to function as a vapor barrier and reduce moisture entering your lid.

Fill your lid with rock wool (preferred) or fiberglass. Do not use flammable material.

Cover the other side with foil, fiberglass welder’s blanket or aramid. Tape around the edge. Your lid is complete.

X) Build Instructions, The Roxies

The Roxies, Larger ISECS

The "Roxies" refer to ISECs built with rockwool sheet/ board, not to be confused with rockwool that comes in batt form like fiberglass building insulation. The advantages of rockwool in either form is that is has much higher temperature tolerance, and does not fall apart when it gets damp. The disadvantages are that it is a little more expensive and hard to get. There are in theory several companies making rockwool sheets, but only one kind seems to be easily available, and that's called Roxul. It comes in various thicknesses from 1 inch up to 4 inch, faced or unfaced. The unfaced is much cheaper, and the facing peels right off the faced stuff, so you want unfaced. You will face it yourself. We have built Roxies of various sizes using 2 inch thick sheets and 4 inch sheets. Roxies built with 4 inch sheets are comparable in performance to First ISECs or Perl. To build a Roxy, first plan the size. Roxul sheets are 2 foot by 4 foot. Don't forget to account for overlapping corners. Mark your sheets with a marker. A kitchen knife will cut the Roxul.

Tape up the Roxy. We have been making a base that is just a flat sheet, with a lid the shape of a box. We put some tension on the tape to pull the corners together. This is a two person job if your Roxy is large.

We have been covering both the outside and the inside of the Roxies using foil. We have been using high temperature silicon as an adhesive, and foil tape to seal corners and edges. On large Roxies, we have also been making metal bases. We don’t know if these methods are optimal.

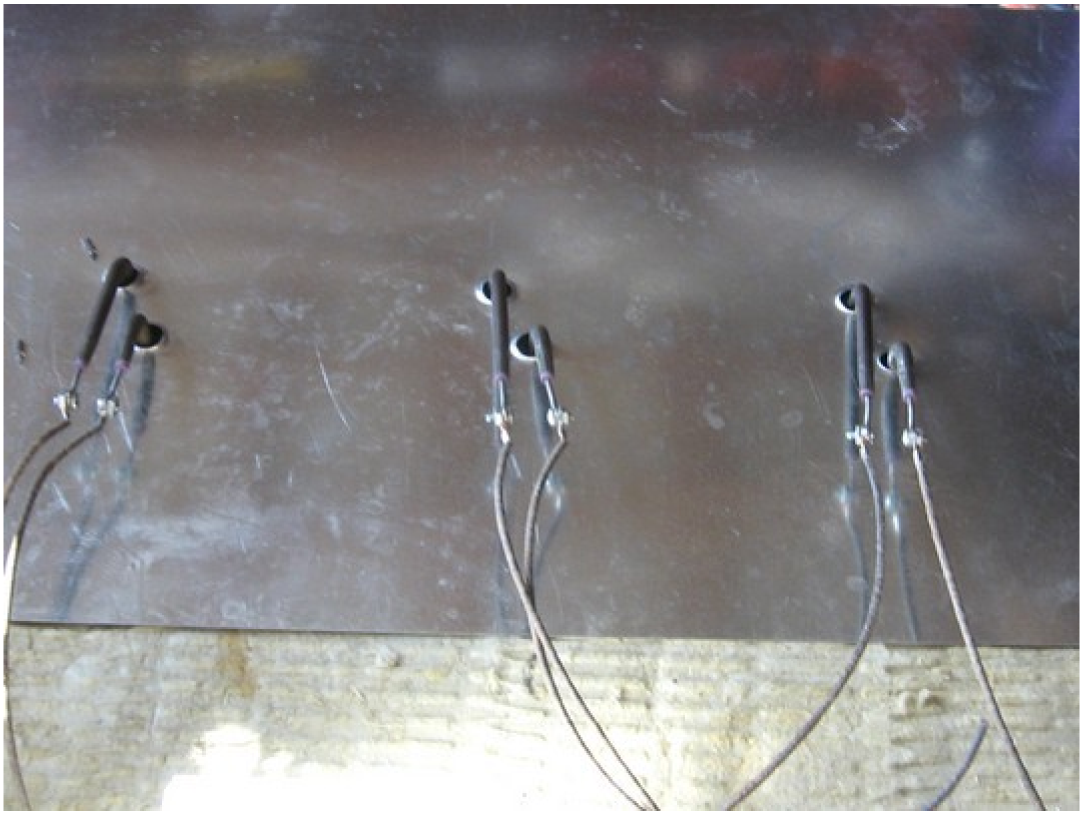
We have been using aramid around the perimeter of both the lid and the base, with high temperature silicon as an adhesive.

This is the lid of our largest Roxy complete.

Our largest Roxy is made to run at 180 volts DC, dayight (direct) drive from our photovotaic panels. For this one, we made a metal base. The Roxul fits snugly into this base.

We cut a metal sheet to go on top of the Roxul. We poked holes so we could put the electrical connections safely under the metal. We are using three regular 240 volt stove burners. By using switches, we can use one, two, or three burners at a time. The lowest power setting puts all three burners in series, thus increasing resistance and giving us a cooker than can run alongside many other machines running simultaneously.

Wire are connected under the metal. Beware, high voltage DC electricity is dangerous in a similar fashion to high voltage AC power. `



All three burners. A large Roxy must have a thermostat or timer.

We put covers over the burners to avoid hot spots.

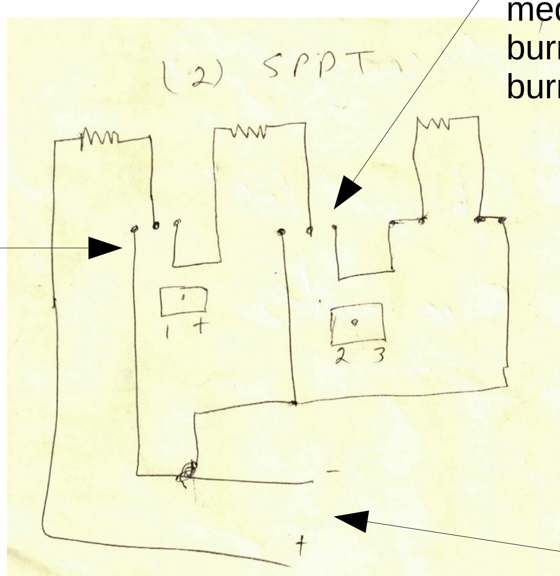
This is a real oven made to run at three different wattage levels (350, 700, and 1400 watts). It runs on 180 volt DC power. Ovens like this could be built to tie into the DC side of existing “grid-tie” solar racks. CAUTION: HIGH VOLTAGE DC POWER POSES A RISK OF SHOCK OR ELECTROCUTION. HIGH POWERED INSULATED OVENS POSE A FIRE HAZARD IF NOT BUILT AND USED PROPERLY. DO NOT WIRE THIS KIND OF OVEN IF YOU ARE NOT FAMILIAR WITH ELECTRICAL CODE AND SAFE WIRING PRACTICES. This oven MUST have some kind of thermal control – a thermostat and/ or timer. The top of the oven also can get hot. This oven will bake six loaves of bread. We made a rack to hold the trays.

The same 180 volt oven with the lid on. The electrical box in front has both a timer and some switches.

Here is a simple schematic for how we used “double throw” switches so we can run the burners one, two, or three at a time. Because the burners are set in series, the lowest heat setting is when all three burners are engaged. This is a cheap and simple way to reduce power flow without any fancy electronics. The burners were eight dollars each.

Second switch toggles between medium (2 burners) or low (3 burners).

First switch toggles between high (one burner) or medium-low (2 or 3 burners).



Timer connects here.

Roxy Jumbo, 48 volt, 330 watt

Roxy Jumbo is a larger ISEC built with 2 inch Roxul. It is powered by a 48 volt, 330 watt radiant buner. The burner is made with 64 inches or 24 gauge nichrome wire. Roxy Jumbo cooks quite well. The top of Roxy Jumbo gets hot after hours of use. Do not stack flammable things on top of ISECS, ever. The heat "leakage" from Roxy Jumbo means the ISEC will have an upper limit temperature beyond which leakage equals input. We control it with a spring wound timer. Finding a DC thermostat that would hold up for years of use is not easy. We can cook a batch of sweet potatoes or winter squash by 1 PM, and another batch for dinner. Construction technique is essentially identical to the Roxies prior mentioned.

The following image shows two Roxies. They have PMAX 18 volt burners. The left is Roxy Sr, made with 4 inch Roxul, and showing a radiant burner. The right image is Roxy Jr. with a 3.5 quart Bain Marie pot. The outside and inside of both are covered with foil. The edges are covered with aramid.

Roxul rockwool sheet, 2 inches thick. This image shows faced Roxul. The unfaced material is much cheaper, and easy to face yourself with foil.

Unfaced Roxul rockwool sheet, two inches thick. The unfaced material is much cheaper, and easy to face yourself with foil.

Addendum, More On Fire Risks

ISECS should be built with materials that do not burn. We are very excited about Perl ISEC in particular as an inexpensive, very effective solar cooker that is easy to build. We have only been able to do limited testing. If there is any significant amount of water in a pot in Perl, or any 100 watt cooker, the water will keep it from getting too hot. We ran a Perl all day with no water at all in it. It got over 500 F inside. The aramid was blackened somewhat and smelled bad. But neither aramid, nor perlite, nor any other materials used in Perl, Ashley, or the Roxies will burn. The ISECs developed by the Cal Poly team use thermal switches and fuses on First ISEC and PCM ISEC. These are not strictly necessary on Ashley, Perl, or the Roxies, but the thermal switches and fuses are inexpensive and easy to install. Thermal switches that switch at 150 C or 180 C will not be activated in normal cooking. (PCM ISEC is a different story, see documents relating to that cooker.) If the thermal switch is only activated very occasionally, it should last a long time. For our larger ISECs, we are using external timers. These are cheaper than thermostats that can handle DC current at higher amperages. ***It is easy to forget than an ISEC is plugged in!*** That creates a risk of overheating, particularly the day after you use it and the sun comes up again. It would be wise to use a thermal switch, thermal fuses, and/ or an external timer to prevent overheating. ***Make sure your ISEC is not still plugged in after you quit using it!***

Resource List

Buckets -- The primary reason we have pursued Ashely and Perl is the assumption that 5 gallon buckets are available. A number of hardware and lumber stores will sell 5 gallon buckets with their brand name on the side for cheap.

Perlite -- Perlite is widely available, but prices are variable. The cheapest prices are from commercial suppliers who provide materials for commercial nurseries. Perlite is sold in 4 cubic foot bags for about $35 - $40 per bag retail. One only needs about half a cubic foot per Perl cooker build. One supplier (for volume purchases) is https://www.7springsfarm.com/ On volume purchases, they are likely much cheaper than the big box stores or online.

High Temperature Wire -- Local electrical supply houses will have it, perhaps your local hardware store might sell it by the foot. The cheaper supply houses include zoro.com and globalindustrial.com. Others include grainger.com (owns zoro), mcmaster.com, mscdirect.com, as well as others. We also use ebay quite a bit. If you have heavy gauge wire around you can use it, but for short runs in the amperage needed for most ISECS, 14 - 16 gauge is fine.

Bain Marie Pots -- We have been buying from webstaurant.com, but beware, their shipping pricing is extortionate. They price their items low, and make their profit on inflated “shipping.” We have not found a better source -- let us know if you do.

Metal Shears -- Brand name “aviation shears” are the best. Ideally, you want one straight cut shear and one “offset” for cutting round metal or stiff metal. See ebay item number 254126179593 (just search using the item number), 223463451369, and 203268145632.

Nichrome Wire -- We got ours from ebay, widely available through other sources. Ebay item number 281789675253

Fiberglass High Temperature Welder’s Blanket -- See ebay item number 301902953193

Aramid -- See ebay item number 153528934391

High Temperature RTV Silicon -- see siliconedepot.com (volume pricing but high shipping costs), ebay item number 282934833088 or zoro.com

Thermal Switches -- We ordered a few of ebay item number number 273119630408 The Cal Poly crew uses Selco BM1−180A−000N. Hopefully, we can make the Selco switches available in the future.

Heavier Aluminum Foil -- ebay item 174416639430

High Temperature Ceramic Beads -- See ebay item 184551973592

Silicon Tubing, High Temperature (for steam venting) -- See ebay item 382868584977

Heavier Aluminum Foil -- ebay item 174416639430
High Temperature Ceramic Beads -- See ebay item 184551973592
Silicon Tubing, High Temperature (for steam venting) -- See ebay item 382868584977
Inexpensive Wire Stripper/ Crimper/ Cutter -- Ebay item number 192959194511
Duct Metal
Refractory Cement
Rockwool Batts
Roxul Rockwool Sheets
Aluminum Tape