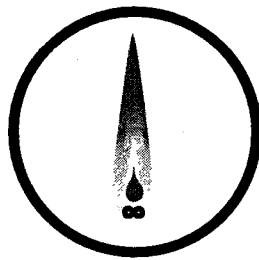


# Brown's Gas

BOOK TWO



Build a high quality  
Brown's Gas electrolyzer that  
will exceed the performance of  
ANY known commercial  
machine to date

George Wiseman

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We define practical as simple, inexpensive, environmentally-considerate, easy to build, low maintenance and, applicable to small scale energy needs.

We gather information from diverse sources, perform comprehensive experiments using rigorous standards, then publish how-to books to share the results with other researchers and the general public.

We believe that writing books insures that these technologies will be secured public knowledge, and that our patent-free philosophy promotes increasingly better energy solutions.

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1. Concept: I think I have an idea!
2. Research Assistant: compiled research to develop a working theory
3. Theory: explore research to develop proof of concept experiments
4. Proof of Concept: hands-on; try methods to make design of prototype possible
5. Initial Prototype Design: to begin experimental prototype
6. Practical spinoff: useful technology developed that is not the main line of research
7. Experimental Prototype: working experiments; proof of technology
8. How-To manual: comprehensive instructions
9. Kit: assembly of parts
10. Device: including operation manual

# Table of Contents

INTRODUCTION .....	1
DESIGNING A BG ELECTROLYZER .....	2
• <i>Application Specifications</i> .....	2
• <i>Series-cell</i> .....	2
• <i>Transformer-less design</i> .....	3
• <i>Simple power supply</i> .....	3
• <i>Power supply options</i> .....	4
• <i>Electrolyte</i> .....	4
• <i>Sealing between cells</i> .....	5
• <i>Plate masking</i> .....	5
• <i>Plate degreasing</i> .....	5
• <i>Plate texturing</i> .....	5
• <i>Plate material</i> .....	5
• <i>Plate thickness</i> .....	5
• <i>Plate spacing</i> .....	5
• <i>Number of cells</i> .....	6
• <i>Pure water</i> .....	6
• <i>Fail-safe features</i> .....	6
• <i>Bubbler tank</i> .....	7
• <i>Liquid-vapor separator</i> .....	7
SIZING A BG ELECTROLYZER .....	7
• <i>Gas volume needed</i> .....	7
• <i>Available power</i> .....	8
• <i>Electrolyzer diameter</i> .....	9
• <i>Plate spacing</i> .....	9
• <i>Kind of electrolyte</i> .....	9
• <i>Electrolyte concentration</i> .....	9
• <i>Power supply option</i> .....	10
BUILDING A BG ELECTROLYZER .....	10
• <i>Safety tips</i> .....	10
• <i>Electrolyzer list of materials</i> .....	10
• <i>Cut rings from tube</i> .....	11
• <i>Size rings</i> .....	11
• <i>Mark out plates</i> .....	11
• <i>Cut plates</i> .....	12
• <i>Straighten plates</i> .....	12
• <i>Degrease Plates</i> .....	12
• <i>Holes in plates</i> .....	13
• <i>End plates</i> .....	13
• <i>Liquid level tube</i> .....	16
• <i>End gaskets</i> .....	16
• <i>End plate assembling</i> .....	16
• <i>Plastic cap on SS bolt</i> .....	16
• <i>Initial cut long shell</i> .....	16
• <i>Assemble rings &amp; plates into tube</i> .....	17
• <i>Final long shell cut</i> .....	17
• <i>Put end caps on</i> .....	17

• <i>Through bolts</i> .....	17
• <i>Drill and tap shell</i> .....	17
• <i>Mixing electrolyte</i> .....	18
• <i>Fill electrolyzer with electrolyte</i> .....	18

DESIGNING ELECTROLYZER POWER SUPPLY	19
• <i>Power supply considerations</i> .....	19
• <i>Voltage measurements</i> .....	19
• <i>Number of cells in series</i> .....	19
• <i>Frequency across the electrolyzer</i> .....	19
• <i>Voltage threshold</i> .....	20
• <i>Pressure switch</i> .....	20
• <i>DC power circuit</i> .....	20
1. <i>Capacitor amperage limiting</i> .....	20
2. <i>Voltage doubler</i> .....	21
3. <i>Voltage doubler with capacitive limiting</i> .....	22
• <i>Main power circuit</i> .....	22

LIQUID LEVEL & TEMPERATURE CONTROLS	23
1. <i>The 12 VDC power supply</i> .....	23
2. <i>Second circuit group; liquid level and temperature processing</i> .....	24
3. <i>The signaled mosfets, relay and buzzer</i> .....	26
• <i>Assembly hints</i> .....	26
• <i>Circuit adjustments (tuning)</i> .....	28
• <i>'Balance' the op-amps</i> .....	28
• <i>Set the circuit temperature</i> .....	28
• <i>Circuit tests</i> .....	28
• <i>Circuit component list</i> .....	30

BUILDING A CONTROL BOX .....	30
• <i>List of components and materials</i> .....	30
• <i>Pressure relief valve</i> .....	31
• <i>Pressure switch</i> .....	31
• <i>Automatic electronic liquid level and temperature controls</i> .....	31
• <i>Install gauges</i> .....	32
• <i>On/off switch</i> .....	32
• <i>Indicator lights</i> .....	32
• <i>Full-wave bridge rectifier</i> .....	32
• <i>Main relay</i> .....	32
• <i>Terminal strips</i> .....	33
• <i>Duplex receptacle</i> .....	33
• <i>Hook main power inlet cord to enclosure box</i> .....	33
• <i>Enclosure box</i> .....	33
• <i>Install capacitors</i> .....	33
• <i>Wire control box</i> .....	34
• <i>Wires from enclosure to electrolyzer</i> .....	34
• <i>Gas pressure hose from liquid-vapor separator</i> .....	34

DESIGNING AND BUILDING A BUBBLER .....	34
--	----

continued...

## Table of Contents (con't)

OPERATING A BG ELECTROLYZER .....	36
• <i>Confirm ready to start</i> .....	36
• <i>Initial start</i> .....	36
• <i>Check for leaks</i> .....	36
• <i>Set pressure switch</i> .....	36
• <i>Set &amp; test the liquid level and temperature circuits</i> .....	36
• <i>Lighting the torch</i> .....	36
• <i>Extinguish torch</i> .....	37
• <i>Shut off electrolyzer</i> .....	37
• <i>How to avoid backfire</i> .....	37
• <i>What to do when you get a backfire</i> .....	38
• <i>Re-filling electrolyzer with water</i> .....	38
• <i>Adding fresh water to the bubbler</i> .....	38
• <i>Draining the electrolyzer</i> .....	39
• <i>Preventing foaming</i> .....	39
• <i>Over-heating</i> .....	39

## BG ELECTROLYZER EFFICIENCY

### MEASUREMENTS AND CALCULATIONS .... 40

• <i>Electrolyzer theoretical gas production</i> .....	40
• <i>Actual gas production</i> .....	40
• <i>Figuring BG proportion of gas: Gas Efficiency</i> ....	40
• <i>Wattage Efficiency per liter of BG</i> .....	41

### OUR EXPERIMENTAL USE OF BROWN'S GAS 42

• <i>Modifier tank</i> .....	42
• <i>Welding glass</i> .....	43
• <i>Welding iron</i> .....	43
• <i>Cutting cast iron</i> .....	43
• <i>Welding cast iron</i> .....	43
• <i>Cutting iron</i> .....	43
• <i>Welding copper</i> .....	44
• <i>Welding aluminum</i> .....	44
• <i>Brazing</i> .....	44
• <i>Cost to operate compared to oxy./acet.</i> .....	44

### COMMENTS ON USING BG WITH IC ENGINES 44

• <i>Jimmy Reed's experiments</i> .....	44
• <i>Calculations to run an engine on BG</i> .....	46
• <i>Hyper-gas</i> .....	47
• <i>Conclusion</i> .....	47

### OVER-UNITY HEAT ..... 48

### BROWN'S GAS CAPABILITIES ..... 48

• <i>Actual BG characteristics</i> .....	48
• <i>Misconceptions of Brown's Gas</i> .....	49
• <i>Heating applications</i> .....	49
• <i>Cooling applications</i> .....	50
• <i>Clean water</i> .....	50
• <i>Energy storage system</i> .....	51

• <i>Atmospheric "over-unity" engine</i> .....	51
• <i>Power potential of BG</i> .....	52
• <i>Compare BN 1000 performance</i> .....	52
• <i>Further notes on testing the BN 1000E</i> .....	52
• <i>The 5 various sensors on the BN1000E are:</i> .....	54
• <i>Operation notes</i> .....	54
• <i>Testing data</i> .....	55
• <i>Testing the BN 200</i> .....	56
• <i>Testing Conclusion</i> .....	57
• <i>Conclusion</i> .....	57

### BIBLIOGRAPHY ..... 57

### RESOURCES ..... 58

### ADDITIONAL SIMPLE CIRCUIT ..... 59

Since writing *Brown's Gas, Book 2*, George Wiseman discovered an additional circuit which he considers to be an even simpler method than those offered in the book.

*The circuit has been added at the back of the book and appears on pg. 59.*

## INTRODUCTION

I wish to thank Ross Stanfield, Jim Fluri, Kiel Schweizer and Jimmy Reed for their great efforts helping develop the information contained within this book. It would have taken much longer to write this book without their help (years perhaps).

I am working with people around the world to duplicate the Brown's Gas technology. I co-ordinate research from all sources, giving credit where due, plus input my own innovations. We have made tremendous progress.

I have written this book to further add to the published general knowledge of Brown's Gas. I have found that there is a lot of misinformation floating around about Brown's Gas. I wish to try to present accurate information that will lead to safe and effective use of this technology. Until Yull Brown writes a comprehensive documentary, I feel experimenters are at risk. I wish to reduce the risk, in my life and in the life of any person experimenting with hydrogen and oxygen.

Note that in this book, I often refer to Brown's Gas as 'BG'. This Book is the second of a series that will allow anyone to experiment with Brown's Gas. I feel it is important to duplicate Yull Brown's work because I feel the world **needs** this technology. Duplication of his work will verify the technology while making public the knowledge that will make the technology safe to use.

Note that I do not refer to an electrolyzer as a 'generator'. It is technically correct to use the term 'generator' but I find it confusing with 'electrical generator' (machine that produces electricity). Thus I always use only 'electrolyzer' to describe these gas producing machines.

I describe (some of) my mistakes as well as my successes and the thoughts that led to both. As an inventor, I know that failure is just as important as success. Both are learning experiences and vital to the eventual understanding

of the process or device. You bought this book so you wouldn't have to repeat my mistakes.

I've had many people build various projects from my plans in the past; many thinking that they could 'do-it-better' and changing parameters when they build the project. Most of the time, they are making changes that I've already determined to be less efficient. I can't write down ALL my mistakes and research, so these people don't know that I've already been there and done that (got the T-shirt).

If you are considering making versions of a project that deviate from my specifications, it is wise to check with me first; it may be dangerous to make that particular modification AND I may be able to save you much time and money. Besides, this research is on-going, we are always coming up with improvements.

A large portion of the history and development of Brown's Gas research is detailed in my Brown's Gas, Book 1. Brown's Gas, Book 1 also gives most of the mathematics needed to understand Brown's Gas and the theory behind Brown's Gas, as far as modern Physics and Chemistry allow. In the latter part of this Book, I point out some misconceptions about Brown's Gas that I've been able to prove with actual experimentation

This Book details experimentation in progress. I include details on what we've actually done and what we are trying to do. At this time I've done very little experimentation with the gas capabilities, I've been concentrating on creating the most **practical and efficient** design of **electrolyzer** I could.

Keep in mind as you read this book, that I base these plans on the KISS principle (Keep It Seriously Simple). The most practical and efficient design in the **simplest** package. There are any number of modifications that can be made to this basic design. Be sure to check with me before implementing improvements of your own.

The result of this experimentation detailed in this Book is a design for a home-build able Brown's Gas welder (electrolyzer). The Brown's Gas books are based on experimentation that I've actually done myself and the data can be assumed to be reasonably accurate. I do advise you not to fall into the trap most readers fall into, assuming just because it is WRITTEN that it is true. Keep an open mind, so you can spot mistakes or anomalies in my work and in the 'text-books.' I **appreciate** being informed of errors or anomalies.

As I write this book I am amazed by two things: How much I've learned since Brown's Gas, Book 1; and how little I know. Still, I find myself taking some things as 'common knowledge' in my mind, that I've found most people who want to learn about this technology DON'T know. It is definitely time to write this book to bring the general knowledge of this technology up-to-date.

### WARNING BYYULL BROWN

Attempts at applications made by unqualified people who do not know all of properties of the gas could be very dangerous and create extremely hazardous conditions leading to the possibility of an explosion. Brown's Gas Electrolyzer/Welder (as sold by Yull Brown) is completely safe when used as a source of heat for welding. Experimentation is not to be attempted with the gas separate from the electrolyzer.

Additional note by Author: Yull Brown is very concerned that experimentation with hydrogen and oxygen will cause explosions that will reflect badly on himself and/or the 'Brown's Gas'. He doesn't want a 'Hindenberg Syndrome' attached to him or his technology. In addition, he would like to receive a monetary benefit for his technology, in which he has invested a large portion of his life. It has come to this author's attention that Yull Brown is writing a book on hydrogen. This author would like to support that undertaking, because knowledge written down will outlive the author while making future use of

the technology safer. This author acknowledges Yull Brown as the best expert on Brown's Gas.

## DESIGNING A BG ELECTROLYZER

To date, commercially available Brown's Gas electrolyzers have been hard to acquire; very expensive; of dubious quality; have limited gas capacity and the technical operation has not been well supported.

Brown's Gas, Book 2 presents a simple electrolyzer design that can be built quickly, with inexpensive, readily available materials, using standard workshop tools and abilities. Further, it can be built to huge sizes.

This Do-It-Yourself version is not only more efficient than the commercial units, but will teach you all you need to know about your electrolyzer: its design; assembly and operating parameters. So, you'll be able to fix it yourself if anything goes wrong.

In addition, Eagle-Research is happy to offer technical advise to people building electrolyzers of any design. We welcome suggestions for improvements of our design.

### Application specifications

The particular BG electrolyzer design outlined in this Book is designed to be applied using ordinary oxy./act. welding tips and/or cutting torch.

This design may also be applied as a combustion enhancement device for stationary power plants, reducing the petrochemical fuel needed to operate. This Book does not include the specialized

information to properly interface two fuel systems on the same engine. That information is available in the Carburetor Enhancer Manual, Electronic Carburetor Enhancer Notes, HyCO 2A Manual, the HyCO 2A Manual Update and the EFIE Manual.

Further details on **mobile** electrolyzer designs and applications are available in Hyzor Technology.

### Series-cell

Sketches shown (Fig. 2 & 3) are for our simplest electrolyzer. This is an experimental prototype that will put out commercial quantities of BG. Eagle-Research has been operating this design for several months.

We discovered that if you put several single-cell electrolysis cells (depicted

in Brown's Gas, Book 1) in series, so that the electricity must flow through each cell in turn, the combined 'voltage drops' (about 2 volts per cell) added up to a total voltage drop of about the number of cells times two.

Thus 120 cells in-series requires about 240 volts to push electricity through them all. This concept eliminated the need for the transformer and all it's waste.

But 120 individual cells (depicted in Brown's Gas, Book 1) in series is a bulky mess. Further experimentation discovered how to build the 'series-cell.' This allows many cells to be put into a compact, simple arrangement (Fig. 1).

In the series-cell design, (electricity flowing negative to positive) each plate

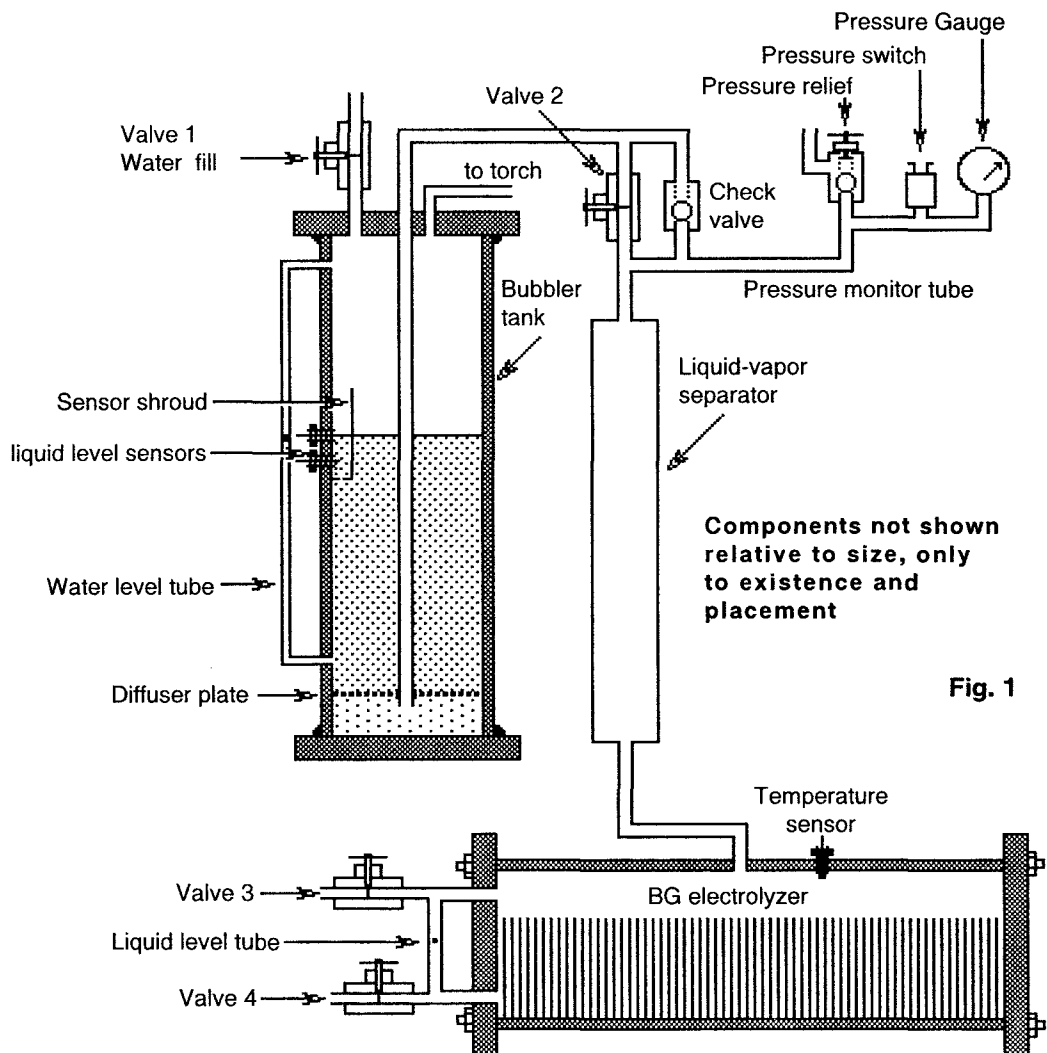


Fig. 1

actually produces both hydrogen and oxygen (on opposite sides of the same plate) because each of the inner plates shares its sides with two cells.

Starting on the negative side of the series-cell: in the first cell, the first plate (fastened to the electrolyzer end plate) just makes hydrogen. The second plate gives off oxygen on the side facing the negative, and hydrogen on the side facing the positive end of the electrolyzer.

Thus oxygen and hydrogen are generated from every plate in the series-cell. Oxygen produced on one side and hydrogen on the other. The 'electrons' travel through each plate-electrolyte-plate-electrolyte-etc. from one end to the other.

The advantages of a series-cell electrolyzer design are immense and well worth doing the little extra to get it right. Series-cell makes an extremely compact, efficient, low cost, quiet operating, light weight, and simple Brown's Gas electrolyzer.

At two square inch per amp (actual submerged plate surface area), our 1,200 watt series-cell electrolyzer is about 6" in diameter. This design will make a 500 Liters/hour BG machine.

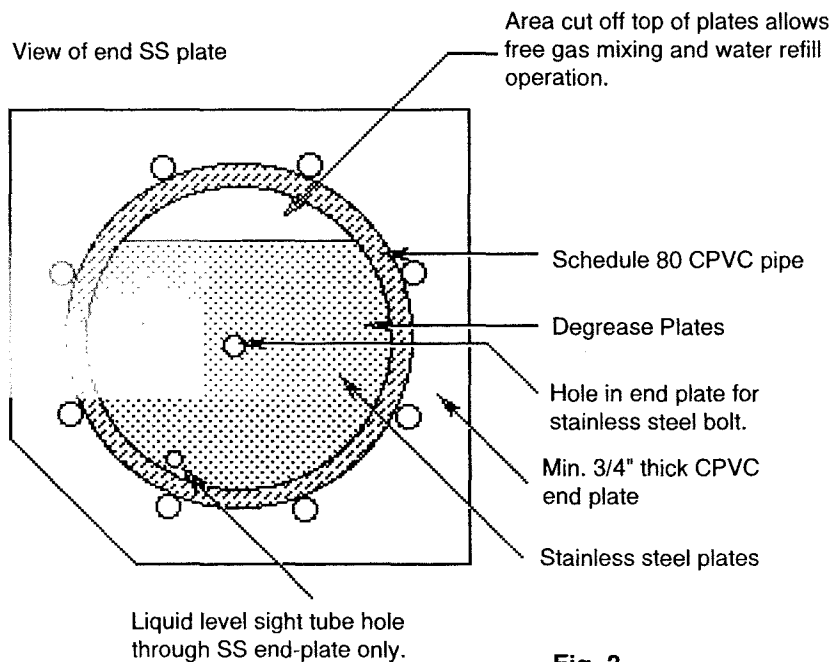


Fig. 2

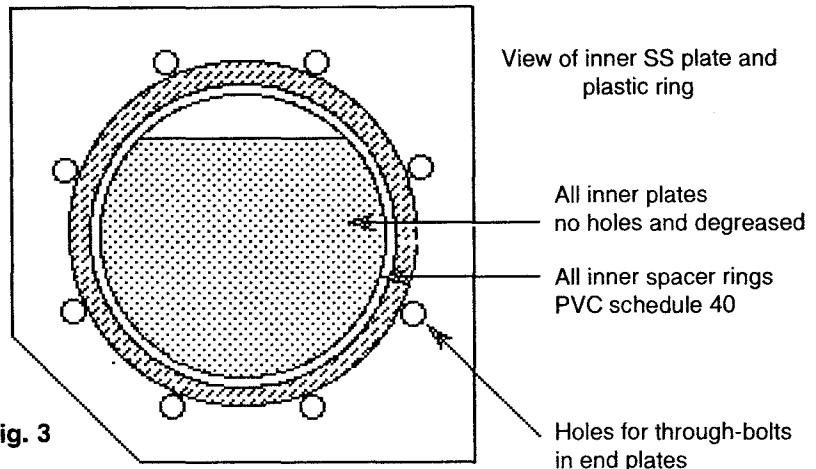


Fig. 3

Make it 8" in diameter for a 1,000 Liter electrolyzer.

### Transformer-less design

The first and most important difference in the BG series-cell electrolyzer designs (and most commercially available electrolyzers) is that this design lacks a transformer of any kind.

This modification is brought about by the theoretical and experimental understanding of the electrical needs of a BG electrolyzer (about 2 VDC per cell) and the electrical potentials readily available to the general public (120 VAC or 240 VAC).

**Traditional** electrolyzers use a 'single cell' design with lots of plate area to handle the hundreds of amps flowing through the cell. Because hundreds of amps (at about two volts) are needed for this traditional design, a **huge transformer is used** to convert readily available 240 VAC at 5 amps to about 3.2 volts at 375 amps (1200 watts drawn from the wall).

Transformers: are quite **noisy**; emit a lot of **heat**; **weigh** hundreds of pounds; are **expensive** (cost hundreds or thousands of dollars); and are **big**, needing room for their enclosure, as well.

The **series-cell** design allows **elimination** of the transformer, with its associated noise, heat, weight, size and additional expense (including the elimination of the fan, to cool the transformer, and the energy it took to run). The heat and noise of the transformer are symptoms of lost electricity (inefficient electrical coupling and induction). That electricity can now be used to directly produce Brown's Gas.

The **series-cell design** turns nearly all the electricity taken from the wall into gas production, **silently** and with very little heat wasted. Series-cell design allows **simple**, inexpensive, **compact** size that is **light-weight**.

### Simple power supply

This efficient, simple power supply design allows our watt-hours per liter of gas produced to be less than

commercial electrolyzers that use a transformer, and safer actually.

No complicated (or expensive) power supply is needed for the series-cell design. In fact, the power is fed in through high voltage wires that are much less expensive (smaller diameter) and simpler to wire than the huge cables needed for the traditional transformer design.

If electronic controls are desired (such as electronic relay instead of mechanical relay), high voltage electronics are less expensive and easier to install than high amperage electronics.

The diodes of a full-wave bridge rectifier are MUCH less expensive when you only need a low amperage rating.

Oversize the diodes by at least twice, because the amperage surges are greater than the average amperage. For a 5 amp electrolyzer, you need ten amp diodes. For a traditional 400 amp electrolyzer you need 800 amp diodes (VERY EXPENSIVE).

Also, the diodes of any full-wave bridge rectifier are much more efficient switching higher voltages at lower amperages. Rectifiers (diodes) each have a 'voltage drop' across them of about 0.6 Volt (a little more than 1/2 volt). When you multiply this voltage by the amperage going through the diode, you get the wattage wasted in the diode. This **wasted wattage shows up as heat**. I explain below:

With a 1200 watt electrolyzer at 2 volts across the electrolyzer, we would have 1.2 volts (the voltage required for the electricity to go through two diodes) times **375 amps** equals 450 watts (heat) in the rectifiers. More than 1/3 of the electricity going through the conventional electrolyzer is wasted as wattage (heat) in the rectifiers.

Further, this heat must be removed from the diodes (rectifiers) or they will fry. A huge heat sink (large, heavy and expensive) and a fan are usually

needed for electrolyzers using this much amperage. This is in addition to the fan required by the transformer.

However, a 1200 watt series-cell electrolyzer at 240 volts only needs to draw **5 amps**. 1.2 volts times 5 amps equals 6 watts heating the diodes. Only a small heat sink is needed to cool these diodes - no fan!

It should be remembered that AMPERAGE makes Brown's Gas, not voltage. And we've eliminated the transformer which allowed us to have 375 amps to make BG.

Again, the **series-cell** proves superior. It turns out that the amount of gas made by the electrolyzer is the product of the number of cells multiplied by the amperage flowing through all the cells in series. So 120 cells times 5 amps gives us **600 amps worth of gas!** We have nearly twice the gas with the series-cell than when we'd used the transformer with the traditional short cell.

### Power supply options

We strongly recommend that you actually take advantage of the 240 VAC that is available in most any home or shop.

Examples of appliances already using 240 VAC include: electric range; water heater; clothes dryer; and electric baseboard heaters. In the shop a lot of electric motors are 240, arc welders are 240, etc.

With an eight inch electrolyzer at ten amps @ 240 volts you can actually make 1,000 liters per hour. This is the rated output of Yull Brown's BN 1000, now (Jan., 1997) advertised retail at \$10,000.

The choice you make affects other design parameters such as how many cells you need and the final efficiency you want out of the electrolyzer.

These are the three options that meet the basic requirements to make

Brown's Gas, (all three use a full wave bridge rectifier):

1. Capacitive Limiting
2. Voltage Doubler
3. Voltage Doubler with capacitive limiting

Explore your power supply options in the Power Supply Designs chapter. Then apply your option of choice to the chapter on Sizing Your BG Electrolyzer.

Remember: to make a quantity of gas, you will need a large quantity of electricity. Lucky for you, you'll need less electricity with this design than if you'd bought a commercial unit.

### Electrolyte

Electrolyte is absolutely required to produce Brown's Gas in this electrolyzer design. The electrolyte is a chemical that acts as a catalyst, which means it assists the water splitting apart (by vastly speeding up the process) without being 'consumed' or changed in the process.

Having the electrolyte in the electrolyzer allows the electricity to efficiently split the water using only a fraction of the power that would be needed if the electrolyte wasn't there.

The electrolyte (catalyst) does NOT get consumed as the electrolyzer makes gas (see [Brown's Gas, Book 1](#) for details). As the water is split into hydrogen and oxygen, the electrolyte stays behind. The electrolyte is put in with the first fill of water and no more should ever be needed for the life of the electrolyzer. As the solution level gets low, just add water!

There are many electrolyte solutions. Some are better than others for reasons of compatibility with various materials, caustic properties, purchase price, availability, etc.

We have been experimenting almost exclusively with Sodium Hydroxide (lye or caustic soda) because of its efficiency, low cost and availability. A



mixture of **four parts water to one part Lye** (by weight) works well.

**WARNING:** The electrolyte (lye) mixture is extremely caustic. Animal fibers (wool, silk...) are readily dissolved. Vegetable fibers (cotton, hemp..) are not attacked.

Hydroxides are formed when metallic oxides are combined with water (Example: calcium hydroxide =  $\text{CaO} + \text{H}_2\text{O} = \text{Ca}(\text{HO})_2$ ). We will be experimenting with Aluminum Hydroxide, Barium Hydroxide, Calcium Hydroxide, Lithium Hydroxide (tested), and Potassium Hydroxide (caustic potash) (tested).

Eagle-Research electrolyzers operate with sodium hydroxide and are **not designed** to be compatible with any other electrolyte solutions.

Compatibility with other electrolytes would involve careful selection and **TESTING** of different electrolyzer materials than we are currently recommending.

### Sealing between cells

**Extremely important note:** The electrolyte in each cell must be electrically isolated from the electrolyte in every other cell. This 'forces' the amperage (electrons) to travel 'in-series' through each plate and electrolyte in turn, from negative to positive. If the electrolyte is common, the electricity will by-pass all the cells except the two end plates and the 'series-cell' will only be a common 2 volt cell.

A good example of this effect is an ordinary vehicle battery. The electrolyte, in each 2 volt cell, is isolated from the other 5 cells. In series, the six 2-volt cells make 12 volts. If the electrolyte in an ordinary automotive battery was common to all the cells, you'd simply have a 2 volt battery.

*Our experiments show that a slight electrolyte leakage between cells is acceptable. The cell spacers don't*

*have to be glued to seal well enough. A simple press-fit, as described, works great. Some people may want to put a tiny (1/16") hole in each plate to guarantee even liquid levels in all cells. This is not recommended. Our experiments show that plate effectiveness is reduced when a small hole is added.*

It is possible to make an automatic filling arrangement. But in our prototypes, we try to experiment with as few variables as possible. At this time, we do not have **automatic filling**. Further, you'd fill the electrolyzer perhaps once a day if you used it continuously at high volumes. We fill ours about once a week. It is good to get down and look over the machine once in awhile to see it's general condition and verify that you have no leaks. Thus we recommend against any kind of automatic filling arrangement.

### Plate masking

We have tested 'masking' the top of each plate. It seems NOT to be needed. Testing many different masking techniques produced no measurable advantage over not masking the plates.

*Originally, we figured that masking the tops of the plates was needed to avoid the bare surface of the plates touching the gas. We suspected that voltage and electron potential on the plates would cause the gas to go di-atomic. This seems NOT to be the case.*

### Plate degreasing

**EXTREMELY IMPORTANT:** if you do not remove the oil (degrease) from the plates before installing them in the electrolyzer, you will lose a huge amount of efficiency. The oil seriously inhibits the electrolysis process that makes Brown's Gas. (see *Degrease Plates*)

### Plate texturing

Texturing the plates is no longer a serious consideration. It seems that the

texturing process we were using was simply an inefficient means of degreasing the plates. The texturing seems to make no difference, but removing the grease/oil sure does.

*Originally, we thought that making little 'peaks' on the plates surface would cause an efficiency increase. Plate texturing does not seem to yield efficiency gains.*

### Plate material

There seems to be no advantage to going to exotic materials. We've tested things like iridium and platinum. Simple 316 stainless steel (SS) seems to be fine. Just remember to degrease the plates.

### Plate thickness

Plate thickness need only be enough to support it's weight without bending, while holding the plate by it's edge in a horizontal position. In most cases you don't need thicker than 0.015 inches. For smaller diameters 0.010 inches is enough. Be very careful the keep the plate flat. It is very easy to bend this thin sheeting.

### Plate spacing

Plate spacing is an extremely vital parameter. Generally, **WIDER** plate spacing is better than narrow. Believe me, this surprised us too. In fact, if the plates are spaced closer together, the voltage between the plates goes down. We thought the voltage efficiency would be increased. It was but the total electrolyzer efficiency **DECREASED**.

By 'electrolyzer efficiency', we mean the Watt/hr's per liter of gas produced. With 3/32" ( $\pm 2$  mm) plate spacing, we used over 5 watt/hr's per liter of gas and got **NO BG** ( $\pm 77\%$  efficiency).

With 3/8" plate spacing, we used less than 3 watt/hr's per liter ( $\pm 162\%$  efficiency). Actually, we noticed a decrease in efficiency at plate spacings wider than 3/8".

*I currently theorize that the wider plate spacing (3/8") allows atomic gasses to escape from the fluid as the ions travel through the fluid, BEFORE the ions reach the plates. Maybe the pulses of electricity help 'shock' the fluid (between the plates) enough to allow the oxygen & hydrogen atoms to break off, before the atoms reach the plates.*

*The flame (we've produced so far) tends to be a bit oxidizing. Perhaps the atomic oxygen separates before (or easier than) the atomic hydrogen does.*

Wider plate spacing also helps by storing more water in the electrolyzer, making it longer periods between refills. Note: you only refill with WATER. The electrolyte stays in the container as the water is split into oxygen and hydrogen and leaves.

### Number of cells

The number of cells depends on the exact voltage that is available to you; the electrolyte you choose; the concentration of electrolyte; the cell spacing and the power supply design you choose.

As you read more about the above parameters, you'll get a better idea of how many cells you want in your electrolyzer.

Generally speaking, try to reduce your options to 'givens'. Then you can figure how many cells you need.

Example 'Givens':

- 240 VAC available from wall.
- plate spacing 3/8 inch.
- Sodium Hydroxide electrolyte.
- 4:1 (four parts water to one part NaOH by weight).
- Voltage Doubler power supply.

These 'Givens' allow you to figure cells at 1.75 volts per cell (see *Voltage Doubler, in Designing Power Supply*). 240 VAC RMS / 1.75 gives 138 cells.

*It does not matter how big a diameter the electrolyzer is for this calculation. The diameter is more a factor of how much gas you need. Therefore, how*

*much amperage you will be putting through the electrolyzer.*

### Pure water

It is vital to add only pure water to your electrolyzer. If there are any impurities in the water, they will 'plate out' on the stainless steel plates, or create sludge or foam in the cells. Some impurities will cause poisonous gasses to form.

If you use pure water for operation refilling, it may be years before cleaning is needed.

We recommend that you use at least 50,000 ohm 'deionized' water, available from your local 'water dealer'. If you don't have access to deionized water, use distilled water.

When buying 'store-bought' water, be sure that *nothing* has been added. ('impurities' are often added to 'improve the taste' of the water.)

### Fail-safe features

The electrolyzer design described in this book is fairly safe. The pressure switch allows easy, automatic operation. The Bubbler reliably arrests backfires. (see *'Designing & Building a Bubbler'* to find a proper design)

The electronic liquid and temperature controls help prevent accidents (but should only be used as assist, not to replace personal monitoring of the electrolyzer). (see *'Liquid Level and Temperature Controls'* for our design)

The pressure relief valve (vented to outside your building, covered and placed high, to prevent garbage, insects & water from getting in) prevents the electrolyzer bursting in case the pressure switch fails.

DO NOT operate any electrolyzer without AT LEAST a PROPER pressure switch, pressure gauge and a bubbler. This can't be stressed often or hard enough. This is the MINIMUM operating equipment. Further, it PAYS to buy or build high quality equipment.

DON'T use cheap or substandard or incompatible materials for these items. Your LIFE depends on it.

*It so happens that I KNOW some of you will use substandard parts. I know this because I've been selling plans for various projects for years and I've seen the cost cutting and 'modifications' that some people apply.*

*For those of you who are tempted to cut corners in cost or quality of construction, I hope you find the next life interesting. It is only a matter of time before you won't have to worry about this one.*

*Worse yet, you might not be killed. You may be in extreme pain as the caustic solution eats your body and you'll live a long life scarred, blinded and crippled.*

*There'll be no sense in suing Eagle-Research for your mistake. Neither Eagle nor I have any assets to sue for. All the equipment and assets that we use for research are owned by others and the use is just donated to the project.*

*Personal use of this home-built experimental electrolyzer requires proper respect. Check the fluid levels often enough (particularly bubbler) to prevent a dangerous situation.*

*Keeping an eye on the pressure gauge and listening to the electrolyzer 'cycling' on and off works OK to prevent bursting due to over-pressure, if the pressure switch fails. You should notice if the 'cycling' stops. (I did. I was using a pressure switch that had an aluminum piston and cylinder. The hydroxide caused corrosion which prevented the piston from moving.) An electrolyzer producing high efficiency gas on an intermittent basis does not over-heat.*

*FEAR is a good thing here. You are working with a gas and equipment that could KILL you if you are not careful. Like driving a car, learn proper habits and adhere to them, EVERY TIME — even if you are in a hurry. This gas*

*demands respect. If you are **not afraid** of the consequences that could happen with this gas, you should **stay far away** from it. It **will KILL** you (or worse).*

*This is **EXACTLY** the fear that Yull Brown lives with everyday (me too), that one of you will kill (or maim) yourself. Yull Brown discourages experimentation. Eagle-Research tries to make it safe. Only time will tell which of our philosophies is best for mankind.*

*Remember, you are building **YOUR OWN** electrolyzer. You are used to **BUYING** equipment that meets government safety and design standards. All the government safety considerations imposed on manufacturers are now **YOUR** responsibility. It is up to **YOU** to build a safe electrolyzer. Do it right and you'll enjoy a wonderful electrolyzer. Do it wrong, and it won't be pretty.*

*If you don't have time to do it right now, when will you have time to do it over?*

### **Bubbler tank**

The bubbler tank prevents a backfire going to the electrolyzer, by separating the gas flow into very small bubbles that are each completely surrounded by water. The gas may explode (and implode) but the explosion **WILL NOT** travel through the water. The bubbler tank, as designed here, will contain the explosion.

The Bubbler is needed. It is the only thing we've discovered, so far, that will operate on a continuous basis, absolutely trouble free, **AND** reliably stop a backfire (explosion).

Design it properly and maintain a certain water level in it (about six inches above the diffuser). If you don't design it properly, it will explode (killing you or worse). If you don't maintain a proper bubbler liquid level, your electrolyzer will explode (killing you and blowing your shop into the surrounding area).

The Bubbler is made of thick Stainless Steel that can contain a backfire. **You WILL get many backfires**, so design a tank to be very strong. Extra money spent here is **CRITICAL**.

*The bubbler in this book is already designed to be twice as strong as the one we use. Our original was already safe. My point is: you do not need to make the bubbler of thicker steel than specified.*

Use a reliable welding shop to weld your bubbler tank together. **DO NOT** accept shoddy work. Your life depends on it.

### **Liquid-vapor separator**

To prevent liquid from being drawn from the electrolyzer, take the gas from the highest point possible. This requires a hole in the shell, not the end-plate.

In some cases, a liquid-vapor separator (l-v s) arrangement is still needed. (I use one as a matter of course), because liquid can be carried by the gas coming from the electrolyzer.

The l-v s is simply a wide spot in the hose going from the electrolyzer to the bubbler. We make it out of ordinary schedule 40 clear PVC pipe and caps, 2" diameter X a foot high.

Locate the l-v s above the electrolyzer so that any liquid it contains can drain back to the electrolyzer.

Use at least a 1/2 inch inside diameter hose from the electrolyzer to the l-v s, to allow for easy draining. Don't allow any dips in this hose, or the 'liquid puddle' that forms in the dip will prevent the liquid-vapor separator from draining.

The hose from the top of the liquid-vapor separator to the Bubbler can be 3/8". Check-valve and valve #2 can be 3/8". We like to use gate valves. Ball valves are unreliable for this service. Get a high quality check-valve. (*see Resources*)

Note: you must keep your check-valve clear or it will get debris stuck in the seal and will leak. If your check-valve leaks, it'll drain your bubbler into your electrolyzer. This will over-fill your electrolyzer and cause dangerously low water levels in your bubbler.

The valve # 2 is in-line coming out of the liquid-vapor separator (Fig. 1). This deliberate arrangement tends to keep contamination from the bubbler tank, getting stuck in the check-valve. Contamination tends to drop straight down onto the gate valve. If any gets over to the check-valve, the gas flow tends to blow it back over to settle on the gate valve. When you open the gate valve to put water into the electrolyzer, the contamination (bits of dirt and metal from the bubbler tank) gets drained to the electrolyzer, where it might contaminate the electrolyzer but won't likely hurt anything.

## **SIZING A BG ELECTROLYZER**

### **Gas volume needed**

You need to decide how much gas volume you need for your applications.

For jewelers'-work and electronics, you only need a very small flame. This is the size of torch that the BN 200 was designed to operate. We think the BN 200 was a bit small. An electrolyzer with less than a 500 liter per hour capability is not recommended.

*We size our electrolyzers as ER XXXX (Eagle-Research). So, an (Eagle-Research) electrolyzers rated for 1,000 Liters per hour would be an ER1000.*

The series-cell design will operate efficiently at any volume up to its total capacity. If you need only 400 liters per hour (L/h), you could use a 2400 L/h electrolyzer, but you'll be paying more money than you have to, to build the electrolyzer. In addition, you'd need a 60 amp breaker.

The operating expense would be the same if you take 400 L/h from a

500 L/h electrolyzer or a 2400 L/h electrolyzer. The 2400 L/h electrolyzer would cost more to build and require a greater amount of amperage from your power supply during the shorter times it is operating (it would switch on for only very brief moments).

Note: it is NOT efficient to operate any electrolyzer at low amperage. Operating below a certain amperage causes LESS mon-atomic gas to be formed. It is best to have the electrolyzer operate at it's rated amperage, then shut off when it's pressure is reached. Turn it back on again when the pressure drops a bit.

Note: For those people who think of just using a pressure-relief valve to control the pressure in the electrolyzer (instead of a pressure switch and relay), consider these points:

1. Your pressure relief valve is likely to fail because of hydroxide film buildup, which prevents the seal from sealing.
2. You spent money in electricity to make the gas that you are throwing away.
3. Electrolyzers that operate full-on, all the time, quickly overheat and melt down.
4. It is not hard to wire in a switch and relay. Further, the switch-relay combination allows many more automatic controls to be added easily.
5. The pressure relief is strictly a final safety precaution to prevent bursting, due to over-pressure. (Actually, it should never open.)

The slight amount of moisture that accompanies the gas presents some trouble for small torch tips (< #000). The moisture tends to condense in the torch hose, puddle and flow along to the torch tip. The 'slugs' of liquid plug a small orifice, for an instant, as they go through it. This effect causes your flame to go out. It could also cause a backfire.

If your application involves very small flames, use a bubbler that is extra high (± three feet) with multiple layers of coarse SS screen in the top 16", to help condense the water moisture. Don't make the screen holes too fine (not less

than 1/4" gaps between wires) or the condensed liquid won't drain back against the gas flow. Don't use too fine a material for the screen (less than 1/16" SS wire) or the backfires will burn it up.

*We've done some testing on torch tip gas volume requirements. For most applications (including cutting 1" thick steel) a #0 torch tip or a #0-3 cutting tip is adequate. A 1,000 L/h electrolyzer will support these applications. 1,000 L/h requires 16 amps @ 240 VAC.*

A 2400 L/h electrolyzer will support up to a #6 torch tip. This requires 48 amps at 240 VAC or 11.5 Kwh of power. You can do some serious melting of various materials with this size of tip, but you are virtually assured of a backfire when you shut it off. It is very hard to shut off the flame quickly enough.

Note: to idle a small four cylinder engine (140 cubic inch), you need in excess of 3000 L/h)

The following chart shows minimum acceptable flame volumes in L/h, and maximum possible volume (the volume at which the flame goes out due to excessive gas velocity). The 'Amps' part of the chart shows the DC amperage requirements of a 126 cell electrolyzer, at 240 VAC, to get the MINIMUM gas volume (L/h) required for the 'Torch Tip'. You can figure the Max. amperage (requires more amperage) in direct ratio to the liters Max. L/h produced.

Tip:	Min.: L/h	Max.: L/h	Minimum Amps:
000	250	300	4.55
00	500	1100	9.01
0	550	1200	10.00
1	600	2000	10.70
2	650	2400	11.80

*Remember that as you clean a torch tip (with little round files) the orifice size gradually increases. This makes it into a larger torch tip and it will require greater gas flow to prevent backfire.*

## Available power

You need to decide how much and what kinds of power you have available to operate an electrolyzer, before you decide how many cells you will put into your electrolyzer.

As you can see from the previous data, a 1,000 L/h electrolyzer will require 16 amps at 240 VAC. Our actual efficiency is better than 4 watt-hours per liter BUT for figuring out your needed power it is better to deliberately figure on the less efficient side.

A 20 amp 240 breaker would just hold this application. Just make sure your breaker is rated for about 30% more amperage than you will be running.

It is unreasonable to expect a breaker to continuously hold an amperage near it's rated capacity. Every time a breaker is tripped, it doesn't hold as well the next time. This is how they 'wear out'.

To figure your needed **power requirements** for any given electrolyzer, figure it's **MAXIMUM** amperage capability. That's what it will do whenever it is on. This is another reason not to over-size your electrolyzer. You may not be able to power it. If you do have an over-sized electrolyzer, there are some tricks to make it use less power (of course it will make less gas too).  
(see *Designing Electrolyzer Power Supply (Capacitive limiting)*)

If you are using only 200 L/h from a 1000 L/h electrolyzer, then you will use (at 240 VAC) 16 amps for one minute in every five minutes. The electrolyzer power requirement math goes like this: Multiply the liters per hour times 4 watt-hours (this equals the total watt-hours required) and then divide the total watt-hours by the voltage to be applied to the electrolyzer; you now have the amps required.

Eg: 1000 L/h \* 4 Wh/L = 4000 Wh  
4000 Wh / 240 VAC = 16.6 amps.

Eg: 1000 L/h \* 4 Wh/L = 4000 Wh  
4000 Wh / 120 VAC = 33.3 amps.

There is a great advantage to going to the higher voltage. Higher amperage parts are very expensive. Higher voltage parts are smaller and less expensive. 240 VAC is available most everywhere.

*In North America, some places use 110 to 220 VAC power, others use 115 to 230 VAC and other places use 120 to 240 VAC power. This small voltage difference makes little difference to most equipment. It WILL make a difference in designing your electrolyzer and power supply. Measure your wall voltage before designing your electrolyzer.*

### Electrolyzer diameter

Extra plate diameter allows higher amperage efficiently. Gas flows assume 240 VAC wall voltage, 126 cells, 3/8 inch plate spacing, 4:1 NaOH and voltage doubler power supply.

Note: it is more efficient to run higher amperages (within the ratings) for shorter times.

Note that the amperages below are for DC voltage across the electrolyzer; you WILL be drawing more AC amperage from the wall than you note as DC across the electrolyzer. Example: our 30 DC amp ten inch electrolyzer draws 48 AC amps from the wall. This is an effect of the voltage doubler.

<u>Dia.</u>	<u>Min. DC amps</u>	<u>Max. DC amps</u>
6"	4 amps (355 L/h)	7 amps (673 L/h)
8"	9 amps (799 L/h)	16 amps (1539 L/h)
10"	18 amps (1598 L/h)	30 amps (2886 L/h)
12"	25 amps (2220 L/h)	42 amps (4040 L/h)

The diameters mentioned are 'nominal' sizes of CPVC schedule 80, which I recommend as the electrolyzer 'shell'. The actual inner and outer diameters of the CPVC pipe are different than the 'nominal' size. You can get the actual

inside-outside diameters, 'out of round tolerance' and the wall thickness (with min.-max. tolerances) specifications from the manufacturer who sells you the pipe.

'Volts' are not mentioned as a consideration for electrolyzer diameter. That is because the only factor that matters here is AMPERAGE per inch of plate surface. Rule of thumb: ± 0.5 amps per square inch of plate surface.

Pressure is a consideration here. Larger diameter pipes generally operate with less pressure. Our twelve inch schedule 80 CPVC is still well within acceptable pressure limits, as long as no backfire EVER goes through the Bubbler and reaches the electrolyzer. I assure you (**BECAUSE WE'VE HAD IT HAPPEN**) that the electrolyzer will pop (burst) like a balloon if its pressure rating is exceeded, spreading plastic and electrolyte everywhere in your shop. It's not nice.

### Plate spacing

All calculations in this book are based on 3/8" **recommended plate spacing**. We've done a huge amount of testing on various plate spacing. 3/8" is the best we've found!

The plate spacing affects the number of cells, and thus the length of the machine.

In a practical sense, this means that the AMPERAGE will increase given a certain number of cells, a set wall voltage and making the plates closer together.

Of course, the opposite is true too. Given a fixed number of cells and fixed voltage input; AMPERAGE will decrease by making the plates farther apart.

As a rule of thumb, don't go closer than 1/4" plate spacing per cell for any reason. Closer than this causes a severe problem with the foam crawling up the plates, making a need to keep

extra low liquid levels in the electrolyzer.

If the plates are too close together, it is more difficult to properly fill the electrolyzer. Air tends to get trapped between the plates.

There is no reason to go wider than 1/2" between the plates. In fact, 3/8" shows up as more efficient than 1/2".

Further, and actually most importantly, both electrolyzer efficiency and the wattage efficiency go down with the plate spacing too close. Too close is closer than 1/4".

### Kind of electrolyte

Unless specified otherwise, this book deals with **sodium hydroxide**. We've already tested a variety of electrolytes and found nothing better than sodium hydroxide.

### Electrolyte concentration

Unless otherwise specified, use a 4:1 mixture (by weight) of sodium hydroxide. This is four parts water to one part hydroxide, or a 20% solution. This is not something to take for granted, but it isn't really caustic either. If spills are cleaned up immediately very little burn will result.

We have done extensive testing with various solutions and discovered the best results with the stronger solutions. Mostly, the strong solutions help reduce the foaming problem and allow a lower voltage resistance per cell.

It is a great advantage to be able to use leaner mixtures, because of reduced initial electrolyte cost, and reduced chance of harm during filling, draining, leaks and (God forbid) explosions. Leaner mixtures (as lean as 72:1) work fine in the electrolyzer, but lean mixtures reduce your natural amperage flow. To get your amperage flow back, just add a lot more capacitance on the voltage doubler (this makes the enclosure larger and more expensive).

## Power supply option

The power supply is VITAL to making Brown's Gas. Straight DC voltage will **not** produce Brown's Gas. The electricity **MUST** be pulsed. We have worked with the natural pulses available to us from the wall. Remember this is a KISS book (Keep It Seriously Simple).  
(see *Power Supply Designs*)

## BUILDING A BG ELECTROLYZER

### Safety tips

Protective clothing should be worn at all times. Coveralls should be vegetable fiber, such as cotton.

Ordinary shop work can be done with leather gloves. Use disposable latex gloves to handle sodium hydroxide.

It helps to have a full rubber apron while handling sodium hydroxide as any caustic solution. Boots should be compatible with sodium hydroxide (lye) solution.

Eye protection should be worn **at all times** in any shop environment. Keep a spray bottle of vinegar on hand to spray on any lye spill, particularly spills on human skin (lemon juice works well too). This helps neutralize the caustic action 'til you can wash it with ordinary water.

An eye flush station should be installed in your shop, along with stored fresh water, because in the case of a major accident your electric power ought to be shut off. Hence, you'll have no running water. (*safety supplies - see Resources*)

### Electrolyzer list of materials

This list of materials is for assembling a general electrolyzer; no sizes or quantities are given, except where all the electrolyzers are the same. This list is for the electrolyzer ITSELF. It does not include the Control box, Bubbler or any connecting hoses or wires. *For specific specifications and sizes of the*

*electrolyzer parts. see the appropriate sections in this book.*

### WARNING; DO NOT USE ALUMINUM ANYWHERE IN THIS ELECTROLYZER DESIGN!

Aluminum reacts violently with Sodium Hydroxide in the presence of water. Aluminum hides in strange places, like wetted parts of most pressure switches and pressure gauges. When purchasing parts, verify compatibility in writing, so you can send the parts back if incompatible. If purchasing 'surplus' you can get great prices, but 'Buyer Beware'. You get NO guarantees.

- One shell, schedule 80 plastic pipe.
- Two plastic end-plates, 3/4" thick (height and width depend on shell diameter). Best to use **CPVC plastic** for shell and end-plates (CPVC can take up to 160°F before it has problems with these pressures, PVC can only take 120°F).
- Steel end-plates, (all other specifications dependent on shell diameter, found elsewhere).
- Spacer rings, 3/8" wide, cut from schedule 40 PVC (all other specifications dependent on shell diameter, found elsewhere).
- Through-bolts, nuts, flat washers, (all other specifications dependent on shell diameter, found elsewhere).
- End-gaskets, two sheets of 1/8 inch thick EPDM rubber, about 60 to 90 hardness (all other specifications dependent on shell diameter, found elsewhere).
- Stainless steel power-bolts, washers, nuts, (all other specifications dependent on shell diameter, found elsewhere).
- 1/8" EPDM O-rings for sealing power-bolts (all other specifications dependent on power-bolt diameter, found elsewhere).

- Plastic spacers for around power-bolts and liquid level tubes, cut out of triangle left by cutting corner off the plastic end-plates.

- Sodium hydroxide, amount determined elsewhere.

*Note: Copper pipe fittings are OK with sodium hydroxide. Brass is slightly incompatible (surface turns black), which means you can use it in non-critical areas (everywhere except inside the pressure switch and gauge).*

- 3/8" MNPT to 1/2" barbed fitting for 'gas out' hose, with one #6 hose clamp.
- 2 of 1/8" pipe nipples for liquid level sight tube.
- 2 of 1/8" Tee, with male on run; for Tee off liquid level sight tube and valve 3 and 4 on run.
- 2 of 1/8" Brass needle valves (or gate valves preferred) for valves 3 and 4. Be sure to install so the 'valve stem packing' is on the outside, not in contact with the pressurized electrolyte.
- 2 of 1/8" MNPT to 1/4" barbed, for the sight tube.
- One length of 1/4" ID clear, braided PVC hose, with 2 of #4 hose clamps.
- One small HDPE plastic ball, to float inside the sight tube.

Note: There will also be additional holes in the electrolyzer (shell or end-plates) for various temperature and pressure sensors, depending on the type of gauges and controls you choose.

(see *Building A Control Box*)

The following list of components and fittings is for the special 8" electrolyzer we are building to demonstrate at the 1997 Tesla Symposium.

These lists (based on our ERXXXX) are included to assist you in making a checklist for your own electrolyzer.

The list for the power supply and bubblers are in the appropriate sections of this book.

<u>Component</u>	<u>Quantity</u>
• 2 1/2' x 8" clear PVC Shell .....	2x
• 2 1/2' x 7/16" Bolts .....	20x
• Box of 7/16" Nuts .....	1x
• Box of 7/16" Lock-washers .....	1x
• Box of 7/16" Flat-washers .....	1x
• 10" x 10" CPVC Endplate .....	4x
• 10" x 10" 1/4" Iron plate .....	4x
• 1/8" thick Rubber Gasket .....	4x
• 5/16" SS Bolt, washers, nuts .....	2x
• 5/16" Plastic Bushings .....	2x
• 7.8" S.S. Plates (disks) .....	132x
• 8" PVC Rings .....	130x
• 2 ft. 1/4" PVC Tubing .....	1x
• 8' of 1/2" Tubing .....	1x
• 8' of 1/4" Tubing .....	1x
• 2' of 3/8" Tubing .....	1x

<u>Fittings</u>	<u>Quantity</u>
• 1/4" Panel Mount Valve .....	2x
• 3/8" Check Valve .....	2x
• 1/2" Barb-3/8" MPT .....	6x
• Tee, 3/8" FPT all ends .....	2x
• 1/4" Barb-3/8" MPT .....	5x
• 3/8" Street Tee, MPT on run .....	1x
• 3/8" Street Elbow .....	1x
• Tee, 1/4" FPT all ends .....	5x
• 1/4" Close Nipple .....	4x
• 1/4" Barb-1/4" MPT .....	16x
• 1/4" Barb-1/8" MPT .....	1x
• 1/2" Close Nipple .....	2x
• 1/2" Cap .....	2x
• 1/4" Barb-1/4" FPT .....	1x
• 3/8"-1/4" Bushing .....	1x
• 1/4" Bulkhead .....	1x
• 1/8"x1-1/2" Long Nipple .....	4x
• 1/8" Barb-1/8" MPT .....	6x
• 1/8" Street Elbow .....	4x
• 1/4" Barb-1/4" F. Flare Swivel .....	4x
• 1/8" MPT-Flare Needle Valve .....	4x
• 1/4" Hex Cored Plug .....	1x
• 1/4" x1-1/2 Long Nipple .....	1x
• 1/4" Street Elbow .....	1x
• 1/4" FPT-MPT Needle Valve .....	1x
• 1/4" MPT- Acet. ....	1x

**Cut rings from tube**

Note: No spacers, to separate the plates in the electrolyzer design, are depicted (Fig. 1). They are there, just not shown. We used PVC plastic 'ring'

spacers, shaped to hold the metal plates apart all around the outer edges. PVC for the rings because it is less expensive than CPVC and doesn't have to hold pressure.

We like using schedule 40 PVC pipe as ring-spacers, getting the same nominal size as the schedule 80 CPVC chosen for the outer shell. The schedule 40 has a thinner wall. This works perfectly as spacers. So schedule 80 for the shell, and schedule 40 for the rings.

The thickness of the spacer should be enough to cover (by at least 1/8") the edge of the plate and any gap. That's why we use schedule 40 pipe. The rings are cut from pipe that is the same nominal size as the shell. This makes it slightly too large to fit inside the electrolyzer. Then a small section is cut from the ring so that the ring will now squeeze to a smaller diameter, fitting inside the shell with a 'spring loaded tension'.

*Assembly tip: Norman Wootan developed a simple jig to cut narrow rings from large diameter plastic pipe (6" to 12"). He set up rollers so that the pipe could be rolled while over a table saw. He set up another roller to act as a stop. We modified this to be a piece of plastic, screwed to the table saw fence.*

*The procedure is to lower the table saw blade, slide the pipe sideways to the stop (saw fence set, for example 3/8" ring, after saw kerf) and then raise the table saw blade with the saw running. The saw would cut upwards into the pipe. When the saw has cut fully into the pipe, you rotate the pipe to finish cutting off the ring of plastic. (note; rotating the pipe one way may be better than the other, try both ways). Then lower the saw blade again so that the pipe can be advanced (slide sideways) to cut off the next ring.*

*Mr. Wootan used a special plastic table saw cutting blade (available from US Plastic Corp.) to assure a smooth cut on the plastic.*

*Note: The cut must be done fairly quickly to prevent plastic from 'cooking' right onto the saw blade. The special saw blade is designed to minimize this problem but it still happens over a period of time. When a residue of plastic accumulates on the blade, just sand off the plastic accumulation with sandpaper and/or a disc sander.*

*Another method to cut rings would be to use a large band saw of the type used to cut steel pipe. Local metal wholesalers would have such saws.*

*Abrasive 'cut-off' saws work quite well. The problem would be finding one large enough. This method worked extremely well for our tiny 2" series-cell test electrolyzers.*

**Size rings**

After you've cut the rings from the pipe, you need to cut a small section out of the ring to allow the ring to (squeeze together enough to fit inside the shell.

Determine the amount to cut out by test cutting one 'til it fits. Insert the rings in a clamp-jig and cut several at a time with a saber-saw. It doesn't matter if there is a slight gap (1/8") when the ring is inserted into the shell.

Ordinary pipe-style wood clamps will work to hold the rings in place while you make the two cuts that remove the section out of all the clamped rings.

**Mark out plates**

Contact a laser-cutting or abrasive water cutting service, to have your plates made for you. Most cutting companies will do small runs at very reasonable prices.

It is possible to have the plates 'stamped out' too, but you'll have to pay an 'up-front' fee (at least \$1,500) for the stamp made to your specifications, and then about \$1.31 in quantities of 1,000.

An alternative is to find someone who can stamp plates in round circles and then you just cut off the flat edge. One such company (for six inch disks) is Bokers, Inc. (*see Resources*). They have a 'standard' stamp that will cut 0.015" thick of 316 stainless steel at 5.603 inches in diameter +/- 0.010". They will charge about \$2.40 per plate for quantities as low as 250.

One of my readers stumbled onto a real find. He found a range manufacturer that is using stainless steel for their range lids. They were throwing the circles they cut out (for the elements) away. Perhaps with a bit of looking you can find a manufacturer that stamps circles out of their product and get a deal too. Then you just choose the pipe diameter that fits your plates.

But, assuming you want to do it yourself, like we did, here's how we did it.

First you make a 'Master Plate' (out of steel); which is a plate that is exactly the way you want every other plate to be. You will measure your pipe and make the plates so they fit inside easily.

Plate height (from flat top to bottom of plate) is important, we want as high as possible without impeding gas flow. And we want to be low enough for easy liquid filling.

**Rule of thumb would be:**

Six inch electrolyzer, 5.6" diameter circle, cut off at 4.85"

Eight inch electrolyzer, 7.5" diameter circle, cut off at 6.5"

Ten inch electrolyzer, 9.4" diameter circle, cut off at 8.15"

Twelve inch electrolyzer, 11.2" diameter circle, cut off at 9.7"

For example: the six inch diameter schedule 80 CPVC pipe has an inner diameter of about 5.657 and so we make the plates 5.6 inches in diameter, with the flat side 4.85 inches. Note the shape of the plates in figures two and three in the first chapter of this book.

Note: the pipe (shell) WILL NOT be perfectly round, careful measuring (with calipers) will show you an oval shape. I think this is from storage stacking or some such reason. In any case, your plates will have to fit on the inside of the thinnest diameter.

Also note: that the pipe has a 'tolerance' of a few fractions of an inch, so it may be wider or narrower than the nominal specifications. Further note: different manufacturers of the same pipe WILL have slightly different diameters. So it is best to get your pipe before cutting your master plate.

You lay your stainless steel sheet out on a large table, then (using a carbide tipped scribe and a long straight edge) you scribe a line across the steel sheet. This line is the height of the plates. In this case we scribe a line 4.85 inches (which is the height of the plates) from the sheet edge.

Once we've scribed the line, we take our 'master' plate (make one perfect plate first) set it against the line and scribe out the plate outline for all the plates on that strip, defined by the original scribe line and the edge of the sheet. If you have extra room, leave as much space between the plates as possible, to help with the rough cut.

### **Cut plates**

We cut off the original scribed strip from the sheet with the electric sheers. Cutting one way will leave the metal straighter than cutting the other. Try both for yourself and use the best. Don't use hand sheers, they make a mess of the steel and it is hard work.

Once the strip is cut off, rough cut all the plates out of the strip (make squares). Then cut them out exactly. This is the method that we've found to home-make the flattest plates.

### **Straighten plates**

An advantage of having the plates professionally cut is that you won't have any wrinkled plates.

But if you cut your own, you may have to flatten bends or wrinkles in your plates. Try to do so without hitting them with a hammer (straighten by hand). A hammer blow causes the metal to stretch at the point of impact, causing a tendency to bulge that is very hard to remove from the steel.

Lightly hammering on some edge wrinkles should be OK.

When finished, every plate should be flat enough that the entire plate disappears behind its edge when viewed edge-on.

If a plate is too badly bent, working on it more will not straighten it past a certain point. You will have to decide if that point is straight enough or you discard the plate. Remember that the plate is held in place around its entire edge (except top) and this holding will hold a slightly bent plate straight.

### **Degrease plates**

There are several good degreasing solutions. All of them are dangerous. Take extreme care handling these solutions. Containers containing solutions and plates are VERY heavy. Keep solutions in warm but well ventilated area, the gasses that come off these mixtures are toxic (smell bad too).

At this time we just use sulfuric acid of 1.26 specific gravity (buy in local automotive supply store, for use in filling lead acid batteries). We soaked the freshly cut out plates overnight in the sulfuric acid, periodically separating the plates with a plastic comb to assure acid wash everywhere.

When the reaction stopped (makes bubbles and the solution turns dark) we'd take the plates out of the acid (wearing disposable latex gloves) and wash them in fresh water, using a brush to wipe off the oily residue.

It is important to handle the plates only by their edges or you'll push the oil right back into the surface of the plate; also brush the oil off the plate surface using a sideways motion, again to



prevent pushing the oil back into the plate. Brushing the plates while under running water is a good idea.

Note: we are still experimenting with various degreasing techniques.

Recommended de-grease procedures by Master-Bond:

1. Sand blast or sand with machine sander to remove surface deposits and to break surface tension. Then preliminary degrease with trichorethylene, then immerse for ten minutes at 70-85°C (160-185°F) in a solution of;

- Sodium metasilicate ..... 2 kg (2 lb)
- Tetrasodium pyrophosphate ..... 1 kg (1 lb)
- Sodium hydroxide ..... 1 kg (1 lb)
- Nansa S 40/S powder ..... 300 grams (5 oz)
- Water ..... 100 liters (10 gal.)

Wash with clean cold water, followed by clean hot water, dry with hot air.

2. Sand blast or sand with machine sander to remove surface deposits and to break surface tension. Then preliminary degrease with trichorethylene, then immerse for ten minutes at 85-90°C (185-195°F) in a solution of;

- Oxalic acid ..... 9.25 kg (18.5 lb)
- Sulfuric acid (S.G. 1.82) ..... 5 liters (1 gal.)
- Water ..... 75 liters (15 gal.)

Wash with clean cold water, brush off black deposit, followed by clean hot water, dry with hot air.

3. Sand blast or sand with machine sander to remove surface deposits and to break surface tension. Then preliminary degrease with trichorethylene, then immerse for fifteen minutes at 50°C (120°F) in a solution of;

- Sodium bichromate (sat. sol.) ..... 0.35 liters (0.35 gal.)
- Sulfuric acid (S.G. 1.82) ..... 10 liters (10 gal.)

Wash with clean cold running water, brush off black deposit, dry with hot air.

**Note: Preparation of saturated solution of Sodium bichromate:** Heat the appropriate quantity of distilled water to 50°C (120°F). Add, with stirring, powdered sodium bichromate until it ceases to dissolve. Allow to cool to room temperature and then stand for one hour before pouring off saturated solution.

**Mixing procedure:** Add the sulfuric acid to the saturated sodium bichromate solution in a slow steady stream while continuously stirring. The precipitate formed will mostly dissolve as the acid is added.

**Holes in plates**

Fluid equalization holes in the plates are not recommended. Our experimentation has shown several problems that make this a bad idea. We achieve fluid equalization by tipping the electrolyzer.

We would put fluid equalization holes in the plates of very large electrolyzers that will also have automatic pressurized water filling.

But in small portable electrolyzers, it is NOT a good idea. Some of the many reasons include and are not limited to; 1) the loss in efficiency as electrolyte 'shorts' through the plate, 2) the loss of efficiency as a significant area around the hole doesn't produce gas, 3) the possibility of one end of the electrolyzer becoming flooded if the electrolyzer is not perfectly level, 4) and the other end of the electrolyzer having too little solution for the same reason.

**End Plates**

The pressure inside an electrolyzer pushes outward by the force in pounds

per square inch times the square inches of end plate exposed to the gas.

All plastic end plates are 3/4 inch CPVC plastic.

Below is a chart of the total force of the end plates pushing against the through-bolts at an operating pressure of 70 psi:

<u>Electrolyzer</u>	<u>Force on through-bolts</u>
6" .....	3,690 pounds force
8" .....	6,390 pounds force
10" .....	9,890 pounds force
12" .....	14,225 pounds force

This is why we use iron re-enforcing plates over the plastic end plates. The flat plastic could not hold these pressures by itself. And the steel allows a safety range.

The round shell has no trouble at these pressures; but you can see that a sudden pressure increase would burst an electrolyzer of this design. We have designed the electrolyzer so that there will be no sudden increases in pressure in the electrolyzer, even under backfire IF your Bubbler tank is designed properly and used properly.

These pressures are also why we use progressively larger through-bolts to hold the end plates onto the electrolyzer. Check out under 'Through-bolts'.

The thickness of the iron end plates varies with the diameter of the electrolyzer:

<u>Diameter</u>	<u>Thickness of plate</u>
Six inch .....	1/8 inch
Eight inch .....	1/4 inch
Ten inch .....	3/8 inch
Twelve inch .....	1/2 inch

Nominal Pipe Diameter	CPVC Pipe Outside Diameter	Estimated Through-bolt Circumference	Estimated Through-bolt Radius	Number of Bolts	Center to center of bolts
6" .....	6.625" .....	22.100 .....	3.518" .....	8 .....	2.782"
8 .....	8.625 .....	28.574 .....	4.550 .....	10 .....	2.857
10 .....	10.750 .....	35.639 .....	5.675 .....	14 .....	2.545
12 .....	12.750 .....	42.115 .....	6.706 .....	16 .....	2.632

To discover the measurements needed for your endplate dimensions and for hole placement, see below:

You will measure the outer diameter of your plastic shell, add the diameter of ONE of your through-bolts, add a 1/16" (for 1/32" clearance between shell and bolts, mostly to allow for the oval shape of the pipe) and this will be the centerline diameter of your through-bolt holes (check with size of through-bolts later in this chapter). Then you add 2.5 inches (for flange width) to get the square outside dimensions of the end plates (remember you need two iron and two plastic of this size).

After you've cut out the four squares (two iron and two plastic), take one of the iron plates, scribe and center-punch the appropriate spots to drill your holes. It helps to use machinists bluing or masking tape where you are marking.

You find the center of a square by scribing from corner to opposite corner (45° angle), center-punch this spot to hold one end of your compass. Set your compass with the radius (1/2 the centerline diameter) of your through-bolts (it helps to make a bit of a line first and measure it with a ruler to make sure your compass is set right).

You want a through-bolt to go through about every 2.5 inches on your through-bolt circumference. We put several bolts around the circumference to have an even pressure on the gasket (helps to seal) and to spread the end plate pressure to several points (helps prevent warping).

The 'cage' of bolts also breaks up the plastic pieces if you happen to burst your electrolyzer, thus only smaller pieces of plastic fly. They still hurt when they hit you.

You do **NOT** want a through-bolt to go through dead center of the top (12: o'clock position) because this is where your gas-out tube will go (in about the middle of the shell, not the end plate).

So space your bolts so that you have a space at the 12 o'clock position.

#### **Below find a typical chart of CPVC pipe specifications:**

Select the number of bolts you want to use and divide your through-bolt circumference (found by multiplying the through-bolt diameter times 3.14) by that number of bolts (as per the above chart). Set your compass for that exact measurement (Center to center of bolts). The above chart is an estimate only, your pipe may be slightly larger or smaller than the diameter indicated. So be sure to do your own measuring and figuring as per these instructions.

Proceed to mark intervals around your through-bolt circumference with your compass, where you want your through-bolts to be. Remember **NOT** to put a bolt through at the top, space your bolts so 12: o'clock position is in the middle of a space. Center punch the intervals.

**Assembly Tip:** It helps to clamp both your steel end plates and your plastic end plates in a sandwich (two plastic plates between the iron ones) before you start to drill the holes; then you only have to mark one plate and drill only one set of holes (and all the holes will line up perfectly).

I advise to use a drill-press whenever possible. Remember to wear gloves and goggles. Always clamp your work to the press before drilling. Make sure the drill bit won't drill into your press-table. Set the press to the appropriate speed for the bit you are using.

**Assembly Tip:** Pre-drill all your holes with a smaller drill bit that is about the size of the web on the tip of your larger drill bits. Holes up to 1/4 inch don't require pre-drilling.

Drill the center hole for your power-bolt size. Drill the through-bolt holes.

**Note:** I recommend two 3/8" power-bolts through each endplate for any amperage greater than 30 amps. Or the bolt will get too hot and melt your

plastic. Be sure to silver-solder both power-bolts to the SS endplate. In any case it is a good idea to use more than one bolt whenever you expect to have higher amperage.

Remember that the power-bolts don't have to be in the center; you can have them anywhere it is convenient for you.

Pre-drill the holes for the sight tube; don't go all the way through the first plastic (don't drill into the second plastic plate with these holes) unless you want to have sight tubes on both ends of the electrolyzer. Note that the sight tube holes are off-set so that you have room for a curve in the hose, or (in the larger endplates) so the clear sight tube will miss the center bolt.

Center power-bolts for six inch are 1/4 inch in diameter, eight inch electrolyzers are 5/16 inch in diameter. Ten inch electrolyzers should have 3/8" power-bolts. Twelve inch electrolyzers should have two 3/8" power-bolts (or more of smaller bolts).

I repeat **Note:** I recommend two 3/8" power-bolts through the endplate for any amperage greater than 30 amps. Or the bolt will get too hot and melt your plastic. Be sure to silver-solder both power-bolts to the SS endplate.

The O-rings around the center bolts can be compressed to 1/3 of their diameter. Use about 50 hardness EPDM material for the O-ring. Drill the appropriate sized counter-sink in both sides of the plastic endplates. The O-ring will make an oval, about 1/3 wider than it's original diameter; so you need to make the counter-sink a bit deeper than that; **NO MORE!!!!!!**. The washer on one side and the plastic spacer on the other will hold the O-rings in place.

To give an example of the countersink hole size: Assuming a 5/16 SS bolt that we are sealing with 1/8" O-rings. The O-ring is normally a fraction less than 5/16" ID (0.309"). 1/8" (0.130) less 30% equals 0.09.  $0.309 + 0.09 + 0.09 = 0.48$  inches. Find a drill bit

extremely close to 0.48 inches. Drill to a depth of 0.18 inches (0.13 + 0.04 + 0.01).

Assembly tip: Use a drill press when drilling a shallow hole in plastic so you can control the exact depth of the hole (set the depth stop). Fasten the plastic securely to the press table so that the drill won't suck it up.

Assembly Tip: Take extra care to mark all your plates for their direction and orientation before un-clamping them after drilling. There are several very important reasons for this. Your holes will not be exact and this will assure that they always line up. Also it is VITAL to make sure the endplate 'tip' angles are cut correctly.

**Cut tip angles:** These are the flat spots that assure you've tipped over to 45° for electrolyzer filling. You will cut one bottom corner of the iron plates off. Which bottom corner is important; you may have some preference as to which way your electrolyzer will tip in your shop.

Cut the corners off the steel plates with a cutting torch. I cut so that the distance from the shell to the floor would be the same when the electrolyzer was rolled 45°. With heavier electrolyzers (10 and 12 inch) it helps to SLIGHTLY round the resulting corner to assist the rolling.

**Take Care** to get the angles cut into the appropriate corners of the steel (and plastic). If you accidentally flip the plates, your through-bolt holes won't line up anymore.

As you cut the steel, think how much easier it'll be with the Brown's Gas. I do not use oxy./acet. to cut with any more. BG cuts iron so fast and clean.

Now, you'll drill out the IRON (not plastic) end plates to allow room for the insulating spacer around the power-input bolts (Drill so that you have about 1/4 clearance around the

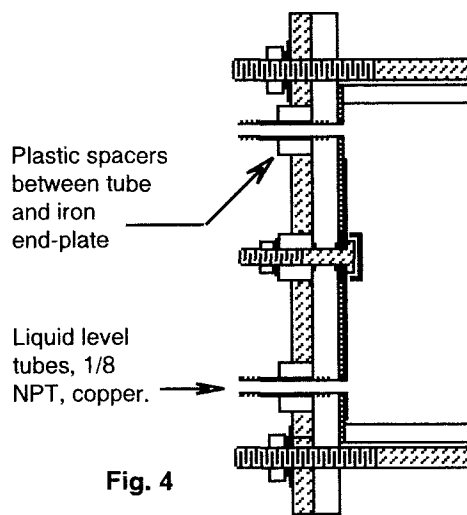


Fig. 4

center-bolt). Example: 6" electrolyzer has 1/4" power-bolt which requires a 3/4" hole in the IRON end plate for the insulating spacer.

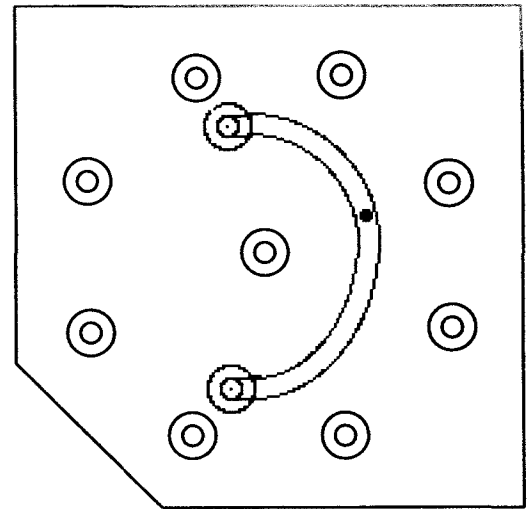
Different sized electrolyzers should have different sized power-bolts. Power-bolts are stainless steel (SS) and you'll use SS washers and nuts too. The size of the power bolts has to do with the amount of power required to flow through the bolts without heating them up.

Six inch electrolyzers can use a 1/4" bolt, 2-1/8" long.

Eight inch electrolyzer should have 5/16" bolt, 2-1/4" long.

Ten inch electrolyzers use 3/8" bolts, 2-3/8" long.

Twelve inch electrolyzers use two 3/8" bolts, 2-1/2" long.



Electrolyzer	Bolt size	Bolt length
6"	1/4"	2-1/8"
8"	5/16"	2-1/4"
10"	3/8"	2-3/8"
12"	2 x 3/8"	2-1/2"

Now drill the appropriate holes in the appropriate iron and plastic end plates for the sight tube assembly. You previously pre-drilled these holes.

The plastic end plate (for the liquid level tubes) will be threaded to 1/8" NPT; so use an 'R'drill.

The iron end plate will be drilled (or cut) out to allow at least 1/4 inch space around the 1/8" pipe stem (about 1 inch total); to allow an insulating spacer to be inserted (the fittings will be in contact with electrolyte and will carry a charge).

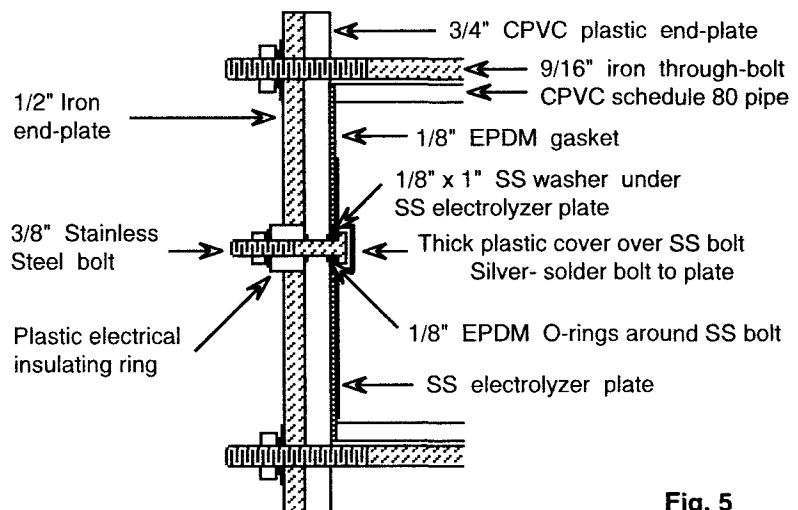


Fig. 5

## Liquid level tube

Notice that the liquid level tube is 'off-set', meaning that the two holes going into the electrolyzer end-plate are not on the center line. This is to accommodate the length of the copper fittings and still allow the liquid level to be visible.

We fasten Tees (1/8" FNPT to FNPT to MNPT on run) on the copper tubes (1/8" NPT) coming through the electrolyzer end-plate. Then we put barbed fittings (1/8" MNPT to 1/4" barbed) on the Tee's to install the level tube. We put 1/8" valves sticking straight out on the 'run' of the Tee. These valves assist filling and draining of the electrolyzer.

This arrangement allows us to position the clear hose in a 'C' (or reverse C) around the center bolt. Allowing us a clear reading of the electrolyte level in the smaller electrolyzers. Otherwise the barbed hose fitting would be covering the spot where the liquid level should be.

Note that I use clear braided PVC hose for the sight tube. I choose this because it is compatible with the sodium hydroxide and has a reasonable pressure rating. The hose does need to be replaced every so often, you'll know when.

We have found it **extremely** helpful to put a small dark plastic floating ball inside the PVC sight tubes (electrolyzer and bubbler). We make our own ball by heating a bit of dark HDPE (hot air gun) and rolling it into a ball. The ball must be big enough to not go through the copper fittings but small enough to travel easily through the hose.

In the larger electrolyzers (ten and twelve), you can just run the sight tube straight down. This is helpful to the floating ball, because there won't be a bend (kink or flattened spot) that tends to catch the ball.

## End gaskets

Note: if you are not clean about building and filling the electrolyzer and/or if you use components or sealing materials that are not compatible with the sodium hydroxide, then you'll get FOAMING. The foam is un-desirable because it 'shorts out' the plates as the electricity travels on the foam instead of through the plate-pack (causing wasted electricity). And the gas flow carries the foam up into the Bubbler, through the bubbler and out to the torch, where it contaminates the flame (causes it to turn yellow).

We cut a round circle of 1/8th inch thick Neoprene or EPDM 'rubber'. The circle to fit past the edges of the shell. We cut the holes for the center washer, fittings and (if we make it that wide) through-bolts with regular gasket hole punches.

## End Plate Assembling

Note that in this sketch I've shown how to get the power into and out of the series cell. I put the electrical input under the electrolyte. You can put the bolt anywhere under the electrolyte; I just find it convenient to put it in the center of the electrolyzer.

The two end plates have a hole in them to accept a stainless steel bolt. We then silver solder the SS bolt to the SS plate to assure a long term sure contact.

The stainless steel bolt extends through the electrolyzer end plates and the electrical wires are attached to them.

Stack SS washer/s between the SS plate and the plastic end-plate; the SS washers to be the same thickness as the 1/8" thick end-gasket. This will prevent the SS plate from becoming warped as it is bolted.

The two electrolyzer end-plates are totally assembled before they are bolted onto the CPVC pipe.

You can use a sight tube to monitor the liquid level in the electrolyzer. A

commercial BG electrolyzer would have automatic liquid level monitor and shut down. It can be built on exactly the same circuit design as the automatic liquid level control for the bubbler, shown elsewhere.

The SS plate on the 'sight tube' end-plate assembly needs an additional hole drilled in the stainless steel plate.

## Plastic cap on SS bolt

The stainless steel bolt head is covered by a piece of plastic to prevent the bolt from participating in the electrolysis. The piece of plastic covering the bolt is just thick enough to just reach the next plate, which holds the plastic cover in place (the plastic cover is there to prevent the bolt from participating in the electrolysis process). Make the plastic bolt covers from CPVC scrap.

## Initial cut long shell

For the electrolyzer shell; I've used PVC pipe and been happy with it, it's less expensive, more readily available, comes in all the same sizes as CPVC; BUT it can only go to 120°F before it is too hot to handle the pressure in the electrolyzer. CPVC can go to 160°F before it is too hot.

I choose schedule 80 CPVC pipe for the outer wall of the electrolyzer because I want the strength and the ability to handle a higher temperature than regular PVC pipe.

Cut the pipe on the same jig you built to cut the rings. When cutting the electrolyzer pipe to length, cut it a little long at first; because your rings and plates may not measure EXACTLY as you figure and even a small error adds up when multiplied over a hundred times.

Later you'll finish trim the shell after the plates and rings are inserted into the shell.

Note: Instead of cutting the shell, you can just add or subtract a ring/plate combination or two, it will make little difference to the actual result. Don't

put in a thinner ring to make the shell the right length. I do not recommend having a thin cell because it will use up it's liquid quicker than the others, causing problems. It's OK to have a THICKER ring for one or two cells, just so the end cell is the proper 3/8 inch wide, so that the liquid level indicator (sight tube for sure, and electronic sensors if used) will be measuring a representative liquid level.

### Assemble rings & plates into tube

I've found that the plates and spacers do not need to be glued in place. Friction holds them in place quite well. Just be sure they are each tight as you go, because it is hard to tighten them later.

In long electrolyzers, I insert the plates and spacer rings into the tube from the center out, this means I only have to reach in from both sides only half way down the tube. Be sure to make a jig to fill the bottom half of the tube while you fill the top half (round wooden plate mounted on a 2x4) so that your plates and spacers remain square to the tube. Make your jig so that you can see past it on the top, so that you can shine a light in the bottom of the tube so that you can see to line up the plates exactly (all flat tops exactly lined up).

In longer electrolyzers I've had to make a 'plunger' jig to push the spacers down (plastic or wood disk on a rod). And wrap the end of another rod with sticky tape (regular tape turned backwards) so that I could insert it to move the plates around.

### Final long shell cut

For the finish trim, cut the shell so that you actually have the end most ring sticking out of the electrolyzer 1/8 to 1/4 inch. The through-bolts will compress the rings into the shell and tighten everything up.

Assembly tip: You will want to remove a few of the rings and plates when you make the final cut to length, so that the saw doesn't cut any of the rings or plates.

Assembly tip: Insert a round piece of cardboard into the shell after removing some of the plates/rings and before you cut the pipe, to keep the plastic dust from getting into your electrolyzer.

Remember to figure so that the end cells will be just as wide as all the center cells; this will allow accurate gauging of the center cells fluid level by monitoring the end cell with the sight tube. It's OK to have a couple of the center cells a bit wider, if needed to make the shell the right length without having to cut it.

### Put end caps on

By this time you've made and assembled the end caps. Putting them on will seem pretty easy after all that. It takes time to manufacture something correctly, but once done you'll be able to assemble and dis-assemble the electrolyzer quickly.

To assemble, put some of the lower through-bolts in place, running through the end plates. Assembling around the electrolyzer or setting the electrolyzer in the 'basket' formed by the bolts.

Tighten the through-bolts evenly, taking care to see that the SS end plates actually go inside the shell. You can loosen and tighten the bolts as often as you wish.

### Through-bolts

I bought my iron rods at a local iron supply dealer. The rods are bought in twenty foot lengths. They rough cut them so that they fit in my car. I still needed to do the final trim after I knew the exact length of my electrolyzer.

The diameter of the through-bolts is important because of the amount of pressure these bolts are required to handle.

They don't have to be huge, because we use several of them around the circumference of the shell.

The following is a guide to the appropriate through-bolt diameters:

<u>Pipe diameter</u>	<u>Bolt diameter</u>
six inch .....	5/16 inch
eight inch .....	3/8 inch
ten inch .....	1/2 inch
twelve inch .....	9/16 inch

Once you know the length of your total assembly (shell and endplates), you can cut your through-bolt rods to length. Give yourself at least an inch on both ends past the total length of the electrolyzer. This will allow easy assembly and allow the addition of 'carrying' brackets if you want them.

Tighten the through-bolts fairly lightly and evenly. You don't want to cut your gasket material or crush the electrolyzer shell. The recommended through-bolt torque specifications (based on electrolyzer design as previously discussed) are:  
six inch ..... about 6 ft/lbs  
eight inch ..... about 8 ft/lbs  
ten inch ..... about 10 ft/lbs  
twelve" ..... about 12 ft/lbs

The through-bolts can exert tremendous pressure on the plate-pack and electrolyzer shell. If your plate-pack sticks out of the shell a bit, the through-bolts will compress them into the shell.

If you eventually notice a leak, in the end plate shell gasket, just tighten the bolts a bit more. You may find that they were loose, which can happen if you over-heat your electrolyzer; the hot shell is soft and will compress. I've only had them leak for that reason, no other time; and I SERIOUSLY over-heated the electrolyzer just to see what would happen. The automatic temperature controls will prevent that from happening.

### Drill and tap shell

You'll drill and tap all the holes into the shell after you assemble the rings and plates into it and you have the end-plates clamped on. You will get some plastic in the electrolyzer, but it is harmless if you have a liquid/vapor separator.

The key thing I want to mention here is that you don't want to tap the threads too deep. Go about 2/3 the depth of the tap and then tap a little at a time 'til your fitting screws in hand tight to about 2/3 it's threads (without sealing tape).

Seal your fitting threads with 'tape type' Teflon thread sealant. I have found NO paste sealants that are compatible with hydroxide in an electrolysis situation.

If you want to use another kind of sealant; DON'T just assume compatibility. TEST by putting the sealant on plates of an open (operate in well ventilated area) 'short-cell' and actually running an electrolysis test, if ANY foam occurs it is incompatible. The tiniest contamination can cause the WHOLE electrolyzer to foam because all the cells will become contaminated.

Do not tighten fittings more than 1/2 to two turns past hand tight in plastic. If you tighten them too much you'll break the plastic, or cause a stress that will break the plastic later.

### Mixing electrolyte

The initial filling of the electrolyzer involves mixing the electrolyte with water and then pouring the mixture into the electrolyzer.

Mixing electrolyte correctly is EXTREMELY important.

Safety is absolutely critical. It is absolutely critical to pour the electrolyte into the water, slowly while stirring the water.

Mixing electrolyte and water causes heat and if mixed too fast, the electrolyte will explode.

This explosion is EXACTLY what will happen if you pour water onto an electrolyte (always pour electrolyte slowly into water). An explosion will splatter caustic solution everywhere. I assure you that this will cause you a 'bit of inconvenience', like burn your face right off your skull.

Electrolyte is mixed in 'ratios' by WEIGHT. So if you see a mixture such as '4:1'; this means four parts of water to one part electrolyte, by weight. For example; four pounds water to one pound electrolyte. Or four Kilograms water to one kilogram water.

A 4:1 mixture is a 20% solution; because in five total parts, we have one part electrolyte. This is 20% electrolyte; actually quite lean as electrolyte mixtures go. But you can make the mixture quite a bit leaner and it will still work, you just have to spend more money on capacitors for your voltage doubler.

Mix your electrolyte in containers that will allow you to easily stir the mixture and then to pour into the electrolyzer. Pour electrolyte outside or in extremely well ventilated area. Use safety equipment previously described.

Do I need to say that the containers need to be compatible with your electrolyte?

### Fill electrolyzer with electrolyte

Once I've mixed the electrolyte; I usually fill the electrolyzer through the 1/2 inch 'gas out' hose, by siphon gravity feed. This is for the initial fill up only, because I don't want any electrolyte in the bubbler tank (you don't either). It helps to have the electrolyzer on the floor and your electrolyte jug on a chair. Having the electrolyte jug too high (like on a table) will fill the electrolyzer too fast.

Take care with spilled electrolyte; for example don't use a chair that the caustic solution will dissolve and clean up any mess by first soaking it up on a cotton cloth (which you can wash in the clothes washer) and then neutralizing the rest of the spill with vinegar, then finish wiping it up.

The electrolyzer should be tipped at it's 45° filling position to fill all the cells with electrolyte.

It helps to occasionally tip it further than 45° during initial fill-up to assure that all the cells get equal electrolyte.

You must leave valve 3 open for the air to exit the electrolyzer as the electrolyte enters. I usually put a slight vacuum on the electrolyzer on the valve 3, this starts the gravity feed solution delivery.

Remember to fill slowly or you'll get liquid coming out the valve 3.

**DO NOT** suck on the hose with your (or anyone else's) mouth. If you get electrolyte in your lungs or stomach, it will eat you from the inside out, causing severe pain until you die.

I use a hand held vacuum pump, an electric vacuum pump, the input for an air compressor, or (my favorite) the inlet for a 'shop' vacuum cleaner.

Tip the electrolyzer back to the operating position every so often as you fill it, to determine the liquid level. Each electrolyzer will take different amounts of electrolyte solution depending on the internal volume of the shell.

Assuming that you have a shell with 138 plates spaced at 3/8"; you'll find a general idea of the electrolyte volume (in US gallons) below:

6" .....	3.5 gallons
8" .....	6.5 gallons
10" .....	11 gallons
12" .....	16 gallons

An example of the general calculation to get the volume of electrolyte: Figure each ring width, 3/8" (0.375") times 138 rings equals 51.75 inches (forget the width of the plates in this calculation). In a twelve inch electrolyzer, we have an inner diameter of the rings of about 10.25 inches. So we have an inner area of (((10.25/2) squared) times 3.14) 82 square inches. We subtract the area that we do not want filled (about 11 square inches) to get 71 square inches. We multiply 71 square inches by 51.75 length to get

3674 cubic inches. A US gallon is 231 cubic inches. So  $3674/231= 15.9$  gallons.

Note that this calculation is even easier using the metric system, but I'm writing this book mostly for average United States of America readers. I apologize to the rest of the world for the archaic measurements. I expect that the USA will step into the modern world someday. In the meantime you'll find this book a mish-mash of both systems.

Remember that as you operate the electrolyzer, you want your liquid level to be well below the top of the plate for two reasons:

First, there will be some rise in the liquid level as the bubbles of hydrogen and oxygen take up some room; increasing volume and reducing density of the solution between the plates.

Second, there will always be some foam and you don't want the foam to rise above the top of the plates or the foam will allow a portion of the electricity to by-pass the plates.

It is better to have the electrolyzer fluid level a bit low than too high. The distance **below the top of the plate** I usually recommend for each diameter of electrolyzer:

6" .....	1/2"
8" .....	3/4"
10" .....	1"
12" .....	1 1/4"

This is why I curve the liquid level sight tube mounted on the end plate of the smaller electrolyzers. The liquid level would otherwise be covered by the hose fittings.

## DESIGNING ELECTROLYZER POWER SUPPLIES

### Power supply considerations

If we apply straight DC current to the electrolyzer, we find the oxygen and hydrogen devolving to their di-atomic state. We get NO Brown's Gas.

The electricity **MUST** be pulsed to an electrolyzer to produce Brown's Gas; 120 cps is sufficient to produce Brown's Gas, even 100 cps will work; so regular wall cycles will work.

The oxygen and hydrogen 'want' to be di-atomic even though they have to 'give up' energy (which shows up as heat) to reach that state.

Unfortunately it is fairly simple to trigger the di-atomic action and there are many factors that can cause the trigger to di-atomic. So our challenge is to prevent the oxygen and hydrogen from devolving from their high energy mon-atomic state to their lower energy di-atomic state.

We are working on various ways to prevent di-atomic formation.

At this time we just use wall voltage and signals for our electrolyzers. The power supply designs just discussed are still in our future, but mentioned here for those of you that are experimenting.

The power supplies outlined in this book are simple and effective (they will make commercial quality Brown's Gas).

### Voltage measurements

You will need to understand the meaning of RMS voltage (no need to learn the mathematics). RMS stands for Root Mean Squared. RMS voltage is the 'calculated effective voltage' of the sine wave of your 60 cycle wall voltage. Most AC voltmeters are automatically tuned to give you a RMS voltage reading.

You measure RMS voltage by putting an RMS voltmeter across your two power leads. This is the voltage that you use to figure the number of cells.

You also need to understand Peak voltage. You can measure Peak voltage by putting a full wave bridge rectifier across the AC wall power, putting a capacitor across the positive and negative of the full wave bridge

rectifier and reading the DC voltage across the positive and negative of the full wave bridge rectifier (be sure to install the capacitor).

Peak voltage is used to size your various electrical and electronic components. For example, the diodes and capacitors in the power supplies.

Peak voltage also gives you an indication of the **MAXIMUM** number of cells you can add in series in the series-cell electrolyzer design. There is no advantage to going to an extreme number of cells, because you'll end up with almost no amperage.

### Number of cells in series

Different plate spacing will affect the number of cells in your electrolyzer. This is important because the number of cells is **also** affected by your power supply option.

*For more on actual calculations of number of plates, see appropriate power supply option. 1) Capacitor Amperage Limiting; 2) Voltage Doubler and 3) Voltage Doubler with Capacitive limiting.*

### Frequency across the electrolyzer

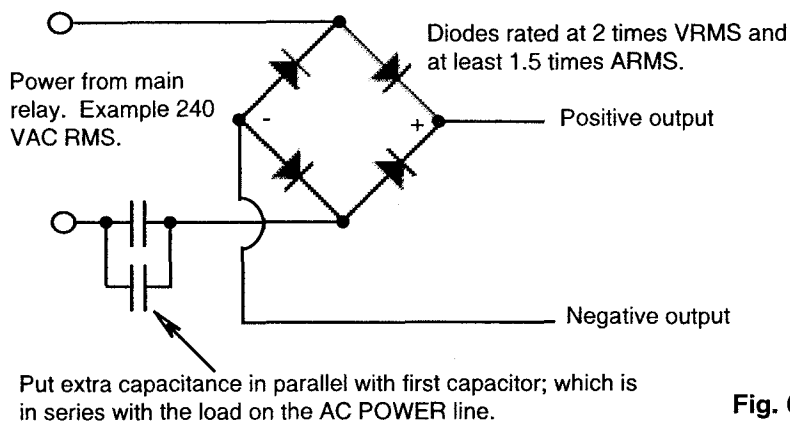
The AC voltage is rising and falling at sixty times a second.

Rectification with a 'full wave' bridge rectifier (four diodes set in a square) will produce about twice the gas of single diode rectification because we get 120 pulses per second from 60 cycle sine wave.

Full wave rectification (120 pulses) can be used with the Capacitive Amperage Limiting.

The Voltage Doubler power supply option allows 240 or more pulses per second, because the bridge rectifier doubles the original 60 cycle (to 120) and the capacitor 'legs' double the 120 to 240 pulses per second (when the capacitance of the voltage doubler is correct). This is my power supply option of choice at this time.

**Capacitive Limiting** circuit for "short" series-cell BG electrolyzer.



**Fig. 6**

Note, I've reached as high as 500 hertz (pulses per second) using this method. The capacitance is raised or lowered 'til there is a 'resonance' effect.

**Voltage threshold**

Most of the time the AC voltage is below the 120 volts needed to push any current across the 60 series-cell. The brief moments that the sine wave goes above 120 volts, reaching about 170 peak volts, is the only time amperage actually goes through the 60 series-cell.

The amperage that can travel in a 60 series-cell is limited by the 'voltage threshold' potential of the cell. After that threshold is reached, the amperage more or less just shorts across the electrolyzer.

With sodium hydroxide, at 1.8 volts per cell, the amperage can barely flow; at 2.4 volts per cell, a lot of amperage can flow.

The voltage 'threshold' can be raised by adding more cells in series, which would further limit amperage through the electrolyzer. Or the 'voltage threshold' can be lowered by using fewer cells in series, which would cause more amperage to flow. Amperage is then limited by the capacitive limiting type power supplies.

Generally speaking I recommend keeping the 'voltage threshold' fairly

high to most efficiently make Brown's Gas. Then use a voltage doubler to bring the voltage (and thus the amperage) up to whatever I require.

**Pressure switch**

A pressure set-point switch (mechanical or electronic) on the electrolyzer will operate a relay-switch (mechanical or electronic) to turn on and off the power to the electrolyzer when needed.

Assuming that your electrolyzer can make more gas than your torch needs (which MUST be the case), this pressure set-point switch prevents gas loss out the pressure relief valve.

Gas loss out the valve is bad because of inefficiency (you paid for the electricity to make the gas and you are throwing the gas away) but also because it could cause wild pressure fluctuations in the pressure of the gas in the bubbler tank, which is likely to cause backfire from your torch.

**DC power supply**

It is possible to make Brown's Gas from a DC voltage source, such as a battery, but you must pulse the current from the battery.

If we apply straight DC current to the electrolyzer, we find the oxygen and hydrogen always devolving to their diatomic state. And your electrolyzer will heat up.

If you are pulsating from a battery pack you would need to make a very short pulse width (for the spike) because of the square wave nature of such pulses.

To find the number of cells for an electrolyzer on DC, I use the rule of thumb of:

Volts per cell	Plate Spacing
2.0 .....	1/2 inch
1.9 .....	3/8 inch
1.75 .....	1/4 inch

NOTE: these 'rules of thumb' are generated from extensive testing of actual electrolyzers using different numbers of cells, types of electrolyte, electrolyte concentrations, power supplies, etc. These 'rules of thumb' will get you into the 'ball park' and give you an operational electrolyzer. I can't guarantee any particular performance. You will notice slight differences.

**1. Capacitor amperage limiting**

Note that this is the 'basic' power supply circuit for the electrolyzer only, without all the controls that turn the main relay on and off. This is the circuit starting from the output side of the main relay.

You use capacitive amperage limiting if you have too few cells to use Voltage Doubler.

Capacitive Limiting is also used if you simply want to reduce the amperage through any electrolyzer at any time (even if you have a voltage doubler). For example, if you have a heating problem (and/or amperage runaway), you can limit the amperage through your electrolyzer.

When an electrolyzer gets too warm, the warm electrolyte allows more amperage flow and may cause too much amperage to flow. Too much amperage could over-heat your electrolyzer and/or toss electrolyte right out of your electrolyzer and/or 'pop' your fuse or breaker.



You can use Capacitive Limiting with Voltage Doubler. But usually the Capacitive Limiting is simply added to a series-cell that has too few cells to qualify for any other power supply option.

You can use Capacitive Limiting from one cell to as many cells as you want up to about line power VRMS. The amperage will be limited to whatever will 'pass' though the capacitor at the voltage applied. For example; at 120 VAC, 25 uF (microfarad) will pass about one amp; at 240 VAC, about 7 uF will pass one amp.

## 2. Voltage doubler

Note that this is the 'basic' power supply circuit for the electrolyzer only, without all the controls that turn the main relay on and off. This is the circuit starting from the output side of the main relay.

You use a voltage doubling circuit if you have too many cells for Straight Capacitive limiting.

The voltage doubler circuit has several advantages that the over Capacitive limiting.

1. It uses very little additional components.
2. It increases the frequency of pulses.
3. It allows you to add extra cells that limit amperage, yet allows additional amperage capacity to be added at will.
4. It allows additional gas production by increased number of cells at the same DC amperage (AC amperage is increased, TANSTAAFL).
5. It allows an electrolyzer designed to operate on a higher voltage to operate on a lower voltage; for example a 220 volt electrolyzer to operate on 110 VAC source.

Voltage Doubler doesn't actually double the voltage; (it would if there was no load), the voltage only rises a little across each cell (to the threshold voltage) and the amperage can be raised quite a bit.

### Voltage Doubler circuit for extended series-cell BG electrolyzer.

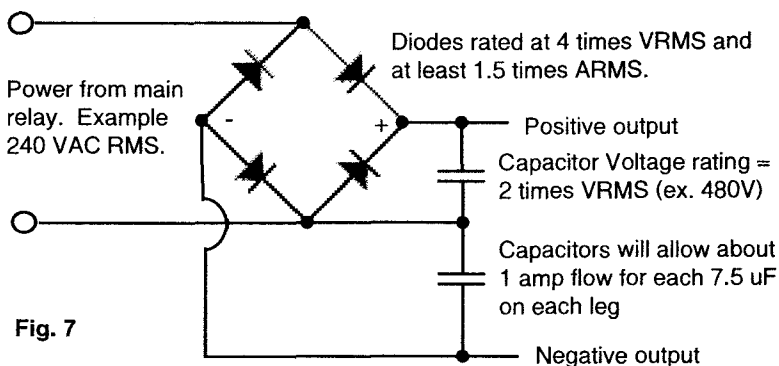


Fig. 7

Again, because this is important, you will notice that a slight additional voltage rise across each cell allows a much greater amperage current to flow. This is why the voltage doubler circuit increases amperage.

The voltage doubler does an additional thing, it increases the FREQUENCY of pulses. With the voltage doubler you will usually get at least 240 pulses per second. In certain cases (combinations of capacitors on the legs of the voltage doubler) it is possible to get up to 500 pulses per second using this circuit plugged into normal 60 cycle AC.

When I am going to use a voltage doubler as my electrolyzer power supply, I usually figure the number of cells at the rule of **1.75 volts per cell**, figured on **RMS** voltage. For example; operating on 240 VAC, I would have 138 cells.

In this way you can actually take more advantage of something called 'Peak

voltage'. For any given wall AC voltage, you'll find that the actual 'peak' voltage is about 40% higher than the 'RMS' voltage that most AC voltmeters read.

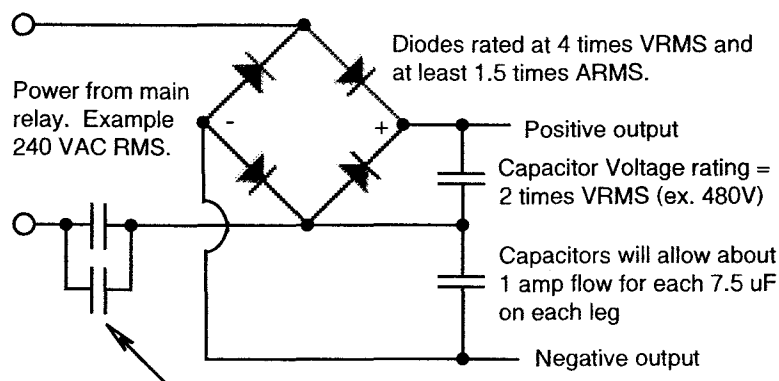
Thus you can operate your 120 VAC electrolyzer at 220 VDC or your 220 VAC electrolyzer at 290 VDC.

Also you'll find that you can limit amperage **WITHOUT** capacitive amperage limiting. The high number of series-cells automatically limits your amperage, because as your electrolyzer requires more voltage to operate, **NO** amperage will flow 'til the higher voltage is reached.

And the higher voltage (required by the electrolyzer) cannot be reached until the voltage doubler kicks the voltage up (twice each half cycle or 240 Hz).

With the 138 series-cell electrolyzer on straight line power, you'll note only a limited amperage 'til you start adding

### Voltage Doubler circuit with Capacitive Limiting



Put extra capacitance in parallel with first capacitor; which is in series with the load on the AC POWER line.

Fig. 8

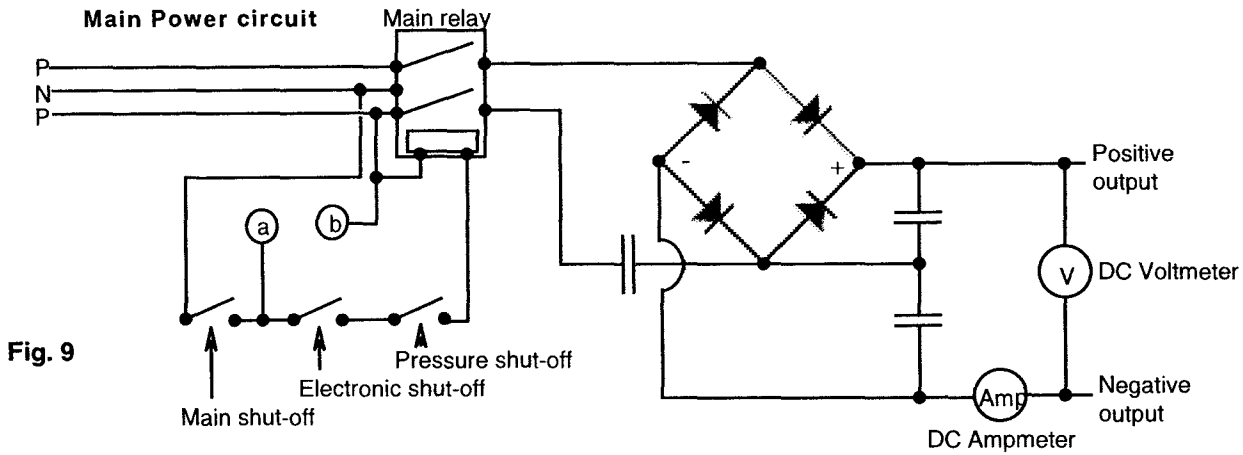


Fig. 9

capacitance to the 'legs' of your voltage doubler. As you add capacitance on each leg of the voltage doubler (equal on each leg):

You'll note that the amperage will rise at the rate of one amp per 50 uF per leg with 120 VAC RMS.

And the amperage will rise at one amp per 11 uF per leg with 240 VAC RMS.

**IMPORTANT NOTE:** 'There ain't no such thing as a free lunch'. When you increase the voltage using a voltage doubler, the 'extra power' comes from AMPERAGE from your RMS source.

When using a voltage doubler circuit, the amperage being drawn from the wall is about TWICE the amperage you see across your electrolyzer. You must be sure your wall fuse or breaker can handle the amperage you will be adding. Remember that the MAXIMUM continuous operating amperage of your breaker or fuse will be only 80% of the 'rated' amperage. For example; a 20 amp breaker should hold 16 amps.

Further Note: When a breaker 'trips', it will not again hold as much amperage as before. After each 'trip' the actual amperage that the breaker will hold is a bit less.

**3. Voltage Doubler with capacitive limiting**

Note that this is the 'basic' power supply circuit for the electrolyzer only,

without all the controls that turn the main relay on and off. This is the circuit starting from the output side of the main relay.

Same as Voltage Doubler, only you have capacitive limiting in series on the input common with the center of the voltage doubler capacitors.

**Main Power Circuit**

We have the main power coming in on an ordinary 240 Volt cord, using properly rated receptacles, wire sizes and plugs. The 'P' is power or hot; the 'N' is neutral, where you wire to when you want 120 VAC.

Note that our electrolyzer draws about 50 amps, so I use a main relay rated at 90 amps. The relay is normally open, three pole, single throw. The relay has a 120 volt coil to activate it.

Note the three shut-off switches wired in series, in series with the main relay coil. This is so that if any one of the switches is open (off) then the main relay has no power and is off! The Pressure switch is normally closed, open on pressure rise (could be a relay). The Electronic switch is a relay that is normally open, held closed by the electronic circuit. The Main switch is normally open, closed only when you want the electrolyzer operational (this could be a relay too), I usually just use an ordinary light switch.

The points marked 'a' and 'b' are where you connect the primary

side of your transformer that provides the low voltage for the electronics, gauges, buzzer and relays.

You'll note that the DC ammeter is on the line going into the electrolyzer; it doesn't matter which one, just so you get the polarity correct. Although I depict a capacitive limited, voltage doubler power supply here, the ammeter is installed in the same place on all the power supplies.

You'll note that the DC voltmeter is mounted between the lines going into the electrolyzer, you have to get the polarity correct. Although I depict a capacitive limited, voltage doubler power supply here, the voltmeter is installed in the same place on all the power supplies.

There are any number of 'extras' that can be applied to this circuit, like indicator lights and receptacles (120 volt and 240 volt); but I left them out of this schematic because I'm trying to keep it seriously simple. What you see will work just great! The electronics has status indicator lights and you can see when the power is on (to the

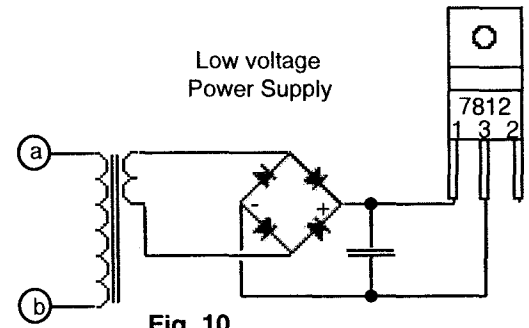


Fig. 10

electrolyzer) by looking at the volt and amp gauges.

## LIQUID LEVEL AND TEMPERATURE CONTROLS

I designed electronic circuits to act as sentinels, monitoring critical parameters of the electrolyzer's performance. The electrolyzer can work quite adequately without these circuits but I don't recommend that you do so. I have these controls on my

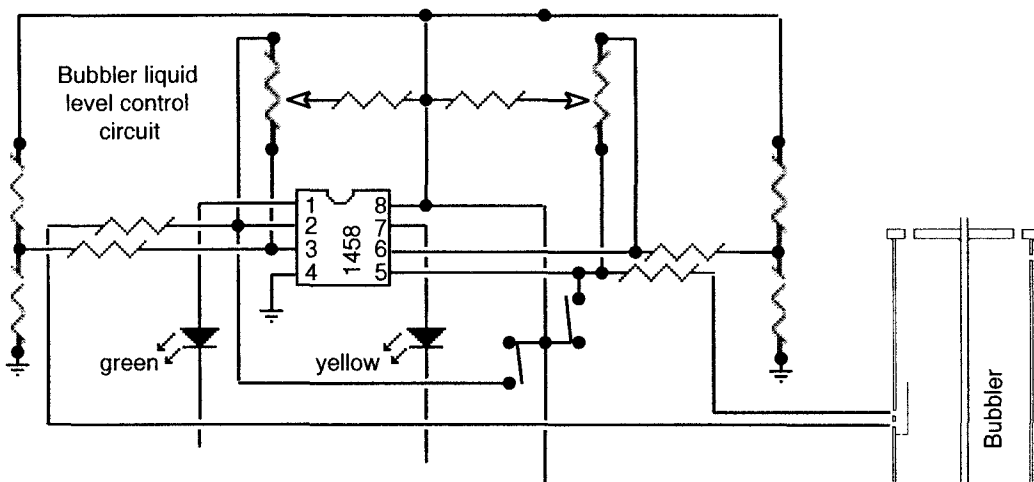


Fig. 11

own electrolyzers, because I often don't pay enough attention to the operation of the electrolyzer; my attention gets concentrated on the job at hand.

The two most critical things to monitor are liquid level in the bubbler tank (backfire arrester) and the temperature of the electrolyzer itself. You will have sight tube and a temperature gauge but that is not enough, you must remember to look at them. The electronics are a fail safe for those people, including me, who fail to ALWAYS check the bubbler liquid level and watch the electrolyzer temperature.

The electronics are designed to be two-step. First, you'll get a warning buzzer, then if the problem gets worse, the electronics will actually shut off the electrolyzer and will not allow a restart

'til the electrolyzer either has water added or cools down.

I have designed a simple circuit that even a novice can build. Novices have already built my circuits using my instructions. Don't be concerned if you don't know how to do it now; you CAN learn how. You can buy all of the electronics at your local Radio Shack and the peripherals at local hardware and automotive stores.

I sincerely recommend that you buy Getting Started in Electronics by Forrest M. Mims, III. I and many others have self-taught ourselves electronics from this simple book. What the book will tell you is how to get 'in the ballpark' on simple electronic circuit design and to understand the electronic language. You will learn how to put electronic components together to make circuits do what you want them to do.

Next, I recommend that you get the 'data sheets' on any electronic component (particularly the chips) that you buy, so you will understand their working parameters. Since (in this circuit) I use all electronics from Radio Shack, they'll be able to make you copies from their Semiconductor Reference Guide. During this chapter, I will be assuming that you have this information.

The electronics are arranged in three groups to make it easier to understand. Power supply, electronic processing, and signaled mosfets.

### 1. The 12 VDC power supply

The low voltage, 12 VDC power supply is for the electronics, the buzzer and the relay. It could also be for 12 volt electric or electronic gauges if you use them. The low voltage could also be used across a pressure switch to

power a relay instead of the pressure switch having to take the full amperage (the amperage would then go across the relay).

a) We have a transformer to step the voltage down from 120 VAC to 12.6 VAC. The transformer must be rated about 50% above the actual amperage you'll be using. You can get a good idea of the amperage by hooking up your circuits to a 12 Volt battery and measuring (with an ammeter) your amperage flow with everything turned on.

b) Then we add a full wave bridge rectifier, which is just four diodes arranged in a square (note that the band on the diode is the negative end, diodes are polarity sensitive). The full wave bridge rectifier turns the AC (alternating current) into DC (direct current) needed by the electronics.

c) Then we add an electrolytic capacitor, rated at least 35 VDC (50 VDC is better) and 1000 uF (uF is micro-Farad) for each amp that will flow through the transformer; in this case about 1,000 uF. The capacitor allows voltage to be 'stored' in the circuit, which smooths out the pulses that would otherwise occur direct from a full wave bridge rectifier.

d) Then we add a 7812 (in a TO-220 case) voltage regulator, for those parts of the circuit that the voltage must stay very stable. You will want to put a

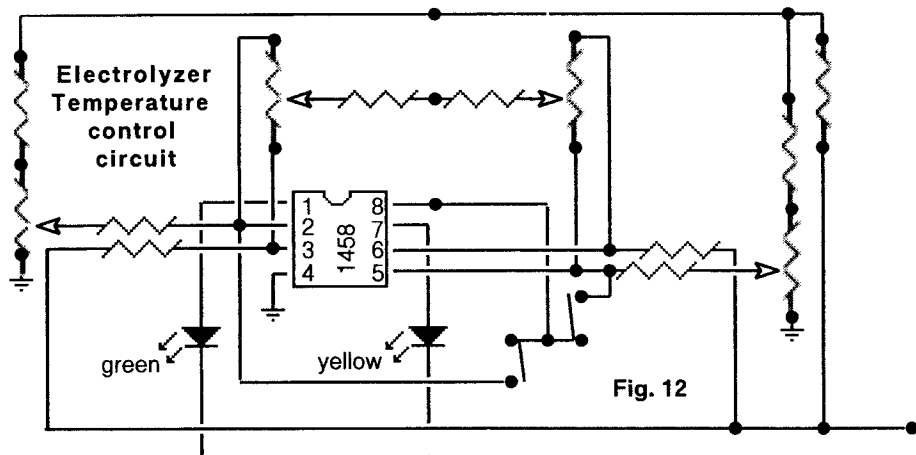


Fig. 12

heat sink (special piece of aluminum made to radiate away excess heat) on this regulator, to keep it's temperature stable or the circuit will go out of calibrated adjustment. Also remember to calibrate it after it has warmed up, minimum of 1/2 hour.

## 2) Second circuit group; liquid level and temperature processing

a) We use op-amps (operational amplifiers) wired as voltage comparitors. In this case, we use two 1458 op-amp chips (two op-amps on one chip).

Or you could use one 324 chip, (has four op-amps on one chip). Using one chip saves board space and slightly simplifies the circuit. I show the two 1458 chips in my schematic here because that's the way I actually built my first circuit, so I know it will work for you. My next circuit will use a 324 chip.

We use the op-amp 'voltage comparitors' to provide a 'snap action' turn on or turn off signal to our mosfets (which are electronic switches). The op-amps allow us to monitor a voltage, compare it to a set voltage and when the monitored voltage reaches a certain level (very precise) to send a full voltage switching signal to the appropriate mosfet. The op-amps, as I have them wired here, can monitor a voltage with a very tiny amount of electric current and can sense a difference of 2 millivolts.

The op-amps each have two inputs; called an inverting and a non-inverting input. When used as a voltage comparitor, if the non-inverting input (indicated by a '+') is of greater voltage than the inverting input (indicated as a '-') then the output of the op-amp is high (on to nearly full chip voltage). If the inverting input is of higher voltage than the non-inverting, then the op-amp output is low (off to ground state or negative). So we only need to provide a reference voltage to the appropriate input and make sensors that vary the voltage to the other input and 'Poof'; we have an electronic monitor that can 'make decisions.'

The op-amps each have a special 'balancing' circuit between the inverting and non-inverting inputs (and positive) that allows maximum reliability and sensitivity, but do make the circuit look more complicated than it really is.

The op-amps circuits also have 'testing' switches and circuit monitoring LED's (Light Emitting Diodes) that should be mounted on your main control panel. This will allow you to test the circuitry for function at any time; also the LED's give a constant status report and indicate what the problem is, should an alarm go off or the electrolyzer shut down.

b) Two of the inputs for the liquid level part of the circuit are sensors located on the bubbler tank. The bubbler tank itself being grounded to the negative of

the electronics and positive voltage (from the electronics) going to the sensors.

When the water covers the sensor tip, the positive voltage is 'grounded' (which means no voltage) and this tells the electronics that you have enough water. When the water DOES NOT cover the sensor tips, the positive voltage rises in the wire to the sensor and the electronics 'knows' that you don't have enough water.

We use two sensors in the bubbler tank so that we can sense the liquid level at two points (which requires two op-amps). The highest point being a warning buzzer and the lowest point being where the electronics actually shuts off the power to the electrolyzer.

I made the sensors by drilling out a 1/8" brass pipe nipple (the kind with hex flats that you can hold with a 7/16" open end wrench) and inserting a #4 stainless steel bolt through it. The #4 bolt being held in the center of the nipple by special epoxy 'JB Weld' or 'Lock-tite Weld.' The #4 bolt sticking out both ends by about 3/8." On one end I tapered the epoxy to a point over the #4 bolt and on the other end I kept the threads clear of epoxy so that I could thread on nuts to hold the electrical terminals. I made spacers to hold the #4 bolt in place 'til the epoxy dried and then I filed the epoxy off the end that I had covered as I tapered the epoxy onto it. Finally, after tightening the sensor in place (using a bit of Teflon tape to seal it), I put a couple of plastic washers on the #4 bolt to prevent my terminal end from shorting between the #4 bolt and the brass nipple.

The bubbler tank ground wire can be clamped onto the outside of the sensor. I fasten mine onto the bottom support bolt.

c) The temperature sensor is a 'thermistor'; which is a fancy name for a sensor that changes it's electrical resistance as it's temperature changes.

A quick and easy way to get a thermistor is to go to your local automotive supply store and get a 'temperature sensor.' You will have to convince the parts person that you are NOT buying it for use in an automobile, so you don't have a part number; and to please just bring out a selection, or allow you to look in the catalog to choose some to test.

You want a sensor that is a thermistor and not a switch; so take along your ohm-meter and measure the electrical resistance of the various samples that the parts person brings out to you. If it measures open (infinite ohms) or closed (near zero ohms), then it is a switch. If it measures over 300 ohms resistance then it is a thermistor. It is best to get a thermistor that is 1,000 or

you don't want huge amp flowing). What matters is the ratio of the resistors.

The op-amps are signaled by very little amperage, so you can use 10 K resistors and the op-amp will not 'load' the circuit.

The 'comparing' voltages of the voltage dividers that the op-amps use are set and do not change. But the thermistor does change it's resistance and thus the voltage between the two resistors (a fixed one and the thermistor) does change and the op-amp gets signaled.

The sensor I got was a 'TS17' at my local automotive supply store, Car Quest. It had 289 ohms at 61°F (store

I turned off the electricity and allowed the water to cool, getting these readings:

Temp. °F	ohms	AM time
121 .....	85 .....	9:30
114 .....	99 .....	9:38
91.5 .....	156 .....	10:25
80 .....	200 .....	11:32

Note that there is a slight thermal lag, the temperature inside the thermistor is not the same as the temperature outside if the outside temperature changes suddenly.

The reason we want to know the resistance of the thermistor as the temperature changes is so that we can figure the resistance value of the voltage divider potentiometers. In this case we use 0-500 ohms. A voltage divider potentiometer allows us to quickly and accurately set any reference voltage we wish when calibrating our circuit (more about calibration later).

As I said before, the circuit actually works better if your thermistor is 10,000 ohms at room temperature, in that case you'd use a 10,000 ohm (10K) potentiometer. The reason the circuit works better is because the thermistor resistance changes a lot more ohms per degree F; making it easier to be very exact with the circuit temperature calibration settings.

It is possible to buy thermistors with 1/8" NPT threads, 10,000 ohm at 75°F, and long wire leads, check out the [Thomas Register of Manufacturers](#). You can even make a thermistor using a pipe plug and the Radio Shack 10 K @ 70°F thermistor.

NOTE: you can use adjustable temperature switches to signal the buzzer and electrolyzer shut-down. There are a lot of suppliers of such switches, just look in the [Thomas Register of Manufacturers](#) located in most city libraries.

Have the (normally open, close on temperature rise, snap action, with less than 5°F temperature difference off to on,

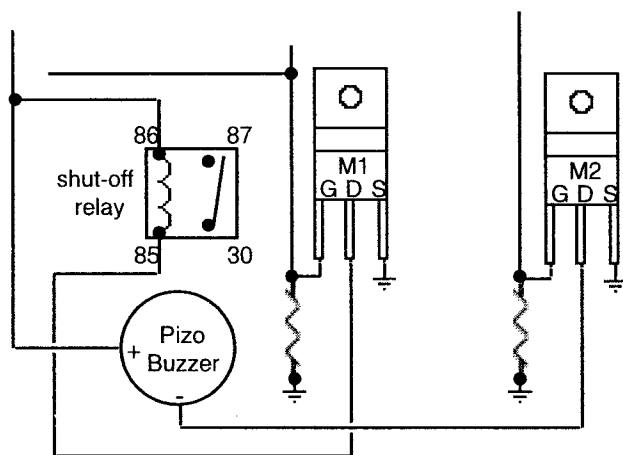


Fig. 13

10,000 ohms, because it is easier to make accurate temperature sensing; but even 300 ohms will work with this circuit design.

The op-amps use the thermistor in a 'voltage divider' arrangement, which is a very common electronic circuit. When you have a certain voltage, say 12 volts and you want less voltage at a certain point, say 2 volts, then if you arrange two resistors in series between positive and ground (negative), the first (closest to positive) being 10 K ohm, and the second (closer to the negative) being 2 K ohm. The voltage measured between the middle of the two resistors and ground will be 2 volts. It doesn't matter how large the value of the resistors are (that just matters because

temperature). I tested the resistance by putting a thermometer in water with the thermistor and an ohm-meter across the thermistor. I heated the water with an electric heater (I used a soldering iron) and got the following readings:

Temp. °F	ohms	AM time
62.1 .....	289 .....	8:42
79.0 .....	205 .....	8:47
84.5 .....	189 .....	
90.0 .....	168 .....	8:51
95.0 .....	158 .....	8:54
100 .....	134 .....	8:58
105 .....	125 .....	9:00
110 .....	109 .....	9:05
115 .....	100 .....	9:09
120 .....	90 .....	9:16
127 .....	78 .....	9:26

adjustable range from 100°F to 160°F) temperature switches (one for warning and one for shut-off) allow positive voltage to go directly from the full wave bridge rectifier to the appropriate mosfets, through these switches. Testing buttons are redundant but you'd still want the indicating LED's.

These temperature switches are more expensive but a bit simpler to understand for some people. If you use temperature switches, you can use just the 1458 (dual) op-amp that goes to the liquid level sensors, eliminating the 1458 op-amp and the circuitry that would have gone to the temperature sensing part of the electronics.

### 3) The signaled mosfets, relay and buzzer

a) the signaled switches are mosfets, short for Metal Oxide Semiconductor Field Effect Transistor. Now that I've scared you; please believe me that these little babies are really easy to work with, and super efficient. You just have to know a few things not usually told to novices on the street.

First, the mosfet is a diode and therefore polarity sensitive, it will only allow electricity to flow through it one direction without destroying it. So pay attention to how I have the circuit wired. Think of it as a 'switch able' diode. It won't conduct any electricity when off, and will conduct only one way when on.

The mosfet is signaled by voltage, not amperage. So a source (like an op-amp) that can't put out much amperage, but can put out a voltage signal, can turn on a mosfet to it's full potential and allow several amps to flow through the mosfet. The mosfet needs at least 10 volts to the gate to fully turn on, and more than 20 volts to the gate will puncture the super thin oxide layer.

**Warning:** This means that the mosfet is extremely sensitive to static electricity, 'til it is soldered into a circuit. All the leads (gate, drain, source) of a mosfet should remain

shorted (with conductive foam) 'til just before the mosfet is inserted in the circuit. Then, before taking the mosfet out of the conductive foam, ground the circuit, the soldering iron, yourself and the mosfet to ground (by touching a ground). Then solder the mosfet in place. Mosfets should be among the last things soldered onto a board and it's still a good idea to ground the wires leading to a mosfet (with test clips) 'til the board is operational.

Mosfets come in N channel and P channel.

N channel is the type we use, in a TO-220 case. N channel mosfets must have nothing between them and ground (negative). The source or 'S' pin must go directly to ground. Thus we switch on the negative or 'low side' of the load; the positive voltage going first to the load, then to the mosfet and then to ground.

We put a resistor on the wire leading from the gate, to drain the gate when the voltage stops. In this case, we use a resistor of the value that would allow a proper amperage flow in the indicating LED.

When turned on, the M1 mosfet allows the electrical flow to the relay (which is normally off, but the electronics turns it on and holds it on 'til there's a problem). I call this the 'electronic' shut-off relay; this relay allows the electrical flow to the 120 VAC coil of the electrolyzer main relay.

When turned on, the M2 mosfet allows electrical flow to activate the buzzer.

Both the liquid level circuits and the temperature circuits can activate the M1 and M2 mosfets.

b) The relay is a 30 amp 'auto' relay bought in Radio Shack, made by Bosch and one of the best on the market. Radio Shack sells them at \$5, which is \$2 cheaper than I can get them wholesale.

c) The buzzer is sold by Radio Shack, nearly any buzzer will work but I

choose a loud Pizo because it doesn't use much power.

### Assembly Hints

1. I use chip sockets when I build a circuit like this, then I can insert the chips after the entire circuit is soldered onto the board. Also, if a chip goes bad, I can replace it quickly and easily. I've found I can do this for mosfets too.

2. All chips have numbered pins, the pin numbers go down one side and up the other (as you can see in my schematic). The top of the chip is indicated by a little indentation, and/or pin #1 is indicated by a small dot next to it.

The chip socket will also have an indication on them (usually a notch on the top edge) as to which way is up or top, so you can wire it correctly and place your chip in it correctly. Some times the only indication is a small dot by pin #1.

3. Remember that the chip pin numbers are reversed on the back side of the board. This is a common cause of failure to get a circuit working; it was wired wrong.

4. I show the TO-220 case 7812 voltage regulator and mosfets as front view in my schematic, so you can put the right wires to the right pins.

5. Soldering can be a bit of an art. I use a 30 watt soldering iron with a fine tip for circuit board work (bought at Radio Shack). You need to clean the tip (use a fine metal file) and to 'tin' the tip with a bit of solder before using it to solder; do this as often as needed. Use thin, rosin core solder.

6. Be sure to heat both areas to be soldered and have just enough solder flow onto each of them to make a good join. If you get too much solder, it can flow over to areas where you don't want it, making connections with the wrong parts of the circuit. If this happens, just re-melt the solder and take it off with the soldering iron,



shaking the soldering iron clean each time after sucking up some solder.

7. A 'cold' solder joint is also a common cause of circuit failure. A cold joint is where the solder flowed around a pin or onto a place, but didn't actually join with that place (it looks good but there is no connection). Solder flows too hot, so you should heat the area that you want to solder and then have the solder flow onto it.

8. You have to balance too cold with too hot. If you heat a place too hot, the solder won't want to flow there. Also too much heat will burn out components. After soldering, I usually blow on a joint to cool it quickly. You'll quickly learn the correct technique.

### Circuit adjustments (tuning)

**IMPORTANT:** P5 and P6 are the potentiometers that you will use to set the temperatures you want the warning buzzer and the shut-off to occur.

During initial wiring of potentiometers P5 and P6, you want to make sure that you wire the 'end' pins in the correct order so that the final adjustment rotation will match my instructions. The center or 'sweep' pin goes to the chip.

P5 is the shut-off adjustment; you want to wire this pot. so that when it turned all the way to the left (counter-clockwise) the pin that shows maximum ohms goes to ground.

P6 is the buzzer adjustment; you want to wire this pot. so that when it turned all the way to the left (counter-clockwise) the pin that shows maximum ohms goes to ground.

The thermistor lowers it's resistance as it gets hotter, thus effectively lowering the voltage being sensed by the op-amps. So higher temperature is LESS resistance.

Wiring P5 and P6 as above will cause the 'reference' voltage (and ohms) to lower as you turn the pot. right (clock-

wise). Lowering the reference voltage raises the temperature at which the op-amp will signal the mosfet to turn on (or off).

### 'Balance' the op-amps

The potentiometers P1, P2, P3, and P4 are 'balancing' potentiometers; they make the op-amps very sensitive and precise. It doesn't matter which of the end pins go to the chip inputs. Always warm up the circuit for at least an hour before making sensitive adjustments.

To adjust P1; you ground the lower liquid level sensor probe (if fully installed, just add water to the bubbler tank) and then adjust P1 to the right and/or left 'til the shut-off relay turns off; then carefully turn P1 'til the shut-off relay just turns ON. You want this circuit to be normally on when energized; lowering water level will turn it off.

To adjust P2; you ground the upper liquid level sensor probe (if fully installed, just add water to the bubbler tank) and then adjust P2 to the right and/or left 'til the buzzer turns on; then carefully turn P2 'til the buzzer just turns OFF. You want this circuit to be normally off when energized; lowering water level will turn it on.

To adjust P3; you ground the wire going to the thermistor from R6 and adjust P5 all the way to the right (clock-wise); this will bring the P5 sweep pin to reference near zero ohms to ground. Then adjust P3 to the right and/or left 'til the shut-off relay turns off; then carefully turn P3 'til the shut-off relay just turns ON. You want this circuit to be normally on when energized; rising temperature will turn it off.

To adjust P4; ground the wire going to the thermistor from R6 and adjust P6 all the way to the right (clock-wise). This will bring the P6 sweep pin to reference near zero ohms to ground. Then adjust P4 to the right and/or left 'til the buzzer turns on; then carefully turn P4 'til the buzzer just turns OFF. You want this circuit to be normally off

when energized. Rising temperature will turn it on.

Remove the ground from R6 (and liquid level probe grounds if you used them). Adjust P5 and P6 all the way left (counter-clockwise).

### Set the circuit temperature

As pointed out before, the circuit can be adjusted to signal at any electrolyzer temperature you desire.

To set the Buzzer or warning circuit; have the P6 adjusted all the way left and operate the electrolyzer 'til it reaches the warning temperature (max. 110°F), then turn the P6 right 'til the alarm comes on.

To operate the electrolyzer continuously, I put my torch outside (or run a hose from the torch tip to outside); then turn on the torch valve so that I'm demanding more gas than the electrolyzer can produce, then the pressure switch never shuts off the electrolyzer. I don't bother to ignite the gas.

To set the shut-off circuit; have the P5 adjusted all the way left and operate the electrolyzer 'til it reaches the shut-off temperature (max. 120°F), then turn the P5 right 'til the electrolyzer shuts off. Note that the warning buzzer will be buzzing all this time, wear ear plugs if it bothers you (it's supposed to bother you). It is important that the buzzer be buzzing when the shut-off circuit is set because of the way the two set-points share the same thermistor.

### Circuit tests

You will see I've included green diodes (D1 and D3) to indicate when the water level and temperature levels are acceptable; these diodes are mounted next to 'momentary on' switches on the control panel (S1 and S3). When you push these test switches, the electrolyzer should shut off, and the appropriate green diode should go out. If the electrolyzer shuts down when you are using the torch, and you don't



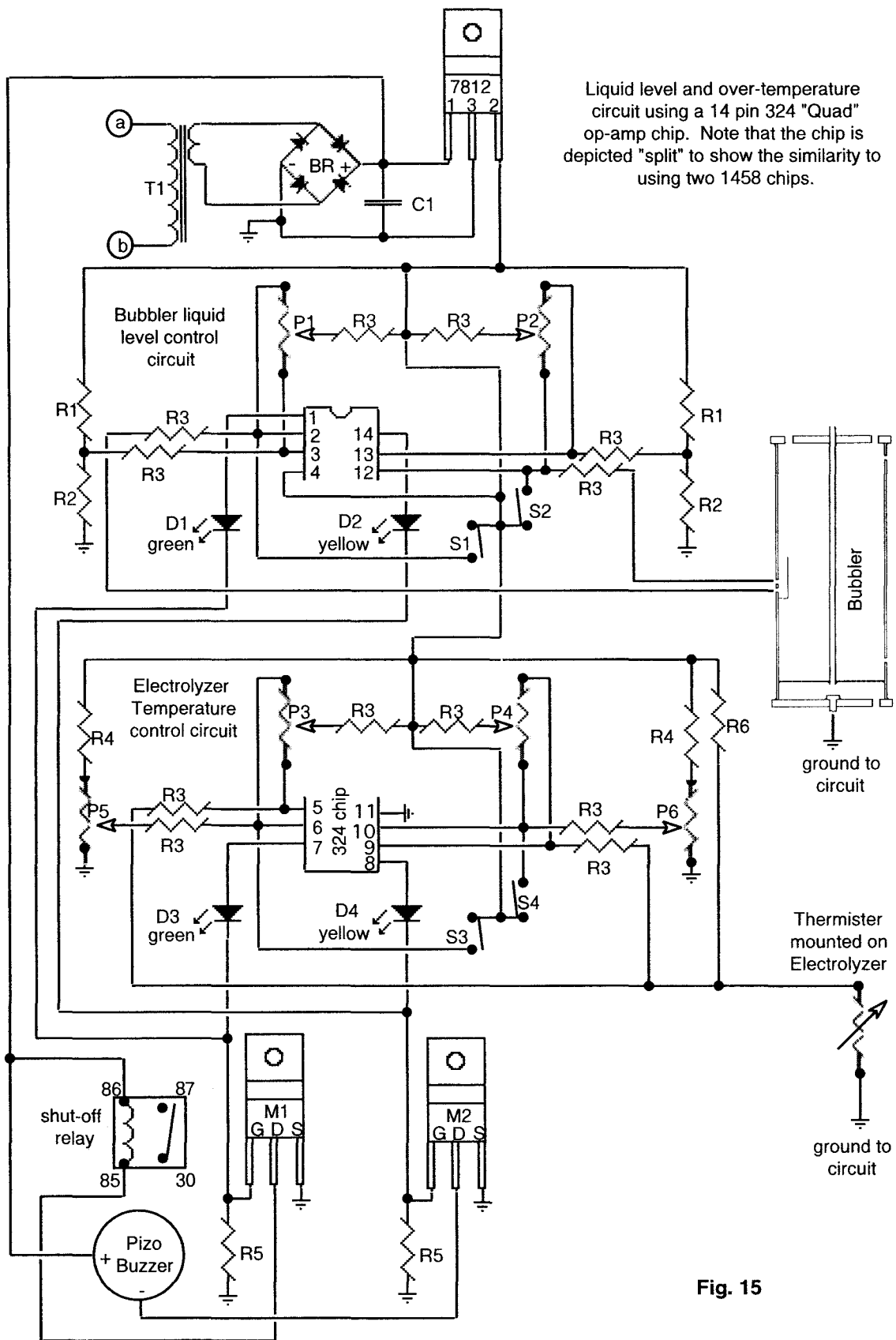


Fig. 15

notice the lack of gas volume, you WILL get a backfire when the torch drops to a low enough pressure. Backfires are nasty.

You will see I've included yellow diodes (D2 and D4) to indicate when the water level and temperature levels are getting close to shut-off; these diodes are mounted next to 'momentary on' switches on the control panel (S2 and S4). When you push these test switches, the electrolyzer should buzz, and the appropriate yellow diode should light up. This warning allows you to shut off the torch in a controlled manner, preventing a backfire.

### Circuit component list

Note that I include notes for those changes to use a 324 chip. If you have any questions about substitute component values, get in touch with myself or any other competent electronics engineer. A resistance variance of up to ten percent is allowed in these circuits, but whatever value you use, you should have all that category of resistors match fairly closely.

#### Resistors:

R1= 33 K ..... 2 X  
 R2 = 100 K ..... 2 X  
 R3 = 220 K ..... 12 X  
 R4 = 10 K ..... 2 X  
 R5 = 470 ohm ..... 2 X  
 R6 = 13 K ..... 1 X

Circuit-board-mounted  
 potentiometers ..... 6 X

Be sure to mount so that you can adjust the pots when the circuit is in operation but once set, you don't want people to be able to re-adjust them.

P1, P2, P3, and P4 are 47 K, Radio Shack # 271-283.

P5 and P6 are fifteen turn, 10 K, Radio Shack # 271-343.

The value of P5, P6, R4 and R6 are all dependent on the value of the thermistor. The values given here are for a thermistor that is 10 K (10,000 ohms) at 70°F. P5 and P6 should about

equal or slightly exceed the value of the thermistor at 70°F; R4 should limit the amp flow but not be so large as to make it hard for the op-amp by leaving a tiny voltage drop across P5 and P6. R6 should be at least 1.3 times R4, 1.5 times is OK.

My example using the 200 ohm (automotive) thermistor would use P5 and P6 of about 200 ohm, R4 of about 2.2 K and R6 of about 3 K.

2 of Yellow LED's, T-1 3/4 size, Radio Shack # 276-021.

2 of Green LED's, T-1 3/4 size, Radio Shack # 276-041.

1 of Pizo Buzzer, operating voltage 12 VDC, internal frequency; Radio Shack # 273-60.

4 of Mini SPST 'momentary' push button switches, Radio Shack # 275-1547.

1 of thermistor, acquire as explained before. Actually it is possible to make one from a Radio Shack # 271-110; just mount it in a blank 1/8" NPT plug; make sure the thermistor is contacting the actual metal and then fill in the hole with a non-conductive metal epoxy like JB weld or Lock-tite Weld.

2 of mosfets, TO-220 case style, IRF 510, Radio Shack # 276-2072.

2 of 1458 dual op-amps, 8 pin dips, Radio Shack # 276-038. (Or a single 324 Quad op-amp, Radio Shack # 276-1711.)

2 of 8 pin chip bases (IC sockets), Radio Shack # 276-1995. (Or one 14 pin socket for 324 chip, Radio Shack # 276-1999).

2 of sensor probes for liquid level. We haven't found a part that will work yet; build your own as per the instructions earlier in this chapter.

1 of 7812 voltage regulator, Radio Shack # 276-1771.

1 of TO-220 heat sink, Radio Shack # 276-1363.

1 of 120 VAC to 12 VAC @ 1.2 amps transformer, Radio Shack # 273-1505.

1 of 4 amp full wave bridge rectifier, 400 PIV, Radio Shack # 276-1173.

1 of electrolytic capacitor, 1000 uF, working voltage at least 35 VDC, Radio Shack # 272-1032.

1 of 30 amp 'auto' relay, Radio Shack # 275-226.

Breadboard, Radio Shack # 276-168. If you're very good at circuit design, you can use a smaller board.

PCB stand-offs, Radio Shack # 276-195.

Three colored rolls of stranded 22 gauge wire, to use as connection wire and as wire to parts of the main circuit that don't require much amperage flow. Radio Shack # 278-1307.

### BUILDING A CONTROL BOX

The control box is more than just the box (which I call the enclosure). The control box houses and includes all the gauges and controls (electrical and mechanical) for the electrolyzer. The only parts of the controls outside the box will be some valves and sensors, which I will detail here too.

#### List of Components and Materials

Be particularly careful about choosing your pressure gauge and pressure switch (and pressure relief valve). The materials inside the gauge and switch may not be compatible with your electrolyte. Check with your manufacturer. In general, it is best to get stainless steel. If there are rubber seals, get ones that are more to the natural rubber.

Of particular importance is that **aluminum is not compatible** with any of the electrolyte solutions that I've

researched, including sodium hydroxide. (see *Resources*)

You can also pick up components surplus at the surplus suppliers listed in Brown's Gas, Book 1. Just remember when buying surplus, it's buyer beware. However, by buying components in this way, I and associates of mine have built these electrolyzers at less than \$500 USD. This doesn't include the torch itself.

Below find a component list for the power supply of a 1000 L/h, 8 inch electrolyzer that has a Capacitive Limited power supply. The electrolyzer is split into two 65 series-cells that are operated in parallel from a 50 amp, 240 volt wall receptacle.

We've found this type of electrolyzer design to be the most consistently efficient (for several reasons) and it is inherently prevented from run-away by the capacitors. We will be demonstrating this electrolyzer design at the 1997 Tesla Symposium.

<u>Component</u>	<u>Quantity</u>
• Diodes, 80 amp/ 500 VDC .....	4x
• Heat Sinks .....	4x
• Pressure Switch .....	1x
• Pressure Gauge .....	1x
• 110 VAC on/off switch .....	1x
• Indicator Lights .....	2x
• 90 amp Main Relay .....	1x
• 50 mf/330 VAC Capacitors .....	20x
• 50 amp Range Cord .....	1x
• Short Terminal Strip .....	2x
• Long Terminal Strip .....	1x
• Box of Spades .....	1x
• Spool of 14 gauge wire .....	1x
• Box of 10/32 -1/2" bolts .....	1x
• Box 1/4" ring terminals .....	1x
• 50 ft. 8 Gauge wire .....	1x
• Box of 1/4" bolts .....	1x
• Plywood for Power Box .....	1x
• Volt Gauge .....	1x
• Amp Gauge .....	1x
• Casters .....	4x

### Pressure Relief Valve

The pressure relief valve needs to be compatible with sodium hydroxide; can be stainless steel, copper or brass.

Seals can be natural rubber or Teflon. The seals must positively seal against 200 psig (don't buy components that will be used at their maximum ratings). Set valve to relieve at 90 psig. Put in hoses that route any released pressure out of your shop. Hydrogen dissipates in air very quickly.

### Pressure Switch

The pressure switch should switch on and off with a maximum of 5 psi pressure difference (a switch set to turn off at 70 psig will turn on again at 65 psig).

You want the switch to be normally closed (on) and to turn off (open) as the pressure rises.

You want the switch to be able to handle at least five amps (inductive) at 120 VAC. It helps if the switch is rated to handle explosions (I've found some that are) but this shouldn't be too much of a problem as you take your pressure reading on the electrolyzer side of the bubbler.

Note: You could use the main pressure switch to signal a 12 volt relay (30 amp lighting relay bought in Radio Shack) the relay then being the switch that actually cuts off the power to the main relay coil. This arrangement would allow your pressure switch contacts to last a very long time, because they'd only have to handle the amperage of the relay coil. And when the relay wears out, it's easy and inexpensive to replace (much easier than replacing the main pressure switch, and less expensive too).

Further Note: a simple electronic switching circuit can make your main pressure switch contacts last for many decades. Simply use the switch contacts to signal a mosfet that would allow current to flow to the relay coil, which would turn on the power to the main power relay coil. In this case your switch contacts only have to handle a couple milli-amps at very low voltage.

Electronic switching using transducers is an option I don't cover here. Personally I'm not yet satisfied that there is a transducer that will work in long term with sodium hydroxide. I found that the sodium hydroxide packs into the tiny orifice and the transducer starts giving a false reading.

### Automatic Electronic Liquid Level and Temperature Controls

Build according to the instructions in this book. It is also possible to purchase such controls but you'll likely pay a lot for them.

I show you how to build the sensors you'll need to signal the liquid level circuit. And I tell you how to select and test a thermistor to signal the temperature controls. See *previous chapter*.

Note: It is a good idea to have the electronic circuit indicator lights (and test switches) mounted so that they are **visible on the control panel**, along with the appropriate test switches. You'll note that I show how to wire it this way in the schematics.

**Low voltage power supply;** 120 to 12 volt transformer/full wave bridge rectifier/capacitor (all set up as low voltage power supply). Needed if you run any low voltage devices, like the Automatic Electronic controls, various relays and/or 12 VDC temperature and pressure switches.

Test all your low voltage devices on a 12 VDC battery (measure the amperage with them all on at the same time) and build your low voltage power supply from Radio Shack parts. Get a transformer rated just above your amperage requirements; size the full wave bridge rectifier to handle at least twice the amperage of your transformer and size the capacitor (can be electrolytic) for 1,000 micro-farads per amp, working voltage rated to at least 35 Volts.

## Install gauges

The **Pressure Gauge** should read about 100 psig, not too much less because you don't want it to burst if you get a slight over-pressure; not too much more because you want to be able to read it easily.

Pressure gauge must be compatible with sodium hydroxide, hydrogen and oxygen. Several good ones can be found in the Cole-Parmer catalog.

You'll note that I mounted the pressure switch and gauge hose connections above the liquid-vapor separator. This is to help prevent liquid from reaching the actual working components of the pressure switch and gauge. It is also a good idea to mount these components so that if any liquid does get in them, that it will drain out. The problem is that all liquid in this system becomes contaminated with sodium hydroxide and eventually the sodium hydroxide can form deposits that may interfere with the switch operation.

There are pressure 'isolator' systems that you can install, to prevent switches from becoming contaminated but I don't think this is really needed in most applications the components (if compatible and installed correctly) will give decades of trouble free service.

Be sure to mount the pressure gauge in such a way that the fittings are easily reached for assembly, dis-assembly and testing.

**Temperature gauge:** optional but recommended. Should read from 0°F to 212°F; although a range from 70°F to 140°F is all that is needed for most use. A good electronic one can be found in the JC Whitney catalog. *see Resources* Also there are various electrical and mechanical temperature gauges that you can use. Whatever style you choose, make sure the sending unit is compatible with sodium hydroxide and can be effectively sealed against the pressure in the electrolyzer.

**DC Amp meter:** recommended but optional and handy to see exactly how

much amperage is actually going across your electrolyzer.

If you're going to put one in, get a good one, either electronic (expensive) or analog (not too bad). If analog, get one that reads a wide sweep (so you can see detail), full sweep just over your maximum amperage. I have one on my electrolyzer.

**AC Amp meter:** optional, to see how much amperage you are actually drawing from the wall. I don't use one on my electrolyzer.

**DC Voltmeter:** optional and handy to see how much voltage you are using across your electrolyzer. Gives diagnostic capabilities, high voltage would indicate plates that are coated with gunk or perhaps low electrolyte level or cold electrolyzer, etc. Again, digital is nice (and expensive) but analog works great. I have one on my electrolyzer.

**AC Voltmeter;** optional, to see how much volts you are actually drawing from the wall. I don't use one on my electrolyzer. For power tests I have a special watt-meter into which I plug my electrolyzers. I just use portable (clip or clamp on) amp and volt meters. Mostly, for actual operation, I'm concerned with the amperage and voltage across the electrolyzer itself.

## On/off switch

I just use a standard 120 volt light switch. You also need to get the electrical box that it goes into. Another option is to use a low voltage switch that signals a relay; this option allows you to have your entire control panel wired all low voltage, all the switches would look similar.

## Indicator lights

Two Indicator lights; 120 volt, can be different colors. Allows operating status confirmation of main switch on and main relay on, at a glance. Optional but recommended. Also, I recommend that you have indicator lights for status of the electronic liquid

level and temperature controls mounted right on the control panel where they are easy to see (It's a good idea to place the 'test' buttons there too, beside the appropriate lights). Another option is to use diodes for the indicator lights, simply add another high PIV diode and the appropriate resistor in series.

## Full-wave bridge rectifier

**Four heavy duty diodes;** (rectifiers) rated at twice the voltage and about twice the amperage that your electrolyzer requires. Get **heat sinks** appropriate to the size of your diodes and the wattage they will have to dissipate.

For example 30 amps at 0.5 voltage drop is 15 watts, your diode only has to dissipate about the same heat as a 15 watt light bulb. Rectifiers and heat sinks are an area where you can save money buying from surplus sources. The surplus sources list all the parameters you need to know and you don't have to worry about things like compatibility with sodium hydroxide.

You'll be wiring these four diodes into a 'full-wave bridge rectifier' as per the schematics shown elsewhere.

Arrange the heat sinks so that cooling air can flow freely through them.

## Main relay

Get a mechanical one rated for a higher amperage than you'll be using. This'll help make it last longer. It is nice to get a three pole single throw (but a two pole single throw will work). Coil operated by 120 VAC (even though there is 240 VAC going through the main contacts to the high voltage electrolyzer power supply). I like to use mechanical rather than electronic because I LIKE to hear when the electrolyzer is operating (you'll hear the contacts turn on and off and you'll hear the slight buzz of the main relay coil when it is activated). Also, mechanical relays are rugged, dependable and it's less likely that one of you will mess it up. My experience with electronic relays shows they can

be sensitive under certain conditions.

Note: some mechanical relay coils are excessively loud, mostly because they are loose and vibrate at the 60 cycle frequency. I just used a 'hot glue' gun and glued my coil down; it worked great!

### Terminal strips

I just made my own, using strips of copper 1/16 inch thick and 3/4 inch wide. I screwed the copper onto a strip of Teflon plastic (could use PVC or HDPE as well) 3/4 inch wide and 1/2 inch deep. Then I drilled and tapped (10/24 thread) holes every 1/2 inch. I use these terminal strips to attach all the capacitors to the main power cables (they work great). Make them long enough to handle all the capacitors that'll fit in your enclosure.

You can buy terminal strips in Radio Shack, item # 274-670. For connecting all the capacitors to a #8 wire, you'll also need a 'jumper terminal strip', Radio Shack # 274-650. The jumper terminal strip makes all the terminals on one side of the terminal strip common (connected together) with a piece of metal thick enough to handle the high amperage. If you were to just run a 14 gauge jumper wire from one terminal to the next, the first 14 gauge jumper would have to handle all the amperage less the first capacitor and it would burn up.

Again I note; it's wise to use connectors or terminal strips for everything, so that every component can be removed independently for maintenance, testing or service.

### Duplex receptacle

I don't show a duplex receptacle in the main wiring schematic. It is optional but recommended. I can't tell you how many times it's come in handy with my electrolyzer. It's handy to have 120 VAC right there. It's not a bad idea to wire in a 240 volt outlet as well.

### Hook main power inlet cord to enclosure box

**Power Cord and plug:** you'll get a proper sized cord and plug for the amperage you will be drawing. Don't get one too small or you'll burn it up. Cords and plugs are amperage rated, so a hardware person will be able to help you get the right ones. On my ten inch electrolyzer (30 amps DC, 48 amps AC) I use a 50 amp power cord meant for electric ranges. You may already have a heavy duty outlet rated for the amperage you will have and you'll just get a cord and plug for it. Remember to rate your breaker about 30% higher than your AC amps.

**Power Receptacle:** while this isn't a component for inside your enclosure, you'll need to plug in your electrolyzer, if you don't already have a receptacle, wiring one in is straight-forward electrical work.

Just wire the receptacle to code in your area. Make sure your wires from your breaker box can handle the current you expect to draw.

If you use an extension cord, make sure it is rated for the amperage and has the proper ends. I recommend Teck (armor-covered) cable.

### Enclosure box

The enclosure box will look different for every home built application, because most people will use components that aren't the same.

To design your own enclosure, you first need to acquire all the components for your control box and then 'lay them out'.

By measuring the components and figuring out where you want them in relationship to each other, you will determine the size and shape of your enclosure box.

Certain things are obvious, like you want your pressure gauge where you can glance at it from anywhere you are using the torch. It is no problem to add

more than one pressure gauge if you want to see the pressure from different angles.

As I mentioned before, it's helpful to have the indicator lights (LED's) and test switches for the automatic electronic liquid level and temperature switches mounted on the control panel as well.

And you want your main on/off switch where it can be reached very easily.

I advise you to build your unit so that you have easy access to all of your interior components, and particularly the components that need adjusting, like the pressure switch and the automatic temperature controls.

I advise you to build, and particularly to wire your control box so that you can remove any component easily. Use of terminal blocks and ferrules is advised, so each component can be removed separately.

It really pays to take a little extra time to plan how you'd remove each component. From the top, front, back or sides and have the appropriate doors or fasteners so that you can remove the covers easily. It may take a little longer to build it right, but you'll be proud of the result and appreciate the effort you put in if you ever have to take it apart. In particular, you'll notice if you didn't design it properly.

### Install capacitors

Several power capacitors are needed for capacitive limiting or voltage doubler. You must rate the capacitors at above the peak voltage you'll be drawing from the wall. You are best off with oil filled capacitors. Note, this is again a good item to look for in the surplus area. Capacitors mostly either work or they don't. Oil filled capacitors tend to be 'self healing'. Just find enough capacitance to do the job for you as per the information given previously.

Note: At 4:1 electrolyte concentration you'll need a lot less capacitance than

72:1. For example, at 4:1 my 126 cell, 10 inch electrolyzer needs only 20 uF on each leg to get 28 DC amps from 240 VAC; but using 72:1 I need 250 uF on each leg to get my 28 DC amps. Obviously the DC voltage is much higher across the electrolyzer with the thin (72:1) electrolyte.

### Wire control box

All wire should be STRANDED, because this is a mobile application. Generally speaking you'll be buying three sizes.

1. A heavy gauge for your main high voltage/ampage circuit (exactly how heavy gauge depends on the amperage you'll be drawing). I'm drawing up to 50 amps AC for my ten inch electrolyzer. I'm using six gauge wire; I can get away with it because my wires are short but I really should be using four gauge (the smaller the number, the thicker the wire).
2. About 14 gauge for the main relay control circuit, this will handle from 4 to 6 amps.
3. And 22 gauge for the electronics; these wires need only handle fractions of an amp.

All wires should be color coded and the color codes noted in your Brown's Gas book, for reference later. I do not recommend that you use only one color for everything; you'll regret it if you do. You can buy a nice wire assortment from JC Whitney.

Generally speaking for AC, Black is power, White is neutral, Red is usually power and Green is usually neutral.

For DC, Black is negative and Red is positive, white, green, yellow etc. are used as 'in between' wires, color coded to make tracing circuits easy.

Use proper terminal ends for every wire, and where using ferrules, solder the ends of the wires (individually) before twisting them together. I recommend soldering the terminal ends onto the wires.

You'll determine the length of all the wires (and hoses) after you've brought

all your control box components together, even mounted them in the enclosure.

When cutting length of wires, don't cut too short or too long, route the wires neatly and together. Remember that you want to be able to get at components to remove them. Use cable holders and wire ties to make the installation neat and to keep the wires from rubbing against anything that will cut them.

### Wires From Enclosure to Electrolyzer

You have to plan on how your wires will be fastened onto your electrolyzer sensors and how they will be routed into your control box.

Some sensors already have a ground wire, some were meant to be grounded through their case to the metal in which they're screwed. But since this design has a plastic shell, it does not allow grounding; for the ground on these sensors, I just clamp the ground wire onto the sensor with a screw clamp.

Use proper wire ties and strain relief devices. Route your wires so that they are unlikely to be caught or snagged on anything (out of the way and neat).

### Gas pressure hose from liquid-vapor separator

This hose will go to the pressure relief valve, pressure switch and the pressure gauge. Use the appropriate fittings, remembering that you may want to remove any one of these devices for service at some time.

Route the hose so that if any liquid gets into the line, the liquid will drain back to the liquid-vapor separator. Route the hose neatly but without sharp bends and without loops that collect liquid.

## DESIGNING AND BUILDING A BUBBLER

This list is for an ER 1000 electrolyzer (which we will demonstrate at the 1997 Tesla Symposium), having a bubbler tank and a modifier tank. The valves and fittings are listed in the 'electrolyzer fitting' component list.

<u>Component</u>	<u>Quantity</u>
S.S. Tank as depicted .....	2x
1 ft. 1/4" PVC Tubing .....	2x
Little Plastic Ball .....	2x
Oxy./Act. Hoses .....	1x
Torch with tips .....	1x

Note: the bubbler tank in the drawing is NOT to scale, pay attention to the sizes given on the drawing.

This bubbler is designed for up to a 1,500 liter per hour electrolyzer. A 4,000 liter per hour bubbler would be identical height, and it would be 5.5" ID diameter, 3/16" walls, 3/8" down-tube and 1/2" end plates.

The bubbler tank must have a sight tube to allow visual monitoring of liquid levels. The sight tube is meant to go between the 1/8" FPT hole 1 inch above the diffuser plate and the 1/8" FPT hole 1 inch below the top of the bubbler.

The bubbler tank has two liquid level sensors in it. The highest to warn of low liquid level by turning on a buzzer, and the lowest to actually shut off the electrolyzer. The lowest is mounted 6" above the diffuser plate and in our shop this is known as the 'Line Of Death.' The upper sensor can be anywhere from 1/4" to 1" above the lower sensor.

Note the sensor shroud. This can be any shape of stainless steel, welded to the side of the bubbler, just so it encloses the liquid level sensors (must be at least 3/8" away from the tip of the sensors as they stick out into the bubbler). The sensor shroud doesn't have to be sealed, in fact needs about (no more than) an 1/8" hole in the bottom and needs at least an 1/8" hole

in the top (the top can be completely open). The reason for the shroud is to provide a calm level of water around the sensors. The main bubbler area is way too agitated for the sensors to operate properly.

Note that I have a 3/8" bolt welded onto the bottom of the bubbler. This is

to solidly mount the bubbler on a frame that will not tip over, EVER.

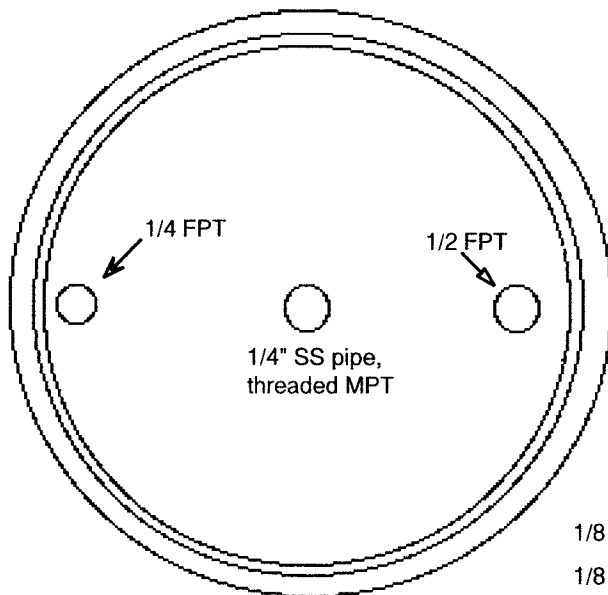
I mount my oxygen bottle right on my frame for my bubbler, because it needs to be right there and I don't want it tipping over either.

You can make up a second bubbler to mount on a cart with an oxygen bottle

if you want to move around your shop. This would keep the backfire distance short. You would need only one hose coming from your main bubbler to the portable bubbler.

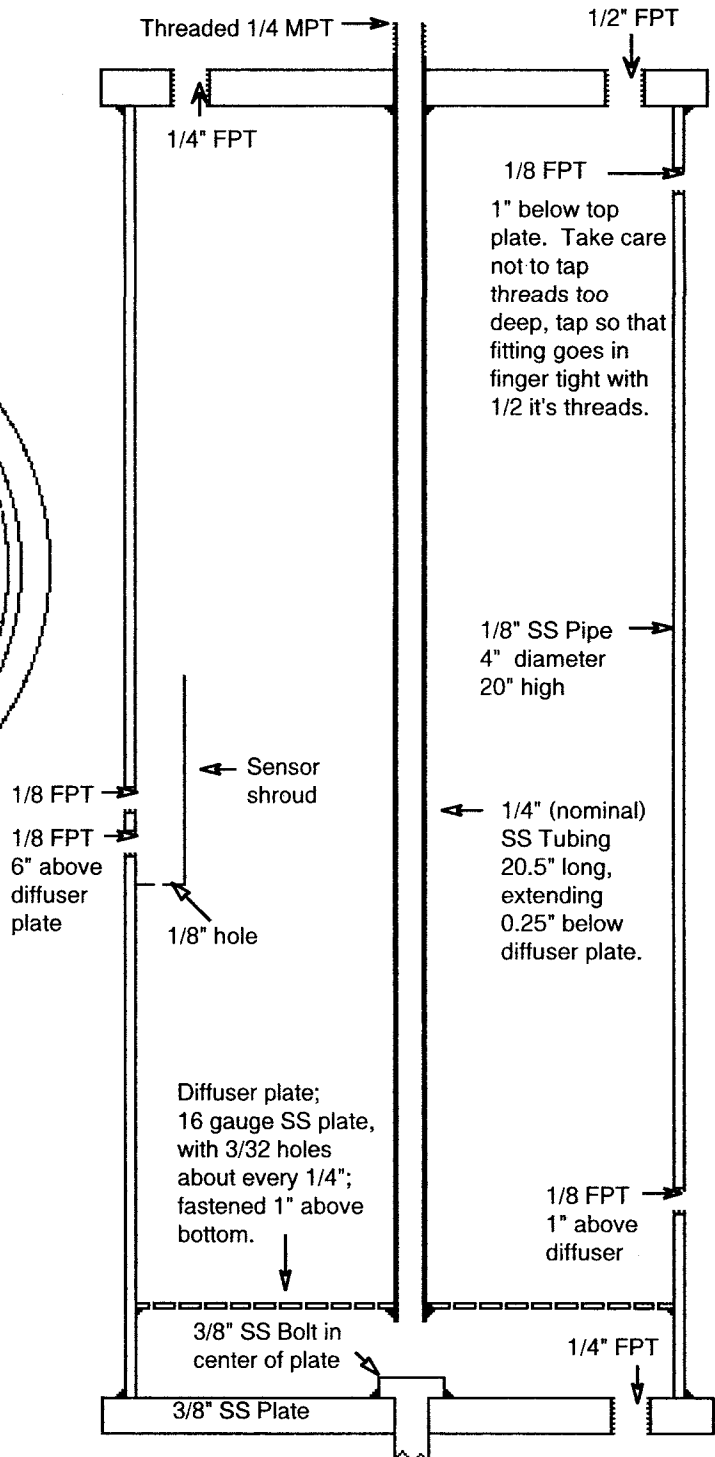
It is my sincerest recommendation that unless you really know what you are doing, to commission a professional welding shop to make your bubbler.

**Bubbler Tank for ER 1000**  
www.eagle-research.com



Instead of drilling the diffuser plate by hand, it should be possible to buy predrilled plate.

**Fig. 16**



Don't mess around with this item, it is your sole defense against an uncontrolled explosion.

The bubbler tank must be designed to be strong enough to withstand an explosion. The problem with designing a strong container is that if it is not strong enough, then the force of explosion when the container bursts is much greater than it would have been if the container had burst easily; so make it extra strong, your life depends on it!

Note: the containers I've designed for you here are already extra strong, stronger than the one I use in my own shop. Making it even stronger is, in my opinion, a waste of money; and you'll quickly see how much money that is.

Generally speaking, gas enters the bubbler tank through the 3/8" tube (recommended) or the 1/4" hole in the bottom (not recommended, because contamination can drop down the 1/4" hole). The gas then rises through the diffuser plate and goes out of the bubbler through the 1/4" FPT hole in the top. The 1/2 FPT hole is for filling the bubbler; this is where you mount valve 1, which I recommend be a brass gate valve (I recommend all the valves to be gate valves, they seal best).

I've also designed this bubbler tank to double as a modifier tank. You can drain the modifier fluid through the 1/4" FPT hole in the bottom. In this case you'll just plug the liquid level sensor holes and depend on the sight tube. Most modifier fluids won't conduct electricity, so the sensor wouldn't work.

## OPERATING A BG ELECTROLYZER

### Confirm ready to start

- All hoses & wires properly connected.
- Proper concentration and level of electrolyte in electrolyzer.
- Water in bubbler to start.

- Preliminary pressure switch setting, near zero.
- Adequate size of breaker on circuit wall receptacle.
- Torch hose connected to bubbler tank, torch turned off.
- All valves turned off.
- Have soapy solution ready to test fittings. (Dish soap mixed in water, to make floating soap bubbles.)
- Plug in main power cord to wall receptacle.

### Initial start

- Turn on main breaker.
- Turn on electrolyzer main power switch.
- Watch for gas or liquid leaks as gas pressure builds to the low pressure you've first set the pressure switch at.

### Check for leaks

Check for and fix leaks before proceeding. Test for leaks with soapy solution, use paint brush. The soap makes a film over anything you paint it on; thus gas leaks will make soap bubbles. If you see ANY bubbles, even very small ones, you have a gas leak. Note: the act of brushing the soap on, will make some bubbles. Wait to see that new ones are being made by gas before assuming that you have a leak. Do I have to tell you NOT to test for leaks with an open flame?

TIP: Unless you have a very bad leak, check all your fittings at the same time while under pressure. Then you can de-pressurize to fix all the leaks at once.

You must de-pressurize before fixing leaks, be sure to vent the gas outdoors (using your torch).

Be sure to re-check ALL your fittings after fixing any leaks. And check them at full operating pressure for a couple of days after final assembly.

Periodically check your fittings as you operate the electrolyzer. A visual inspection of the pressure gauge after a

prolonged shut-off is usually enough to find out if you have very small leaks (your pressure will drop).

### Set pressure switch

Using a pressure switch allows you to set any pressure you desire and keeps the electrolyzer fairly inexpensive, easily built, simple, safe and compact.

Adjust the pressure switch up a few psi at a time, 'til you reach your operating pressure. I recommend 65-70 psi. You want a high enough pressure to help prevent backfire, yet low enough to not stress the electrolyzer.

### Set and test the liquid level and temperature circuits

Even though I list these circuits as optional, I seriously recommend them. It is possible to operate the electrolyzer safely without these circuits, but they offer that slight degree of extra safety that may save your hide. If it means anything, I have these circuits mounted on my electrolyzer.

### Lighting the torch

In the past it has been recommended that Brown's Gas electrolyzers be purged of the contaminated gasses in the electrolyzer. It was thought that the contaminated BG would be explosive, and it is.

Actually, I've found a purge to be unnecessary. I just turn the electrolyzer on and allow it to come up to pressure and then light the torch normally. I've found that the gas burns fine regardless if it is mon-atomic or di-atomic.

Besides, unless the gas is totally mon-atomic, it is EXPLOSIVE. As I've explained before, any di-atomic gas will EXPLODE before it implodes.

Light the torch only with the electrolyzer pressurized. I operate between 65-70 psi. This higher pressure allows me to operate with larger torch tips. If you don't have enough pressure, the gas will backfire to the bubbler with a loud BANG.



Light the torch as you would any other torch. Turn on the BG a bit, not too little or you'll backfire (because the gas velocity out of the torch tip will be less than the velocity of the flame and the flame will travel back into your torch. Don't open the valve too much or the torch won't light because the gas velocity is too high (it blows the flame out).

Note: the actual operating gas pressure at the torch tip is determined by your valve setting. It doesn't matter that you are feeding the torch with 70 psi, if the torch valve is mostly closed, the actual gas pressure at the torch tip is much less and you can vary the tip pressure at will by adjusting the valve.

Turning the torch valve on enough so that you can clearly hear the gas gently hissing is usually about right. You'll know if it is too little because you'll have a backfire. You'll know if it is too much, because the torch will be hard to light.

Light the torch with any ordinary method, match, lighter, striker, etc. You have to hold the striker quite close to the torch tip or the torch won't light.

Note: It will be hard to light the torch with a match, because the gas velocity will tend to extinguish the match before the torch lights. DO NOT turn down the gas velocity too far or you'll backfire.

You will quickly learn the things that cause a backfire and learn to avoid them. The backfire is loud and can make you jumpy; and you'll have the chore of emptying the water out of the hose after every backfire.

### Extinguish torch

The usual and quickest method is to **suddenly shut off** the gas adjustment valve. If you shut it off too slow, you WILL get a backfire.

Another way to extinguish torches is to **quickly** open the torch adjustment until the flame is extinguished by the gas velocity. Then shut off the gas flow.

All electrolyzers have some gas storage, so are able to momentarily maintain a higher gas volume; but this must be done quickly or your pressure will drop too far and you'll backfire. **Note:** this works only if your electrolyzer has enough pressure to create a gas velocity far exceeding the flame velocity.

You'll want to extinguish the flame whenever you're not actually using it (it re-lights easily and cleanly). Not only is this safer, but you use less electricity and water to get your job done. Further, the electrolyzers do tend to heat up as they are used; by extinguishing the flame, you give the electrolyzer a chance to cool.

### Shut off electrolyzer

It is my sincere recommendation that you **shut off your electrolyzer whenever you are not using it**. By this I mean shut off the main power switch. This will give you two advantages:

First, you'll be able to tell if you have a gas leak because the pressure in the electrolyzer will drop overnight.

Second, you'll still have a shop in the morning. Imagine this; your pressure switch fails and your electrolyzer builds pressure (doesn't shut off) 'til the electrolyzer tank bursts (say around 300 psi), releasing a huge amount of flammable gas into your shop, some arc or flame in your shop ignites the mixture and the resulting explosion levels your shop and any nearby buildings.

Even with a pressure relief valve you are not completely safe, running the electrolyzer for extended periods causes it to overheat, if your temperature controls fail (or you don't have any); then your plastic electrolyzer shell gets soft, causes leaks, puts flammable gas in your shop and it blows up.

Shut off your electrolyzer when not in use. If it has no major leaks it'll hold it's pressure for days.

### How to avoid backfire

Keep gas pressure up, too low of electrolyzer pressure can't maintain gas velocity at speeds faster than the combustion of the fuel.

Larger torch orifices require higher pressure to maintain the gas velocity at higher speeds than the combustion velocity.

Do NOT allow the electrolyzer to run out of water. If the electrolyzer runs out of water, you'll lose gas pressure and you'll backfire.

**Again: the electrolyzer system MUST be high enough pressure to keep the gas velocity at the nozzle above the combustion velocity of the flame, or the system will backfire, causing implosion or explosion, depending on the characteristics of the gas at the time (usually explosion). Larger nozzles require higher pressures to prevent backfire.**

This is a very good point to bring up at this time: If you had pure Brown's Gas (200% gas) then you'd only have an implosion. If you have anything close to di-atomic gas, then you'll have a **BIG explosion, then an implosion.** The **END** result of burning mon or di-atomic hydrogen and oxygen is always a vacuum, because the gas turns to a liquid (water). You'll always get a vacuum in your bubbler tank, regardless if you had mon-atomic or di-atomic gas.

This is because the di-atomic gas must first split into mon-atomic gas (which is Brown's Gas) and this splitting (breaking of atomic bonds) causes an explosion; then the newly split atoms recombine directly into water, going from a gas to a liquid just as Brown's Gas does (because at that point it IS Brown's Gas).

Gas with mostly di-atomic explodes violently (sounds like a 'bang'). Gas with a lot of mon-atomic explodes too but not as hard, because you're getting an explosion and implosion at the same time (sounds like a 'poof').

And Gas with mostly mon-atomic mostly just implodes, (making a

'ping'). So the QUALITY of the gas is vital; at least as far as avoiding explosions.

### What to do when you get a backfire

Before you change your underwear (due to spotting fore and aft), you **SHUT OFF YOUR TORCH**. Then you check to see if any damage occurred to any part of the electrolyzer.

The shock wave will usually knock anything flying that is just laying on the bubbler. My funnel gets knocked off.

The electrolyzer should immediately start re-filling the bubbler container with gas stored in the electrolyzer, and then building the pressure up from there.

Don't use your torch again 'til you've verified no leaks and proper operation of the electrolyzer. Usually a quick visual check while it rebuilds pressure and shuts itself off.

When you open the torch gas adjustment valve, you'll find copious amounts of water in your torch hose. This is normal, due to the oxygen and hydrogen having converted to water in your hose. And perhaps some water that got sucked up from your bubbler.

You must carefully drain the water from your hose. Turning on the gas flow and slowly raising the hose along it's length will get most of it. After the main draining, small drops will still occasionally come out your tip as you operate the torch but they usually won't cause a problem.

### Re-filling electrolyzer with water

Note that I have arranged this system so that I can 'back-fill' the electrolyzer with water from the bubbler tank. This is because the water in the bubbler tank eventually becomes contaminated with sodium hydroxide carried over from the electrolyzer with the gas. 'Back filling' allows me to put most of the sodium hydroxide back into the electrolyzer.

The procedure to put water into the electrolyzer involves:

1. Pressurizing the entire system with gas (doesn't have to be high pressure), shut off the main power switch.
2. Rotate the electrolyzer 45° (to allow free electrolyte flow between all the cells (through the gas space at the top of the plates).
3. Open valve 3 a crack to reduce the pressure in the electrolyzer (allow only gas to escape, no liquid). You don't need to have total pressure loss; about a 10 psi pressure difference between the bubbler tank and the electrolyzer is plenty. I just vent this little bit of gas into my shop, but if you want to be truly safe, you should vent this gas outdoors.
4. Open valve 2 to allow water to flow into the electrolyzer from the bubbler tank. The higher pressure in the bubbler tank (10 psi difference) will quickly fill the electrolyzer.
5. When you think the electrolyzer has enough water; close valve 2 and rotate the electrolyzer back to it's operating position. Check the liquid level in the electrolyzer to make sure you've added enough and not too much.

If you've added too much (electrolyte is higher than recommended in previous text) then you turn the electrolyzer 45° again and drain electrolyte out valve 4 (electrolyzer must be tipped or you'll only drain the end cell). Then the next time you need water, you put this electrolyte back in; BUT you don't put it through the bubbler, you have to open the 'gas out' hose at the liquid-vapor separator and pour the water containing electrolyte DIRECTLY into the electrolyzer. It is never a good idea to put electrolyte in your bubbler, this will cause contaminated flame and foaming problems.

Note: During assembly, be sure to mount the valve 3 so that the electrolyzer gas output will be above the liquid level both during normal operation and during refill. If your liquid level output isn't high enough, then mount valve 3 elsewhere. Mine is actually mounted on the shell, but

we've put it in various places on the electrolyzers we've built. Valve 3 MUST be in a different spot than the gas outlet/water inlet.

### Adding fresh water to the bubbler

A person could fill the Bubbler tank with a pressurized water supply or pump (must also have a shut-off valve and/or check valve). This would be an automatic water filling arrangement and could easily be done. I do NOT do this on my own electrolyzer and do not recommend automatic filling of the bubbler (or the electrolyzer) on these small electrolyzers. I WANT operators to occasionally look their electrolyzers over and water filling time is good for that.

I am now designing electrolyzers that will put out an excess of 100,000 liters per hour (2,400,000 Liters/day). These will have automatic water feed systems. I've designed some nice simple and effective ones. I can easily design electrolyzers for a million liters per hour. If you need such gas production, then contact me.

Personally I've found no problem shutting down to add water; I only have to add water once every few days. Obviously, whenever you move some water from the bubbler to the electrolyzer, you need to refill the bubbler back to it's operating level.

**Step 1** is back filling the electrolyzer as mentioned in previous text. Tip electrolyzer 45°, reduce pressure in electrolyzer by opening valve 3, open valve 2 to move water from the bubbler to the electrolyzer, close valve 3, tip electrolyzer back up-right, check water level.

**Step 2** is bleeding off the entire gas pressure in the bubbler and the electrolyzer (vent torch to outside with electrolyzer main switch shut off).

**Step 3** is filling the bubbler with a funnel (fill through valve 1). Don't fill too much (you'll get water in your torch hose) or too little (a backfire may go back through it).

**Step 4** is close valve 1 and turn on the electrolyzer again. Allow the

electrolyzer to re-pressurize and you're on!

**NEVER** operate the electrolyzer with less than six inches of water above the diffuser plate. Less than this and you risk a backfire going back to your electrolyzer, blowing it up and destroying your shop. We developed electronics that help prevent you from making that mistake.

Visually check your liquid level often; DON'T depend on the electronics to save your ass. If your check valve leaks (perhaps because of a bit of foreign matter stuck in the seal) then your bubbler fluid could drain into your electrolyzer. Then when you went to start up again you'd be operating an un-safe unit.

### Draining the electrolyzer

You shouldn't have to totally drain your electrolyzer very often, perhaps never. Mostly if you've got dirty plates from bad water, or you didn't de-grease your plates well enough and you're not getting the performance from your electrolyzer that you should.

Before totally draining the electrolyzer, reverse the polarity of the electricity going into the electrolyzer for about ten minutes. This will knock the impurities off the plates and into the electrolyte solution, so they will drain out with the solution. If you reverse the current for too long, the impurities will travel over and stick to the opposite plate.

To drain the electrolyzer, I pressurize it with compressed air through valve 4 when the electrolyzer is turned completely upside down, so that the electrolyte can drain out the gas-out hose. I direct the gas-out hose into buckets to gather the electrolyte. DON'T put too much air pressure into the electrolyzer 2 to 5 psi is plenty. Have someone hold the hoses, because the pressurized electrolyte will come out FAST. Take care not to have it splash on you; use appropriate eye and skin protection, have vinegar or lemon juice ready to neutralize spills.

Note: I put the electrolyzer on blocks when I turn it over, so that the gas out fitting doesn't get knocked off and to allow the solution to flow without the hose being kinked.

Once the electrolyzer is drained, you can completely dis-assemble it if you wish, just undo the end plates and it comes right apart (again, use safety equipment) examine the components and clean them further if needed.

Re-fill the electrolyzer with fresh (de-ionized or distilled) water and electrolyte solution. Dispose of the contaminated solution in an environmentally friendly manner. The sodium hydroxide can be recovered.

### Preventing foaming

If you've got a foaming problem, you likely have incompatible materials in your electrolyzer that are reacting with the electrolyte. We had such problems for MONTHS.

We have found very few fitting thread sealants that are compatible with sodium hydroxide. I've found it NOT helpful to phone the manufacturer. In my experience, they'll feed you misinformation. ('OH we're SURE that it's compatible'. Yeah, right.....)

Take my recommendation and use only Teflon TAPE. If you feel you want to use liquid or paste sealant, you just have to TEST IT in a small test cell built in a mason jar. If you see any foam AT ALL, it is incompatible and will give you troubles. I've found even the oils in my skin to be incompatible; so I use rubber gloves after I've degreased the plates.

EPDM end gaskets and o-rings are good to seal the end plates and power bolts. Teflon TAPE is good for fittings (TAPE, not paste).

### Over-heating

All electrolyzers heat up because of the di-atomic gas formation (see Brown's Gas, Book 1). Brown's Gas electrolyzers heat up less than 'normal'

electrolyzers but if they are not making 200% gas (pure Brown's Gas) then they will have some heat to get rid of.

There are several ways of dealing with the heating problem:

The first is to design the electrolyzer to produce as much BG as possible, thus not making the heat in the first place. We're trying this method as much as possible.

The second way is to passively get rid of the heat, designing the electrolyzer so that it absorbs the heat from the electrolyte and radiates the heat away. Also, a goodly amount of the heat leaves the electrolyzer as water vapor (steam) along with the BG.

The third way is to design an active cooling system, likely using a water cooling coil or a standard refrigeration system. I've designed such systems for the huge commercial applications, if you need a lot of gas on a continuous basis, get in touch with me.

For this electrolyzer design, designed for home shop experimental use; I've made the BG production reasonably efficient, so not much heat is produced. Then I depend on a slight amount of radiation (plastic is a pretty good insulator) and steam (going out with the gas) to get rid of heat.

If you operate the electrolyzer for hours at it's full possible capacity, it WILL heat up enough to cause a problem with the plastic. As the plastic gets warmer it loses it's ability to hold pressure. With PVC the limit is 120°F. With CPVC the limit is 160°F. This is why I recommend CPVC even though it is twice as expensive and harder to get than PVC.

Still, my personal electrolyzer is PVC and I've only had a temperature problem when I over-drove it for hours just to see what would happen. I've also designed, installed and tested temperature controls that buzz if the electrolyzer is getting warm, and shut off the power if the temperature reaches 110°F.

Note: when you shut down the electrolyzer, you'll note that the temperature will rise a few more degrees before it starts to cool off. You can cool off the electrolyzer quicker by draining the pressurized gas out of it, then you take out the steam, which contains a lot of heat.

For normal operation you'll never have to worry about a heating problem. My electrolyzer has never exceeded 90°F during normal cutting-welding-experimenting.

## BG ELECTROLYZER EFFICIENCY MEASUREMENTS AND CALCULATIONS

### Electrolyzer Theoretical Gas Production

Refer to Brown's Gas, Book 1. Note that it is AMPERAGE (not voltage) that causes electrolysis to happen.

To calculate the theoretical maximum production of 2H<sub>2</sub>:O<sub>2</sub> per hour, use this formula:

$$((A / 26.8) * 16.8) * C = \text{Liters of } 2\text{H}_2:\text{O}_2$$

A = Actual DC amps flowing through your electrolyzer.

26.8 = amps per hour (one Faraday).

16.8 = molar volume (in liters) of di-atomic hydrogen and oxygen gas produced per Faraday.

C = Number of cells in your series-cell electrolyzer.

Example, if we have 10 amps flowing through a 60 cell electrolyzer. Our formula looks like this:  $((10 / 26.8) * 16.8) * 60 = 376$  Liters per hour of 2H<sub>2</sub>:O<sub>2</sub> (ordinary di-atomic hydrogen and oxygen).

Note: Theoretical maximum production of 2H<sub>2</sub>:O<sub>2</sub> per Faraday is about 933 liters at Standard Pressure and Temperature. This means if we produce more liters than that, we are doing something that needs explaining. Scientists are having trouble explaining this phenomenon.

### Actual Gas Production

My standard volume measurement technique is to take a plastic 'gallon' (four liter) jug, fill the jug, measure the amount of water it holds completely full (please do all measurements in liters and grams if you can).

Refill the plastic jug with water and hold the jug upside down in a five gallon bucket of water. Insert a hose from your electrolyzer into the gallon jug. As the gallon jug fills up with gas, water will be displaced (pushed out of the jug), measure the speed at which water is displaced with a stopwatch. For example; four liters (one of my jug-full) every 22 seconds (or one liter in 5.5 seconds).

Be sure to hold the plastic jug so the liquid level inside and outside the jug remain about level, or your measurement will not be as accurate. If the gas has to work against water pressure, it will pressurize the gas and you won't get as much measured volume as you actually produced at atmospheric pressure.

These kind of tests must be made with the electrolyzer at constant pressure. When I test an electrolyzer under pressure; I turn it on and adjust my torch 'til the pressure remains constant for some time (which means I'm producing as much gas as I'm allowing to escape), and then I test the volume flow.

I've found this volume displacement method to be fast and accurate. Using gas flow meters has not worked well; the slight amount of liquid that condenses on the hoses tends to make flow meters inaccurate. Also, the gas is much lower density than air, causing the calibration of 'ball'type flow meters to be inaccurate.

### Figuring BG proportion of gas: Gas Efficiency

Once a volume test has been made, a simple calculation will determine if you are making 'super-efficient'

Brown's Gas and if so, what is the 'quality' rating of your Brown's Gas.

So let's do an actual calculation to see how much Brown's Gas Mario LeBell and his brother Ray were making in Vancouver, BC. Using the volume measuring technique described above they measured one liter every 22 seconds using 3.5 amps at 128 volts coming out of their 60 series-cell electrolyzer (with capacitive power supply).

Remember, voltage doesn't matter to the actual electrolysis, only to the overall wattage efficiency of the machine (discussed later).

Mario measured 3.5 amps going into his 60 series-cell. Theoretical maximum production of 2H<sub>2</sub>:O<sub>2</sub> is:  $((3.5 / 26.8) * 16.8) * 60 = 131.64$  liters 2H<sub>2</sub>:O<sub>2</sub>.

They measured one liter every 22 seconds. There are 3600 seconds in an hour, so they are making  $(3600/22)$  163.63 liters per hour of gas; which is greater than 131.64 liters, so they were making 'super-efficient' Brown's Gas. 131.64 liters / 163.63 liters shows that they were making about 80% 2H<sub>2</sub>:O<sub>2</sub> and 20% Brown's Gas.

$163.63/123.36 = 1.24\%$  'quality' gas. This means 24% more gas than 2H<sub>2</sub>:O<sub>2</sub> could possibly have given. We therefore assume (because we have no other explanation) that some of this gas is mon-atomic as per the explanation in Brown's Gas, Book 1.

Note: 26.8 amps per hour would make 33.6 liters of mon-atomic Brown's Gas. This is what I call 200% 'quality' gas, because it is twice the volume of the di-atomic gas. **Pure Brown's Gas would be 1866 liters per hour per liter of water.**

Yull Brown leads people to believe that his gas is 1866 liters of gas to one liter of water. But it is NOT so; I've actually tested a BN 1000E and found the electrolyzer produces what I call 120% gas (at best). So the electrolyzer design in this book produces identical

or HIGHER quality of gas. This design is superior to the BN 1000E in every way (see *Details in Comparison chapter*).

The actual volume of mon-atomic to di-atomic is still somewhat unknown because we don't know if we have exact ratio's of 2:1 H and O or if there is somewhat more O than H or vice-versa. It could be (and actually seems to be so) that the H is more likely to form H<sub>2</sub> than the O to form O<sub>2</sub>, so we could have a ratio of H:O that is not 2:1. Determination of the exact constituents of the gas have not yet been done by us (May, 97).

### Wattage Efficiency per Liter of BG

This is a vital ratio to know because it determines the amount of gas you get for the electricity you put into the electrolyzer.

I will first clarify a 'technical' point that sometimes confuses people. It confused me for some time. This is a vital point that not only makes this section clearer; but explains a misconception about Brown's Gas 'atmospheric motor' that I will explain later.

Watts are a measurement of **power**.  
Watts are volts times amps.  $W = V \times A$

One volt times one amp is one watt.  
Two volts times one amp is two watts.  
One volt times two amps is two watts.

If you measure **work per time** you get **POWER**. Work and power are not the same, this is a common misconception.

Work tells the total work done; for example raising a one pound weight from the floor to a height of five feet would be five foot-pounds of work; it doesn't matter how long it took (it could take a second or a year, either way the same work gets done).

A horsepower is a measurement of **power**, because it is defined as raising a certain amount of weight in a certain amount of time (550 ft/lbs/sec). A

horsepower is equal to 745.7 joules/sec.

**Power** can be defined as the 'rate-of-doing-work'

If you measure the time it took to raise the weight mentioned above, then you are measuring **POWER**, because power is work over time.

If it took one second to raise the weight five feet then you have a **POWER** of five foot-pounds per second. If you divide 5 ft/lb/sec by 550 ft/lb/sec, you get 0.009 horsepower.

If it took you five seconds to raise that one pound five feet, then you have a **POWER** of one foot-pound per second.

You'll still end up doing five foot-pounds of work, it just takes five times longer because you are using only a fifth of the power. We'll divide 1 ft/lb/sec by 550 ft/lb/sec to get 0.0018 horsepower. Just to check, 0.0018 times 5 = 0.009; how about that?

Now back to **WATTS**. A watt is a measurement of **power** (volts times amps), because an amp is a measurement of coulombs per **SECOND**; so we have **work over time** which is power.

A **watt-second** is a measurement of **work!!** Because we have work per time divided by time; so time cancels, leaving only work.

A '**joule**' is a **watt-second**. That means one watt for a duration of one second. So a joule is a measurement of **work**. I mention this now because we'll be back to it later.

Another measurement of **work** that we commonly hear is the **Kilowatt-hour (Kwh)**. A Kilowatt is a 'rate-of-work' of one thousand watts (volts times coulomb/seconds). An hour is 3600 seconds. So we have a power of 1,000 watts continuously for 3600 seconds, which equals total work because the seconds (time factor) canceled in the equation.

By the way, you can see that a Kilowatt-hour is 3,600,000 joules, because there are 3,600,000 watt-seconds in a Kilowatt-hour. This is important for later.

We put electricity into the electrolyzer as Kilowatt-hours (Kwh). This is the actual **WORK** that you pay for as registered by your utility's electric meter. Now this is the confusing part. A large part of our technical society has accepted Kilowatt (power) and Kilowatt-hour (work) as one and the same; it's even stated so in some dictionaries.

For example, a Kilowatt is power, representing 1000 watts; this is a 'total' power figure; representing a certain number of electrons (coulombs) flowing at a certain pressure (volts) in a certain time (seconds). If we use 10 amps at 100 volts, we have 1000 watts. If we use 100 amps at 10 volts, we have 1000 watts.

A Kilowatt-hour is work, because we have the work of 1000 watts divided by the period of one hour, canceling the time. Example: 1000 coulombs per second (amps) times 3600 seconds (time power applied), times 1 volt, divided by 3600 seconds (time power applied).

Now for the part that confuses people. Kilowatt power can be 'accumulated' in a 'power' meter like is installed on most homes. The meter is actually an 'accumulated work' (total Kilowatt-hour) meter. It can be used to measure the 'rate of work' (power), which is how fast the meter wheel spins, (I use these meters for this function all the time). **BUT**, the meter actually records 'total accumulated work' in Kilowatt-hours (NOT Kilowatts). The 'power' meter mounted on most homes is actually used as an 'accumulated work' meter; thus the meter is misnamed and causes confusion.

To make the situation a touch clearer: Imagine a home using a power of 5000 watts per hour (5 Kwh) for four hours. The meter wheel has been spinning madly, indicating a power (rate of

work) of 5 Kw, **but** because the household used 5 Kw for four hours the 'accumulated work' done was 20 Kilowatts and THAT is what is recorded on those cute little dials.

Note: if the house had used 20 kilowatts for one hour, we still would have seen 20 Kwh recorded on the 'accumulated work' meter, but the meter wheel would have been spinning much faster, indicating a power of 20 Kw.

Let's further assume that everyone went to bed and the house is now using only 500 watts per hour (0.5 Kwh). In ten hours the meter would have 'accumulated' the work of 5 Kwh (5000 watts), registered on it's little dials.

Now to clear up a final point. The 'accumulated work' recorded by the meter is BASED on an hourly rate (because the gears are sized so that a certain number of turns of the wheel will record one Kilowatt-hour. How **fast** the meter turns indicates the **power** or 'rate-of-work'.

Now on to electrolyzer efficiency:

As we apply certain amount of electricity (watts) into the electrolyzer for one hour; in one hour we would get a total of gas volume, which could be measured as liters per second (or cubic feet per second).

If we are using in 48 amps DC at 220 volts DC then we are using 10,560 watts or 10.56 Kilowatts. If we keep the electrolyzer turned on at that 'work rate' for one hour, then we've used 10.56 Kilowatt-hours.

Now if we are producing 0.83 liter of gas per second, then we are making 3,000 liters per hour. If we divide 10,560 (total watts for one hour) by 3,000 (total liters for one hour) we get 3.52 watt-hours per liter (Wh/L).

Our example shows a total **WATTAGE EFFICIENCY** of 3.52 watt-hours per liter. Note that this is a measurement of work; because we are including **TIME** as a factor in the

answer. **To be meaningful**, both factors (watts and liters) needed to have a **common TIME**. Watts/hour and Liters/hour.

This need to measure different factors against a common time to get meaningful data is why the 'joule' was defined. Any measurement of work can be converted into joules. For example (you already know watt-seconds) 1,980,000 foot-pound-seconds or 1 horsepower-hour is converted as 2,684,000 joules.

As a matter of interest, the wattage efficiency of our first ten inch electrolyzer **Faraday gas efficiency** depends on the actual amperage flowing through the electrolyzer; which (126 cells and voltage doubler power supply) is 28 DC amps at 270 volts DC.  $((28 / 26.8) * 16.8) * 126 = 2211.58$  liters/hour total theoretical electrolyzer gas volume  $2H_2:O_2$ . Actual measured gas volume was 3,000 Liters/hour, thus  $3000/2211.58 = 136\%$  efficient.  $((28 \text{ amps} * 170 \text{ VDC}) / 3000 \text{ L/hr})$ . (It's wattage efficiency is 2.52 Wh/L).

Not bad; it beats the BN 1000E by 16% in gas quality. The BN 1000E got only 120% while making 1837.35 liters/hour when we bypassed the controls. Note: With the controls in place the BN 1000E would only produce 900 liters/hour at about 112% quality and wattage efficiency of 4.9 Wh/L.

## OUR EXPERIMENTAL USE OF BROWN'S GAS

We haven't actually done much experimenting with the gas. And no experimentation using a modifier tank. Our main purpose to date has been to design and build a simple and efficient BG electrolyzer. But we have performed a few basic experiments.

Note: unless specifically specified otherwise, all the experiments mentioned in this chapter are using the Brown's Gas in it's 'pure' form (about 130%) and with no modifier.

## Modifier Tank

I'll mention that it is fairly common practice when using oxy./hydrogen to use what's called a 'modifier.' A modifier tank is another bubbler tank, shaped like the first but having a combustible liquid (like benzene, all types of alcohol, gasoline, diesel, acetone, or any other flammable fluid) inside instead of water.

Note: Adding a modifier will change the characteristics of the flame. The first thing you'll notice is the clear (transparent) center cone of the pure Brown's Gas flame will turn white, like a normal oxy./acet. flame. With most modifiers you'll also have to add additional oxygen (from a bottle) to get them to burn properly.

The modifier tank is identical to the bubbler tank, except you'll have to take care to use components (like the clear PVC tubing) that are compatible with the whatever modifier fluid you choose.

The modifier tank mounts in series after the water bubbler and before the torch. You'll want to have a check valve and shutoff valve mounted in series (not parallel) going into the modifier tank because you'll have to fill the modifier tank occasionally (with the modifier fluid) and remove the excess water that eventually builds up in the modifier tank (from liquid carry-over and water formed by backfires) that displaces the modifier fluid.

Note that I have a 1/4" hole in the bottom of the 'bubbler' tank, to be used as a drain if you wish to change modifier fluids.

You will also want a valve arrangement so you can bypass the modifier tank anytime, allowing you to use the 'pure' Brown's Gas. The pure BG will certainly have different properties than the modified gas and it will be an advantage to readily switch from one to the other.

You might even want more modifier tanks, each with a different fluid, so that you can switch between them at will, changing the flame characteristics as required.

It's also possible to use modifier tanks in series, thus putting the gas through two or more modifiers, this could further modify the flame.

Note: the level of the fluid in the modifier tank DOES make a difference to how much the gas is modified.

It's also easy to put plain water in the modifier tank/s, simply to act as additional backfire arresting bubblers.

MYTH, a backfire will blow up a modifier tank that has gasoline (or some other modifier fluid) in it. **FACT**, a backfire to a modifier tank is extremely unlikely, because most flammable vapors have a very narrow range of flammability, mixed with oxygen, and the vapor mixtures in the modifier tank are far too rich to burn. **FACT**, in the unlikely event that a backfire does go to a modifier tank; (a hydrogen explosion is 16 times more powerful than a gasoline explosion) a tank designed to contain a hydrogen explosion will easily contain the explosion of any flammable fluid that you are likely to find. OK, OK, not nitro, but anyone fooling around with that kind of fluid won't be around to tell me I was wrong.

We have not experimented much with modifier fluids to date, but here's some information from the torches listed in Brown's Gas, Book 1. Note that I just list the information, which is sometimes contradictory; I haven't tested it to find the truth.

Water burns at 5972°F (3300°C).  
Water burns at 6000°.

Alcohol makes a green flame, burns around 3000°F (1650°C); results in oxide free precious metal soldering.

Methanol makes a blue flame which will oxidize soldered work unless the

work is fluxed in the conventional manner prior to fluxing.

Methyl alcohol burns at 3992°F (2200°F).

Methyl alcohol burns at 3500°.

M.E.K. burns at 3362°F (1850°C).

Acetone burns at 1300°F (705°C) and allows the repair of white metal jewelry.

Acetone burns at 2192°F (1200°C).

A flux (borate) can be added to modifier fluids to help prevent oxidation of material being welded.

### Welding glass

BG works great to weld glass and fuse it around various materials.

If the torch is directed directly upon cold glass, it shatters. I've found that I must heat the glass from an edge slowly with the torch at some distance 'til the glass heats up; then I can direct the flame around on the glass to perform whatever welding or shaping I wish.

If you do glasswork, you'll have to let the glass cool very slowly, putting it in an oven or hot sand, or it will shatter do to the stress of cooling unevenly.

### Welding iron

I found the flame tended to oxidize the iron, cutting it instead of welding it. It was difficult to form a 'puddle' to weld with. In short, my experiments with welding iron have been un-successful to date.

Note: I was able to weld iron using gasoline as a modifier fluid.

### Cutting cast iron

Our BG cutting torch cuts cast iron clean and fast. It is my understanding that cast iron is hard to cut with an oxy./acet. torch; though I have been able to cut cast iron with an oxy./acet. torch.

### Welding cast iron

A welding torch (#3 tip) was able to make a nice puddle and easily welded cast iron. I was just melting it together with no flux of any kind. In fact I didn't even clean the parts. I would have made a nicer weld if I'd had some cast iron welding rod to feed into the puddle. I then took the glowing cast iron that I'd just welded and DUMPED it into water (room temperature). It DID NOT BREAK. After it had cooled down, I broke it to look at the weld; it looked perfect!

I've also been able to weld cast iron with an oxy./acet. torch, nearly as easily as with the hydrogen torch.

### Cutting iron

I hooked the BG to the red hose, normally the acetylene hose and I hooked the oxygen hose to an air compressor set at 30 psi. I was using a 1-3 cutting tip. When the iron was hot enough to cut, I depressed the lever and shot compressed air onto the metal. The metal immediately cooled, did NOT cut. I suspect that there is too much nitrogen in the compressed air, preventing the oxidation by cooling the iron.

I hooked the BG to the red hose, normally the acetylene hose and I hooked the oxygen hose to a compressed oxygen bottle, with regulator set at 20 psi. I was using a 1-3 cutting tip. When the iron was hot enough to cut, I depressed the lever and shot oxygen onto the metal. **IT WORKED GREAT**. The hydrogen torch cut thick iron smooth and clean. Further, when I missed my cut from traveling too fast, I was able to pick up the cut right where I left off; the oxidation layer was absolutely no problem for this torch. In fact, I discovered I could start a cut faster if I started it on the oxidation layer.

Remember, the flame itself is cold. The flame directed against a material causes that material to go to it's melting temperature. Oxidized iron

has a lot higher melting temperature than non-oxidized iron.

I finally learned the trick of cutting steel with the hydrogen. Don't turn the flame up too high, or it blows itself out as you cut. Only cut as fast as the puddle forms, this will assure that the metal is always ready to cut. Turn your oxygen pressure up enough to cut right through the thickness of steel you are cutting. Use about the same oxygen pressure as you'd use with oxy./acet.

Do NOT hold your cutting torch too close to the metal. If you hold your torch too close, you'll be touching the metal with the 'transparent' cones, which are vacuum and DO NOT heat the steel. I've noticed that proficient torch users have a hard time learning this; to cut steel, you must keep your torch at LEAST 1/4 inch off the steel. I cut 1 inch thick steel cleanly (using a tiny 1-3 tip) holding the torch nearly 1/2 inch off the steel. I mean it when I say this flame is 'laser-like.'

Watch to make sure the steel is cutting right through, I've lots of times cut a slice in the steel only part way through; this effect could be used in certain applications. Not cutting all the way through is an indication that you do not have enough oxygen pressure.

Use the smallest torch tip you can get away with, it seems to actually work better and your cuts will be very thin. This splashes a lot less steel onto your boots and allows the cut to proceed faster.

### **Welding Copper**

The Brown's Gas easily welded copper, using plain copper rod. I just used the 'puddle' method. Copper sheds it's heat so quickly though that you need a fairly good sized flame, or insulate the areas of the copper that you are not actually welding. The surface of the copper turns black (copper di-oxide) but otherwise seems great!

I was able to weld copper with oxy./acet. too. Also get the copper di-oxide.

### **Welding Aluminum**

I have gotten good welds with aluminum, using the type of rod that has the flux inside it. I need more practice before I can describe a good technique.

### **Brazing**

I have had no troubles using brazing at any time. The Brown's Gas seems to braze as well as oxy./acet.

### **Cost to operate compared to oxy./acet.**

The electrolyzer is extremely economical to operate compared to oxy./acet. torches.

Here we are paying about four cents per Kilowatt Hour ().

Our 2500 Liter/hour electrolyzer draws about 10. So in one hour would use 10. Which is \$0.40. At present, this electrolyzer uses about one liter per hour of water when producing gas at 2500 liters per hour. I buy my water at about \$0.25 per Liter. Total cost per hour \$0.65.

I bought my own little oxygen (50 cubic feet) and acetylene (40 cubic feet) bottles years ago. The deal is; I exchange these bottles for full ones whenever I need more gas, paying for the gas but not paying rent on bottles. This arrangement has worked well.

It so happens that if I use my bottles down to dangerously low pressures, I can get 2500 liters of volume out of them. So if I use gas at 2500 L/h, I can get one hour of use. It costs me \$52 to fill those bottles. So total cost per hour is \$52.

Thus MY cost to operate the hydrogen torch is nearly 99% less.

If I was paying \$0.18 per; it would cost \$2.05 per hour to operate (water

included). This would be 96% less operating cost.

At least in this respect, Yull Brown actually understates the advantages. He states that it costs seven times less to operate the BG torch. Of course, it is possible that he could get his oxy./acet. at much less cost than I pay.

But, when I'm actually cutting steel, I'm still using oxygen; but ONLY when I'm actually cutting. I use no oxygen to maintain my flame. And remember, the oxy./hydrogen cuts iron faster than oxy./acet.

## **COMMENTS ON USING BG WITH INTERNAL COMBUSTION ENGINES**

### **Jimmy Reed's experiments**

Jimmy Reed in Texas has actually idled a Dodge 225 'slant six' engine at 700 rpm on water as it's only fuel. The experiments lasted for fifteen to twenty minutes each and have been performed three times to date; July 4, 1996.

Jimmy brought the electrolyzer to the 1996 Tesla Symposium and it Did Not run his engine on water, though it did produce more gas than it should have. We brought Jimmy and his electrolyzer up here (Canada) and with a month of experimentation were not able to get it to do anything special. All Jimmy's experiments to date (May, 97) have not resulted in running an engine on water.

But this spontaneous huge gas production with limited power did happen, not only to Jimmy but in our own (and others) research. So far no one we know has been able to duplicate it consistently.

Jimmy Reed's electrolyzer was a 'short' cell design of 60 3.5 x 1 inch plates (30 neg. and 30 pos.), built into a horizontal tube. The electrolyzer drew 2.5 volts at 14 amps (35 watts) directly from the alternator. Jimmy bypassed the alternator diodes and normal vehicle battery circuit on one 'phase' of the alternator.



The 225 ci engine is started on gasoline, (idling at 650 rpm) then the gasoline shut off and when the fuel in the carburetor was exhausted and the engine would start to stumble, the BG was turned on (the rpm would rise to 700). The BG was controlled with a very small needle valve on the end of a 1/4 inch hose. The 1/4 inch hose was just inserted into the top of the carburetor along-side the choke plate.

The experiments were shut down each time when the electrolyzer pressure would reach 50 psig. The electrolyzer had no pressure relief valve or pressure shut-off switch; the only venting being through the needle valve feeding the engine. The electrolyzer actually was producing more gas than was being vented through the needle valve (running the engine), thus the electrolyzer internal pressure would rise, causing the experiment to be terminated; because he didn't want to burst his electrolyzer. There was no other reason to shut down the engine.

Note: he could not speed up his engine because his needle valve was several feet from the carburetor and he couldn't open the throttle plate and manipulate the needle valve at the same time.

The results given in the first paragraphs of this chapter were obtained with electricity taken directly from one of the alternator windings of his engine's regular alternator.

Jimmy Reed's 'experiment #8' did not perform as expected at the Colorado Springs International Tesla Symposium. It did **not** produce enough gas to idle the engine continuously on water as the engine's only fuel. Jimmy described the actual effects that he had done four times in Texas and from that I've concluded that something fundamentally different was happening in Jimmy's #8 (see *Hyper-Gas*).

Actual examination and testing of #8 (my testing in Sheraton Hotel parking lot during the Tesla Symposium) did

show a few of anomalous results that were interesting.

First, during my first test (of two) the #8 actually **COOLED DOWN** during operation. This cooling effect was not measured with a thermometer, because we didn't have one handy; but the coolness was easily determined by placing a hand on the electrolyzer (which several people did during the three hours of the test). The coolness was much more noticeable on the underside of the electrolyzer than on the topside, indicating that the actual electrolyte fluid was doing the cooling, not the stored and pressurized gas. Further, the probes going into the electrolyzer were quite warm, again indicating some kind of actual **ACTIVE** cooling in progress (or the electrolyzer would have heated up from that alone). A normal electrolyzer would have gotten quite hot with the wattage we were putting in over an hours time. This test took place inside the van, which was over 85°F. Note: during this time we were only building pressure, we **DID NOT** remove any of the gas from the electrolyzer; so all the energy we pumped into the electrolyzer was still there and should have made it hot. Second, the #8 seemed to become more efficient as the electrolyzer pressure increased; because the pressure of the electrolyzer increased at exactly 1 psi per minute regardless of the pressure already in the electrolyzer (operating at full wave rectification, 14.5 amps at 2.4 volts). We noticed that as we increased the engine rpm, the actual gas production went down. Frequency of pulses during full wave rectification at about 650 rpm were about 800 hertz. Third, calculations showed that #8 was producing about 20 times more volume than it should have; still well under what it would take to idle the engine but very significant anyway.

According to Jimmy's explanation of the effect he was getting in Texas, somewhere between 30 and 40 psig he expected the pressure gauge to suddenly start rising 'like the second hand on a watch.' This is an

'impossible' effect, because the amperage into the electrolyzer is fixed. I do not deny that it happened to Jimmy; actually it just confirms reports I've gotten from other sources. What we need to do is find out how to do it on a consistent basis, because this is the effect that allows an engine to run **efficiently** on water. Also, this seems to be a different gas than Brown's Gas. Brown's Gas is really consistent in it's nature, and never produces mega-quantities of gas with minimum (and fixed) electrical input. Also Brown's Gas, while more powerful than  $2H_2:O_2$ , doesn't seem to be as powerful as this 'new' gas. As a result, I'm calling this new gas '**Hyper-Gas**.'

We actually ran Jimmy's Dodge 225 ci engine on the gas that we stored up in the #8 electrolyzer. It took about one hour (idling the engine to use the engine's alternator to produce the gas) to store 60 psi worth of gas in the #8 electrolyzer. The stored gas ran the engine for 'about' 45 seconds. I was operating the needle valve to allow the BG into the engine. I found that just cracking open the needle valve at 60 psi was plenty to operate the engine at 650 rpm.

As the electrolyzer pressure dropped I needed to open the needle valve farther to maintain the engine's rpm at 650 (just as one would expect). During one test (the first) I kept feeding in too much BG and killing the engine by 'flooding' it (too much gas). During that test we repeatedly started the engine using BG (no gasoline).

At no time during any of the tests did we notice a knock, backfire or detonation in the engine; the engine ran smoothly on BG when the mixture was correct; the engine stumbled and died when the mixture was too rich or lean, just as it would have on gasoline. At all times while I was testing it, Jimmy's #8 showed typical Brown's Gas behavior.

I tried to keep track of the pressure drop as the engine was running on Brown's Gas in the Sheraton Hotel parking lot. When the electrolyzer

pressure was high (over 40 psi) we dropped 6 psi in 23 seconds, as the pressure dropped, the rate of drop increased; so that when the pressure was low (under 10 psi) we dropped 6 psi in 9 seconds. This was for the engine running on Brown's Gas.

To operate on **Hyper-Gas**, the electrolyzer would have had to produce about 60 times the gas AT THE SAME WATTAGE; to keep the pressure up in the electrolyzer as the gas was being bled off to run the engine. This HAS BEEN DONE, not only by Jimmy but by another inventor whom I may not disclose at this time (due to a promise I made to him). I have not personally duplicated this effect.

Further details of Jimmy Reed's work will be detailed in future publications.

### Calculations to run an engine on BG

*For electrolyzer efficiency testing methods and calculations, see the appropriate chapter in this book.*

We now have enough experimental evidence to put some mathematical figures on some of the results. These calculations will also point out how much more evidence needs to be acquired.

First, let's see how much  $2\text{H}_2:\text{O}_2$  (normal electrolyzer hydrogen/oxygen) would be required to operate a Dodge 225 engine at 650 rpm. It is given that normal  $\text{H}_2$  requires a minimum of 4% in air by volume before it is a combustible mixture. A 225 cubic inch engine will pump  $((225/2) \times 650 \text{ rpm} \times .8 \text{ volumetric eff.}) = 58,500$  cubic inches of air per minute or 3,510,000 cubic inches per hour or 2032.29 cubic feet.  $2032.29 \text{ cubic feet} \times 0.02832 = 57.55$  cubic meters/hr.  $57.55 \times 0.04 = 2.302 \text{ m}^3$  or 2303 liters of  $\text{H}_2$  to operate the engine for one hour at 650 rpm at the leanest possible combustible ratio.

18 grams of water makes 11.2 liters of  $\text{H}_2$ . To make 2302 liters of  $\text{H}_2$ , we

need to electrolyze 3699.64 grams or 3.7 kilograms of water in an hour.

A Faraday will electrolyze 18 grams of water in one hour. A Faraday is 26.8 amps for one hour.  $3700 \text{ grams}/18 \text{ grams} = 205.55$  Faradays required to make 2303 liters of  $\text{H}_2$ .  $205.55 \text{ Faradays}/\text{hour} \times 26.8 \text{ amps}/\text{Faraday}/\text{hour} = 5508.74$  amps continuously for one hour. At 2.1 volts, this would be 11,568.35 watt/hour (or 15.5 hp/hr). No automobile alternator could make that kind of wattage continuously. In addition, the 'load' of 15.5 horsepower would require more hydrogen in the engine than the bare minimum I've done in this calculation. Thus I say, **it is not possible** to operate an engine on  $2\text{H}_2:\text{O}_2$ , when the engine's alternator is making the  $\text{H}_2$  to operate the engine.

However, we (the research cooperative) have two situations where WE HAVE operated an engine on the electrolyzed gas made from water where the engine was making enough gas to operate itself; thus effectively operating on water as it's only fuel. Just remember that we haven't been able to consistently do it.

The first method is with **Brown's Gas**. There are several reasons why Brown's Gas can operate an internal combustion engine only on water:

First, Brown's Gas takes up twice the volume of  $2\text{H}_2:\text{O}_2$  (because it is H & O, see Brown's Gas, Book 1), thus less than half the electricity is required to make a combustible mixture.

Second, Brown's Gas has a huge advantage over  $2\text{H}_2:\text{O}_2$ ; Brown's Gas doesn't need energy to break any atomic bonds before it can recombine (combustion) with other materials. Because of this BG doesn't require a 'self-propagation' temperature and that means **less BG** is required to make a combustible mixture (particularly in a compressed gas situation).

Third, Brown's Gas is also a higher energy gas than  $2\text{H}_2:\text{O}_2$ , (442.4 Kcal

per gram-mole compared to 57.85 Kcal per gram-mole for  $\text{H}_2$ ) this means that a leaner mixture will still explode with an acceptable force.

Fourth, Brown's Gas WILL explode at leaner mixtures than  $2\text{H}_2:\text{O}_2$ . We don't know how much leaner yet.

Fifth, Brown's Gas also explodes faster than  $2\text{H}_2:\text{O}_2$ ; this means little in open air where the energy of velocity is mostly wasted, but in a closed combustion chamber it means we can take advantage of the Kinetic Energy equation,  $\text{KE} = \text{one half Mass times Velocity squared}$ . A faster flame gives more energy by the SQUARE of the increased velocity.

All this means is that it is possible by theory to operate an engine on BG. We know we can in practice too, because we've done it, but it is always comforting to be able to prove we can with numbers too.

A specific example comes back to Jimmy Reed's experiment #8. We were using 14.5 amps at 2.4 volts at the time in a 'short-cell' type of electrolyzer. In one hour we should have made 17.038 liters of BG. Ordinary  $\text{H}_2$  would require 0.639 liters per second (using previous calculations); and at 17 liters of  $\text{H}_2$  the engine would run for 26 seconds, leanest possible conditions. Note that 14.5 amps for one hour would only have made 5.61 liters of  $\text{H}_2$  (ignoring volume of  $\text{O}_2$ ).

We ran the 225 ci engine (twice) for about 45 seconds on the BG we accumulated for one hour. We were making actual Brown's Gas but I don't know the actual percentage of BG to ordinary  $2\text{H}_2:\text{O}_2$  because we didn't make volume measurements.

However, it doesn't stretch the imagination too far to see that if we'd used another alternator on the engine, set up to operate at 120 volts (modify regulator); we would have been able to power a 60 cell series-cell electrolyzer at 14.5 amps and produce the gas

needed to operate that engine. I realize that the alternator would put a load on the engine, requiring a richer mixture of BG/air but I think it would work! And in fact, this is exactly what Reed Huish's experiment proved can work!

The second method that we've actually used to operate an engine on water is **Hyper-Gas**. Hyper-Gas is so new I have very little clue as to its characteristics. It is proven that less than 40 watts of power from the ordinary engine's alternator can cause this Hyper-Gas effect. The Hyper-Gas is not Brown's Gas; it is a **much** higher energy gas. Hyper-Gas is somehow made in an electrolyzer at much greater volume than any existing theory I know of can explain or account for. I do not know any more at this time.

### Hyper-Gas

To produce Hyper-Gas, my favorite theory at the moment involves 'ionization.' I think the Hyper-Gas is ionized O and H, it doesn't matter (as far as I can tell) which way the gas is charged, just so it all has the same charge. Like particles repel, so the same gas will want to take up a much greater area and/or make pressure faster if in an enclosed container. I think ionization negative will give different flame and explosion results than ionization positive.

A second theory is 'harmonics.' It's been postulated that specific frequencies will split water with minimal input of power. I haven't (yet) been able to verify this in a practical way.

I've known for a long time that we **MUST** get the gas away from the plates as quickly as possible to prevent it from becoming  $2H_2:O_2$ , due to extra electron activity. It may be that Jimmy lucked onto the exact conditions needed to achieve a harmonic resonance in his electrolyzer that actually vibrated the plates themselves. The vibration knocking the bubbles off the plates while they were still just H and O in their very highest energy state.

Timothy Trapp, from Anchorage, Alaska has just joined our BG research team. He mentions that iron resonates at about 400 Hz, so the stainless steel plates (that contain a lot of iron) could have been resonating. Timothy is somewhat of an expert on electrical materials resonance, so we will be asking for more information from him in that area. Timothy has built a 'square' series-cell BG electrolyzer out of clear PVC, having mitered grooves for the plates and gluing the whole arrangement together with Master Bond epoxy. He has achieved the continuous operation of a torch with a 22 gauge tip at 25 psi, using 8 amps at 120V. He deliberately caused an implosion in his bubbler container to see if he was getting BG, it imploded with a 'poof'. He then verified the vacuum by sticking the hose into water and having water suck up into the bubbler container. I pointed out to him that a 'ping' indicates a high percentage of BG, a 'poof' indicates that there was a slight explosion before the implosion indicating a lower percentage of BG. Timothy will make some volume measurements to determine the efficiency of his electrolyzer.

### Conclusion

When operating a series-cell with an ordinary automotive alternator, it is much simpler for the alternator (to be modified) to produce 120 volts at high frequency and 10 amps than it is to produce 100 amps at 12 volts. Amps cause an alternator to heat, and 100 amps causes a **lot** of heat. Jimmy Reed was using the 'short' cell design; I recommend using the series-cell design because it is easier to modify an alternator to produce a higher voltage than to produce a higher amperage (simply increase the rpm while maintaining amperage through the rotor windings).

Modern auto alternators are amperage limited by the cooling capacity of the alternator (and the stator winding design) but can actually increase their voltage quite high, at the same amperage as ever; thus we can increase

the wattage of the alternator without increasing its heat. Amps make heat, not volts. Actually, the work involved seems to heat the alternator anyway.

Jimmy has a good idea to add an additional alternator to his engine to act as the electrical supply for the BG generators. He intends to have three BG generators; hooking one up to each phase of the alternator. My recommendation is to use the series-cell design for each of the BG generators and to make an external regulator to cause the BG alternator to go to at least 120 VAC. The electrical insulation in most alternators will handle at least 600 VAC.

You are perhaps aware that there are devices already on the market that will convert an alternator to operate 120 volt hand tools (usually Universal wound motors and resistive loads). This type of circuit is what I'd try to use to power the BG Generators from the BG alternator. An excellent source for this type of circuit is Alternator Secrets, by Lindsay Publications Inc., PO Box 12, Bradley, IL, 60915.

Note: Never operate an alternator with the output wire open (not connected to a battery or load) or the internal voltage could rise high enough to short out the alternator windings.

For those of you who are powering stationary power units that already have a 120 VAC alternator attached, you simply hook up your BG Generators to that.

For those of you that wish to apply the BG generator design depicted in this report to a gasoline engine (not diesel yet, we are using spark plugs to ignite flame), DO use the bubbler.

Remember that this is an experimental design. Automatic water filling and mobile application designs are not yet finalized and depend on the results obtained from this design.

## OVER-UNITY HEAT

Everyone is looking for over-unity using Brown's Gas. I haven't yet confirmed **any** over-unity (more energy out than put in) from Brown's Gas directly. I have some ideas but haven't tested them.

However, as noted in Brown's Gas, Book 1, we found (by error) a possible over-unity heating method by building an electrolyzer that DID NOT make Brown's Gas, or much  $2H_2:O_2$  either. Instead it made STEAM (boiled water). And the apparatus heated water MUCH faster than an electric resistance heater (totally submerged) could; using the **same** electricity (volts, amps and watts).

## BROWN'S GAS CAPABILITIES

### Actual BG characteristics

Brown's Gas is an exact mixture of two hydrogen and one oxygen in their atomic molecular form, written  $2H:O$ . I often call this mon-atomic to differentiate from 'normal' hydrogen and oxygen gas in their di-atomic form, written as  $2H_2:O_2$ . Atomic (or mon-atomic) H and O gas is **COMPLETELY DIFFERENT** from di-atomic  $H_2$  and  $O_2$ .

It is very important for experimenters to realize that Brown's Gas has properties and operating characteristics completely different from 'ordinary' di-atomic hydrogen and oxygen mixtures. I cannot express the DIFFERENCE enough times, because it is a common mistake for people looking at Brown's Gas to use 'ordinary' hydrogen formulas and logic to interpret Brown's Gas properties and characteristics. Using 'ordinary' di-atomic calculations will give the wrong answers for this mon-atomic gas.

Brown's Gas,  $2H:O$  is **COMPLETELY DIFFERENT** than  $2H_2:O_2$  mixtures. Some of the **DEMONSTRABLE** properties and characteristics of Brown's Gas cannot be explained with 'accepted' Physics and Chemistry.

Please **DO NOT** use ordinary di-atomic logic for Brown's Gas; such logic could get you hurt.

The first Brown's Gas characteristic that astonishes anyone familiar with di-atomic hydrogen and oxygen is Brown's Gas **IMPLOSIVE** nature; when burned in its pure mixture, Brown's Gas forms a **VACUUM** of high purity. Of course a diatomic mixture will make a vacuum too, but there'll be an explosion and then an implosion. Brown's Gas has only implosion.

**NOTE: Di-atomic** hydrogen and oxygen will also cause an implosion, **AFTER** they explode. First the break their atomic bonds (which we see as an explosion) and become atomic gas (like BG). Then they turn into water, which we see as an implosion. So exploding normal  $2H_2:O_2$  in a sealed container **WILL cause a vacuum** to form in that container.

This effect makes some people think they have Brown's Gas when in fact they do not. You do not have pure Brown's Gas unless there is **NO** explosion, which you would hear as a slight 'ping'. If you hear a 'poof' you have mostly Brown's Gas and if you hear a 'bang' you have little or no Brown's Gas. With 130% gas we still hear a bang.

**NOTE: Our (Eagle-Research)** electrolyzers put out a mixture of di-atomic (100%) and atomic (200%). The more atomic portion in the gas volume, the less hard the explosion, 'til at 200% we have only implosion.

Because of the implosive characteristic of the Brown's Gas flame (even with a substantial component of  $2H_2:O_2$ ) the actual welding takes place in a vacuum. Anyone who has welded with a TIG or MIG welder knows how important an inert (oxygen free) gas environment can be to a weld. Welding in a vacuum is considerably better, but previously required equipment beyond the means of the average shop. Welding in a vacuum is now possible for everyone.

Second, Brown's Gas flame temperature changes when it is applied to various materials. The Brown's gas flame is about 275°F (135°C) in open air. Without any torch adjustment, applying the flame to aluminum causes the aluminum to heat to 1295°F (702°C). Applied to brick, the temperature reaches 3,100°F (1704°C).

Applied to tungsten, the temperature is over 10,200°F; the tungsten melts and then vaporizes. **NOTE** the tungsten is **NOT** sublimating, as Yull Brown says. Sublimation is conversion directly from solid to gas. The tungsten first melts (goes liquid) **THEN** boils (turns to gas). You can verify this yourself by putting on a welding helmet and observing the effect of the BG flame on a tungsten rod, you'll see the rod actually melting; **NOT** turning directly from a solid to a gas. Use a welding helmet with a dark glass because the light generated is very bright. By the way, an oxy./acet. torch will melt and boil tungsten just about as fast as the hydrogen torch!

Third, Brown's Gas torch flame is extremely directional. The Brown's Gas flame burns through a block of wood or a ceramic fire brick 'like a laser' (I've done this). This should allow precision welds, but I haven't welded anything yet. I've tried but my welds don't stick. It could just be my technique.

Brown's Gas is supposed to allow (when combined with the vacuum characteristic) the two materials being welded to actually be different temperatures. Thus, the heat required to melt steel is less likely to vaporize the copper being bonded to it. I haven't succeeded in welding dissimilar metals together, but am still exploring the possibilities.

Fourth, Brown's Gas can cut materials that ordinary torches couldn't touch, like iron oxide, because the Brown's Gas flame instantly causes the material to raise **IT'S OWN** temperature 'til it is sufficient to melt or burn itself.

Fifth, Brown's Gas can cause changes in the molecular structure of some materials. For example, melting a chip of ordinary fire brick creates a stone with a hardness of 9.5; almost as hard as diamond (I haven't repeated this experiment yet). Brown's Gas can be used to glaze surfaces (I have done this).

Yull Brown says that Brown's Gas that is not in a perfect ratio of 2H:O becomes **EXPLOSIVE!** This includes pure mixtures of H and O, mixtures of H and O that have a bit of contaminating gas in them (like the addition of a bit of air), and mixtures of air that have a bit of H and O in them. Personally, I haven't made ANY mixture which I'd call purely implosive, (though I've gotten close, the 'poof' stage) including the mixtures that came directly out of a BN 1000E.

I say again, it is my experience that air becomes highly explosive when H and O are introduced as a fraction of one percent by weight. Experimental verification of just how lean the mixtures can be has not yet been done. But demonstrable experiments show extremely lean mixtures will explode if compressed about 8:1 (We've run a gasoline engine on BG).

### **Misconceptions of Brown's Gas**

I will now make some comments on misconceptions being spread about Brown's Gas.

I wish to present to the world accurate information. It has come to my attention that Yull Brown is misrepresenting his own gas. He has been spreading misinformation for decades, which is fully documented and easily proven wrong. Don't get me wrong, I have the greatest respect for Yull Brown's work and developments. Personally I think Mr. Brown has done his technology a great dis-service, by not explaining fully about the technology and also by telling people things that are just not true.

I have offered to Yull Brown, the option of getting a book written about Brown's Gas, by Yull Brown, with my technical and writing assistance; so far he has refused. His patents have now run out and it is up to people like us to bring the truth to light. And to get this technology out into general use. This is a technology that is needed NOW!

People, including Yull Brown, persist in using  $2H_2:O_2$  calculations to determine the performance of Brown's Gas. While you can get away with this in most cases because the gas is not usually pure enough to demonstrate the difference (even from Yull Brown's own electrolyzers). It must be pointed out that Brown's Gas in its pure form is significantly different, requiring some new thought and calculations.

I agree that Brown's Gas is a viable option to apply to a self-sufficient home, BUT not in the ways that are usually presented. I will explain:

I agree that BG can be made to work without what I would call major modifications, replacing normal hydrogen and petro-gasses. BUT definitely not as usually outlined.

The biggest problem I've seen with BG 'home-use' outlines is the lack of understanding of the concept of a practical power system. First, why use Brown's Gas at all, for 'home-use'? Brown's Gas **REQUIRES** a huge amount of electricity to make. If you've got the electricity to make Brown's Gas, just use the electricity directly to power your home appliances.

Or use your excess electricity to pump water up into a storage container (using a conventional pump) to recover with a turbine later. Why bother with the expense, maintenance and danger of an explosive gas?

The second largest 'home power outline' problem I've seen is the assumption that you can somehow get more work out of the flame than the electricity you've put in, so you can run an engine to make enough

electricity to make your Brown's Gas and have electricity left over. My experimentation has shown this to be bunk! (Hyper-Gas is a different story, but we can't do it consistently yet)

The third problem with the 'home power outlines' is that they show serious ignorance of Brown's Gas actual characteristics and that will at least cause loss of research time and money and at worst loss of an entire home and lives. **PLEASE refer to the Brown's Gas, Book 1. All my comments have been experimentally verified.**

You will also note that nowhere in the world is Brown's Gas being used to actually power a home. That's because it can't. Yull Brown was great for saying the gas could do this and that, but in a lot of cases, it simply can't, or if it could, there are a lot better 'conventional' ways of doing it.

### **Heating applications**

Usually 'Brown's Gas home power' outlines base cooking elements and space heating on existing hydrogen technology, not on Brown's Gas. It is true that hydrogen in its di-atomic form burns at 400-800°C with a catalyst, BUT Brown's gas in its pure form would quickly burn up your catalyst (usually nickel/platinum, I've burned up a lot of it). And if you mix Brown's Gas with air before using it in the catalyst, you would have a gas with an explosive potential many times greater than normal di-atomic hydrogen, the catalyst could still be destroyed, along with the house. Also mixing BG to burn with normal air will cause oxides of nitrogen to be formed.

As for using pure Brown's Gas in a normal burner, so that you won't produce oxides of nitrogen, that is just as bad. Even Yull Brown will tell you two things:

First, unlike any other flame, BG burns in open air at 127°C, which isn't hot enough to use for heating, so forget using BG in any heating application like water heaters, clothes dryers, space

heating furnaces, etc., you'll just be wasting huge amounts of electrical power to make the BG and getting practically no heat from the flame, UNLESS you turn it di-atomic but then you no longer have Brown's Gas, you have normal  $2H_2:O_2$  and just treat it as such.

Second, BG causes different materials to change to their melting (or vaporizing) temperature and with laser-like accuracy. If you set a cooking pot on a pure BG flame, the BG flame will burn right through the pot in seconds (or less), even if the material has a melting point of greater than 6,000°C.

### Cooling applications

Again, it takes huge amounts of electricity to make BG. Releasing pressurized BG to make cold would work, but is an extremely inefficient way to use high grade electricity (making compressed BG gas), better by far to use a normal air compressor, you'll get the same refrigeration effect with a fraction of the power (about thirty times less power) AND you're not releasing combustible gasses into the atmosphere (or exploding/implosioning them in an enclosed system).

Better yet, simply use an 'off the shelf' refrigeration system. You have to have electrical power anyway to make the BG, so just run a refrigerator. Then you can get many many times the refrigeration effect that you can get releasing pressurized BG or air.

Secondly, using BG as per the pioneer frigidaires to create refrigeration by making heat; it wouldn't work. I grew up with that type of refrigeration because my father's ranch had no utility power. It wouldn't work for the reasons mentioned previously; first a BG flame has no real heat unless directed on something and second if directed on something BG will burn right through it in short order. These refrigerators require a steady or intermittent heat to be applied to a bulb or tank of refrigerant. Burning through the bulb will release the refrigerant.

Let's do some math. To make cold by reducing pressure of BG, we electrolyze a liter of BG by adding 3 of power, which in an hour is about 10,242 Btu worth of electrical energy. We fill a container of about  $0.54\text{ m}^3$  to about 6.8 atmospheres (100 psi), at 20°C. If we do a pressure drop to get maximum temperature change at atmospheric pressure, we find that  $T_1 = (P_1 V_1 T_2) / (P_2 V_2) = (1 * 3.7 * 293) / (7.8 * .54) = 15^\circ\text{C}$ . We can cool about  $3.7\text{ m}^3$  of air by 5°C; this is about 10 Btu. So we throw away 10,232 Btu of electrical energy.

A four horsepower compressor uses about 3 worth of electrical energy to compress 52 cubic feet per minute to 100 psi. In an hour this is 115 cubic meters of compressed air. If we let this air cool and release it as per above, we get 312 Btu of cooling.

If we used an 'off the shelf' heat pump at 3:1 CoP, we would get 30,726 Btu cooling for the same 3 electrical energy.

So releasing compressed BG WILL COOL as Yull Brown says, but hey folks...it's like un-practical.

### Clean water

If you ignore Yull Brown's method of imploding the BG over the contaminated water (this would cause an explosion) and use instead a separate chamber to implode the BG and then allow the already existing water vapor in the contaminated chamber to be sucked into the BG container, to be condensed; YES it will work, BUT again the electricity required to produce enough vacuum by this method would be much better spent driving a conventional vacuum pump, you'd get several times more water without the possibility of explosion.

Let's do some math. We'll assume we have excluded all air from a container containing contaminated water and that container is at 20°C. Water vapor in the contaminated container would be at

a pressure of  $0.02\text{ kp/cm}^2$  and would contain  $0.01729\text{ kg/m}^3$ . One liter of water turned to pure BG would occupy about  $3.7\text{ m}^3$  of volume. We introduce the water vapor to the vacuum created by the imploded BG; which at  $.01\text{ kp/cm}^2$  and 20°C, water vapor density is  $0.0072516\text{ kg/m}^3$ . Thus, one liter of BG (imploded) would recover a maximum of 0.037 liters of water (less because BG water already occupies volume and as gas from the contaminated tank rushes into the BG tank, BG tank pressure rises).

Each liter of water takes about 10,800,000.00 joules to create 3700 liters of BG, recovering a maximum of 0.037 liters of water. Assuming temperatures remain the same. If we assume this process took one hour, then we use a constant of 3 Kwh to purify 37 grams of water per hour using this BG technique.

If we use a simple vacuum pump, we move water vapor from an environment of  $0.01\text{ kp/cm}^2$  to  $1\text{ kp/cm}^2$  (vacuum to atmospheric pressure). Increased pressure at the same temperature causes the excess moisture to condense out. The moisture holding capacity of vapor per cubic meter is fixed by temperature, not pressure. Thus pumping  $3.7\text{ m}^3$  to atmospheric pressure recovers about 0.024 liters of water. Our pump would use about 0.1 Kwh of power.

If we use a simple evaporation system, working at atmospheric pressure and heating the contaminated water (with solar is best, but we'll assume using electric) to 30°C, then we could recover 0.024 liters of water with 0.02 Kwh of power.

Why purify water with BG when a simple evaporation system is simplest and least expensive to operate? The evaporation system is simple and inexpensive to build, is not dangerous and uses only a very tiny fraction of the power used by the Brown's Gas technique. Of course, evaporation systems using solar power do require some space and are not really portable.

Are you starting to get a picture here? Yes, Brown's Gas can do a lot of things, but can it do those things in a more practical manner than other (already existing) options?

### Energy storage system

We use electricity to create Brown's Gas. So if you are trying to 'store' energy by raising water, or if you are trying to run an 'atmospheric' engine; you end up using huge amounts of electricity for little result. In this case I'll do the math for you:

To raise water, the working parameters are: 1 gram-mole of water (18 grams of water) requires about 192,960.00 joules to turn it to BG (26.8 amps at 2 volts for 3,600 seconds = 192,960.00 watt-seconds). 1 gram of water will turn into 3.73 liters of (pure atomic) BG. Dropping one liter of water 10 meters in one second generates 98 watts of power. 98 watt-seconds is 98 joules. So we spend 192,960.00 joules to store 3281.04 joules of power ( $1.86 * 18 * 98$ ). Note that the head pressure of the water being raised causes the volume of BG to reduce by about half. As you can see, this is a very inefficient way to store excess electrical power (requires **58 joules to store one joule** and this doesn't count the inefficiency of turning the raised water back into electricity).

### Atmospheric 'over-unity' engine

This is one of the biggest misrepresentations Yull Brown allows to exist. The figures as shown seem to indicate over-unity energy storage and the possibility of an atmospheric driven engine. In fact, the energy storage by pumping water using the pressure and vacuum created by Brown's Gas is **severely under-unity**. You need to convert the figures you have into a common language to understand the proper relationship ( I choose joules or watt-seconds). Yull Brown is saying that it takes four watts-seconds (four joules) to make a liter of BG; in fact his electrolyzers take **four watt-HOURS (14,400 joules) per liter of BG**. He has been told this by myself

and many other scientists. His own published specifications on his machines say that! I don't know why he persists in perpetuating this misinformation. But I do know that anyone building an engine based on Yull's figures is doomed to failure. I base this opinion on actual experimentation, to back up these calculations.

Note: Most accurately, I just tested Yull Brown's electrolyzer BN 1000E (May, 97) and it draws 4.9 watt-hours per liter of gas. See the 'comparison' chapter

I refer you back to my Wattage Efficiency calculations, my mention of joules and my careful explanation of meaningful factors by using common **TIME** for all factors. What Yull Brown has done here is measure a Time of only one second for the cycle of his 'implosion' machine versus the Time of one hour to generate the gas to do that one second's work.

It has become a secondary part of my inventing in the alternative energy field to point out when someone is wrong and I've become quite good at it. This comes from continually critiquing my OWN work. Note that I'm also careful to point out when I believe someone is **RIGHT**, regardless of the blind opinions of most 'conventional' scientists.

I (and many others) have pointed out this time factor to Yull Brown himself (and he'll get a free copy of this book) but he refuses to change his statement. Personally I **APPRECIATE** it when people point out my bad thinking; so I can get on with right thinking. My life is too short to persist in wrong thinking.

**An atmospheric engine based on implosion would be grossly inefficient.** The math goes like this: One horsepower is 550 ft/lbs/sec. One horsepower is 746 watts. Assume a piston of ten centimeters (four inches) in diameter that travels 30 centimeters (about one foot). This displaces 942 cubic centimeters (about 150.72 cubic

inches). Atmospheric pressure is one bar (14.7 psi at sea level). The working area of the piston is 31.4 square centimeters (12.56 square inches).  $12.56 * 14.7 * \text{one foot per second}$  (one stroke of engine per second), equals 184.63 foot lbs per sec or 0.34 horsepower (184.63/550). It takes 2729.25 joules ( $(192960/18) / 3.7$ ) to make the BG that pushed the piston down against atmospheric pressure. (At two volts this is 1364.63 amps or 2729.25 watt-seconds or 3.66 horsepower ( $2729.25 * 0.00134$ )). **It takes over ten times the electricity to run the 'atmospheric engine' than if you'd simply ran an electric motor without worrying about Brown's Gas.**

I did witness a demonstration by Dennis Lee in Missoula, Montana during August of 1996. One of the technologies demonstrated was a Brown's Gas BN 1000. The gas did **EXPLODE**, then implode in the cylinder; just as I said it would. Dennis was trying to prove that the 'implosion engine' was viable; and succeeded quite well in proving that it was not viable as per the above information.

The problem is that the general public can be fooled by these demonstrations because they are ignorant of some basic facts of Physics. This is not the public's fault, no one can be expected to know everything. That's why people like myself are needed, to balance out the education, expose incorrect statements and tell people the truth.

I noted with a grin (but didn't say anything at the time because I trying to be polite) that Dennis closed a valve which isolated his pressure gauge from the cylinder **BEFORE** igniting the gas in the container. This was to prevent the explosion from blowing out the gauge. If he truly got a vacuum without an explosion, then he could have used an absolute pressure gauge and not needed to isolate it with a valve.

Uh, . . . an additional note: Dennis Lee is an exceptional speaker and can hold

an audience mesmerized. In my opinion, it might actually be dangerous to point out the 'little' facts that Dennis 'forgets' to mention about the various technologies he is presenting.

After the explosion/implosion (as I've explained before) the cylinder raised about a hundred pounds of weight about one foot in one second, easily demonstrating that there was a vacuum in the cylinder. Dennis would just have you believe there was no explosion first. Typical Dennis Lee presentation.

If one of you see such a demonstration, ask that he put a pen on top of the cylinder before igniting the gas. An explosion will cause the pen to jump off the cylinder, an implosion will not. Of course, he'll likely read this before you do and will not allow it.

**Power Potential of BG**

Brown's Gas energy level is much greater than 50,000 Btu/lb. 50,000 Btu/lb is the power of normal 2H<sub>2</sub>:O<sub>2</sub>. See Brown's Gas, Book 1 to see why BG has so much more power potential.

We have not yet done comprehensive tests on BG power potential.

**Compare BN 1000 performance**

Yull Brown, in his sales literature for the BN 1000, (found in ExtraOrdinary Science issue OCT/NOV/DEC, 1993, PAGE 20) specifies (actual measurements on next page)

Gas Production (L/h) ..... 1,000  
 Operating Pressure (Mpa) ..... 0.45  
 ..... (about 65 psi)  
 Power Supply Voltage (V) ..... 220  
 ..... (assume 220 VAC)  
 Maximum Input Power (kW) ..... 3.3  
 Max. Water Consumption (L/h) ... 0.55  
 (this assumes 1700 liters of gas/liter of water)  
 Weight (Kg) ..... 200  
 ..... (about 440.8 lbs)  
 Cost retail \$5,500.

(Dennis Lee is now (Jan., 97) promoting this electrolyzer for \$10,000 and to the best of my knowledge

(April, 97) still has not delivered a single unit to those people who have paid for one. The list of excuses I've heard is impressive.) Further note: I have just heard (May, 97) of a BN 2000 being delivered to a Dennis Lee customer, he paid \$6000 wholesale.

Now, we have had the opportunity to actually test a BN 1000E, bought directly from Yull Brown himself. First I'll give you the direct test results as per above (you'll see some differences). Then I'll give you the data on the electrolyzer YOU can build from THIS book (you'll see how you can BUILD a better electrolyzer than you can BUY, and for a fraction of the cost).

**Actual test results of a BN 1000E**

(May, 97):

Gas Production (L/h) ..... 907  
 ..... (we could not get 1,000 L/h)  
 Operating Pressure (Mpa) ..... 0.06  
 (about 8 psi, obviously something wrong with the pressure controls. The digital readout would go to 0.6 Mp (87 psi) but the actual pressure measured only 8 psi (0.06 Mp))  
 Power Supply Voltage (V) 235 (VAC)  
 Maximum Input Power (kW) ..... 4.5  
 Max. Water Consumption (L/h) ... 0.89  
 (based on 112% eff. = 1045 liters of gas /liter of water. Greater water consumed because only 907 L/h produced)  
 Weight (Kg) ..... 225  
 ..... (± 495.9 lbs)  
 Cost \$5,500 USD direct from Yull Brown.

Note that Yull Brown's own specifications show inconsistency. I further note that all the above figures that we tested and found to be true, I later noticed that the original specifications had been changed (to our figures) by hand written notes in the BN 1000E operating manual. I was told that Yull Brown himself wrote those notes when the electrolyzer was sold to Ben & Co.

**We have built** (and you can too, with this book) a 1,000 L/h electrolyzer with the following specifications:

Gas Production (L/h) ..... 1,000  
 ..... (can go to 1600 L/h)  
 Operating Pressure (Mpa) ..... 0.45  
 ..... (operate between 65 and 70 psi)  
 Maximum Input Power (kW) ..... 3.3  
 Max. Water Consumption (L/h) ... 0.42  
 ..... (1259 liters of gas/liter of water, based on 135% eff.)  
 Weight; all components (Kg) ..... 95  
 ..... (about 210 lbs)  
 Cost about \$1,000; home built.

Note: we have achieved intermittent results as high as 188% gas efficiency at LESS than 2 watt-hours per liter of gas. Note that this STILL won't allow the 'atmospheric' engine to work.

**Further notes on testing the BN 1000E**

This report is by George Wiseman, intended for public release to increase the awareness for buyers and operators of BN 1000E Brown's Gas machines. I (George Wiseman) have fully and independently duplicated the technology needed to create Brown's Gas and this is the first time I will have been able to operate a 'commercial' Brown's Gas machine. I am uniquely qualified to test this BN 1000E, having independently duplicated the technology from scratch, I know what I'm looking at, what should be there and what should not be there.

Kiel and I arrived at Ben Missler's shop (7402 SW Macadam, Portland, Oregon), May 18, 97 at 1:PM. Ben Missler and Gary Robinson were there.

We talked, had lunch, set up some equipment and started examining the BN 1000E. After getting somewhat familiar with it (and having read the cryptic operation instructions), we fired it up and figured out the controls. We had a backfire (not really loud) when I was shutting off the torch. We saw the flash in the clear tubes (plastic).

Note: the China torch is (in my opinion) really rinky-dink. The tip would be nearly impossible to clean and it has a knob to add oxygen instead of a lever (it would be hard to hold the torch still while twisting the oxygen



knob to begin your cut). I recommend changing the torch to an American model. I use a Victor 100C on my electrolyzer in my shop. For our tests of the BN 1000E we used (after initially trying the China torch) my Victor 100C. Fittings to adapt the BN 1000E hose to the American standard are available in most welding supply stores.

Note: Main power in wiring code is Brown and White Power (240 AC) and purple is neutral (note, BN 1000E manual has different colored wires). Neutral is hooked to the electrolyzer full wave bridge rectifier heat sink bracket, which is grounded to the entire frame of the machine. There is a 30 amp main relay that most of the electrolyzer power goes through (there is a small pair of wires that routes 240 VAC directly to the electronics (has smaller transformer dedicated to the electronics), so the ON button can activate the relay coil.

All the main transformer power (one lead of the 240 AC from the main relay) goes through what seems to be an SCR; which seems to be controlled by the electronics.

The main transformer drops the AC voltage from 240 AC to about 24 VAC, which is then rectified by huge diodes in a full wave rectifier set up. These diodes are mounted on a heat sink that is cooled by a large fan. The fan turns on as soon as the main relay is turned on and stays on 'til the main relay is shut off (main power to machine is shut off).

There are six tubes mounted transversely in the bottom of the box; they are about four inches in diameter and 17 inches long. Each tube has TWO 'short cells' mounted in it; welded together in the middle. Thus the six tubes are each two cells; and the electrolyzer consists of TWELVE cells. All twelve cells are connected on the top with a hose (left and right) and on the bottom with a hose (left and right). These hoses seem to be there to allow the electrolyte solution and the

gas to separate properly, yet keep the cells as full as possible of electrolyte.

All four cell hoses go up to the first transverse container, that I'd call a liquid-vapor separator. The two hoses from the top of the cells go to the mid level of the liquid vapor separator (on the left and right) and the two bottom hoses from the cells go to the bottom of the liquid vapor separator (left and right). The liquid-vapor separator is about four inches in diameter and 17 inches long; it is located at the back of the machine just above the end cell.

The liquid-vapor separator has three towers on it. The first (left when facing front of machine) is 8 inches high and has the pressure and liquid level sensors on it. The second is 13 inches high, and is the 'flame modifier' tank. The third is also 13 inches high and is designated as the 'back arresting' solution container (backfire container, or bubbler in my electrolyzer design).

The two end towers (left and right) are further connected at their bottoms (just above the liquid-vapor separator) by a second transverse container 4 inches in diameter and 17 inches long. The actual connection is by two short 4 inch tubes. I'd call this tube a 'surge' tube, I think it is meant to allow storage space for pressurized gas and/or to prevent serious over-filling of water from affecting the gas quality too much by allowing water/electrolyte to be carried over into the torch hose.

Personally, I see the surge tube as way too large, or un-needed altogether. In my opinion the whole arrangement could have been simplified and/or modified to be more versatile and effective. For example, it would be nice to be able to switch between pure and modified gas with a valve (without having to drain the modifier tank to eliminate the modifier from the flame); or even to be able to run pure and modified gas at the same time (with two torches). Also, I see no reason that the water fill for the electrolyzer couldn't have been mounted on the sensor tower, leaving the back arresting

tower simpler and cutting out the surge tube entirely. But I will qualify my opinions by saying I don't know exactly all the plumbing arrangements inside these various tubes. My electrolyzer designs are simpler, more versatile and fully documented so that people aren't guessing about their function.

The gas seems to go up the two hoses on the top of the cells (connecting all the cells together), through the liquid-vapor separator, through the modifier tank first, then go back down (with some sort of inner U-tube) and up through the back arresting tank, then out the hose to the torch.

Water for the electrolyzer cells is put in the back arresting tower, where the water is poured through a down tube directly to the liquid-vapor separator; bypassing the back arresting apparatus in the back arresting tower.

The water level probes in the sensor tower indicate that the maximum liquid level in the liquid-vapor separator to be about mid level, lowest about 1 inch off the bottom.

Water for the back arresting tank is supposed to be filled by disconnecting the gas-out hose (found at the top-backside of the tank) and using a small flexible hose to pour water into the tank. Top cover of the machine must be removed to do this. We were unable to get our hose past the fitting; so we drilled and tapped an 1/8 inch plug in the top of the back arresting tank. We then filled the back arresting tank 'til water came out the drain (was about 1/2 quart), then closed the drain and added 1/2 quart more (0.5 liter) that the manual specified. It was unclear whether this second 0.5 liter was needed, so we added it anyway.

Advise for operators of BN 1000E operators; drill new filler plug to the left of main water filler facing from front of machine), so water being poured into the plug hole (for the back arresting tank liquid level) doesn't drain into the gas-out hose (water in your torch hoses is a bother, causes

your flame to spit and go out). And always drain your back arresting tank before re-filling it, or it will be impossible for you to know what the liquid level is (need only 0.5 liter above filler).

I think it'd be a good idea to drill and tap a 'sight tube' (with a floating ball) on the side of the 'back arresting' tower; then you could see at a glance your back-arresting water level. Don't drill the lower hole too low or you'll be below the bottom plate and cause the gas to by-pass the backfire arrester. You want your liquid level to be well above the diffuser plate; you'll see the diffuser plate (has holes in it) when you drill the new hole in the top of the gas-out tower. But you don't want your liquid level to be too high or you will get water splashing up and out into your torch hose.

Although the BN 1000E has proven that it can take a backfire without blowing up (we accidentally backfired it by turning the torch off too slow and we discovered that we had no water in the (separately filled) back arresting tank) I notice the fittings in the plastic hoses are now seeping a bit of fluid (even though this machine has not reached pressures over 8 psi); this seepage could have been caused by the backfires that this machine has had in the past, with no water in the back arrester. My recommendation is to keep water in the back arresting container to prevent the electrolyzer and hoses from having to deal with the shock of a backfire.

Note: my design does not have the dozens of fittings that this electrolyzer has. Every fitting is a potential leak of fluid or gas.

The modifier tank is to be filled with water first, to above the drain level, then drained, plugged and modifier added (no more than about 1/2 liter or 1/2 quart). To be sure that all of the modifier has been removed, it may be necessary to add water after draining the modifier, let sit for at least 1/2 hour and then drain it again. Most flammable fluids float on water.

Different modifiers will give different flame characteristics, and I discovered it may be necessary to add oxygen to get the best performance out of the modifiers. Some examples of modifiers include; gasoline (will change it's characteristics as the 'light ends' evaporate first), diesel, acetone, benzene, white gas, all types of alcohol, and many other flammable liquids. You could just use water in this tank too, and it'd work as a second backfire arrester.

#### **The five various sensors on the BN 1000E are:**

1. A temperature sensor (resistive?) on the fourth electrolysis cell from the front. Disconnecting this sensor causes the temperature readout to go to '00' and doesn't immediately shut down the machine. The temperature seems to be shutting off at about 35°C. The temperature readout is in °C even though the button you press to check the temperature is labeled 'F'.

2. A pressure sensor (transducer?) on the third tower, (back left of machine). Disconnecting this sensor doesn't immediately shut down the machine, the 'actual' pressure reading goes to '00'. When this sensor is disconnected the pressure continues to rise past the computer set maximum. The pressure rises VERY fast and may rise enough to burst the BN 1000E even with the torch running.

3. A liquid level sensor, which is three probes put down into the solution. They seem to be simple copper rods, which form some sort of on/off switch. Examination of the LED's on the front panel indicate that they are arranged in three groups. So I expect that as each probe (three different lengths) touches the solution, the appropriate group of LED's light up. I note that the liquid level is supposed to be about even with the hoses coming in from the cells; highest level about 2.5 inches off the bottom of the liquid-vapor separator, lowest level about 3/4 inch off the bottom of the liquid-vapor separator. Disconnecting this sensor does not

immediately shut off the machine, the panel of LED's does go out.

Note that in our testing of this BN 1000E, we found one LED to be 'blown' and the three probes of the liquid level probe to all be shorted to each other; thus I assume the liquid level probes to not be working as originally designed or intended. At the moment, when the liquid level goes to below the bottom probe, all but two of the LED's go out, and the 'low water' light comes on (which is good).

Note: we operated the machine with the liquid level 2 inches higher than the highest set point with absolutely no problem.

4. A current sensor, which seems to be a calibrated resistance on one of the DC leads coming out of the full wave bridge rectifier. The wires to it from the electronics are yellow and blue.

5. A voltage source, which seem to be the blue wire (same one from the DC amps) and a red wire going to the other DC side of the full wave bridge rectifier.

#### **Operation notes**

1. The BG 1000E makes significant noise during operation, mostly from the fan; it is so loud that we can't even hear the noise of the transformer. The problem is noise pollution, making normal conversation difficult and making stress.

The noise also covers the sound of the gas hissing out of the torch tip, which I use on my electrolyzer to know if I've got a 'just right' torch adjustment to prevent backfire during lighting the flame (my electrolyzer operates nearly silently). With the BN 1000E, lighting the torch is a guessing game, though I will admit I never had a backfire lighting the torch. Which was surprising, because the gas pressure was so low (due to the electronics problem), the torch must have been on the verge of backfiring at any time.

2. To check the **main** water level, you start the BN 1000E by pushing the green button (make sure that you're on at least a 30 amp breaker). You can have the power turned on to the electronics and NOT have the power turned on to the electrolyzer. The power to the electrolyzer is only turned on when you push the 'start' button on the control panel. While the BN 1000E is in this 'stand-by' mode, you can release any residual gas pressure by opening your torch valve; and check your liquid level.

If all the LED's are lit up, you may have too much water in the electrolyzer, if you drain some out (save it to put back in when you've used up some water) and be careful, the solution you drain out is caustic, it will burn your skin and eyes if you spill it on you (use safety equipment to protect skin, eyes and clothes). Have vinegar and fresh water available to clean up spills. By the way, we find the water (electrolyte solution) drain (in fact all the drains) to be inconvenient, as they are just plugs on the ends of pipes; this is messy and causes solution to get on your hands.

Note: if you look down the water-fill tube in the 'back-arresting' tower, you'll see liquid at the bottom. If you fill 'til the water you are pouring in just touches the end of the water fill tube, you'll not have too much water in the main electrolyzer. You'll have too much according to the electronics, but I've found no problem with an even higher liquid level.

Note: the water in the back-fire arrester is filled SEPARATELY from the main electrolyzer. You can also use the 'modifier' tank as a second backfire arrester, just by putting water in it instead of some other fluid.

3. After you have a proper level of liquid in all three places (back fire arrester, modifier (if used) and main electrolyzer) You shut off your torch valve, so you'd have no gas leaks and you set your control panel. The control panel will automatically choose it's maximum settings if you don't set

anything and just press 'start' to start the gas production. I personally can see no reason why anyone would want to set the machine to less than it's maximums, since it automatically regulates itself to the actual gas volume you're using anyway.

If you want some other setting than the electrolyzer maximums, the control panel has to be set every time you turn the machine on, the electronics have no memory. This is a bit of inconvenience because you tend to shut the machine off instead of letting it set in 'stand-by' mode because the fan is so loud. Besides, it is just good practice to shut off electrolyzers when they are not in use.

Note: my electrolyzer design can be used at any volume or pressure as well, much easier than setting electronics each time.

There are two parameters to set on the control panel; the maximum desired operating pressure and gas production. If you just push 'start', the computer will assume you want the maximum values of 1,000 liters per hour and 0.5 Mp.

You push 'P' to tell the computer that you're wanting to set the maximum operating pressure. The computer will ignore any setting above it's maximum of 0.6 Mp (which is about 90 psi). So to set 0.5 Mp (about 75 psi) you'll push 'P', then '0' and '5', then 'enter'. (Actual maximum at this time is 0.06 Mp)

You push 'GP' to tell the computer that you're wanting to set the maximum operating Gas Production. The computer will ignore any setting above it's maximum of 1,000 L/h (liters per hour). So to set 1,000 L/h you'll push 'GP' then '1', '0', '0', '0', then 'enter'.

4. Then press 'start' to actually start the gas production. Watch the pressure rise, if the pressure doesn't rise quickly, within a few seconds, then shut off the machine and check all your hose connections for a leak (I had a leak when I switched to my torch from

the China torch; I forgot to tighten one of my hose connections).

As the pressure is rising, you'll see the voltage and amperage readouts fluctuating as the computer keeps the gas production within the parameters you've set. I think the gas production is 'inferred' from the amperage and voltage (I see no gas metering device), so it's possible that the actual gas production could be different than the readout says. When the electrolyzer operating pressure is reached, you'll note the amperage drop off quickly and the voltage to drop off more slowly. This is the electronics cutting off the power to the main transformer, using the SCR as a switch.

5. Light the torch as you would a normal oxy./acet. torch; except that you hold the striker very close to the torch tip or the gas won't want to light. If you have too much gas volume, it also won't want to light. If you have too little gas volume, it will backfire.

### Testing data

1. I found the flame characteristics to be identical to my electrolyzer gas. See my [Brown's Gas, Book 2](#).

2. Preliminary testing of total wattage efficiency showed close to 5 watt hours to a liter of gas. This is total machine power draw to make a liter of gas; includes the fan and computer power as well as the transformer and diode losses. These kind of losses are fully explained in this book as are the reasons I choose to have an electrolyzer design that doesn't have a transformer.

We put a 100 amp watt-meter (Kh = 7.2) in line, to measure the watts drawn from the wall.

We first measured the 'stand-by' wattage, used by the fan and electronics with no gas production. It took 145 seconds to make one revolution of the watt-meter wheel. So  $(7.2 \times 1 \times 3600)/145 = 178$  watts 'stand-by' power. (Very efficient fan!)

The wall power available is nominal 240 VAC and the electrolyzer was pulsing about once a second, drawing up to 36 AAC then settling down to a steady 30 AAC 'til the computer shut off the SCR. This made the watt-meter move fast, then nearly stop and it was difficult (but not impossible) to get an accurate reading.

To measure total machine efficiency, we used our regular technique of filling a 4.082 liter plastic container with the gas; displacing the water out of it. With the BN 1000E set at 1,000 Liters per hour, we filled the container with gas in 16.2 seconds. We used 280 marks of the watt-meter wheel to do this (2.8 revolutions of the watt-meter wheel). We did this several times and were very close each time.  $(7.2 \times 2.8 \times 3600)/16.2 = 4480$  watts.  $4.082/16.2 = 0.2519$  L/sec.  $0.2519 \times 3600 = 906.84$  liters per hour. So  $4480/906.84 = 4.9$  **watt-hours per liter of gas.**

We are now experiencing a shut-down problem in the machine (started during testing yesterday), and it's getting worse. The electrolyzer will only run a few minutes (Initial shut-off happened after about an hour of continuous use) and then it shuts itself off by turning off the main relay; which, as I understand it, it isn't supposed to do until the red shut-off button is pushed. All computer controlled shut-downs are only supposed to turn off the SCR (electrolyzer itself) leaving the computer and fan running.

The shut-down gets progressively worse as you continue to try to operate the machine, first shutting down after fifteen minutes of operation, then (after immediate start-up) shut-down after five minutes and then (again after immediate start-up) shut-down after one minute. Combine this problem with the 'water' light coming on when you first start up the electrolyzer and I suspect that the main computer PID chip is malfunctioning; perhaps heating up and causing the shut-down condition.

To test the BN 1000E at a lesser amperage and with capacitive limiting,

we installed 40 of 4 uF @ 440 VAC capacitors in series with the main transformer. We disconnected the main relay from the computer's control and turn it on with our own switch. We left the fan in the circuit, to cool the transformer and the diodes. This allows us to test the BN 1000E in a 'steady state' condition; allowing more precise measurements. This test allowed 8 amps AC @ 235 VAC into the transformer, which allowed about 52 amps DC through the electrolyzer @ 24.2 VDC. We filled our 4.083 Liter container in 35.3 seconds. It took 14.4 seconds to make one turn of the watt-meter wheel. This works out to about **106%** gas. Wattage efficiency = 4.322 Wh/L

The next test was to remove the capacitive amperage limiting and run the electrolyzer in a 'steady state' at full power. We drew 35 AAC @ 230 VAC from the wall and had 203 ADC @ 26.4 VDC across the electrolyzer. We filled a 4.083 liter container in 8 seconds and it took 29.4 seconds to turn the watt-meter wheel ten revolutions. The electrolyzer Faraday efficiency was **120%**. Wattage efficiency was 4.798 Wh/L.

The electrolyzer pressure kept building as the gas production increased as the electrolyzer slowly 'ran away'; using more amps as the cells heated up, and heating up the cells faster as the amperage increased. The BN 1000E uses a calibrated resistance to form a 'current sensing' device, which causes the computer to shut down the amperage to the electrolyzer (by shutting off the SCR) if the amperage exceeds about 180 ADC.

**NOTE:** The pressure on the BN 1000E read at 0.5 MP and an actual pressure gauge (we tried two) read at 8 psi. Since a Mp is about 145 psi, there is a serious problem with the pressure coming out of the BN 1000E. The pressure is too low; I don't know why it didn't backfire as we were using the torch.

Testing the torch with BG allowed us to cut and weld cast iron (with oxygen

added), vaporize tungsten and weld copper; also did brazing on iron. Adding gasoline as a modifier (1/2 quart) allowed us to weld iron, but only when we added oxygen to the flame.

We used the same torch tips and duplicated all the above feats with normal oxy./acet.

Neither torch was able to weld stainless steel, aluminum or weld different metals together.

The BG torch did cut thick steel faster and cleaner than the oxy./acet. torch did.

### Testing the BN 200

These poor people bought this tiny electrolyzer at \$2500 from Yull Brown himself (twice retail value). We took it out of the box (cut the seals ourselves) and discovered that it had been used (hydroxide spills and rust) and that it had no power cord.

We went to town and bought the components to make a power cord (12 gauge all weather stranded wire, a 240 VAC plug to fit the outlet we are using for the BN 1000E and a heavy duty 'computer' cord with female plug (that being the power outlet for the BN 200).

I wired the cord (soldered all connections) and it looked and worked great. I put electrolyte @ 5:1 in the electrolyzer and turned it on. Nothing happened; well, OK, the power light came on.

Quick testing shows that the electronics are not turning on the electronic switch to allow the amperage to go through the electrolyzer. I think the electronic switch is good, but some other parameter (like malfunctioning pressure transducer) is causing the problem. Don't have time to fix it at this time; though the electronics seemed simple enough and could be reverse engineered.

## Testing Conclusion

The Brown's Gas BN 1000E makes lower quality gas (about 120%) compared to our current electrolyzer design (136%), and our design takes almost exactly 1/3 LESS electricity to make the same volume of gas.

Operation of the BN 1000E is simple enough, once you know how to do it. In my opinion, the instruction manual and technical support from Yull Brown are not adequate to assure safe operation for a novice user (this includes someone knowledgeable as myself). This report will assist users of the BN 1000E to operate the machine safer. My own electrolyzer designs are fully documented and we give enthusiastic technical support to anyone using ANY (but particularly ours) electrolyzer.

The BN 1000E is quite presentable, looks good. And I'd consider it well designed, just not designed as well as it could be. I'd suggest several changes to make it safer and easier to use, but then we'd end up with my design.

The BN 1000E seems to suffer from a 'China syndrome' of quality control. We found several problems, particularly in the electronics, that could be traced directly to inadequate quality control. In short, the machine barely functioned, crippled by faulty electronics; for which there are no wiring schematic or technicians on this side of the Pacific.

The BN 1000E is made of mild iron, and already shows rust both inside and out. Personally I don't expect long life spans for these (expensive) machines. It will be particularly important to make sure the backfire arrester has adequate water in older machines, because the rust will eventually cause the electrolyzer to weaken and it will not be able to contain a backfire.

The BN 200 suffers from the 'China syndrome' too. In my opinion, the torch tips are also too large a diameter for the electrolyzer capabilities. Backfires assured.

Report by George Wiseman

## Conclusion

Quite a few people mistake or confuse Brown's Gas with normal  $2H_2:O_2$ . Brown's Gas can only be created with electricity in special designed electrolyzers. Brown's Gas has completely different operating characteristics than  $2H_2:O_2$  and CANNOT be thought of in the same way.

I have experimentally **proven** many of Yull Brown's statements to be wrong! Why he has allowed these mis-statements to continue, I don't know, BUT I do know that if you try to design machines and/or processes around that information, you will be **very** disappointed, perhaps even hurt. **Please** take this advice to heart, at least enough to check it out.

Yull Brown has little actual lawful rights left, due to the patents having run out and the information having become public knowledge through independent efforts such as mine. Second, you must be aware that Yull Brown has been spreading misinformation, I do not know why, but must assume he doesn't want others duplicating his technology and uses misinformation as a tool to accomplish this. I find it nearly impossible to believe that he is actually so ignorant of his own technology that he BELIEVES the misrepresentations he has told.

Again I tell you, we've independently duplicated virtually all Yull Brown's work with Brown's Gas. The things I tell you are based on ACTUAL experimental proof, not only by myself but by people who are independently duplicating the technology from the information I've made publicly available. The things I've told you so far have been done by others besides myself, at several locations around the world! You **MUST** take my comments seriously if you truly intend to get Brown's Gas technology out into the world 'in every home' as it were.

As I've stated before, "**I agree that Brown's Gas is a viable option to apply to a self-sufficient home, BUT not in the ways that are normally outlined**".

I will explain:

We can already run normal internal combustion engines with Brown's Gas assist, reducing the actual cost of operation while making the engine last longer. It is absolutely valid to use the heat generated by the IC engine to heat the home and to use the IC engine to run an electrolyzer. The electricity generated can run the Brown's Gas electrolyzer, refrigeration systems, charge batteries and power the home. In my opinion, purifying water should primarily be done with direct solar power but can be done with distillation. This type of home power system (based on an IC engine, usually diesel) has been proven many times and is very practical. The only major difference is that we are **partially** burning water instead of only petrochemicals.

In addition to powering a home; we can help all automobiles this way, either as direct conversion (adding Brown's Gas to gasoline), or by using electric autos charged by BG driven electrolyzers, or quite a few other options.

I wish to freely support you in your attempt to implement BG technology, as I support anyone who is willing to try. I feel that a world-wide grass-roots development **MAY** be the way to get this technology implemented. At the very least, public distribution of practical information will make a huge difference.

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Planetary Association for Clean Energy, Vol. 6, (4). ppg 8 to 12, Transmutation of Radioactive materials with Yull Brown's Gas.

Published by Planetary Association for Clean Energy, Inc.

100 Bronson Ave., Suite 1001,  
Ottawa, ON, K1R 6G8, Canada.

Material Safety Data Sheets (MSDS) on Hydrogen, Sodium Hydroxide, Potassium Hydroxide. Available from anyone who commercially sells these products.

Pocket Ref, compiled by Thomas J. Glover, seventh printing © 1992. Published by Sequoia Publishing Inc., Dept. 101, PO Box 620820, Littleton, CO, 80162-0820.

• **Wiseman, George**, © 1995, Brown's Gas, Book 1. Published by Eagle-Research  
www.eagle-research.com

## RESOURCES

Though some Resources are listed, be advised to: 'Let your fingers do the walking'. Try to locate various alternative suppliers and options. Doing this may save you a great deal of money. You'll also learn a lot about the available options on components you are trying to locate.

The Thomas Directory of Manufacturers is a GREAT resource, available in most Public libraries. You can go looking for a component, like a pressure switch and find pages of manufacturers.

In addition, check out the Resources listed in Brown's Gas, Book 1. You can often get great deals on components that are described well enough that you'll be safe using them; like heavy duty relays, diodes, heat-sinks, capacitors, etc. Be careful with components that have 'wetted parts' like pressure switches and pressure gauges, because they could have material compatibility problems.

• **Bokers, Inc.**,  
3104 Snelling Avenue,  
Minneapolis, MN, 55406-1937.  
Phone: 1-800-927-4377  
- *six inch disks for making plates*

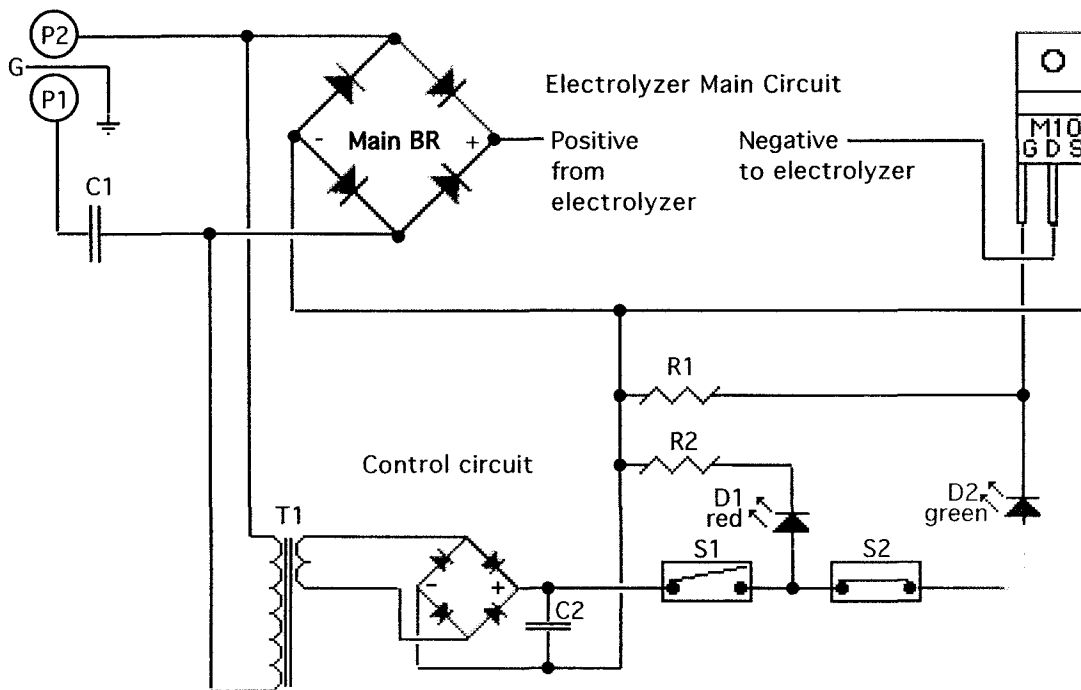
• **Cole-Parmer**  
7425 North Oak Park Ave.,  
Niles, IL, 60714  
Phone: 1-800-323-4340  
*The Cole-Parmer catalog is actually a bonanza of stuff, and includes a fairly comprehensive materials compatibility chart in the back.*  
- *0 to 100 psi pressure gauge, with 316 SS tube and stem, #H-68811-05*  
- *60 amp 3 pole relay with a 120 VAC activation coil; #H89950-40. Also find electronic relays here.*  
- *Brass needle valves #H-68831-00 (have 1/4 NPT(F) openings)*  
- *Check-valves, #H-98676-02 is a 3/8 multi-position brass*  
- *Diaphragm seals are recommended to prevent eventual clogging*  
- *Electrical Multi-meters*  
- *Hose and pipe fittings*  
- *Liquid level sensors and controls*  
- *Pressure relief valves*  
- *Pressure switch #H-07355-43 has a 316 stainless steel diaphragm and stem (1/2" FNPT); and a pressure range (field set able) from 10 to 100 psi, with 1.5% set-point repeatability*  
- *Safety equipment (A huge amount of).*  
- *Stopwatches*  
- *Temperature shut-off switches three wire design allows you to shut-off the electrolyzer and ring an alarm from the same switch. #H-93880-54 is a stainless steel, 125°F (52°C) snap action switch rated at 3 amp inductive at 120 VAC. Note: Install capacitor across mechanical relay coil to reduce inductive arcing.*  
- *Torch set (Little)*

• **Harvel Plastics, Inc.**,  
Box 757, Easton, PA, 18044-0757.  
Phone: 610-252-7355.  
- *CPVC plastic pipe.*

• **Industrial Safety Co.**,  
1390 Neubrecht Rd., Lima, Ohio,  
45801. Phone: 1-800-537-9721.  
- *Safety supplies (A full range of).*

• **Industrial Specialties Mfg, Inc.**,  
2741 West Oxford, Unit #6,  
Englewood, CO, 80110.  
Phone: 303-781-8486  
- *Gauges and many other items.*

• **United States Plastic Corp.**,  
1390 Neubrecht Rd., Lima, OH,  
45801. Phone: 1-800-537-9724.  
- *CPVC 3/4" plastic sheet*  
- *Funnels*  
- *High Density Polyethylene (HDPE) tubing and hose fittings*  
- *Table saw blade (Special) to cut plastic*  
- *Tygon tubing (clear), get highest pressure rating. Formulation R-3603 has a working pressure of 62 psi with ID of 1/4 @ 1/8" walls. Recommended for sight tubes (put a small dark HDPE ball in the tube to float on the liquid level).*



Copyright George Wiseman February 2000. I consider this to be the absolute bare bones simplest circuit. The control circuit tells the Mosfet when to feed power to the electrolyzer in the main circuit.

See Brown's Gas Book 2 for specifications not mentioned here. Main current is limited by C1. Rate C1 as per Brown's Gas Book 2. Main Bridge Rectifier should have an amperage rating as per Brown's Gas Book 2; use a heat sink and thermal paste.

Mosfet M10 is rated at higher than the main power supply peak voltage. Be sure to use a heat sink with thermal paste and voltage isolator kit (if needed). If one mosfet has too low of an amperage rating, mosfets can be placed in parrallel to increase amperage rating of the circuit, all Gates connected to D2 with 20 ohm resistors. Note that the Source of the mosfet needs to be connected to the negative of the control circuit.

S1 is simply to manually shut off the electrical circuit. Mosfet turns on when voltage is applied to it's Gate.

S2 (mounted off board) is a normally closed (open on pressure rise), direct acting pressure switch, made of stainless steel with a teflon diaphragm. It should have at least a 20 watt rating and either be adjustable or factory set at your desired electrolyzer pressure.

Add an S3 (mounted off board), temperature switch (not shown above) if you need to limit the electrolyzer temperature. Make the switch normally closed (open on temperature rise) and pre-set at your maximum temperature. I'd put the switch between S2 and D2.

The T1 needs to be 10 volts (rated) on the secondary. The voltage can go up to 15 volts with no damage to the mosfet; which is very likely to happen because it may be hard for you to find a transformer small enough for this circuit's requirements, so the secondary voltage will rise above it's specified rating. The primary of T1 should be rated for whatever the main circuit voltage is.

The control circuit bridge rectifier can be tiny, half amp at 50 volts is more than needed. C2 is an electrolytic capacitor minimum rating 100 uF and 50 volts. D1 is a red LED, to indicate when the control circuit is turned on. D2 is a green LED, put there to see when the power is being fed to turn on the mosfet; it will flash very quickly as the S2 keeps the pressure to within 0.001 psi. R1 and R2 are 1/2 watt 400 ohm resistors.

T1, C2 and the control circuit bridge rectifier can be replaced with a 12 VDC battery.

You can use Capacitive Limiting with Voltage Doubler. But usually the Capacitive Limiting is simply added to a series-cell that has too few cells to qualify for any other power supply option.

You can use Capacitive Limiting from one cell to as many cells as you want up to about line power VRMS. The amperage will be limited to whatever will 'pass' through the capacitor at the voltage applied. For example; at 120 VAC, 25 uF (microfarad) will pass about one amp; at 240 VAC, about 7 uF will pass one amp.

## 2. Voltage doubler

Note that this is the 'basic' power supply circuit for the electrolyzer only, without all the controls that turn the main relay on and off. This is the circuit starting from the output side of the main relay.

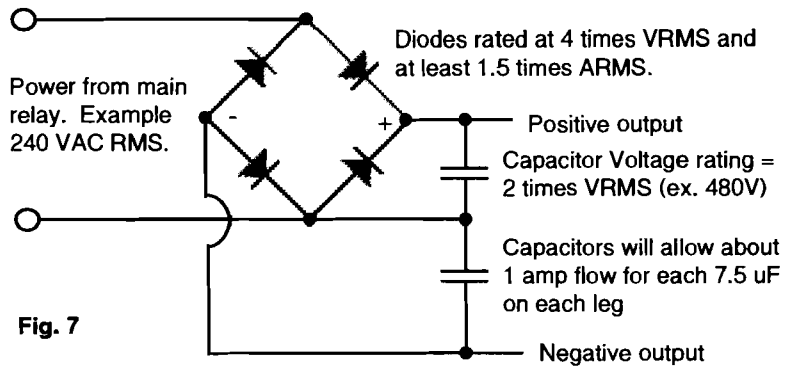
You use a voltage doubling circuit if you have too many cells for Straight Capacitive limiting.

The voltage doubler circuit has several advantages that the over Capacitive limiting.

1. It uses very little additional components.
2. It increases the frequency of pulses.
3. It allows you to add extra cells that limit amperage, yet allows additional amperage capacity to be added at will.
4. It allows additional gas production by increased number of cells at the same DC amperage (AC amperage is increased, TANSTAAFL).
5. It allows an electrolyzer designed to operate on a higher voltage to operate on a lower voltage; for example a 220 volt electrolyzer to operate on 110 VAC source.

Voltage Doubler doesn't actually double the voltage; (it would if there was no load), the voltage only rises a little across each cell (to the threshold voltage) and the amperage can be raised quite a bit.

**Voltage Doubler** circuit for extended series-cell BG electrolyzer.



**Fig. 7**

Again, because this is important, you will notice that a slight additional voltage rise across each cell allows a much greater amperage current to flow. This is why the voltage doubler circuit increases amperage.

The voltage doubler does an additional thing, it increases the FREQUENCY of pulses. With the voltage doubler you will usually get at least 240 pulses per second. In certain cases (combinations of capacitors on the legs of the voltage doubler) it is possible to get up to 500 pulses per second using this circuit plugged into normal 60 cycle AC.

When I am going to use a voltage doubler as my electrolyzer power supply, I usually figure the number of cells at the rule of 1.75 volts per cell, figured on RMS voltage. For example; operating on 240 VAC, I would have 138 cells.

In this way you can actually take more advantage of something called 'Peak

voltage'. For any given wall AC voltage, you'll find that the actual 'peak' voltage is about 40% higher than the 'RMS' voltage that most AC voltmeters read.

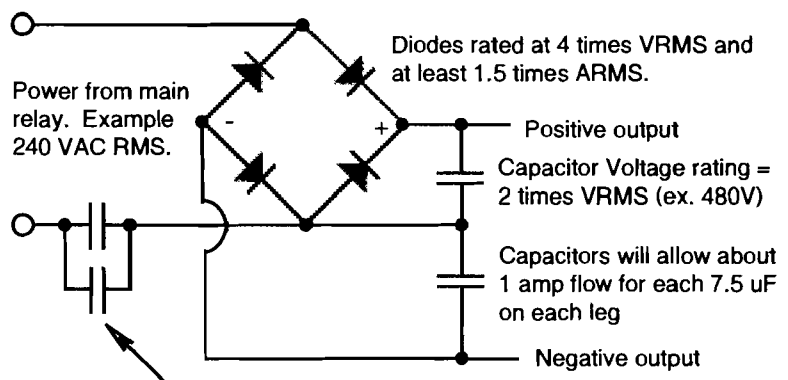
Thus you can operate your 120 VAC electrolyzer at 220 VDC or your 220 VAC electrolyzer at 290 VDC.

Also you'll find that you can limit amperage WITHOUT capacitive amperage limiting. The high number of series-cells automatically limits your amperage, because as your electrolyzer requires more voltage to operate, NO amperage will flow 'til the higher voltage is reached.

And the higher voltage (required by the electrolyzer) cannot be reached until the voltage doubler kicks the voltage up (twice each half cycle or 240 Hz).

With the 138 series-cell electrolyzer on straight line power, you'll note only a limited amperage 'til you start adding

**Voltage Doubler** circuit with Capacitive Limiting



Put extra capacitance in parallel with first capacitor; which is in series with the load on the AC POWER line.

**Fig. 8**



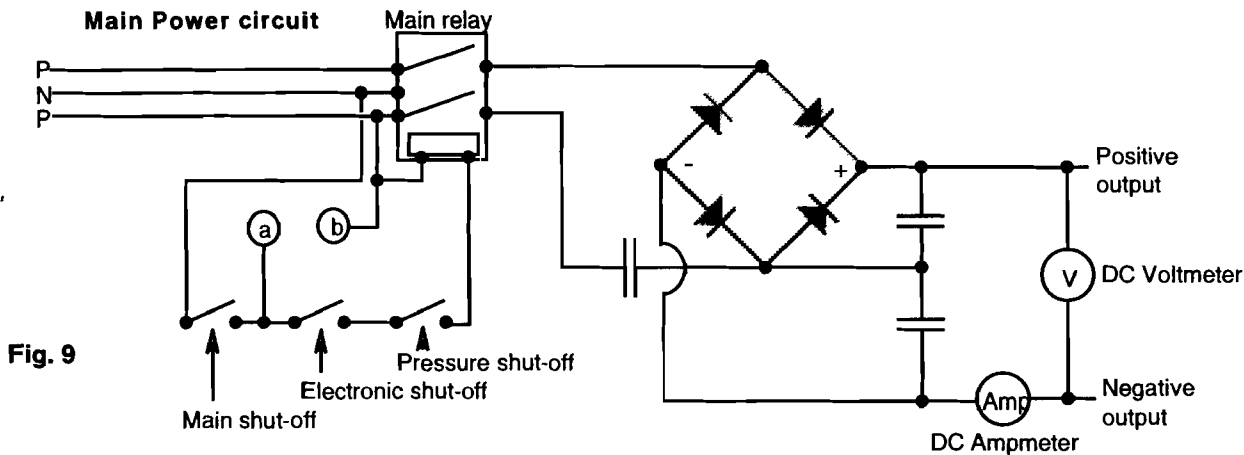


Fig. 9

capacitance to the 'legs' of your voltage doubler. As you add capacitance on each leg of the voltage doubler (equal on each leg):

You'll note that the amperage will rise at the rate of one amp per 50 uF per leg with 120 VAC RMS.

And the amperage will rise at one amp per 11 uF per leg with 240 VAC RMS.

**IMPORTANT NOTE:** 'There ain't no such thing as a free lunch'. When you increase the voltage using a voltage doubler, the 'extra power' comes from AMPERAGE from your RMS source.

When using a voltage doubler circuit, the amperage being drawn from the wall is about TWICE the amperage you see across your electrolyzer. You must be sure your wall fuse or **breaker can handle the amperage** you will be adding. Remember that the **MAXIMUM** continuous operating amperage of your breaker or fuse will be only 80% of the 'rated' amperage. For example; a 20 amp breaker should hold 16 amps.

Further Note: When a breaker 'trips', it will not again hold as much amperage as before. After each 'trip' the actual amperage that the breaker will hold is a bit less.

### 3. Voltage Doubler with capacitive limiting

Note that this is the 'basic' power supply circuit for the electrolyzer only,

without all the controls that turn the main relay on and off. This is the circuit starting from the output side of the main relay.

Same as Voltage Doubler, only you have capacitive limiting in series on the input common with the center of the voltage doubler capacitors.

### Main Power Circuit

We have the main power coming in on an ordinary 240 Volt cord, using properly rated receptacles, wire sizes and plugs. The 'P' is power or hot; the 'N' is neutral, where you wire to when you want 120 VAC.

Note that our electrolyzer draws about 50 amps, so I use a main relay rated at 90 amps. The relay is normally open, three pole, single throw. The relay has a 120 volt coil to activate it.

Note the three shut-off switches wired in series, in series with the main relay coil. This is so that if any one of the switches is open (off) then the main relay has no power and is off! The Pressure switch is normally closed, open on pressure rise (could be a relay). The Electronic switch is a relay that is normally open, held closed by the electronic circuit. The Main switch is normally open, closed only when you want the electrolyzer operational (this could be a relay too), I usually just use an ordinary light switch.

The points marked 'a' and 'b' are where you connect the primary

side of your transformer that provides the low voltage for the electronics, gauges, buzzer and relays.

You'll note that the DC ammeter is on the line going into the electrolyzer; it doesn't matter which one, just so you get the polarity correct. Although I depict a capacitive limited, voltage doubler power supply here, the ammeter is installed in the same place on all the power supplies.

You'll note that the DC voltmeter is mounted between the lines going into the electrolyzer, you have to get the polarity correct. Although I depict a capacitive limited, voltage doubler power supply here, the voltmeter is installed in the same place on all the power supplies.

There are any number of 'extras' that can be applied to this circuit, like indicator lights and receptacles (120 volt and 240 volt); but I left them out of this schematic because I'm trying to keep it seriously simple. What you see will work just great! The electronics has status indicator lights and you can see when the power is on (to the

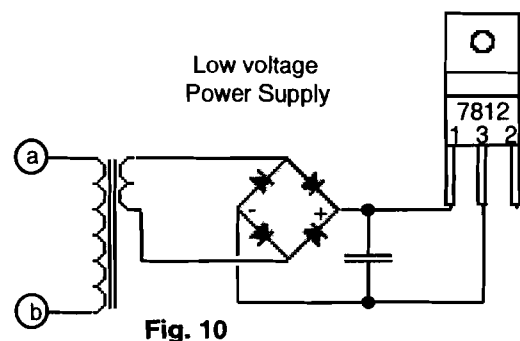


Fig. 10