OMNIFUELED GASIFIER/WATER-HEATER/ENERGY SYSTEM

DETAILED CONSTRUCTION PLANS with clear 3D color renderings

INTRODUCTION

I have a design for a gasifier that I want to share with the world. It is the culmination of my 38 years of work in the field, and I think it will solve many of the problems that now plague those modeled after the old WWII Imbert gasifiers. While many recent improvements have been made by dedicated gasifier enthusiasts, it is still an evolving technology, with much scope for new approaches and improvements in the utilization of huge quantities of locally-available waste biomass fuel sources. Biomass- and waste-fueled energy has the potential to contribute much more to global green energy demands. To learn more on this subject, read my Department of Energy report on "Biomass Energy, State of the Technology, Present Obstacles and Future Potential" at http://www.fundamentalform.com/html/doe_report-1.html

I have finally achieved an optimized gravity flow design that follows more elegant thermodynamics than previous approaches, through a labyrinth of concentric shells and spiral ducts. It thrills me to give the complete set of plans for this new household energy system to you, that you might build and test one and give me feedback in order to improve it, that more local waste products become clean efficient energy.

This latest design, a gasifier/hot water heater I have named Round John Virgin, Roundy for short, honoring the comfort of the winter hearth. Virgin doesn't apply yet, as it's still in the womb, so to speak...but just wait 'till she gets in heat! Roundy is large household size, 110,000Btu/hr, 32kWe, which will heat water for heating needs or generate electricity through a genset fueled from the gasifier.

Actually, since this is a radical take-off from previous prototypes, I don't know how much energy Roundy will put out in practice……could be substantially more than 32kWe, or less. I expect a very large turn-down ratio, at least 20/1 in combustion mode, with very high efficiencies in condensation mode, perhaps 95% of the High Heat of wet fuels (most furnaces are rated at Low Heat efficiency, since they don't condense the moisture to get back the heat of vaporization. Since green biomass can often be half water, this represents a significant increase in energy available from condensing the woodgas or exhaust).

Since this unit has not been built yet, I don't know the performance parameters it will exhibit in actual operation, but I expect it to create a high quality gas, clean enough after the condensing heat exchanger (CHX) for the engine without further cyclone separators or filters. There will be an operating range where the gas is the cleanest, and another condensing range where efficiencies of

both gas and hot water production are highest. These parameters will have to be tested to know for sure.

Any fuel that will fit in the hopper and produce a combustible gas can be gasified ~ logs, chips from the tree trimmers, bark, sawdust, corn cobs, leaves, wood-, straw-, municipal solid waste-pellets, green and wet biomass (up to 2/3 water, at least for the water-heating mode), household and farm waste, etc. Ideally, anything that will burn can be vaporized or gasified and turned into a fuel.

A quality fuel gas contains mainly Carbon Monoxide (CO) and Hydrogen (H2), combustible gases, along with the 79% Nitrogen (N2) from the air and the considerable water vapor (H2O) generated by the combustion chemistry as well as held in the fuel. Ideally, the Nitrogen Oxide (NOx) content is very low, and soot, hydrocarbons and other smoke pollutants are non-existent. The steam can mostly condense on grains of fly-ash and the cleansing rain will scrub the gas clean in a properly designed HX. However, the difference between ideal and practical has been significant in the history of gasification, largely because waste fuels are not homogeneous and meterable like gasoline and natural gas. The pieces gasify at different rates, and the difference in moisture, ash, elemental composition, slagging temperature, oxygen and CO2 penetration, feed considerations, etc. present many uncontrolled variables. These challenges have been grist for my explorations into this technology. Round John has been designed from the following

OBSERVATIONS AND DISCOVERIES:

- Fuel in a hopper gasifies best and most evenly, without bridging, when it is burned, vaporized, gasified evenly at the base of a vertical-sided hopper. Whenever there is constriction without size-reduction from burning or gasification, as is often the case in the upper throat of an Imbert or constricting throat gasifier, where combustion doesn't consume the fuel to the contour of the throat, bridging and uneven gasification occurs.
- Whenever there is bridging of the fuel, air supports combustion beneath the bridge, creating hot flames and a spent gas with excess oxygen and little if any energy value. If the bridge burns through, the gas is greatly diluted and cooled by excess air, which can totally rob the fuel gas of energy. Then the bridge collapses, quenching the flames and heat with cool damp fuel and steam, creating a burst of sooty gas, followed by diminished cool gas production.
- Providing the above feed conditions are addressed, preheating the incoming air can almost entirely solve this problem, if it is hot enough, because the endothermic gasification is sustained in a deeper coal bed by the heat of a lesser volume of air. This is quite different from conditions created by a larger volume of cool air, with its oxygen content creating combustion to supply the heat along with lots of diluting nitrogen and CO2. With this approach, higher-energy-content-gas can be created.
- Of the three fundamental thermodynamic ingredients of Time, Temperature and Turbulence, Time is too often neglected in favor of Turbulence, as in the jet of speedy air shooting from the

tuyers of a downdraft gasifier. I have found it better to let the air slowly permeate the fuel, heating up a large mass of fuel slowly, evenly, creating a large hot coal-bed, letting the gas become saturated with CO and Hydrogen over time and temperature. Instead of turbulence for mixing and HX efficiency, Roundy has been designed for laminar and internal vortex currents propelled by natural convection flow.

- Steam and CO_2 are primary combustion enhancers, speeding heat transfer significantly by their bipolar molecular property of absorbing and radiating radiant energy. Radiation is the primary mode of heat transfer at the temperatures of gasification. N_2, O_2, CO and H_2 do not absorb radiant energy, so heat transfer must come from neighboring bipolar molecules or be delayed. Steam and CO_2 also react with the charcoal, creating CO and H_2, both fuel gases.
- Contrary to expectations, adding all this heat and insulation does not deteriorate the materials of construction as much as allowing local hot spots of 2500-3,000F combustion, which is far above the required gasification temperatures of 1300 - 1600F. Temperatures above 1500F rapidly oxidize metals and thermal-shock ceramic, as when cool fuel suddenly lands on orange-hot refractory or cool air rushes in an empty open hopper.

THIS GASIFIER/FURNACE IS DESIGNED AROUND THESE CONSIDERATIONS, WITH THE FOLLOWING FEATURES:

- The hopper and entire construction is cylindrical, creating more even feed and flow, less thermal stress, simpler construction, more reliable seals, thus the name “Roundy”.
- When burning the gas to heat water, the generated gas is burned in a concentric combustion shell, which feeds heat to the incoming air and fuel in the hopper, augmenting the calorific value of the produced gas, thereby requiring less air for more gasification of a higher quality gas, which is mixed with preheated air and burns super-clean in the combustion shell.
- Highly preheated gasification air is introduced to the preheated fuel around the base of the hopper, where it is burned and gasified, creating a steady-state fuel feed without disruption of the fuel. Residence time of all heat transfer and chemical reactions can be much greater than conventional practices, which greatly expands fuel options.
- Any fuel that will fit in the hopper and produce a combustible gas can be gasified ~ logs, chips from the tree trimmers, bark, sawdust, corn cobs, leaves, wood-, straw-, municipal solid waste-pellets, green and wet biomass (up to 2/3 water), household and farm waste, etc. Since this first version of the gasifier has a thin-shelled ceramic hopper lining, large heavy chunks of fuel should not be dropped in, especially without a cushioning coal-bed. Testing of this prototype will indicate whether a lighter, thinner stainless steel hopper will withstand the internal temperatures.
- A conical grate at the base rotates to dump ashes and break up any bridging. The grate can be activated more frequently to collect biochar with the ash, instead of turning it into more fuel

gas. Biologically-activated biochar is a major discovery in soil fertility, which can make the family farm more productive, just from the waste biomass accumulated around the farm.

- Although this first prototype will be operated manually, ideally, a microprocessor control system monitors gas quality, changing conditions at the base of the fuel column & rotating grate, preheated air and other temperatures to operate dampers and fans and optimize gas generation quality and quantity, dramatically reduce thermal shocking & metal deterioration, and can also be adjusted to create maximum biochar production instead of CO + H2 if desired.

The interior hot zones are either cast-ceramic or the cheapest high-chromium stainless steel, #304. I have incorporated ceramic parts in the hottest parts because my experience has been that stainless steel deteriorates too fast. If testing proves that the gasification reaction can be kept relatively cool, (under 1500F), then the ceramic may be replaced with a high-temperature stainless, like #310, which will allow a lighter and more compact unit, especially when manufactured with optimum materials and thickness.

A manufactured version might weigh 50% less. This furnace will weigh around 1400lb, with 512lb of that being refractory ceramic. This is heavy compared with most gasifiers, but lighter than the best wood-fueled hydronic hot water heaters (Garn 1500 = 3,200lb at $16,000; Tarm-30 = 1,080lb; Greenwood Model Frontier CX = 1480lb. To put things in perspective, consider the advantages of being able to produce both hot water and woodgas at higher efficiencies and cleanliness, with a greatly extended range of usable fuels and energy output.

Although this design with all the interrelated heat-feedback features is where I want to begin testing, you may wish to begin with a simpler version. Many variations and degree of refinement are possible, beginning with a simple insulated inner shell and moving conical grate configuration, or reducing the size of the heat-exchanger or air preheater. However, adding air-preheating and gas-cooling shells will substantially improve performance.

We will undoubtedly find areas for future improvement, perhaps grate modification for specific fuels, coal bed-grate configuration adjustments, improved cleanout features, addressing thermal deterioration of critical metals, flow optimization and other preliminary details to be refined down the road, but I hope this gets the show on the road! The plans are extensive in detail, but there will always be room for improvements, material layout drawings, suggestions for superior sources of material, valuable tips on construction, etc. I will add a few drawings to compliment these as I build it, and I hope you will too.

This is no longer a patentable design, as I hereby release it to the public domain, in the hopes that others will implement these new design features and do the R&D work necessary to bring biomass gasification to a new level of practicality, offering a greater contribution to decentralized alternative energy technologies.

This first prototype is experimental, with no guarantees, although past experience and flow analysis says it should work great. It is not a simple vehicle-size unit made from scrap metal from the junk yard, although those and other options should be explored by you backyard tinkerers. I have designed it to test several new concepts that could be the foundation for a new approach to gasification.

If you get inspired to build a gasifier incorporating some of these new features, be advised that it is a complex project, and you had better be skilled and dedicated enough to pull it off. The materials are expensive, perhaps $1300 for the mostly stainless steel and another $1000 for castable refractory and insulation. Study the plans thoroughly before you begin. Assembly must be in a logical order, or some of the welds become impossible and misalignment can occur…..but what a thrill to have such a responsive, sweet-burning, efficient multi-purpose gasifier powering your house!

These plans represent much labor of love to get better technologies out in the world. Please point out missing information or whatever would make them better. Best to use the OpenSourceEcology.org gasifier forum where you can. That way all can benefit from the dialog.

Please share your experience and photos with me. I am available for consulting and further design work, and most grateful for contributions to further R&D work.

I am currently working with parties to commercialize variations of this gasifier ~ if you wish to invest in a hot invention or be informed when it is on the market, phone or send email stating fuel and heat needs.

Warm regards,

Larry Dobson
lad@fundamentalform.com
360-579-1763

7118 Fiske Rd
Clinton, WA 98236

AIR/GAS FLOW CHARACTERISTICS:

Air and gas flow throughout this system is governed by fundamental principles of gravity, temperature and density.

1. When a fluid is heated, it expands, gets lighter, and travels upward, augmenting natural draft.
2. When a fluid is cooled, it contracts, gets heavier and travels downward, also augmenting natural draft.
3. When these principles are adhered to, the strongest natural draft is facilitated, pumping throughout the system without a fan (although one may be necessary for starting and increasing the throughput and responsiveness of the system.)
4. When these principles are incorporated into a counter-flow heat exchange, the hot fluid being cooled flows fastest downward next to the heat-exchange surface, and the cool fluid being heated flows fastest upward next to the heat-exchange surface. This increases heat transfer greatly by decreasing the boundary-layer of insulating fluid next to the heat-transfer-surface and allowing gravity-stratification, which **increases efficiency as throughput is reduced**,

increasing residence time for greater temperature gradient. This principle is extremely important for efficiency, quality of gas, cleanliness of burn and greatly extended turn-down ratio. This means that a larger system is actually more efficient when turned down.

5. Adhering to these laws of flow means that the most efficient system has the exhaust exiting from the bottom of the furnace, not the top, and the natural draft created throughout the system can be so strong as to eliminate the need for an outside chimney.
6. even with a fan, gravity-stratification improves efficiency until the speed of the fan causes too much turbulence in the passageways for gravity-acceleration to occur.
7. I have operated a hot-air-furnace at 200,000Btu/hr on convection flow alone, where the cooled exhaust was condensing large quantities of water at 130F, while the heated air was exiting the furnace at 430F. This is impossible when turbulence takes over.

AIR/GAS FLOW THROUGH THE SYSTEM:

Refer to the above drawing for orientation.

- Primary air for gasification enters through holes in the periphery of the bottom plate & travels to the air damper in the center of the plate above. This removes heat from the bottom plate and bottom of ash-shell, preheating the air. The air then travels up outside the ash-shell, extracting more heat, then enters the ceramic duct next to the combustion shell, where it is heated by the burning gas (or 1400F hot producer-gas), rises up over the ceramic shell to the inside, then travels down next to the cooler hopper shell, heating the fuel inside as it flows.
- The hot primary air exits at the base of the hopper, where it volatizes the fuel and moisture and burns it until the oxygen-starved gas travels down through the coal bed. The chemical reactions at this point are all endothermic, taking heat away from the hot gas and charcoal as more combustible CO and H2 are liberated. There are many variables for different fuels, so we may need to develop several modular grate designs to provide an even gasification rate through a uniform coal bed of the depth to optimize woodgas production or biochar. The fuel gas can be generated cooler and wetter and sootier for direct combustion --- it all burns clean at the right temperature and residence time, with the right amount of air mixed evenly. Within the turn-down range of super-clean combustion, there will be a narrower optimum range for production of a clean gas for I.C. engines, phase-change refrigerators, and other such remote applications.
- The cooler, but still hot, woodgas (producer gas, biomass gas, garbage gas) exits from the hearth through the central conical grate, between conical slats that provide large openings that prevent the fuel from falling through because they provide overhanging ledges. This design has proven quite superior to just holes, which let through small aggregate fuel particles and easily get clogged with charcoal and ash. The grate is adjustable up and down to optimize the charcoal depth, and can be agitated by turning to drop out ash (and biochar if that is also wanted). Ash collects below, where it can be removed through the front access door.
- The hot fuel gas then flows through the four woodgas-to-combustor-ducts at the top of the ash bin. Most of the ash is deposited here, since the gas must turn 180 degrees to flow upward, while the ash falls with gravity.
- In the annular combustor ring, when in combustion mode, the hot gas is mixed with secondary air, where it burns cleanly due to hot temperature and even mixing of gas and air. The secondary combustion air enters two dampers in the bottom plate, where it is heated by the primary air shell, also cooling the lower region and saving on insulation.
- The combustor preheats the primary gasification air, which creates a higher quality gas while lowering the temperature of combustion, which reduces deterioration of materials and lowers levels of NOx pollutants. The outer shell of the combustor is insulated from the heat exchanger (HX) to facilitate optimum combustion and maximum HX efficiency.
- If the system is being operated as a gasifier, no combustion air is introduced and the hot producer gas performs the same heat-transfer function, although not as intense as when combustion is present.

- At the top of the combustor the exhaust or producer gas enters the spiral HX through an annular duct, which distributes the gas evenly around the entrance to the HX. The spiral HX consists of a spiral water duct with a larger spiral gas duct in between. The gas is cooled by 150ft2 of water-cooled surface area, which causes gravity stratification of the gas as it gets denser and falls next to the water jacket, while the opposite flow occurs within the water. Under most operating conditions water-vapor will condense before the exhaust or gas exits, thus retrieving the considerable heat of vaporization and scrubbing the fly-ash from the gas in the most effective filtration method available, where each tiny particle becomes a nucleus for a drop of "rain" to condense around and fall out of the gas stream. It is expected that, when operating in this condensing mode, the producer gas can be directed straight to an internal combustion engine without the need for further filtering.
- At the lower outside exit from the HX, a flue/gas-outlet damper directs either the exhaust up the chimney or the producer gas out another duct to an I.C. engine or whatever other appliance can burn the gas. Condensate water is drained out at the base.

FABRICATION NOTES:

- These drawings should give enough details for a skilled metalworker/craftsman to fabricate the complete gasifier according to spec. I have stipulated thicker metal than necessary for optimized functionality, so that a good TIG pr MIG welder can assemble an air-and-water-tight unit, which is necessary for proper performance and holding water in the CHX. A manufactured version would use thinner metal in most areas and possibly replace some ceramic with metal.
- Begin assembly from the bottom plate and proceed outward, always thinking about how to fit parts together & weld most effectively.
- Some of the sheetmetal parts have cutout shapes that cannot be dimensioned as straight lines or arcs. If you are cutting these out by hand, you will have to print out a full-size DXF drawing and trace the cuts. It will be much easier and more accurate to have the parts CNC laser-cut, or CNC plasma-cut. The latter will require filing for a smooth-edge and optimum welding, and the accuracy will not be quite as close.
- Insulation should be packed in the lid and within the outer shell all around the HX and below. Where the parts will get red hot (lid and top of HX and ceramics, use an inch or 2 of high-temperature ceramic insulation blanket, like Kaowool. Outside that, you can pack in fiberglass insulation –much cheaper but not as good an insulator, and it will melt at higher temperatures. Get uncoated fiberglass insulation if you can ~ otherwise it will stink as it burns out.
- The outer shell is slid into the flanges of the top and bottom plates, hammered snuggly, then secured with at least 10 screws around the flanges to hold the unit together snuggly.

CERAMIC CASTINGS

- I have made the cylindrical ceramic pieces ½" thick for lighter weight, quicker heat transfer, less expense, less shipping. However, industry-standards are much thicker, so you must do it right. Ceramic is brittle when whacked, so I have usually used super strong castable refractory, especially the quite dense, low water, low cement, vibrated into molds refractory ceramic with alumina above 60%. You could experiment with cheaper casting cements, especially for the 2nd shell out (between the 2 air ducts).
- It is most important not to have bubbles in the castings. Rent a small concrete vibrator and move it all around the mold as you fill it with the stiff castable mixture. Make sure you understand proper mixing and application of that particular product. I'm not up-to speed on who sells what these days, but your local firebrick supplier should be able to direct your choice. Curing and firing are also important, and, since a castable refractory has a curve of strength relative to its firing temperature, I highly recommend having it fired at a local pottery studio to the optimum temperature for the optimum time. You can fire it yourself in place, but it may be of uneven crystalline structure with weaknesses that could crack down the road.
- If all this is too much for you, you can make all the ceramic shells of #304 stainless instead, but will probably get burnout, especially at the base of the hopper, where super-hot combustion takes place. You could try lining that area with a more exotic 310 alloy.

FAN

- A fan in the flue will provide trouble-free start-up. Simplest is a draft-assist-fan, which installs into a hole in the flue and only blocks a portion of the flue, allowing natural draft operation when desired. Grainger Item # 4C730, TJERNLUND Draft Inducer is a low-power model suitable for start-up and moderate increase in throughput when operating the furnace. When operating the unit as a gasifier, after bringing the furnace and fuel up to clean-gas-temperature with the draft-assist fan, turn the fan off, flip the flue/gas damper to gas, then start the I.C. engine.
- The presence of the fan in the stack reduces the high natural convection burn. A bypass damper will solve this and allow a more efficient squirrel-cage fan to be used. In the lower section of flue, add another parallel section of flue with a built-in fan. Any properly sized fan (50cfm or less) may be used, including squirrel-cage or axial, since the exhaust will go straight up the chimney when the main flue damper (in the straight flue between bypass entrance and exit) is open. The damper should be a good seal, not an off-the-shelf loose-fitting damper. Use 22.5 degree elbows to avoid turbulent flow.
- Gasification throughput is regulated by the primary air damper, and combustion air/fuel mix is regulated by the secondary damper.

- A $22 auto hood-latch mechanism (shown above) for the hopper lid might be a perfect fit! It lets the gasifier lid pop open when a pressure-activated latch release mechanism releases the lid to dissipate the pressure of a potential internal explosion. The lid is kept from flying all the way open. The latch is mounted on the gasifier external shell, mated with the simple male latched shape mounted on the lid.
  Whoever comes up with an adjustable mount design, we will all benefit if you post some drawings.
- Perhaps an even better and simpler explosion vent latch would be a hinged counterweight adjustable to increase the lever arm just enough to provide a tight seal with the outer rubber gasket. A sudden increase in internal pressure will lift the lid immediately, especially if the counterweight arm is springy. We may have no internal explosion, but we must allow for it, especially on this first prototype. Who has not witnessed in a woodstove an explosive mixture of smoke and air suddenly ignite and poof smoke into the room?
- The front ash-cleanout door should provide a seal through an adjustable spring mounted on the hinge to allow pressure venting in case of internal explosions. This is also an important safety consideration.
- Temperature readings from various places in the furnace are essential to tell how the system is operating and know how to optimize settings. Type K thermocouples should be placed in the locations shown in the drawing, while it is being assembled, otherwise most of these strategic placements will be inaccessible once assembled. Thermocouple meters are available from various sources, including Harbor Freight, and the wires can be switched with a multi-gang switch from an old appliance, as long as the switch and the meter are in the same location at the same temperature. Double-check for accuracy. You can make your own thermocouples by twisting the Chromel-Alumel wires together and fusing with a TIG welder. Use large wires (10-14ga) for the hottest region to prevent burnout. Only short wires are necessary – they can be twisted and melted to smaller cheaper transit wires.

OPERATION NOTES:

- Igniting the fuel is best done by laying down a good dry crumpled-paper-kindling layer at the bottom of the hopper, followed by dry small-aggregate fuel. If the fuel is green, make sure the kindling layer is thick enough to provide a hot fire sufficient to heat up the ceramic and steel components to assure that natural draft is sustained. Ignite the fuel by lighting crumpled newspaper in the front access door and keep pushing it in with more lit crumpled newspaper until a roaring fire is established. The HX will provide cool exhaust, even when the system is warmed up to steady-state. Since I haven't built this furnace yet, the best ignition technique is yet to be proven.
- Eventually, you will probably have to remove the top and the top ceramic casting to clean ash out of the HX with a hose. Remove the screws attaching the top to the outer shell, then gently hammer the lid up and off. Remember to align the screw holes when replacing it.

TOPICS TO DISCUSS on the forum

Some areas of construction on this gasifier could benefit from group inputs.

WELDING CHX SPIRAL

- The spiral heat exchanger is a crucial advantage in compact design and gravity-stratified condensation efficiency, but a challenge to weld. The spiral sheets have been sized 24 gauge (.0239" thick) so they are easily bent. The spiral top and bottom plates, that sandwich between the spiral sheets, are 1/8" (.0125") thick to facilitate welding without burning through. If the assembly is wound tightly, with the spiral sheets fitted between the spiral top and bottom plates, then clamped together with a band at the top and bottom, it should be possible to TIG-weld all the junctions from outside, top and bottom, to make a water-tight seal. If the spiral sheet sticks up slightly beyond the outside surfaces of the 1/8" spiral top and bottom plates, you will insure thorough melt of the 24 ga water/gas HX plates to the thicker seam melt. Should be strategically tack-welded when clamped in tension. Laser cut is smoother, but maybe plasma cut, then smoothed by filing to accept the 90 deg sheet between, forming the interface
- Alternatively, brazing the junctions could be easier and provide a more reliable seal, since the brazing will penetrate evenly through the 1/8" depth without actually melting the stainless steel sheets, yet the joint will not melt in use because it is being cooled by the water within the HX. Silver solder is the best, but prohibitively expensive today. Does anyone know of other suitable brazing/flux alloys that would work?
- Those of you with experience with joining metal are invited to share your recommended approach to assembling this HX. Do you recommend a particular welding technique, brazing alloy, cleaning approach, flux? What are further concerns with fabricating? Let's get a discussion going so we can all find out what works best.
- The bottom welds of the CHX may be susceptible to corrosion and pitting if water stays pooled there much of the time. Leveling the furnace will help prevent this. The ultimate solution would be to build the HX in a downward-spiraling configuration, so that it would naturally drain, but that proved too big a challenge for my CAD program and my puny brain,since the interface seals will be more complex. If anyone knows of a miracle sealant that could be used to treat the bottom surface and welded joints, let me know. I know of nothing that would last very long.

This discussion will continue for some time at the gasifier forum on the OpenSourceEcology.org website, which I will be moderating. I am confident that I have left out some necessary information in these plans. Your task is to thoroughly study all the information presented here and let me know what is missing or unclear.

I will answer short questions and post a few new drawings reflecting appropriate changes, but if you want changes in the design for a new application, different size, or other details involving significant design-time, I will charge you consulting time. Just email or call me.

Enjoy!

Larry Dobson
lad@fundamentalform.com
360-579-1763