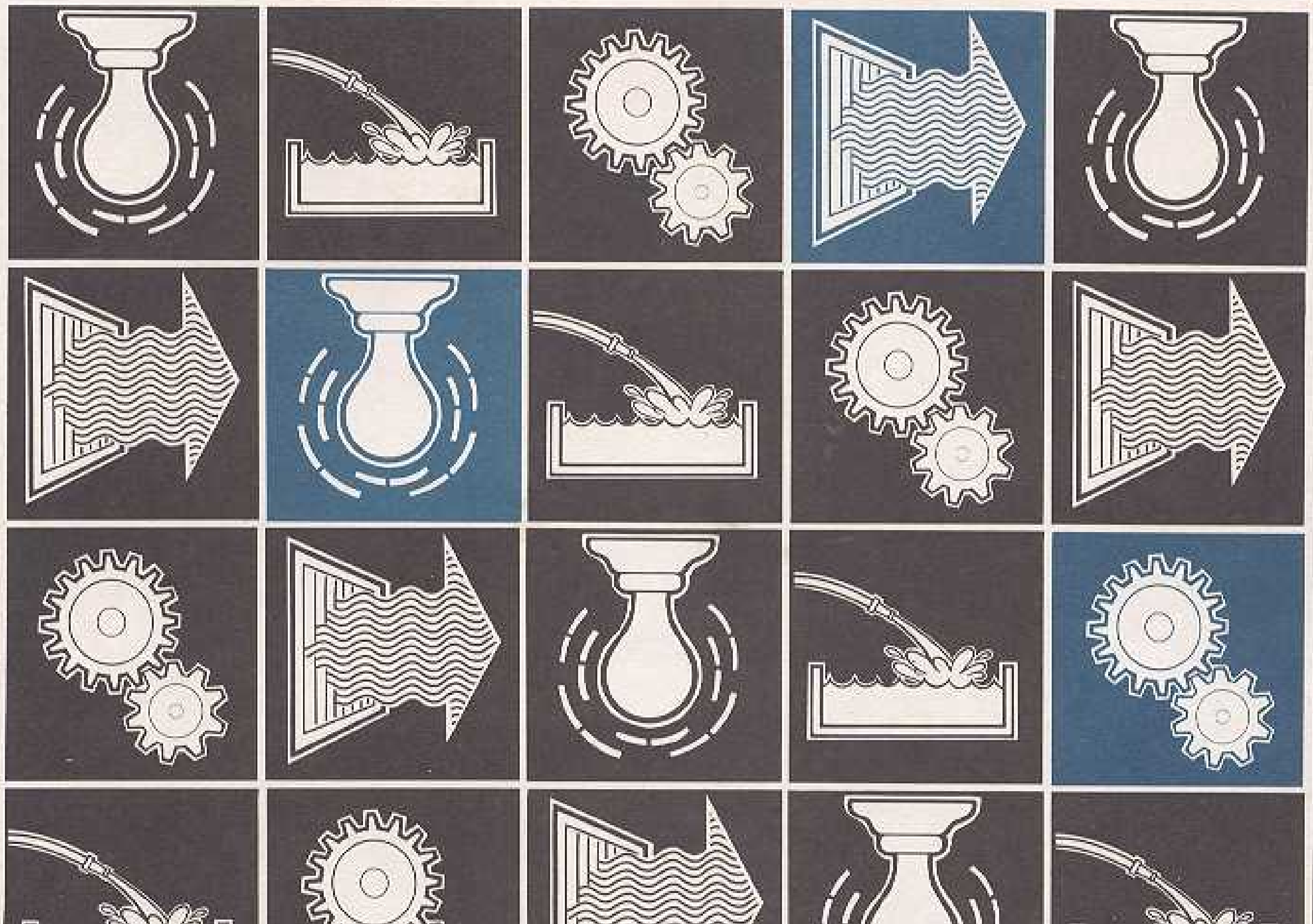
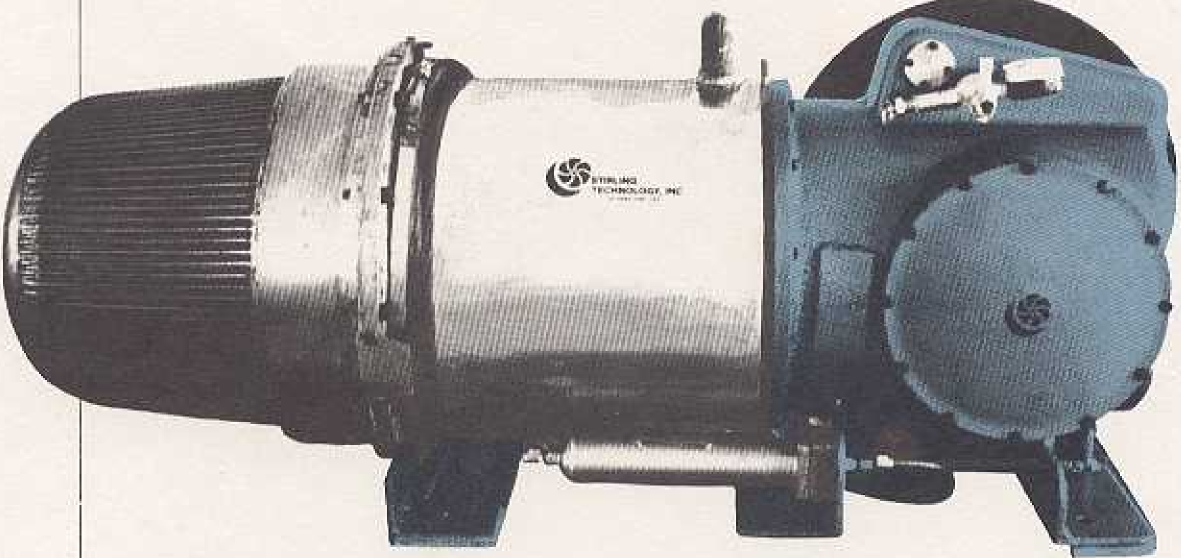
# THE ST-5

## And Total Energy Independence



# What The ST-5 Offers You



**The ST-5 Multifuel External Combustion Engine**

**Over 5 HP Of Shaft Power At 650 RPM**—level power output over a range of speeds

**Multi-Fuel Operation**—produce your own fuel and be truly energy independent

**No Spark Plugs, Carburetor, Distributor, Muffler, Injector**—few failure modes

**Reliability**—low maintenance and service requirements result from simplicity of design

**Very Quiet Operation**—since the fuel is burned continuously outside of the engine the noise is minimal

**Little Pollution**—minimal carbon monoxide, unburned hydrocarbons, nitrogen oxides

**Absence of Oil**—no need to monitor and change oil

**Safety**—no boiler or high pressures as with steam engines

**Long Life**—high quality bearings, seals, materials & commitment to quality control assure ruggedness

**User Serviceability**—field repairable with basic tools and the service manual

**High Quality**—backed by a one year parts replacements warranty

# Total Energy Independence

**T***he ST-5 has been designed for those who either cannot obtain grid electricity easily and economically or have realized the uncertainty of total dependence on utilities to supply their power needs.* If you need electricity at remote locations where grid power is not a feasible proposition; have experienced the inconvenience of grid power failure; wish to avoid the predicted utility "rate shock"; have found the internal combustion engine an undesirable backup for your wind or photovoltaic system; actively seek alternative sources of energy for your security and peace of mind, or if you simply desire an *Independent Home Energy System* for your home or greenhouse, the ST-5 may be the solution you have been looking for.

## The ST-5

The ST-5 is a rugged engine designed to produce over 5 hp of mechanical power reliably and on demand, directly from a variety of renewable and gaseous fuels. Its external combustion Stirling cycle eliminates spark-plugs, fuel-injection systems, mufflers, noxious fumes and, very noticeably, the noise of internal combustion engines. This lack of complexity coupled with the use of high quality sealed bearings and long life Teflon impregnated seals, eliminates the need for messy oil changes and makes possible a long, trouble-free engine life. The ST-5 has been designed to be user serviceable with a minimum of basic hand tools.

**M**ost important of all, ***virtually any combustible material is a suitable fuel for the ST-5.*** Among various acceptable fuels are wood, wood pellets, husks and chaff, peanut shells, weeds and hay, cotton waste, other agro-byproducts, natural gas and propane. This wide variety of fuels ensures ***you produce your fuel on your own land.***

## The ST-5 System and Operation

The ST-5 system comprises two main components—the ST-5 (engine) and the burner. The function of the burner is to provide heat to the heater head of the ST-5, which is inserted into the burner. Two burner options are now available for the ST-5. One is a cyclone burner for small particle fuels such as sawdust or other shredded biomass. The second is a two stage wood burner. The fuel is fed into the burner either manually, as is the case with the wood burner or through a hopper, if one is using small particle fuel. Gaseous fuels may be used in the cyclone burner by modifying the intake orifice. The wood burner can hold enough fuel to run the engine at full output for two to four hours (depending on the wood used).

**I**n order to obtain the high temperatures necessary to run the engine, both burners have a forced air blower. Once the engine is started, the blower is operated by the ST-5 itself. Before the engine can be started, however, the blower needs to be operated for 10 minutes either by a battery or by hand cranking until the desired heater head temperature is reached. Once the temperature is high enough (the ST-5 will start at temperatures around 950ºF), an easy pull on the flywheel starts the engine. Once up to temperature this engine is an easy and sure starter, eliminating the need for multiple pulls on a recoil rope as is often experienced with conventional engines.

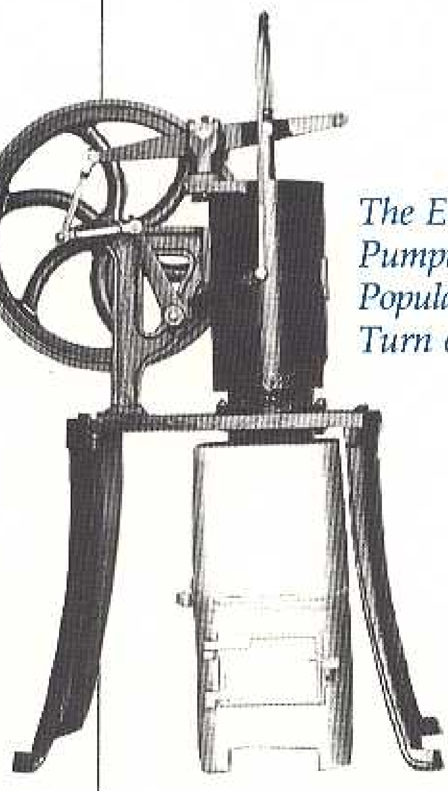

**Wood Burner— Heater Head Schematic**

Just as the ST-5 takes a few minutes from the time you fire it up until the time you start it, it also takes a while to come to a stop even after the fuel supply has been cut off. This is because the heat retained in the heater head is sufficient for it to operate for 10 to 15 minutes, although at decreasing power output.

The cooling loop works like any automotive cooling system. A small pump, operated by the engine, circulates the cooling liquid (water or water and glycol) through an automotive radiator, while a fan mounted on the flywheel blows air across the radiator and dumps the unused heat into the atmosphere.

# History of the Stirling

When in 1816, the Scottish minister Robert Stirling patented the Stirling cycle, he could hardly have foreseen that his invention would be experimented with in the years to come for such sophisticated applications as artificial hearts, high performance automotive engines and space-station power plants. The earliest applications of the Stirling were low power output prime movers, water-pumps and kerosene fans. These devices enjoyed great popularity in the latter half of the nineteenth century because of their great reliability, safety, long life and ease of use. Thousands of Stirling cycle machines were manufactured in the United States and Europe before the advent of the internal combustion engine.



*The Ericsson Hot-Air Pumping Engine was Popular at the Turn of the Century*

Around the beginning of the twentieth century, cheap refined fossil fuels and engines which utilized them began to erode the market of the Stirling, which, it seemed, just could not improve sufficiently to compete with the gasoline engines. Despite their undeniable qualitative advantages over the noisy, oily, unreliable gasoline engines, Stirlings began to lose ground. The one most important reason? The Stirling relies very heavily on efficient heat transfer for its performance. With the materials and processes at the disposal of the early twentieth century engineers, they could not get the Stirling to even approximate the power-to-weight ratio of the internal combustion engine.

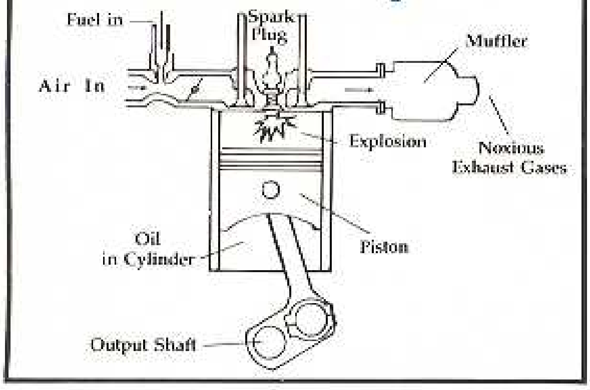
In the 1940's and 1950's, N. V. Philips of The Netherlands started the interest in modern Stirlings. The rising price of fossil fuels together with the realization of the environmental damage caused by internal combustion engines induced many others to follow suit. The automotive industry started working on an automobile engine for their twenty-first century vehicles. NASA is working on the design of a nuclear-powered Stirling power plant for the commercial space stations of the 1990's. The U.S. Department of Defense is engaged in a multi-million dollar development program for free-piston Stirling alternators for field use because of the tremendous qualitative advantage they have over conventional gen-sets. Oil and gas exploration companies and the medical profession are also investigating various possibilities with the Stirling.

What differentiates these modern-day Stirlings from their nineteenth century counterparts is the use of high-temperature alloys and manufacturing processes unknown earlier. These have enabled engineers to improve the power to weight ratio of the Stirling by up to 200 times over that of the 19th century Stirlings. And with the uncertainties of gasoline cost and supply, the Stirling once again makes sense.

While most research organizations are pursuing exotic applications for the Stirling which will not be commercially viable before the late 1990s, Stirling Technology pursued a very different path. It combined the availability of high-tech materials and processes and computer-aided design with the traditional uses for the Stirling to produce a practical device manufactured for everyday use. This user-oriented product is the ST-5.

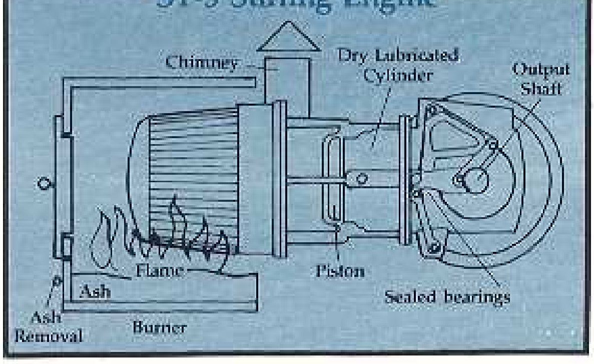
# The ST-5 and IC Compared

## Conventional IC Engine




The ST-5 is fundamentally different from conventional internal combustion (IC) engines. The IC process relies on injecting fuel into the engine and causing it to explode intermittently. The combustion takes place against a cooled cylinder face and under high pressure resulting in high levels of carbon monoxide, unburned hydrocarbons and nitrogen oxides. Since the fuel is injected into the engine, it has to be removed by means of exhaust so that additional fuel may be injected.

## ST-5 Stirling Engine




With the ST-5, the fuel is burned continuously outside the engine, against hot surfaces and at atmospheric pressure. This results in almost no carbon monoxide pollution. The level of unburned hydrocarbons and nitrogen oxides is much lower than that from IC engines and for most biomass fuels there is no sulphur production. The heat from the fuel is transmitted into the engine by means of a heat exchanger (the heater head) and since no fuel is injected into the engine, no exhaust system is necessary from the engine itself.

The differences between the two systems give the ST-5 significant qualitative advantages. First of all, the need for spark plugs, carburetors, distributors and other fuel injection systems is eliminated. In their place, the ST-5 utilizes a simple burner, very much like a high quality wood furnace. So, in place of complicated parts which are prone to failure, the ST-5 has a simple firebox.

IC engines require mufflers to reduce the noise of the intermittent exploding of fuel. Since the ST-5's operation uses a constant flame temperature outside the engine, there is no sound from the fuel-combustion process. Hence, the ST-5 does not have a muffler. In fact, it does not have an IC type exhaust system at all, requiring only a chimney and a means of ash-removal.

Maintenance of conventional engines always involves frequent oil changes, and a used oil disposal problem. The ST-5 takes care of that. Oil and the ST-5 don't mix. If oil were to get into the hot end or the regenerator, it would seriously damage the engine, so the ST-5 is fitted with sealed bearings and dry-lubricated cylinders. This not only protects the engine from the possibility of oil infiltration but frees the user from the trouble of changing oil Periodically. It also keeps the environment clean as there are no oil residues or odor.

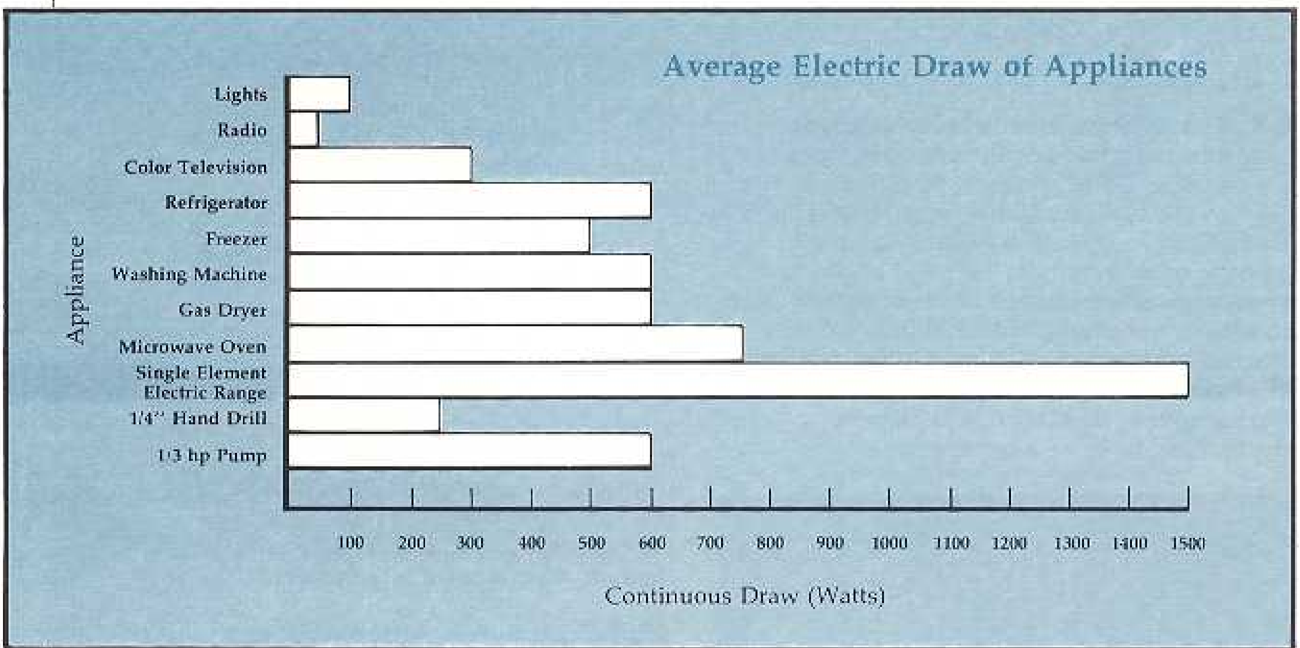
Because the engine components which make maintaining an IC engine difficult are unnecessary for the ST-5, this power system is extremely simple to keep operating. The mechanical arrangement is about as complicated as a 10 speed bicycle, although the engine itself is considerably heavier. A person with minimal mechanical aptitude, a hoist or assistant, a few universal hand tools (wrenches, a hammer, etc.) and the service manual provided with the ST-5, can completely strip the engine and rebuild it in a matter of hours.

***Multifuel capabilities, maximum reliability, low pollution, user-serviceability and quiet operation; all hallmarks of the ST-5 power system!***

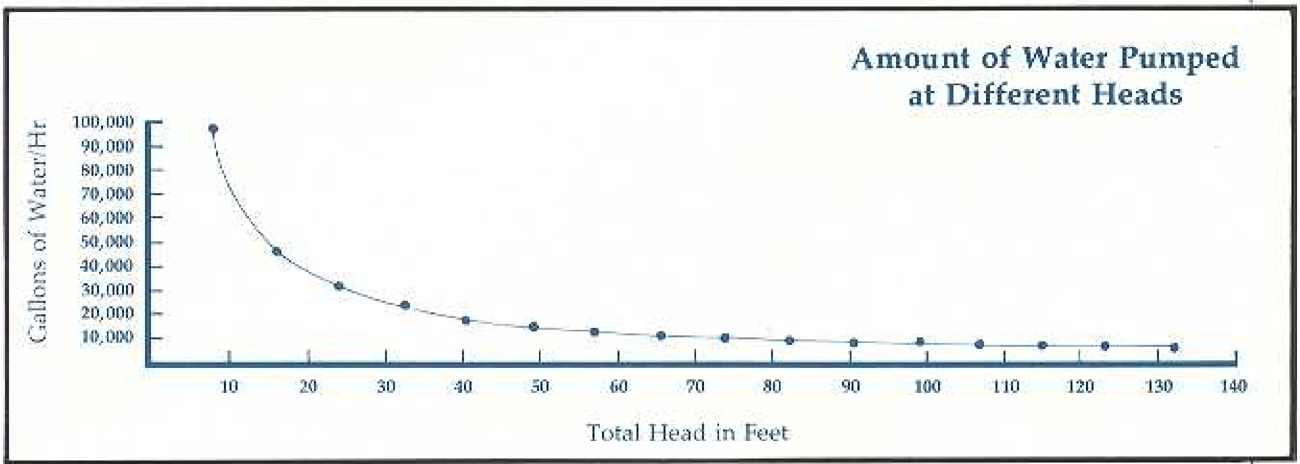
# Uses of the ST-5

The ST-5 has been designed for long periods of stationary use for residential and small-scale agricultural and industrial purposes. Any application which requires a long life prime mover and continuous hours of operation is a good candidate for the ST-5. Recommended uses are electricity generation, water-pumping and powering of small scale implements, compressors, etc.

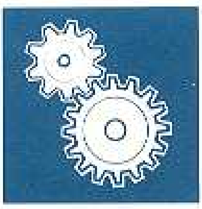
*Notes: These are the average. Check your equipment for exact wattage. The starting loads on some equipment may be considerably higher. Check your equipment for individual starting loads.*




The ST-5 is ideal for powering a rotary electric generator producing up to 3.5 kW of electricity, either AC or DC. The engine has been designed so that it can operate at full output for extended periods of time. This is why the ST-5, despite being only a 5-plus hp prime mover, is sufficient for a 3 kW generator which would use a 7 or 8 horse power IC engine to power it. The engine's speed is governed to operate at 650 RPM so that the electric frequency can be maintained at 60 hertz, but slight variations are inevitable. A voltage regulator would be required for appliances such as television sets and computers. Incorporating the ST-5 into a gen-set configuration requires a radiator, an engine-driven radiator fan and a suitable generator matched to the engine with pulleys, belts or gears to provide for required frequency output. Examples of the appliances which can be operated with 3 kW of electricity, along with the constant and surge (starting) loads for each are shown above.




For water pumping, the ST-5 requires only a suitable centrifugal water pump, as the cooling for the engine is supplied by the water being pumped. The amount of water pumped will depend on the efficiency of the pump and on the depth from which the water is pumped. The above graph assumes that the water pump is 60% efficient; i.e. 60% of the 5 hp put out by the engine is converted into pumped water.

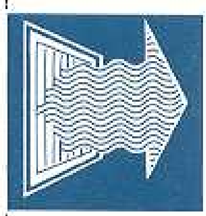


Compressors, small machines such as shredders, log splitters and grinders, like the generator, require the addition of a radiator and fan, and pulleys or gears to match the engine speed to the load. Among applications currently being examined are oil jacks for wells less than 3,000 feet in depth where the ST-5 runs directly off the impure natural gas or crude oil found at well sites, a small scale rice milling system using part of the waste husk as fuel and small scale milk condensing plants, utilizing both the heat from the engine as well as the mechanical power.

## *Useable Heat—A Stirling Phenomenon*

The burner of the ST-5 behaves like a high quality biomass-burning stove. As a result, a tremendous amount of clean heat is available for use. In addition to the burner heat which is easily recovered, the cooling water of the engine also provides useable heat.

By the use of simple heat exchangers, this heat can be used for space heating of your house, dairy or greenhouse as well as supplying your domestic hot water needs. At full output, the engine produces over 25kW of recoverable heat—far in excess of the needs of an average house. ***The ST-5 makes cogeneration—recovering this heat for space and domestic water heating while simultaneously generating electricity—practical.***



# Cogeneration— Total Home Energy System

The heat from your ST-5 powered electricity generating system can be recovered and used in a number of ways for space and domestic water heating. The following is an example of ***one possible system***, to show you how this is feasible. It is being installed at the home of one of Stirling Technology's founders.

The system comprises two parts, one for generating and storing electricity, the other for recovering and storing heat.

Electricity is generated by attaching a 4kW AC alternator to the ST-5. The engine has been sized to provide up to 3.5 kW of electricity, enough to take the surge loads of induction motors used in washing machines and other domestic appliances. One option would be to run the engine for 4 to 6 hours a day, during which period high and intermediate draw appliances—washing machine, freezers and power tools—can be used. At the same time, a bank of batteries can be charged to provide electricity for domestic lighting and other small load equipment when the engine is not operating.

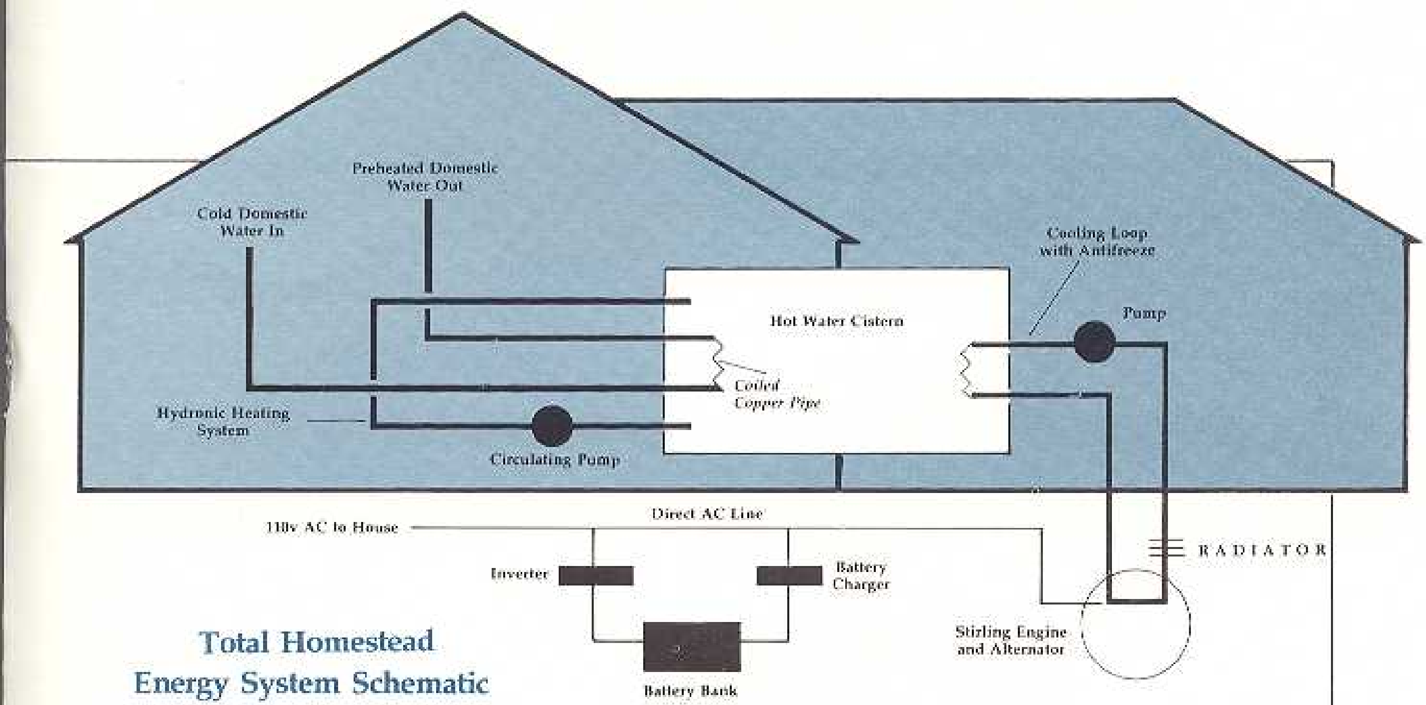
A bank of 4 deep-cycle, extra heavy duty batteries, interfacing with the alternator through a commercially available battery charger should be sufficient. When deciding upon the type and number of batteries needed, the rule of thumb is that the battery bank should store about twice as many amp hours as will be used between recharging. This is essential to prolong the life of the battery and get the best possible service from them. With the tremendous advancements in battery technology, it is now possible to get batteries capable of holding charges of over 600 amp hours. The life on these batteries is extremely long, with constant, uninterrupted service of 20 years recorded by some users. It is recommended that 6 or 12 volt batteries with charging capacities of 400 amp hours or more be used; 8 volt batteries are not recommended, as there could be problems finding matching inverters and other compatible equipment.

The length of time it takes to charge batteries depends on the amount of charge necessary and the rate of charging. The slower the rate, the better it is for the life of the battery. The safest way to charge your battery bank would be to run the AC current from the alternator through a battery charger. To strike a balance between the time required and the rate of charging, it is recommended that a 200 to 300 amp charger be used. The latter would enable a 660 amp hour charge within 5 hours. (A 660 amp charge for a bank of four 12 volt batteries is about 8 kWh of stored electricity.)

Since Watts = volts x amps, a 12 volt battery with a 400 amp hour charge can deliver 12 x 400 = 4800 Watts for an hour, or 4.8 kWh. Again, the batteries should not be discharged to less than 50% of their capacity, so using a maximum of 2.4 kWh per day per battery is optimal. Four batteries, then, would provide for usage of up to 9.6 kWh between charging.

The next step is converting the DC current to AC and feeding it into the electric line for the home. This is accomplished by means of a DC to AC inverter. These are available in sizes up to 12,000 Watts and in various types. The best type would be one with high surge capacities and a sine wave output. Sine wave inverters eliminate the hums and flutters experienced from appliances when using square wave inverters.

The correct size is arrived at by estimating the usage and surge load, and type of inverter. Some inverters allow for surge loads of up to 4 times their constant draw. These inverters could start most motors with a constant draw equal to the size of the inverters. If the inverter does not provide for surge loads, its size would have to be large enough to handle such loads. To be absolutely safe, the inverter should be able to handle the maximum possible load you anticipate. This, however, has one drawback. Inverters are most efficient (85 to 90%) while operating at or near their capacity. If the draw is below 40% of capacity, their efficiency drops rapidly. Hence, if the




## Total Homestead Energy System Schematic

inverter is too large for your normal usage, you would be wasting a great deal of stored electric energy. Another possibility is obtaining modular inverters. This development in inverters lets you use a small size inverter for lower draws and merely hook on additions to increase the draw capability. Efficiency can be maximized by this means.

The connection between the direct AC line from the alternator to the house and the line from the batteries and inverter is in the form of a switch, which enables either one or the other source of electricity to be used. While the engine is in operation, the switch enables the current to be used directly from the alternator, while the batteries are charged. Otherwise, the switch is thrown to draw the current off the batteries.

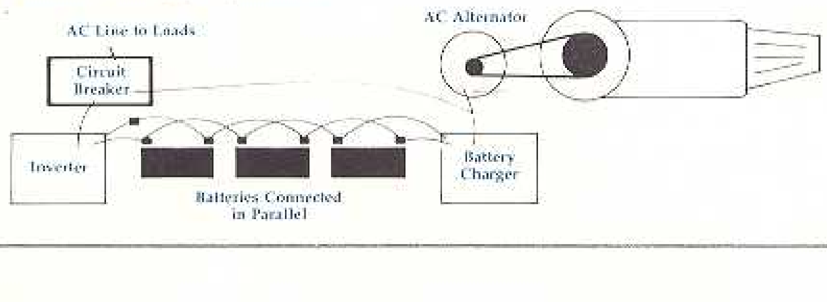
**A word of Caution: If you are connected to the grid and are considering using the ST-5 for emergency or backup power, observe all precautions mandated by your local utility.**

In order to minimize the load on the batteries and the size of the battery bank, every attempt should be made to use as much power as possible while the ST-5 is in operation. Running the washing machine, freezer, vacuum cleaner, power tools etc. while the ST-5 is operating and using the energy stored in the battery bank for lights and other low draw appliances will prolong the life of your system while decreasing fuel usage.

### Estimated Electricity Usage Per Day

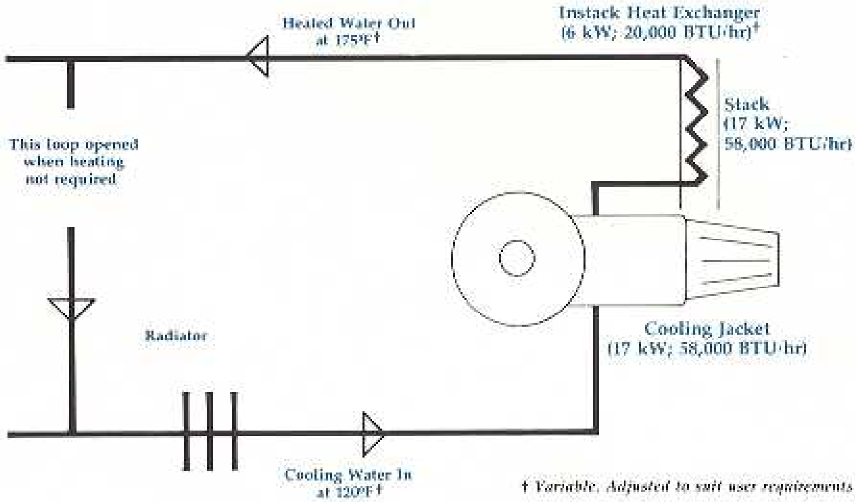
| Appliance | Watts | Hours Operated | kWh Used |
|---|---|---|---|
| Lights | 300 | 8 | 2.4 |
| Refrigerator | 600 | 3.5 | 2.1 |
| Freezer | 500 | 3.0 | 1.5 |
| Color Television | 300 | 4 | 1.2 |
| Clothes Washer—Gas Dryer | 600 | 1.0 | 0.6 |
| Circulating Pump | 300 | 6 | 1.8 |

## Electric Circuit for Total Energy System



# Total Home Energy System —Heat Recovery

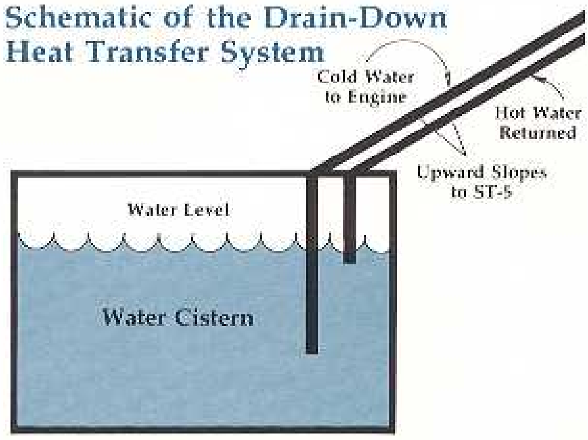
### Schematic for Heat Recovery



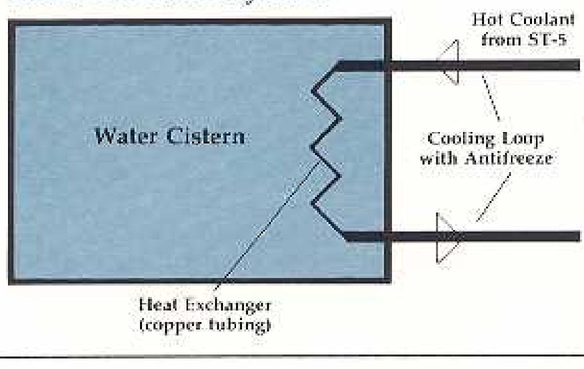

Heating the house is accomplished by recovering the "waste" heat from the ST-5. Operating at full power, the engine rejects about 58,000 BTU's per hour to the cooling water. Another 20,000 BTU's per hour (about a third of the total available heat) can be recovered from the exhaust stack (the chimney) by placing a one inch coiled stainless steel tube 13 feet long in the stack. Combining the two, you get about 470 gallons of water at 180°F per hour.

This heat is then dumped into a central water cistern for a hydronic heating system either by emptying the water itself into the cistern, or through a heat exchanger (36 feet of ¾ inch coiled copper tube) if a closed engine cooling loop is desired. If the water is drawn from and emptied into the cistern, a drain-down cooling loop is necessary to prevent freezing. If a closed loop is used, the loop should contain a glycol solution for the same reason. The following shows the two possible means of transferring the heat to the cistern.

### Schematic of the Drain-Down Heat Transfer System




### Schematic of the Closed Loop Heat Transfer System



Components for hydronic heating systems and installation assistance are available from most heating contractors and provide very even and comfortable home heating. The boiler in conventional heating systems, however, is replaced by a cistern for an ST-5 powered cogeneration system. Once up to temperature, the cistern can hold enough heat for up to 5 days of heating, depending on its size and the heating load.

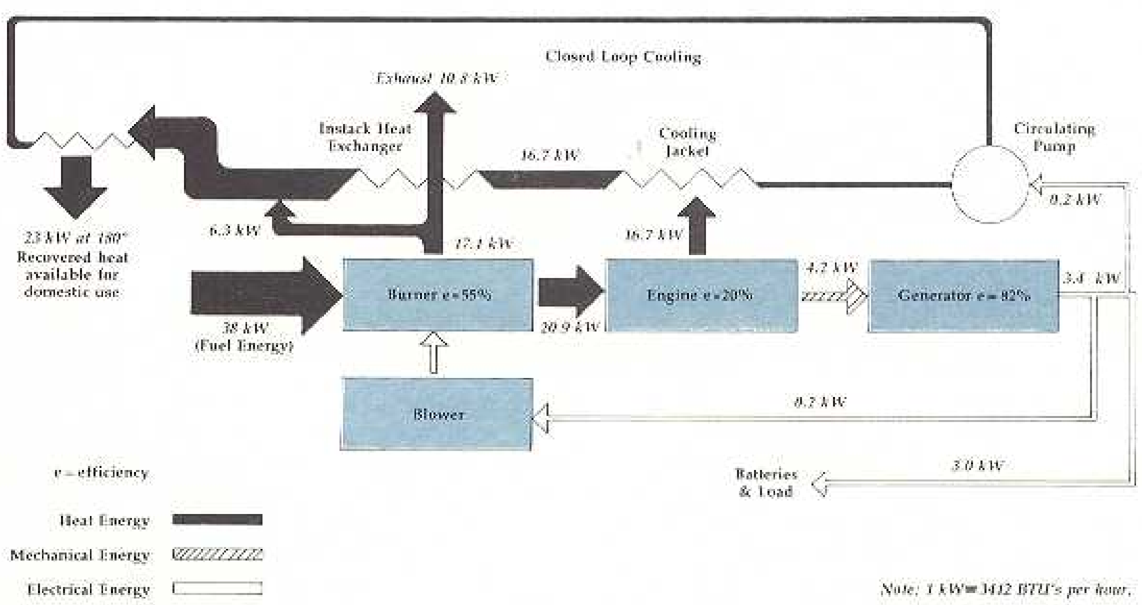
A further addition to this system could be another water-to-water heat exchanger in the cistern which would enable the pre-heating of domestic hot water. Passing the domestic water through another coil of copper tubing in the cistern is an easy and cost effective way to provide for this heat exchanger. A sufficient length of tubing will bring the domestic water temperature up to the desired level.

Finally, the remaining heat from the burner exhaust stack (about 38,000 BTU's per hour) can be ducted through the fuel storage area to dry the fuel and keep it ready for use.

A combination of a hydronic heating system with battery storage is not the only means of providing all the user's energy needs. The heat could be stored in another medium, such as sand, which could then be used in conjunction with a warm air heating system. Another possibility is running the engine constantly at a low output and not storing the heat at all. Each method has its advantages and drawbacks, and the user should determine the suitability of the system for his needs.

This *Total Home Energy System* is a most efficient one, utilizing up to 80% of the fuel energy either in the form of electricity or heat. Because of their high energy utilization, cogeneration systems are seen as the energy systems of the future. The concept is not limited to homes, but can also be applied to greenhouses, dairies and any other application needing both forms of energy.

## Energy Balance in Total Home Energy System



# Resource Management

## *Producing Your Own Fuel*

The ST-5 would enable you to be truly independent only if you produce your own fuel, whether it be wood, agro-residues or gaseous fuels. The amount of fuel required depends on the schedule of engine use. While the volume of space to be heated, amount of insulation and climatic conditions determine your heating requirements, it is likely that the 115,000 BTU/hr of available heat from the ST-5 system will be more than enough for an average home. The objective is to minimize your fuel consumption by matching the ST-5's operation to your daily electricity needs. To determine this, check the charts in the sections on "Cogeneration" and "Uses". Next, determine the extent to which the engine operating time can be reduced by running washing machines, vacuum cleaners, freezers and other such appliances while the ST-5 is in operation. This will minimize the time required to charge batteries, which is a slow process. For the loads assumed in the section on cogeneration, it has been determined that between 9 and 10 cords of oak (with 20% moisture content) would be required for 12 months of operation.

In order to determine the amounts of various kinds of fuel necessary for an hour of operation at full output, it is necessary to know the amount of heat required by the engine and the calorific value per unit of fuel used. The ST-5 requires approximately 38 kW (130,000 BTU/hr) of energy input. The second part—the calorific value of the fuel—would vary from fuel to fuel. The following table lists a few.

**Calorific Values of Various Fuels**

| Fuel Used | Unit | kWh |
|---|---|---|
| Oak | 1 lb† | 1.9 |
| Pine bark | 1 lb | 2.8 |
| Corncobs | 1 lb | 2.7 |
| Cattle manure | 1 lb | 2.2 |
| Cottonseed cake | 1 lb | 2.8 |
| Rice straw/hulls | 1 lb | 1.7 |
| Bituminous coal | 1 lb | 4.2 |
| Propane | 1 cu. ft. | 0.7 |
| Methane | 1 cu. ft. | 0.3 |
| Gasoline | 1 gallon | 33.5 |
| Used oil | 1 gallon | ? |

*† 1 cord of oak = 3,800 lbs*

From these figures, it is possible to obtain the amounts of fuels required per hour of operation. Some examples are listed below.

**Amounts of Fuels per Hour of Operation**

| Fuel Used | Unit | Qty. |
|---|---|---|
| Oak | lbs | 20.0 |
| Pine bark | lbs | 13.6 |
| Corncobs | lbs | 14.1 |
| Cattle manure | lbs | 17.2 |
| Cottonseed cake | lbs | 13.6 |
| Rice straw/hulls | lbs | 22.3 |
| Bituminous coal | lbs | 9.0 |
| Propane | cu.ft. | 54.3 |
| Methane | cu. ft. | 126.7 |
| Gasoline | gallons | 1.1 |
| Used oil | gallons | ? |

Having determined the fuel requirements for your circumstances, we encourage you to ensure a constant supply of fuel. For those using wood, as is the most common case, reasonable management of forest resources is desirable. It has been estimated that maturing forests yield between one third and one half cord of wood per acre per year without detriment to long term forest growth. So, if you anticipate using 9 cords of wood per year and you own 20 acres of forested land, you could quite safely provide for your fuel requirements through reasonable management practices. However, if you do not have established forest acreage, it is suggested that a 'home fuel wood plantation' be started.

There is excellent information available on managing woodlots from your local U.S. Department of Agriculture Forestry Specialist, who can recommend locally specific tree species, land preparation and cultural practices. The U.S. Department of Energy, too, has sponsored and coordinated work on Short Rotation Woody Crops for a number of years and has information available through the Oak Ridge National Laboratory. While most of this information is site specific and has been developed with very large plantations in mind, it is a good starting point for scaling to your home needs.

# Economics

The exact cost of operating the ST-5 will vary from person to person and location. An attempt has been made based on the assumption that the engine will be used for 1,500 hours a year at full output and that the fuel is available without cost to the user. A comparison has been made with a 5 hp diesel engine and a 5 hp gasoline engine, assuming that the cost of diesel is 83¢ per gallon and gasoline is $1.15.

**Economic Analysis of ST-5 at Full Output**

| | ST-5 | Gasoline | Diesel |
|---|---|---|---|
| Expected Life (Hours) | 20,000 | 500 | 6000 |
| Price | $2975.00 | $250.00 | $1050.00 |
| Cost of Fuel Used over Life | $0.00 | $321.04 | $1784.50 |
| Oil Changes and Maintenance | $0.00 | $100.00 | $300.00 |
| Bearings and Seal Changes | $900.00 | $0.00 | $0.00 |
| Major Overhaul | $1000.00 | $0.00 | $500.00 |
| TOTAL | $4875.00 | $671.04 | $3634.50 |
| Cost Per Hour of Operation | $0.24 | $1.34 | $0.61 |

*ASSUMPTIONS:*

*Fuel Usage: Gasoline .67 gallons/hour @$1.15/gal. Diesel 0.43 gallons/hour @ $0.83/gal. ST-5 fuel is available free of cost.*

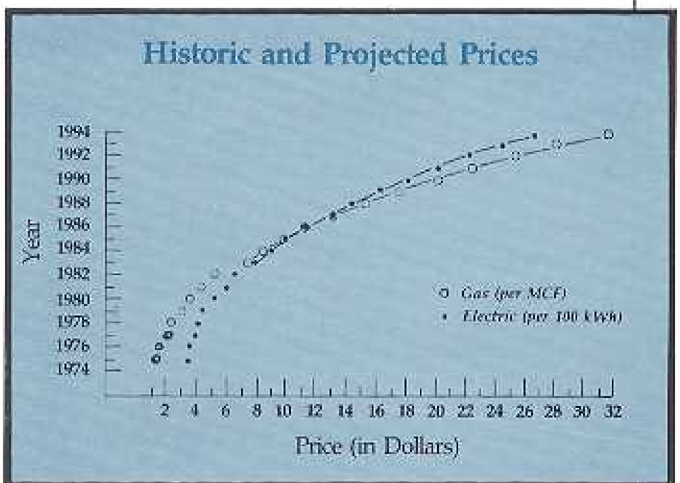
*Oil changes and maintenance: Gasoline every 25 hours @ $5.00 per change Diesel every 200 hours @$10.00 per change.*

*Bearings and seals on ST-5: every 2000 hours @$100 per change*

*Major overhaul: once at half life for both the diesel and the ST-5*

It is apparent that when heavy usage is expected from the ST-5, it is more economical than IC engines. The higher capital cost is more than offset by the savings in fuel, longevity, dry lubrication and self-maintenance.

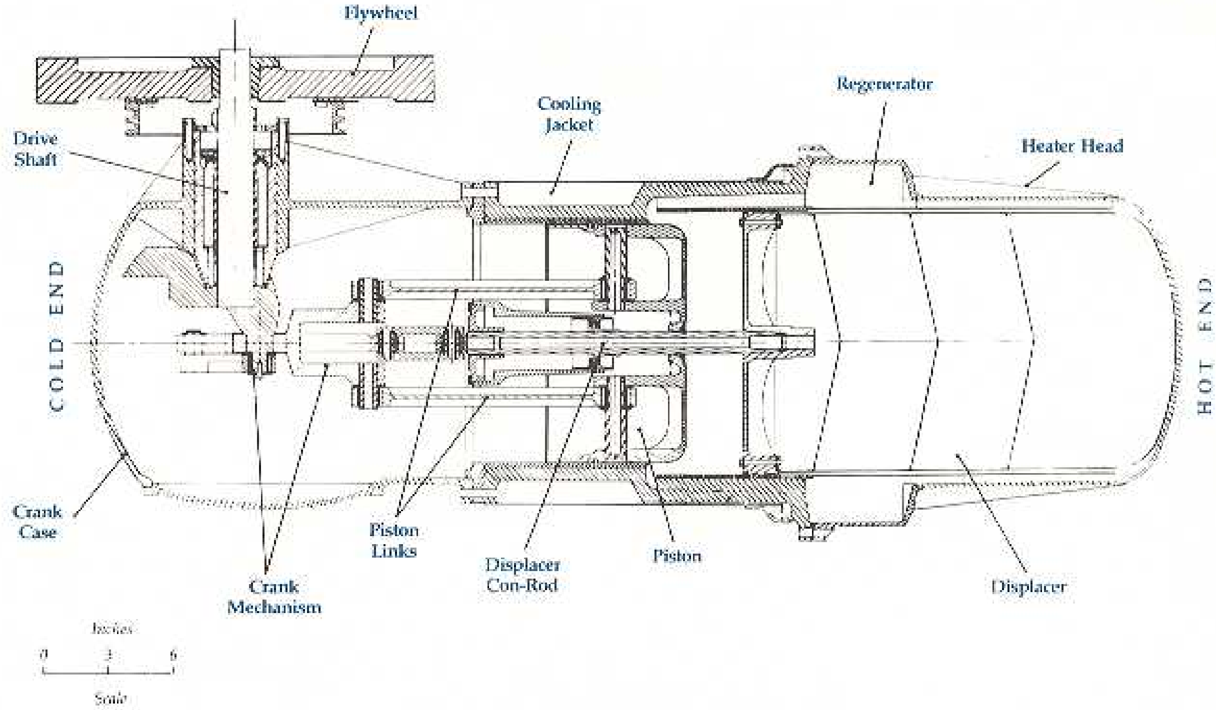
Determining the economic advantages of a *Total Home Energy System* over grid electricity and utility gas is much more difficult. This would vary widely, depending on the usage, geographical situation, location in rural or urban areas, local utility costs, etc. However, the one hard fact, which is a growing source of anxiety to some, is that utility rates are rising rapidly and will continue to do so. This increase reflects the pricing structure for utilities, which allows utility companies a certain rate of return. With tremendous capital investments in nuclear reactors and other assets, utility company rates will rise even more dramatically than in the past. The following is a chart showing the historical performance of countrywide average utility rates and a computer extrapolation of their probable future performance.




(Source: U.S. Statistical Handbook, 1985)

**However, the real strength of the ST-5 lies not as much in its favorable economics, as in its ability to eliminate some of the dependencies and uncertainties of our world while providing reliable power, with a minimum of environmental damage, where and when desired. The ST-5 can make you truly energy independent.**

# How The ST-5 Operates




The ST-5 operates on the temperature difference between its hot and cold ends. At one end is the heater head which is inserted in a burner; at the other, the cooling jacket and crankcase. These are the three components of the engine body which contain air, pressurized to 5 bar (approximately 72 p.s.i.) by a built in air compressor.

When heat is applied to the heater head by burning some combustible material in the burner, the air contained in the head is caused to expand and move to the cold end through a heat sponge called a regenerator. At the cold end, the air is cooled and compressed, and is then moved back to the hot end again through the regenerator. The purpose of the regenerator is to improve efficiency by absorbing heat when the air is shuttled to the cold end and releasing heat when the air returns to the hot end.

When the air in the hot end expands, it produces work which drives the piston towards the cold end. At the end of the piston's stroke, the displacer is moved by a mechanical linkage which pushes the expanded gas through the heater, regenerator and cooler into the cold end. The piston now returns from the end of its stroke, compressing the cold gas, and the displacer moves down towards the piston, squeezing the compressed gas in a reverse direction through the heat exchanger loop to the hot end. The cycle then repeats itself. This linear movement of the piston is converted into the rotary movement of the flywheel by means of a simple linkage contained in the crankcase. The crankcase has been designed to run dry, not needing any oil or grease. The bearings in the linkage are sealed and require no lubrication.

The only moving parts in the engine are the displacer, piston and linkage. This is what makes the engine extremely reliable and easy to service and maintain.

# Specifications
## *of the ST-5 Stirling Engine*

| | |
|---|---|
| **Engine type:** | External combustion, Stirling cycle, crank drive |
| **Engine output:** | 5 horse power (shaft) at 650 RPM |
| **Fuels used:** | Wood, saw dust, husks, corn cobs, weeds, other agro-byproducts, natural gas, propane |
| **Fuel consumption:** | 38 kW of heat (approx. 10 kg/hr of wood) |
| **Lubrication:** | Dry bearings; no oil used |
| **Working fluid:** | Air |
| **Working pressure:** | 5 bar, self-pressurizing |
| **Heater head temp:** | 650ºC (1200ºF) |
| **Cooling:** | 0.25 quarts/sec of water |
| **Expected life:** | 10,000 hours minimum |
| **Expected overhaul:** | 2,000 hours; bearings and seal check; replace if necessary |
| **Expected servicing:** | Periodic brushing of head fins; ash removal, cleaning of air filter |
| **Dimensions:** | 49″ x 16″ x 16″ |
| **Weight:** | 440 lbs (200 kg) |
| **Degree of skill for operating:** | Minimal |
| **Degree of skill for maintenance:** | Basic Training |

STIRLING TECHNOLOGY, INC.

9 Factory Street
Athens, Ohio 45701
U.S.A.

Phone:
(614) 594-2277

TLX 241-196
Sunpower Ahen