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[54] **UNIFLOW STIRLING ENGINE AND FRICTIONAL HEATING SYSTEM**
 8 Claims, 6 Drawing Figs.

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[56] **References Cited**

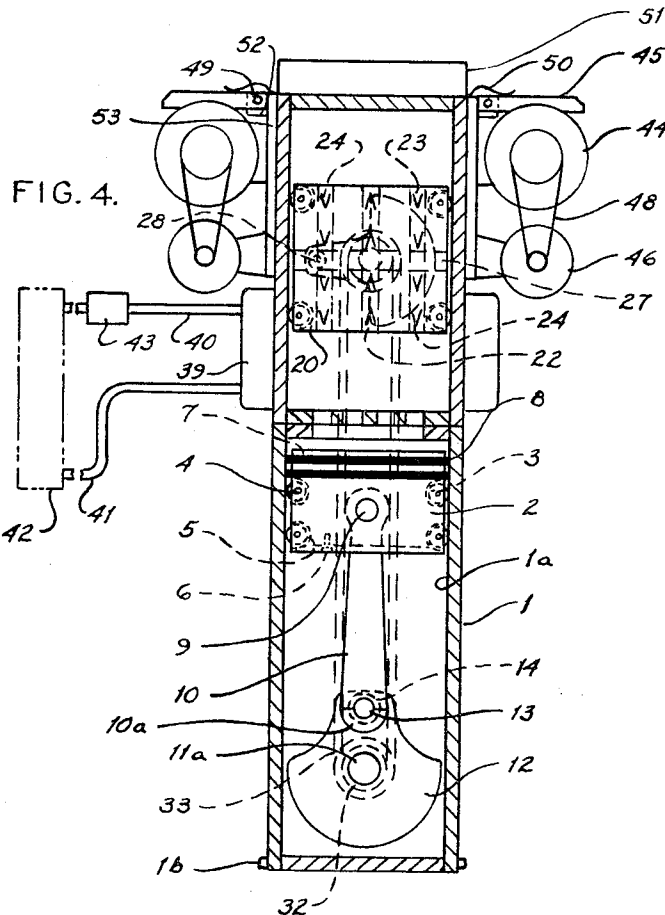
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ABSTRACT: The Uniflow Stirling engine consists of multiple power and displacer sections which are arranged in in-line form. The in-line arrangement allows for the ganging of the piston sets so that a simple modular, easily-serviced engine is produced.

Hot and cold conduction rods within the thermal zones aid in transferring heat within the displacer sections.

Alternating one-way gas flow bores within the displacer blocks provide a uniflow gas flow loop for improved thermal effectiveness.

A frictional heating system is advocated as a sustaining heating means, which utilizes an electric motor and battery system to drive a friction drum against replaceable heat transfer elements to produce sufficient heat energy for the hot displacer zone.



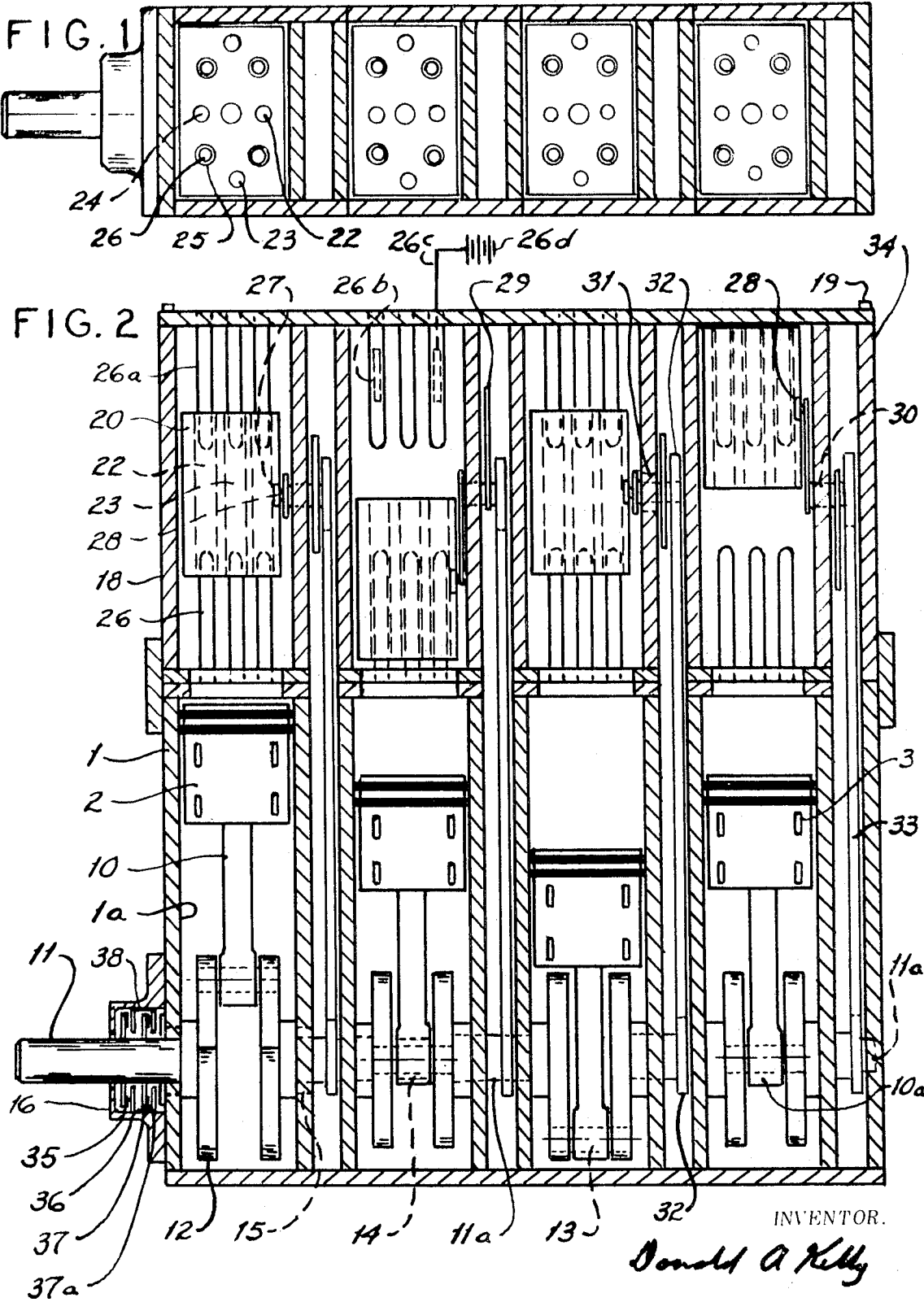


FIG. 3

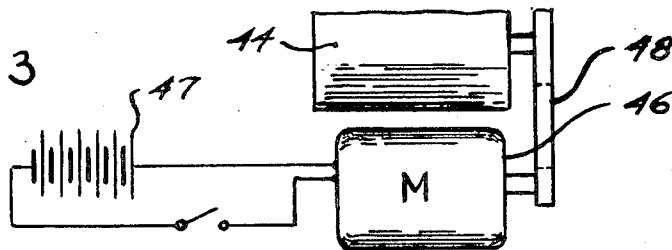
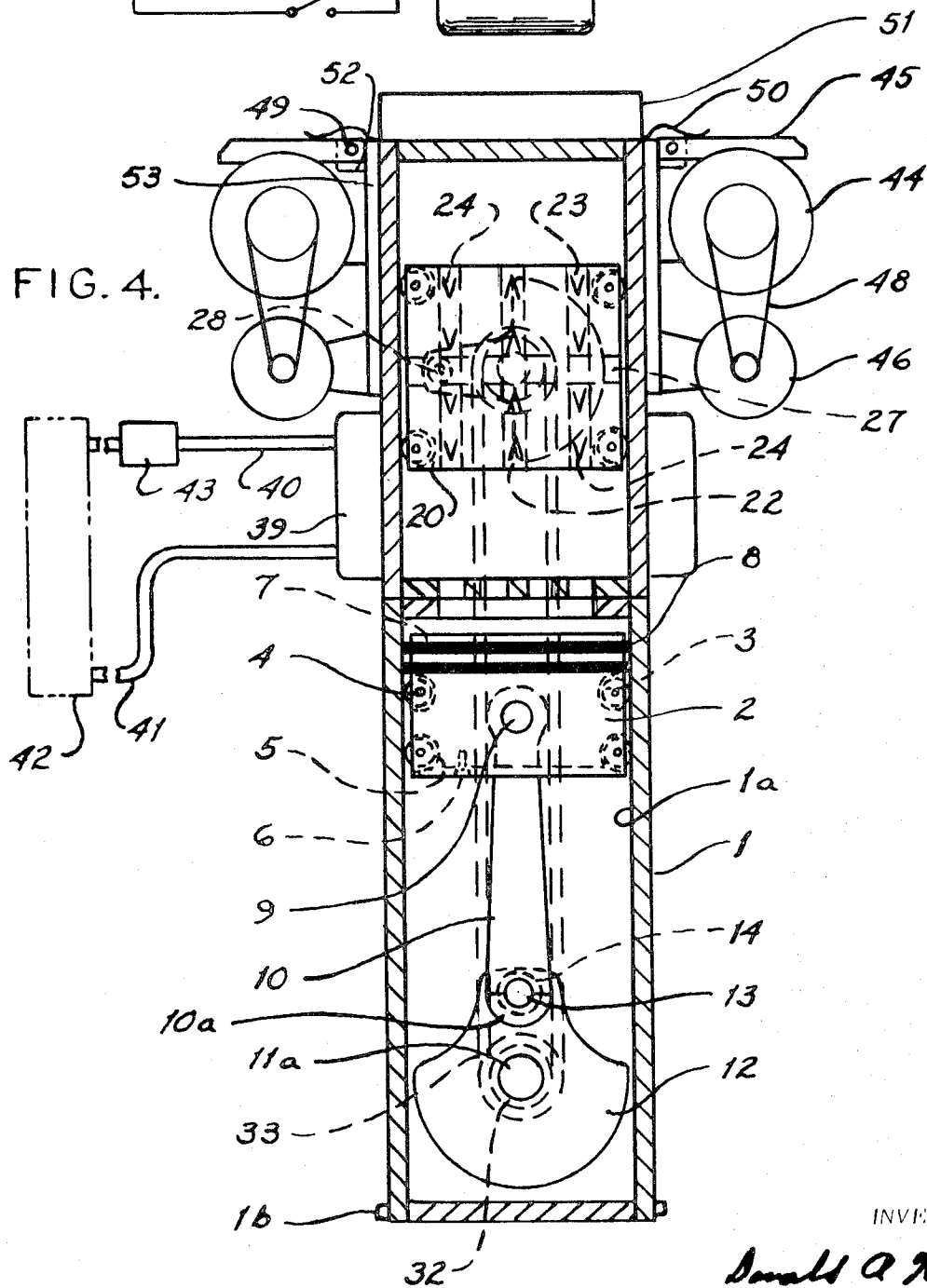


FIG. 4.



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FIG. 5

UNIFLOW
STIRLING
CYCLE

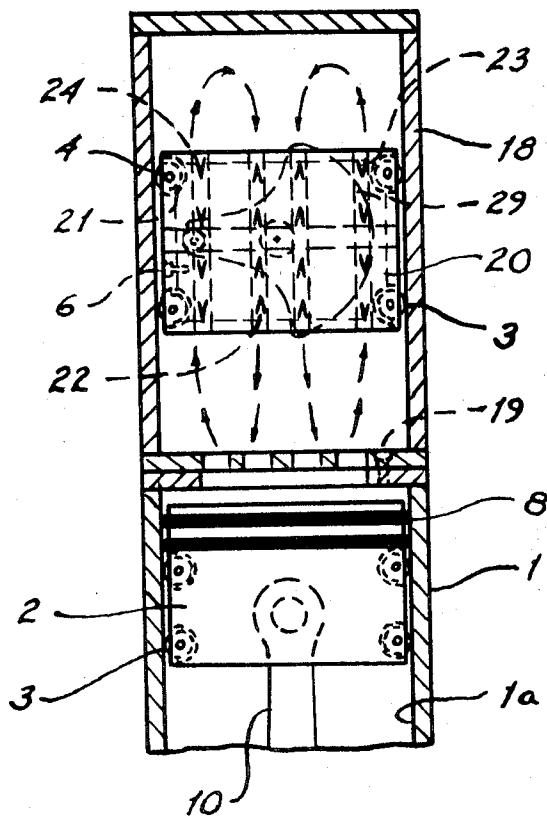
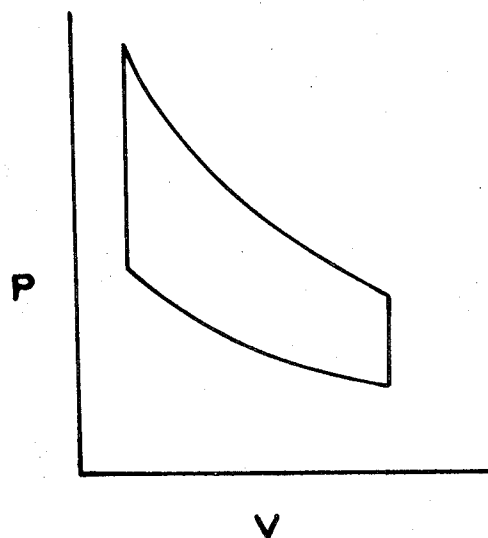


FIG. 6



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UNIFLOW STIRLING ENGINE AND FRICTIONAL HEATING SYSTEM

The invention relates to improved reciprocating, multiple piston Stirling engines with an auxiliary frictional heating arrangement. The principal features of this in-line engine is that a generally circular gas flow loop is established with effective heat transfer provided by both hot and cold multiple conduction rods. A unique feature provided for the operating pistons is the addition of special ball bearings which significantly reduce the operating friction level in both sections.

This in-line engine design is generally similar to a Stirling T engine described in patent application, Ser. No. 760,256, now U.S. Pat. No. 3,508,383. It will be recognized that this form of Stirling engine is similar to existing Stirling cycle machines, but with the addition of effective thermal transfer means for both hot and cold zones. The adoption of effective thermal transfer means aids in producing a compact closed cycle engine and makes high operating efficiency and fuel economy possible.

The multiple conduction rod technique is only applicable to reciprocating machines since the reciprocating displacer is provided with corresponding clearance bores, so that the displacer may freely pass over the conduction rods.

The adoption of the uniflow gas flow loop is necessary to avoid passing the hot expanding gas near the cold displacer walls. One-way hot gas flow bores near the center of the block displacer allows the hot gas to act directly on the power piston. On the reverse stroke the gases are directed along the cold walls, through the displacer block and thereby away from the hot central displacer zone, so that a generally circular gas flow loop is established. The uniflow gas flow is accomplished by placing multiple interconnected conical baffles within the designated hot and cold bores. The hot conical baffles will be placed with the cone apex pointing toward the hot displacer volume, while the cold conical baffles will have their cone apex pointing toward the cold displacer volume.

By arranging the hot uniflow bores near the center of the displacer block and the cold uniflow bores around the outer portion of the block, a separation is made between the thermal flows and a series of circular gas flow loops is established.

Regeneration of the gas flow is obtained through the interconnection of the conical baffles which take on and give up heat to the opposite gas flow. The interconnected conical baffles act in the same manner as any suitable filament or other regenerative material within the uniflow gas bores.

This form of Stirling engine requires that the two operating sections, the power and displacer pistons be chained or geared together with each section independently dyna-balanced and made as lightweight as possible. Since the displacer block must nearly half fill the displacer volume, the counterbalance arrangement must be externally placed within an adjacent pressurized drive section. The chain or gear drive connecting the two sections drive shafts will be enclosed within the pressurized volume so that only a single pressure seal is required at the output shaft.

The in-line engine is in modular form so that the adoption of square or rectangular displacer or power blocks facilitates the use of special ball bearings in order to lower the operating friction level within the engine. The ball bearings were not subjected to unreasonable temperature levels within the engine, so that their life will not be adversely affected. A controlled airgap between the reciprocating power block and the internal housing walls is desirable to that excessive side loads and wear on the sealing strips are minimized. The sealing strips which provide the pressure sealing means for the power block are made from filled-Teflon and are half-lapped at the ends to achieve a continuous sealing surface. The sealing strips are provided with thin, wave springs behind them so that constant sealing contact with the sidewalls is assured.

The multiple conduction rods are uniformly spaced within the hot and cold volumes and secured to the hot and cold end plates, respectively, which are insulated from the main housing. The multiple conduction rods provide a means of

thorough internal thermal transfer without excessive heating or cooling of the external housings and avoids the necessity of splitting the housings into hot and cold halves.

Some of the conduction rods are fitted with electric heating rods for rapid heating and starting of the engine. The electric leads from the heating rods are fully insulated and shielded where they exit the housings. A battery assembly and switch control means is provided for the heating rods.

A conventional cooling system is utilized for the engine with a liquid cooling jacket secured to a maximum area of the engine cold side. A large radiator, or multiple radiators, and pumping arrangement would be connected to the cooling jackets through incoming and outgoing fluid lines. The total radiator cooling area would have to be two to three times that of conventional I.C. engines in cars, because of the greater cooling requirement of Stirling engines.

A frictional heating system would be provided as an auxiliary or sustaining heating means, when the primary heat source is not operating. The frictional heating arrangement would consist of a friction drum revolving at moderate speed against a replaceable heat transfer plate, which is in direct contact with the hot side of the displacer housings. The friction drum or drums would be driven by an electric motor or motors and a battery assembly. The replaceable heat transfer plate or plates must be pivoted and spring loaded against the drum to insure proper contact as the transfer plate and drum wears. The drum should outlast the transfer plate since the plate is easily replaced and would cost less. A suitable gear reduction assembly must be provided from the high-speed electric motors to the drums for the necessary mechanical disadvantage.

A multiple-disc labyrinth type of shaft seal must be provided at the output shaft to retain the internal working pressure at a minimum friction level. Several of the discs contain multiple unidirectional vanes to create a dynamic back pressure in order to aid in the retention of the working gas.

It is expected that the uniflow engine will be capable of operating at pressure levels around 100 atmospheres so that a high high power-to-weight ratio will be realized. Although advocated as an in-line engine the modular design lends itself to a radial form arrangement. The preferred in-line design has the advantage of allowing a compact heating and cooling means within a minimum sized engine package. The radial design may have some advantage in providing a relatively flat package with the possibility of gyroscopic stability and a vertical drive shaft.

It is an object of the invention to create an improved Stirling engine which operates at high thermal efficiency.

It is an object of the invention to provide a Stirling engine which is relatively inexpensive to manufacture and repair.

It is an object of the invention to create a Stirling engine which operates with a minimum of lubrication and requires a minimum of maintenance effort.

It is an object of the invention to provide a quick-starting Stirling type engine.

It is a final object of the invention to provide an auxiliary frictional heating means as a backup for the primary heat source.

The above objects and general aims will be apparent from the detailed description to follow when taken in conjunction with the drawings.

It should be understood that variations may be made in the detail design of the engine without departing from the spirit and scope of the invention.

Referring to the drawings:

FIG. 1 is a top sectional view through the uniflow engine.

FIG. 2 is a side elevational section through the engine.

FIG. 3 is an elevation view of the auxiliary frictional heating arrangement.

FIG. 4 is a front elevational section through the engine.

FIG. 5 is a front elevation view of the Uniflow Stirling Cycle diagram.

FIG. 6 is the Stirling cycle diagram, showing pressure vrs. volume.

Referring to the drawing in detail:

The power stage housings 1 are built up of steel or aluminum plates to form a rectangular chamber which is pressure tight, with the internal surfaces 1a made flat and smooth to minimize seal wear. The machine screws 1b join the plates together. The power blocks 2 are built-up of aluminum and fiberglass in a rectangular form, and fitted with 12 ball bearings 3. The ball bearings 3 are supported by 12 small shafts 4, with the bearings revolving in the slots 5. The machine screws 6 join the plates of the power block together. The power blocks 2 are provided with sealing grooves 7, into which the sealing strips 8 are closely fitted. The sealing 8 are half-lapped at the ends so that a continuous perimeter sealing is maintained.

The wrist pins 9 connect the power blocks 2 with the connecting rods 10. The crankshaft assembly 11 is built up of several shaft sections 11a and multiple counterbalance discs 12 with the crankpins 13 connecting each pair of counterbalance discs 12. The crankend of each connecting rod 10 is connected to the crankpin 13 which revolves in the roller bearing 14. The crankshaft assembly 11 is thereby made up of shaft sections 11a, counterbalance discs 12 and crankpins 13, to form a continuous integral unit. The built-up construction allows the placement of roller bearings 14 on the crankpins before the bearing caps 10a of the connecting rods 10 are clamped into place.

The crankshaft assembly is supported within the engine housing by the bearings 15 and sealed where it exits the housing 1, by the labyrinth disc seal 16, housing.

The displacer stage housings 18 are constructed in rectangular form and sealed pressure tight. The displacer housings 18 are mounted coaxially in line with the power stage housings 1. The assembled power stage housings 1 and the displacer stage housings 18 are a unit engine module, with four or more modules assembled to form the complete in-line uniflow engine. The displacer stage housings 18 are secured to the power stage housings 1 with the screws 19.

The displacer block 20 is built up of aluminum and fiberglass sheet and fitted with 12 ball bearings 3. The ball bearings 3 are supported by 12 small shafts 4, with the bearings free to, revolve within the slots 5. The machine screws 6 join the plates of the displacer block 20 together. Multiple uniflow regenerator bores 23 are uniformly located through the displacer block 20, parallel to the axis of motion.

The multiple regenerator bores 23, are evenly divided between hot and cold bores with the conical baffle assemblies 24 place uniformly within each bore 22 and 23. The conical baffle assemblies 24 within the hot bores 22 are placed with the apex of each cone pointing toward the hot displacer volume, and the baffles 24 within the cold bores 23 placed with the apex of each cone pointing toward the cold displacer volume. The cold bores 23 are arrayed around the periphery of the displacer block 20, and the hot bores 22 arrayed on and near the center of the displacer block to provide the uniflow gas flow loop. The displacer block 20 is also provided with multiple clearance bores 25, which provide operating clearance over the multiple conduction rods 26. Some of the hot conduction rods 26a are fitted with electric heating rods 26b, with the electrical leads 26c connected to a controlled power source 26d.

A horizontal drive slot 27 is located at midlength of the displacer block 20 side into which the drive ball bearing 28, of the crankdisc 29 closely fits.

The crankdiscs 29 are secured to the displacer drive shafts 30 and supported by the bearings 31. Chain sprockets 32 are secured to the displacer drive shafts 30 between the bearings 31. Identical sprockets 32 are secured to each of the shaft sections 11a, with the sprocket chains 33 provided to couple the two operating stages.

Keying the cycle

The piston sets must be phased in each module, so that the displacer blocks 20 lead the power blocks 2 by one-half stroke or approximately 90° shaft position.

Drive section plate assemblies 34, are secured and sealed to both the power stage housings 1, and the displacer stage housings 18, which seal the sprocket and chain drive. The drive

section assemblies 34, provide bearing support for the crank shaft assembly 11 and the displacer drive shafts 30.

The multidisc shaft seal assembly 35 is made up of stator discs 36 and spacers 38, with the rotor discs 37 sealed to the shaft. The rotor discs 37 are provided with airflow vanes 37a to aid in the retention of the internal working gas during operation. The stator discs 36 are sealed to the disc housing, 16.

The cooling system for the engine consists of a liquid coolant jacket 39, secured to the cold side of the displacer housings 18, with a maximum of engine surface area in contact with the coolant jacket 39. Inlet tubes 40 and outlet tubes 41 connected to the coolant jacket 39, circulate the coolant to the radiators 42. The coolant pumps 43 provide the circulation means for the coolant through the cooling system. The pump 43 would be engine driven as is the usual engine practice.

The heating system would normally consist of an oil or propane burner 51 as is the usual arrangement for Stirling cycle engines.

The auxiliary heating system would consist of fraction drums 44, revolving against replaceable heat transfer plates 45, which are in direct contact with the hot sides of the displacer housings 18. The friction drums 44 would be driven by an electric motor 46 and battery assembly 47. A gear reduction unit 48 would be provided between the electric motor 46 and the friction drums 44. The heat transfer plates 45 must be pivoted on the pins 49 and spring-loaded against the friction drums 44 by the springs 50. A transfer bracket 52 secures the pins 49 to the side of the displacer housings 18. A bracket 53, mounts the friction drums to the side of displacer housings 18.

I claim:

1. A uniflow Stirling cycle engine comprising multiple rectangular power stage housings, multiple squarish power blocks fitted with ball bearings in rolling association with the internal surfaces of said multiple rectangular power stage housings, rectangular sealing strips disposed within corresponding square grooves within one end of the said squarish power blocks, wrist pins secured inside the squarish power blocks, connecting rods pivoting on said wrist pins, a crankshaft assembly disposed at the lower portion of said multiple rectangular power stage housings, bearing means for said crankshaft assembly, sealing means associated with said crankshaft assembly, multiple rectangular displacer stage housings disposed at one end and coaxial with said multiple rectangular power stage housings, communication means between the two said stage housings, hot and cold end plates secured to each end of said multiple rectangular displacer stage housings, insulation means disposed between the said hot and cold end plates and said multiple rectangular displacer stage housings, squarish displacer blocks fitted with multiple ball bearings, in rolling association with the internal surfaces of said rectangular displacer stage housings, multiple uniformly disposed regenerator bores within said squarish displacer blocks, multiple interconnected conical baffle assemblies uniformly disposed within said regenerator bores, multiple uniformly disposed metallic conduction rods secured to said hot and cold end plates, electric heating means disposed within some of the hot said metallic conduction rods, axial clearance bores uniformly disposed within said squarish displacer blocks in association with said metallic conduction rods, a vertical slot disposed midway on one side of said squarish displacer block, output shafts and bearing means secured midway in said multiple rectangular displacer stage housings, a crankdiscs secured to said output shafts, ball bearings secured to the ends of said crankdiscs in rolling association with said vertical slot of said squarish displacer blocks, multiple chain sprockets secured to said output shaft and said crankshaft assembly, drive chains connecting said multiple sprockets, a half-stroke phase relationship between the said squarish power blocks and said squarish displacer blocks, pressure tight cover assemblies disposed over said multiple chain sprockets and drive chains, a liquid fuel burner

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means disposed at the said hot end plate in association with the hot side of said multiple rectangular displacer stage housings, a liquid cooling means and circulating system disposed adjacent to and in contact with said cold end plate in association with the cold side of said multiple rectangular displacer stage housings.

2. A uniflow Stirling cycle engine according to claim 1 including a frictional heating system comprising multiple rotating friction drums in rubbing contact with replaceable heat transfer plates, electric motors and an electrical power source to rotate said rotating friction drums, gear reduction means between said rotating friction drums and said electric motors, pivots and pivoting brackets for said replaceable heat transfer plates in communication with said hot end plates spring means in association with said replaceable heat transfer plates, mounting brackets for said rotating friction drums and electric motors in association with said multiple rectangular displacer stage housings, speed control means for said electric motors.

3. A uniflow Stirling cycle engine according to claim 1, wherein the said sealing means associated with said crankshaft assembly is comprised of multiple rotor discs equally spaced and sealed to said crankshaft assembly, multiple stator discs equally interspaced between said multiple rotor discs and sealed to a stationary disc housing sealed in association with said multiple rectangular displacer stage housings, multiple tiny air flow vanes uniformly arrayed on said multiple rotor discs disposed to cause an outward air flow when said uniflow Stirling cycle engine is in normal operation.

4. A uniflow Stirling cycle engine according to claim 1, wherein the total number of said multiple interconnected conical baffle assemblies are equally divided into hot and cold gas flow directions, half said multiple interconnected conical baffle assemblies have the apex of the cones pointing toward the cold end of said multiple rectangular displacer stage housings, the remaining half of said multiple interconnected conical baffle assemblies have the apex of the cones pointing

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toward the hot end of said multiple rectangular displacer stage housings, the said half multiple interconnected conical baffle assemblies having their cone apex pointing toward the cold end of said multiple rectangular displacer stage housings are uniformly arrayed around the cross-sectional periphery of said squarish displacer blocks, the remaining half of said multiple interconnected conical baffle assemblies having their cone apex pointing toward the hot end of said multiple rectangular displacer stage housings are uniformly arrayed on and near the cross-sectional center of said squarish displacer blocks.

5. A uniflow Stirling cycle engine according to claim 1, wherein dry film lubrication is uniformly applied to all internal working surfaces and bearings of both said multiple rectangular power and displacer stages and said squarish displacer blocks.

6. A uniflow Stirling cycle engine according to claim 1, wherein a gas fuel burner means is applied in place of said liquid fuel burner means disposed at the said hot end plate in association with the hot side of said multiple rectangular displacer stage housings.

7. A uniflow Stirling cycle engine according to claim 1, wherein said liquid cooling means consists of a liquid containing jacket in close maximum surface area contact with said cold end plate associated with the cold side of said multiple rectangular displacer stage housings, multiple connecting tubes from said liquid containing jacket to multiple air-cooling radiators forming a circulating cooling loop system, pumping means driven directly from said uniflow Stirling cycle engine.

8. A uniflow Stirling cycle engine according to claim 1, wherein said output shaft and crankshaft assembly are fitted with large spur gears in place of said chains and sprockets, an idler gear is interposed and meshes with said large spur gears, said large spur gears are of equal size so that a one-to-one ratio is provided.

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