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FREE-WHEELING HYDRAULIC POWER MILLS

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ABSTRACT

Free-wheeling power plants using free replenishable hydraulic forces of winds and water currents would consist of most or all of the following: Fore and after cones to increase throughput; duplex impellers; rotors with dc/ac excitation, ac/dc inverters and dc field coils; stators with ac output of varying frequency, voltage and power; solid-state ac/dc inverters, dc electrolytic cell banks for GH_2 and GO_2 production; and neon refrigerators for reducing these to LOX and chilled GH_2 for ease in shipment or storage.

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Introduction

Free-wheeling hydraulic power mills driven by a fraction of the kinetic energy present in winds or flowing currents of water would be windmills or watermills. Such power mills could consist of most or all of the following:

1. Multiple impellers driving a single rotor
2. Free-wheeling generators
3. Power mill nacelles
4. Swivel mounts to support nacelles
5. Reinforced concrete pedestals
6. Rectifier/electrolyzers
7. Hydraulic throughput increasers
8. Neon refrigerators
9. Cryogenic storage and transmission
10. GH_2-GO_2 fuel cells/inverters

Figure 1 shows a schematic diagram of a hydraulic power mill system.

Figure 2 shows concepts for windmills and/or watermills.

Hydraulic power mills have inherently low specific power, so each component and subsystem must be arranged to capture energy over the full range of hydraulic flow velocity and be light weight/low cost as well. Free-wheeling hydraulic power mills as described with ac output of varying frequency voltage and power can do much even in remote power plant sites to ease the international power dilemma. Impellers would have multivane design based on concentric rows of blades which are 2.2 m long and 0.08 cm thick for windmills, and 1.1 m long and 0.16 cm thick for watermills. Allowing 1 m for streamlined hubs, windmill blade mounting plate diameters in m would be 4.4xrows+1 and watermill blade mounting plate diameters in m would be 2.2xrows+1. Intermediate mounting plates would be in pairs to allow segmental fabrication for shipment, with final assembly taking place at or near point of use. Hydraulic throughput increasers would also be made in segments for remote assembly. Power mill outputs are taken as 29.6% of available hydraulic power, although each row of curved blades can have optimized attack angles. Hydraulic speed increasers would consist of convergent fore cones, impeller casings and divergent after cones supported from power mill nacelles by curved anti-vortex strut plates.

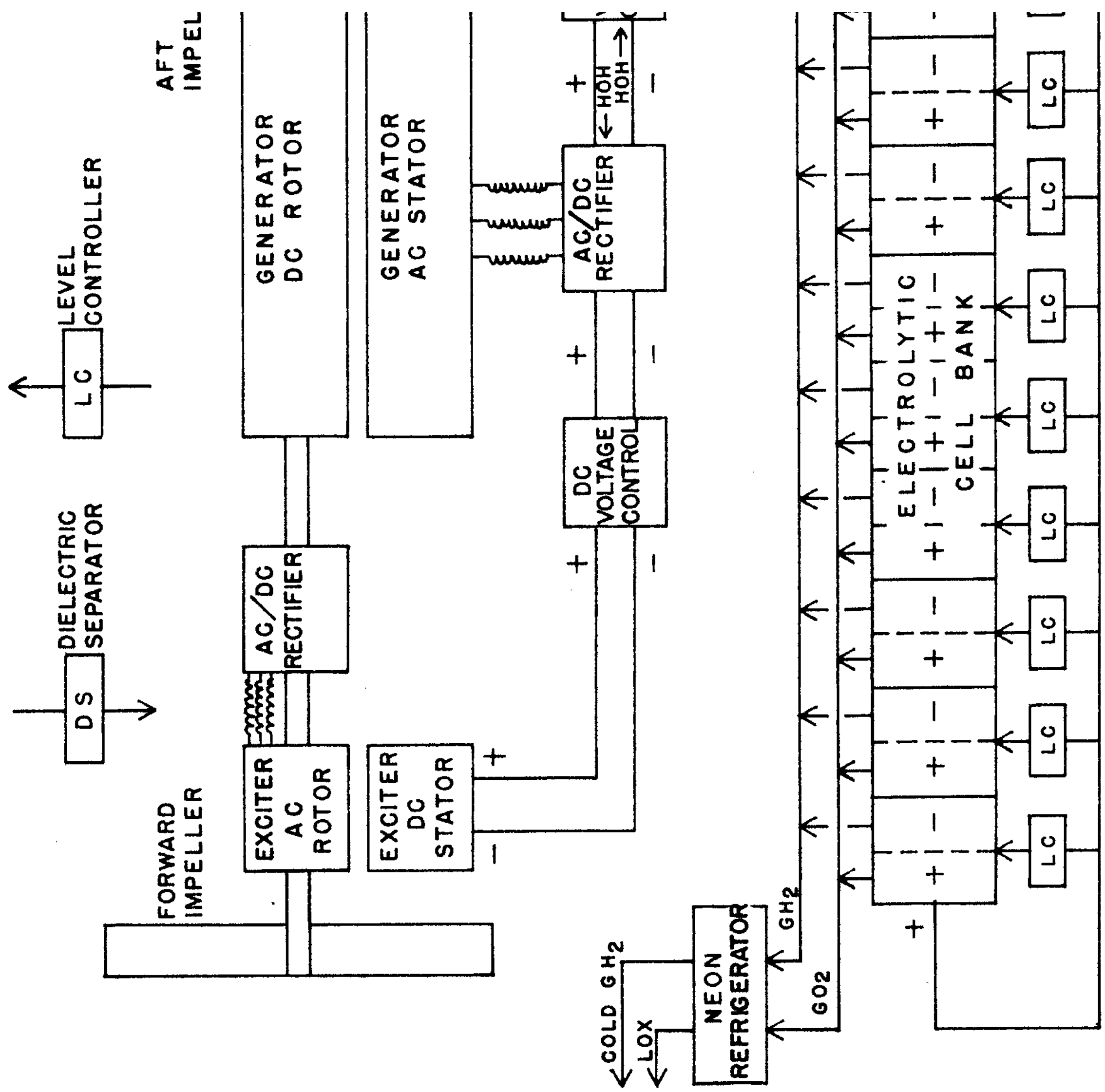
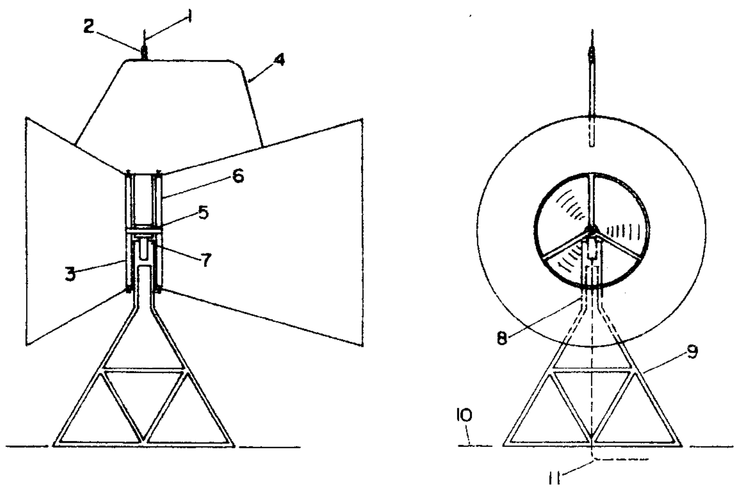

LEVEL CONTROLLER
LC
DIELECTRIC SEPARATOR
DS
FORWARD IMPELLER
AFT IMPEL
EXCITER AC ROTOR
AC/DC RECTIFIER
GENERATOR DC ROTOR
EXCITER DC STATOR
GENERATOR AC STATOR
DC VOLTAGE CONTROL
AC/DC RECTIFIER
HOH
HOH
ELECTROLYTIC CELL BANK
NEON REFRIGERATOR
COLD GH2
LOX
GH2
GO2

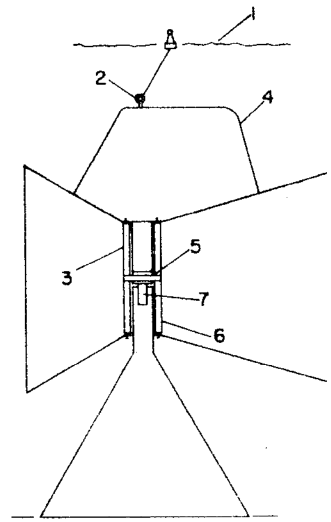
FIGURE I



1. LIGHTNING ROD
2. AIRCRAFT WARNING LIGHTS
3. FORE CONE AND LEAD IMPELLER
4. STEERING VANE
5. AC GENERATOR NACELLE
6. AFT IMPELLER AND AFTER CONE
7. SWIVEL MOUNT
8. CONCRETE PIPE COLUMN
9. CONICAL CONCRETE BASE
10. TERRA FIRMA
11. AC POWER TO RECTIFIER/ELECTROLYZER

NOTES

1. AC GENERATOR RPM = PROPELLER RPM
2. AC FREQUENCY AND VOLTAGE VARY WITH V
3. AC POWER VARIES WITH CUBE OF V
4. AC/DC RECTIFIER VOLTAGE IS REGULATED
5. HYDROGEN GAS PRODUCTION VARIES WITH KW



1. WARNING BUOY ANCH
2. LIFTING EYE
3. FORE CONE AND LEA
4. STEERING VANE
5. AC GENERATOR NAC
6. AFT IMPELLER AND
7. SWIVEL MOUNT
8. CONCRETE PIPE COL
9. CONICAL CONCRETE
10. TERRA FIRMA
11. AC POWER TO RECTI

FIGURE 2

Description of Free-wheeling Power Mill Components

1. Multiple Impellers Driving a Single Rotor

If wind or water currents maintained the same direction a number of impellers might be mounted on an extended shaft having a centrally mounted generator assembly. Winds and tidal eagres do not have constancy of direction and a practical arrangement would be to mount two impellers, one fore and one aft, on each generator rotor. This will almost double the output of each unit at a modest increase in investment. Impellers can be airplane propeller type air foils having 2, 3, or 4 blades or the multivane type. Propeller type impellers are more efficient but have an inherent problem due to having tip speeds of close to seven times the velocity of wind or water. Multivane impellers inherently have tip speeds that are equal to the velocity of wind or water. Multivane impellers can easily be designed to operate in winds blowing at 160 Km/hr when tip speeds will not exceed 45 m/s. Propeller type impeller tip speeds in such winds would exceed 300 m/s and it is necessary to turn impellers downwind and let the blades flutter whenever gale force winds occur. Multivane impellers are of interest because of the low tip speed characteristic, because these can be manufactured from rust inhibiting steel alloy sheets and each annular row of blading can be preset to have optimum angles of attack and avoid the need for elaborate blade pitch adjustment systems.

2. Free-wheeling Generators

Generator rotors would be arranged to eliminate commutators and brush assemblies by having an ac side exciter winding, solid-state ac/dc rectifier and dc side generator winding all mounted on the generator rotors. Generator rotors can be either driven directly by the twin impellers at low impeller rotational speeds or can be located above or below impeller rotor and driven at higher speeds using step up gearing or V-belts and sheaves. Selection of drive arrangement is an economic trade-off keeping in mind that the free-wheeling arrangement obviates the need for a rigidly preset number of poles as is necessary for generators operating in a 50 Hz or 60 Hz system. Generator stators would consist of exciter dc side windings and generator ac side power output windings. The ac frequency and voltage will vary with the speed of winds or water currents.

3. Power Mill Nacelles

Power mill impeller and generator rotor(s) and generator stator would-be housed within stream-lined nacelles arranged to support all rotor bearings and suitable for attachment to top-mounted or bottom-mounted swivel mounts as discussed below. Power mill nacelles would be furnished with a top-mounted steering vane or rudder to keep impeller rotors aimed into the swiftest winds or water currents. The top of the fin would be above the tops of the twin impellers and would be designed to support the weight and hydraulic thrust forces. Shorter side fins would be employed if necessary to stabilize top-hung units. In the case of windmills a tubular mast would be mounted on the steering vane with its top well above the tops of the impellers. The mast would act as a lightning rod and would be equipped with aircraft warning lights. In the case of watermills, a stranded wire rope would be extended from the tip of the steering vane to a floating buoy marker equipped with warning lights where this is necessary.

4. Swivel Mounts to Support Nacelles

Power mill nacelles can be supported from above using stranded cables in tension or can be mounted atop towers erected from below. In either case, the mounting must be the swivel type to permit power mills to be continuously aimed into the swiftest hydraulic currents. These mounts must be arranged with stops to prevent endless winding up of flexible, looped power, control or grounding leads and are provided with a positive means of swinging about. Top-mounted units might be windmills hung in narrow valleys with support cables anchored at the tops of ridges or watermills hung from anchored barges floating on the surface.

5. Reinforced Concrete Pedestals

Where power mill nacelles must be supported from below this can be done using reinforced concrete columns with power control and grounding leads run internally. Necessarily such a column must have a height that is close to impeller diameter to permit impeller rotors to be reasonably short. The columns in turn must be mounted into concrete bases designed to carry thrust forces into the ground from any direction. One means of transferring wind thrust forces into the ground at reasonable cost is to buttress the columns using conical reinforced concrete bases. These bases can be made equiangularly with slant sides at 60° to the ground and with base diameter proportional to impeller diameter. Impeller rotor would be located at a height above ground at least equal to impeller diameter. In the case of windmills, bases can be of the thin-wall type and all station equipment can be located inside the hollow conical base. Bases for watermills would be similar except the conical base must be of solid reinforced concrete to resist overturn due to water current forces. In either case, unit weight and base area friction must be such as to prevent scudding. When thrust forces try to move cone apexes in any direction one-half of reinforcing steel will go into tension to prevent displacement.

6. Rectifier/Electrolyzer

Both an ac/dc converter and its voltage regulator would be modern, highly efficient solid-state devices. Ac power output from power mills would thus be converted into constantly controlled voltage dc power at a loss in overall efficiency of 4% or less and at reasonably low cost. Hydraulic power mills or any other power plant which depends on free, replenishable but varying forces of nature for its input must have a means of storage and/or transmission of energy in order to have a firm capacity rating. The controlled voltage dc output of windmills and/or watermills can be applied to end-plates of electrolytic cell-banks or electrolyzers for a one-on-one conversion of KW into fuel value of dissociated hydrogen gas. The off-gassed oxygen should also be saved since GH_2 and GO_2 together are worth more than fossil fuels which are to be fired in air. At low ac input to rectifiers cell-bank I^2R losses will be less so dc voltage can be lowered and dc current increased. Overall conversion efficiency of electrolyzers can be very high at design loadings. Electrolyzers can also be overloaded by a wide margin at only a loss in dissociation efficiency so they are an ideal load for windmills designed to operate continuously no matter how high average wind velocity may become.

7. Hydraulic Throughput Increasers

In the case of large windmills the hydraulic throughput and wind velocity can be increased by reshaping the terrain upwind from the power mill but this is not necessarily good because of the unreliable source direction of winds. Fore cones of reinforced plastic or metal can be mounted on power mills of any size to increase fluid velocity at impellers. A fore cone having a diameter twice that of an impeller, a divergence angle of 60^{o} and a length equal to 0.866 of impeller diameter will increase water velocity by a factor of 4 and power output by a factor of 64. The decision to use Venturi type casing is strictly economical. These increase costs, but a larger diameter impeller will cost still more. The entire assembly can be made rigid by stretching stranded cables from the foward edge of the fore cones to the after edge of the after cones.

8. Neon Refrigerators

GH_2 at ambient temperature is very fluffy. Its bulk volume can be reduced by pressure and electrolyzers should be designed so that GH_2 and GO_2 off-gas pressure matches that of fuel-gas transmission pipe lines at up to 70 atma (atmospheres absolute). The volumes needed for storing GH_2 and GO_2 can be further reduced by chilling. Neon as a refrigerant is enormously more effective than other gases in the cryogenic region. Neon refrigerators can be used to simultaneously liquefy oxygen (LOX) and chill GH_2 to as low as $33^{o}K$. At this temperature GH_2 contains almost two-thirds of the weight of liquid hydrogen (LH_2) but remains lighter than air and is far less dangerous if leaked. The diversion of power to refrigeration is reduced if coupled with a LOX cryostat unit. The bulk reduction of GH_2 at $33^{o}K$ is a factor of 9 at any pressure.

9. Cryogenic Storage and Transmission

Double walled tanks with annular spaces roughly evacuated using LOX cooled molecular sieves and then pumped to 10^{-7} Torr or lower using sputter-ion type vacuum pumps will suffice to store LOX or GH_2. Use of multiple wraps of super insulation will further reduce leakage of heat from the ambient world. Shipment can be tanker or pipe lines. The latter should be buried under 2 m of earth to provide thermal insulation.

10. GH_2-GO_2 Fuel Cell/Inverters

Where local power generation is needed when winds have died or tidal velocities are nil, stored GH_2 and GO_2 can be fired in fuel-cell power packs having solid-state dc/ac inverters to maintain local 50 Hz or 60 Hz power generation. Alternately GH_2 can be fired with GO_2 or air in conventional boiler-steam-turbine-generator plants, gas-turbine-generator plants or engine driven generator plants at less efficiency. Also, a dc/ac inverter can be used to supply power locally when hydraulic forces are available.

Impellers and Venturi Type Flow Casings

Power derived from about one-fourth of the kinetic energy of winds or water currents varies as the square of impeller diameter and the cube of hydraulic velocity. Normal wind and water velocities are low and impellers used alone cannot be large enough to capture significant energies economically. Impellers located at the vena contracta section of Venturi type flow casings having entry and leaving diameters 2 times that of the impellers can do much better. Hydraulic velocities will be increased by 4 and power capture by 64 for any entry velocity. This combination allows use of smaller impeller diameters while transforming zephyrs into mountain top gales and normal water currents into raging torrents. Table 1 shows the probable limits of KW production from a reasonable range of impeller diameters, fore cone - after cone diameters, wind velocities and water current velocities; and, estimated weights of equipment (2 impellers plus generator nacelle plus swivel mount), Venturi type flow casings (60° divergent fore cones, vena contracta cylinders and 30° divergent after cones) and column above cone, reinforced concrete bases (hollow for windmills and solid for watermills) where conical bases are equiangular (base diameter is equal to slant height). It is noted that the D^2V^3 relationship for hydraulic power mills indicates high hydraulic velocities easily justify the use of hydraulic throughput increasers. It is concluded that hydraulic power mills, as described, can do much, even in remote, free, replenishable hydraulic power sites to ease our international power dilemma.

Table 1

Impeller Diameter Meters	Forecone Diameter Meters	Windmill Power, KW — Wind Velocity at Impellers 4 m/s	8 m/s	16 m/s	32 m/s	Watermill Power, MW — Water Velocity at Impellers 4 m/s	8 m/s	12 m/s	16 m/s	Windmill Weights, Eq.	Cone
3.2	6.4					0	1	4	10		
5.4	10.8	0	4	32	260	0	4	12	28	6	6
7.6	15.2					1	7	23	55		
9.8	19.6	2	14	110	880	1	12	39	92	19	15
12.0	24.0					2	17	58	138		
14.2	28.4	4	29	230	1,840	3	24	81	192	36	37
16.4	32.8					4	32	108	256		
18.6	37.2	6	50	396	3,170	5	41	139	329	62	58
20.8	41.6					6	52	174	413		
23.0	46.0	9	76	605	4,840	8	63	213	504	94	95
25.2	50.4					9	76	255	605		
27.4	54.8	13	108	860	6,880	11	89	302	715	137	135
29.6	59.2					13	104	352	834		
31.8	63.6	18	145	1,158	9,260	15	120	407	964	191	182
34.0	68.0					17	138	464	1,101		
36.2	72.4	23	188	1,501	12,006	20	156	526	1,249	259	236

Notes

1. Windmill power in KW for two impellers is taken as $0.0002796_2 D^2 V^3$ when overall genera
2. Watermill power in KW for two impellers is taken as $0.2327\ D^2\ V^3$ when overall generati
3. When fore-cone and after-cone diameter is twice that of impellers, hydraulic velocity by 4 and power output by 64.
4. Water at standard conditions is 832 times as dense as air and watermill power outputs when impeller diameter and hydraulic velocities are the same.
5. Average hydraulic velocities at impellers will be 16 m/s for windmills and 8 m/s for w