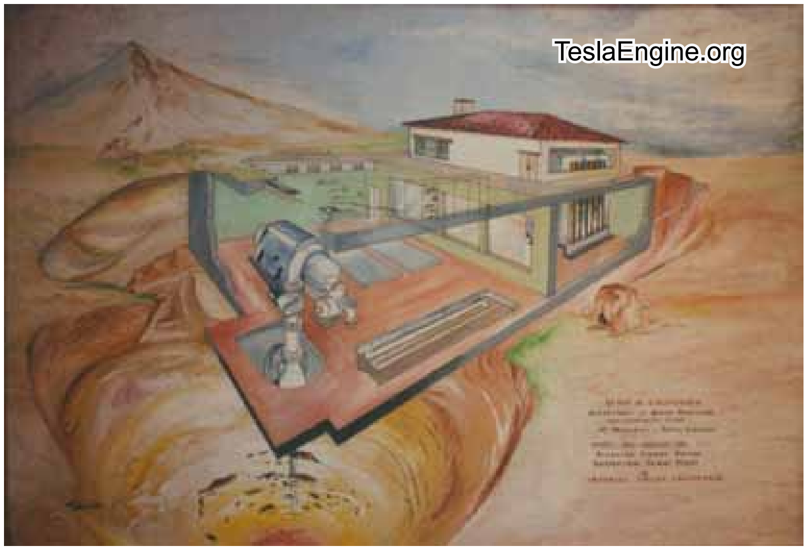
Tesla's Geothermal Solution

Back in the 1960's the late Jake Possell discovered the Tesla turbine, after being introduced to the concept by his mechanic Kenneth Dunn. Jake went on to attempt control of the technology, patenting various configurations and applications. Jake was involved with several projects to employ Tesla disk turbines. The following text and graphs are reconstructed from literature published in the 1980's by Turbines International Inc., a company for which Jake was providing engineering, As well as more recently built turbines by TEBA member Sonny Entrican (fig. 2 & 3). This literature presented the revolutionary potential of the technology. Disk turbines for geothermal energy recovery were built and tested in the 1980's.



Though simple in construction, Tesla's turbine must be built and applied correctly for proper result. The original Tesla designs are now available via TEBA.

Jake significantly modified the Tesla pump design, allowing his one time business associate, machinist Max Gurth, opportunity to provide superior pumps of higher efficiency, closer to the original Tesla design. This resulted in an entirely new "Quantum Leap" for the pumping industry beginning in the 1980's, www.discflo.com .

Tesla believed passionately in the geothermal concept, coining it; "Our Future Motive Power." Describing in 1931 this grand concept in an article so titled (serialized in back issues, see website). It is truly unfortunate that an actual Tesla turbine has yet to be employed in commercial geothermal service. Only a Tesla type turbine can survive in applications employing *"Total Flow"* direct connection to Salt Brine geothermal resources.

A special Thank You goes out to TEBA member Robert Leff for providing the "Turbines International" document; Reconstructed as follows:

Turbines International, Inc., is a privately held company set up specifically to research, develop and manufacture an economically feasible geothermal turbine which would accept the total effluent at the well head. After several months of intensive research, TI designed, built and tested four different turbine configurations. Tests were conducted with working fluids ranging from ambient temperature, high pressure air to ambient temperature, high pressure water. And from 100 percent quality steam to 0 percent quality (hot water) with a temperature range from 190° to 500°F.

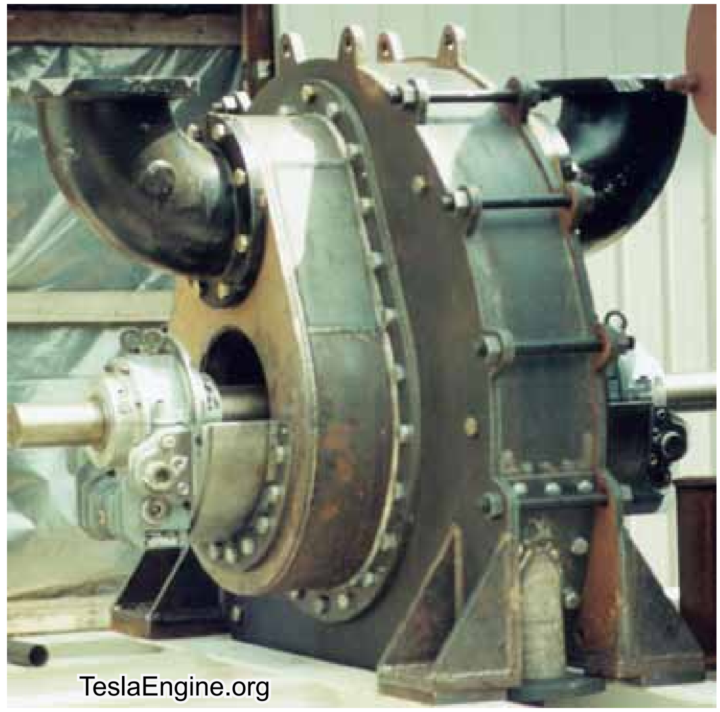
Using the latest design minicomputer, modern computer modeling and analysis; TI has analyzed the test data and can effectively "custom design" our production model turbine to fit the well head conditions of virtually any geothermal or geopressure area in order to optimize the output from that particular well.

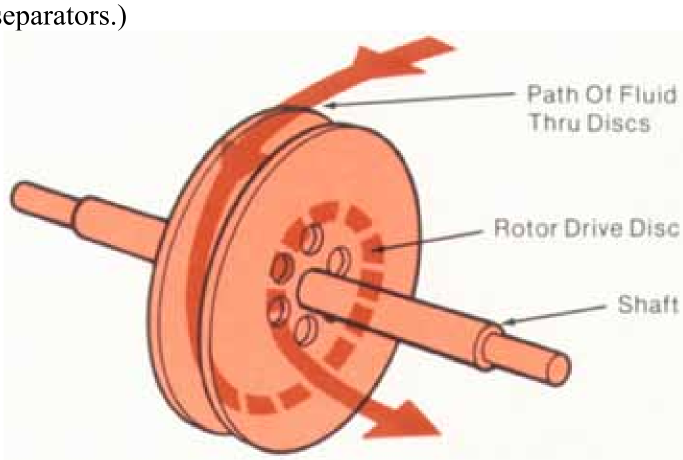
TI's engineering and manufacturing staffs are thoroughly trained, have a wide variety of experience and are capable of interfacing our turbine/generator units with your system or designing the total system and managing the project from sinking the well to final "on site" checkout.

Geothermal Energy — The Problem / The Solution

For geothermal energy to take its place among the major energy sources, there must be a revolutionary breakthrough in steam turbines and power plant systems which will eliminate, or at least minimize, the huge energy losses between the well head and the turbine. These losses often amount to 70 percent of the available energy. Several criterion are therefore established for turbines and systems.

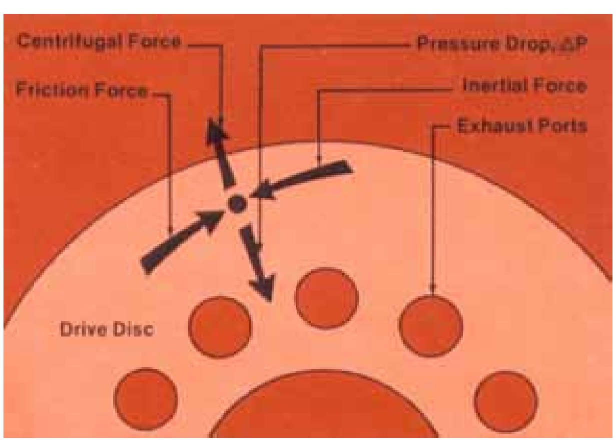
- The turbine must be sized for an individual well and be located as near the well head as possible. (Eliminates the long piping runs, small size reduces manufacturing costs and improves system availability.)
- The turbine must accept the total effluent of the well.
- The system must be of the closed loop type. (Eliminates large cooling towers, virtually eliminates environmental pollution problems.)
- The turbine must be capable of operating efficiently and economically with working fluids from 90ºC to 300ºC and pressure ranges from 100 PSIG to 2000 PSIG.
- The turbine and system must maintain a relatively flat operating curve with working fluids which contain dissolved or suspended solids up to 35,000 parts per million.
- The turbine must be capable of operating economically with wet steam and/or hot water as the working fluid. (Eliminates need for cyclonic phase separators.)





Obviously, from the above criterion, the turbine has been the major bottleneck to economical geothermal energy until this time. Recognizing the great need, TI set out to develop a turbine which would meet those criterion. After several months of research and concept development, TI designed and built four turbine configurations and four subsequent modifications which were subjected to a matrix of tests including all the temperature and quality ranges found in the foregoing criteria.

Using modern computer modeling and data analysis techniques, TI is now able to "custom design" their standard production model turbine to fit virtually any geothermal or geopressure well to optimize its output. TI's turbine promises to be **the solution** to today's geothermal and geopressure requirements.

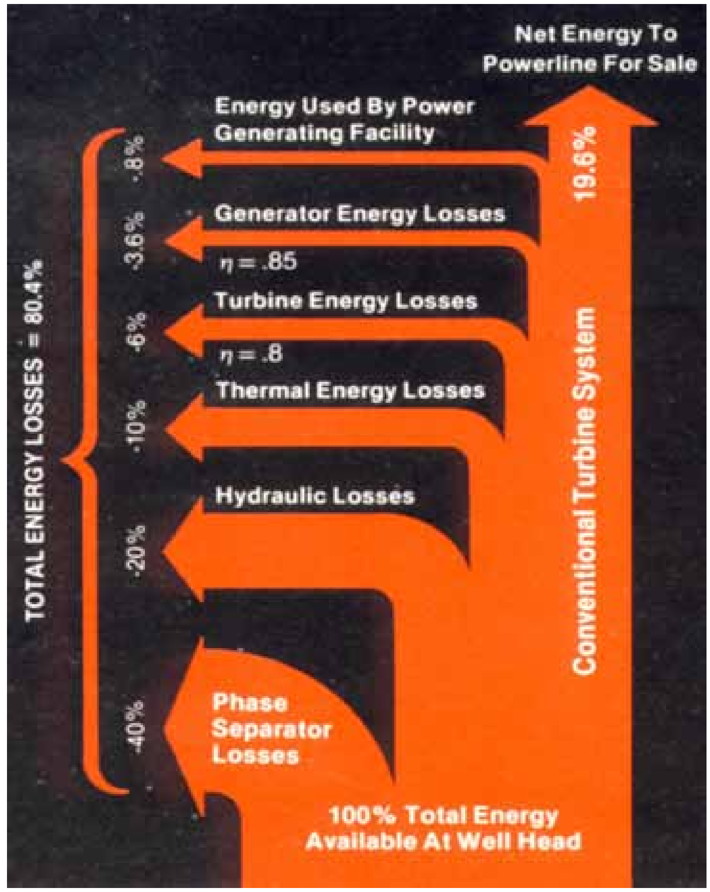


TYPE OF WORKING FLUID	TI'S SYSTEM	CONVENTIONAL SYSTEM
Clean, Dry Steam	Yes	Yes
Wet Steam	Yes	No[1]
Low Temperature, High Pressure Fluids	Yes	No
Low Temperature and Pressure, High Volume Fluids	Yes	No
Fluids Containing a High Degree of Particulates	Yes	Yes[2]
High Pressure Gases	Yes	No
High Pressure Liquids	Yes	No
High Pressure Liquids with Entrained Gases	Yes	No

[1]Must separate the moisture from the steam before it enters the turbine.

[2]Extremely high maintenance and repair costs due to accelerated erosion of turbine blades and other components.

Tesla's Geothermal Solution



Shear Torque Turbine

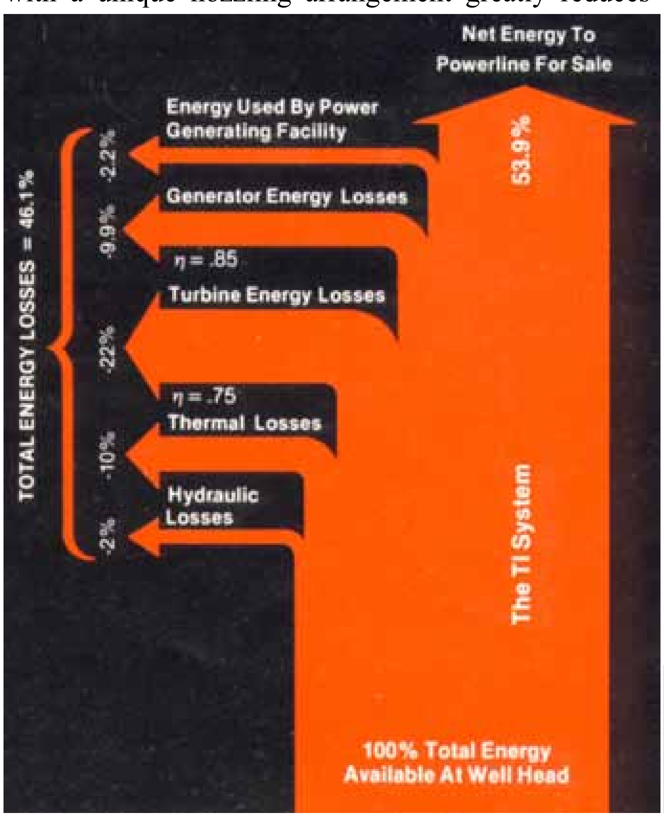
Fundamentally, the turbine uses the basic flat, parallel disc design of Tesla and then incorporates a new, full admission nozzle with integral flow guides and a new regenerator concept which optimizes the pressure drop across the working surfaces and conditions the exhausting fluid to present the maximum energy to the secondary stages.

Unique Characteristics:

The ability to function with virtually any temperature fluid and with low quality fluids sets TI's turbine apart from conventional geothermal steam turbines. This capability makes conventionally unfeasible wells productive and economically feasible. The ability to utilize low quality fluids eliminates the need for expensive, energy robbing liquid/gas phase separators upstream form the turbine.

- The primary working portion of TI's turbine rotor is the **Drive Disc** section. Several thin, flat, specially ported, circular discs and spacers are mounted in a unique arrangement on a single shaft. Well head conditions and desired output dictates the number of drive discs, disc spacing and disc arrangement on the shaft.

- TI's departure from conventional turbine design results in a **much simpler** design with significantly lower manufacturing costs. TI's use of drive discs in place of blades or buckets in conjunction with a unique nozzling arrangement greatly reduces manufacturing difficulty. That savings is passed on to the end user in a selling price 50 percent less than conventional systems. And the lead time for a system installation is reduced from five to eight years to less than two years.

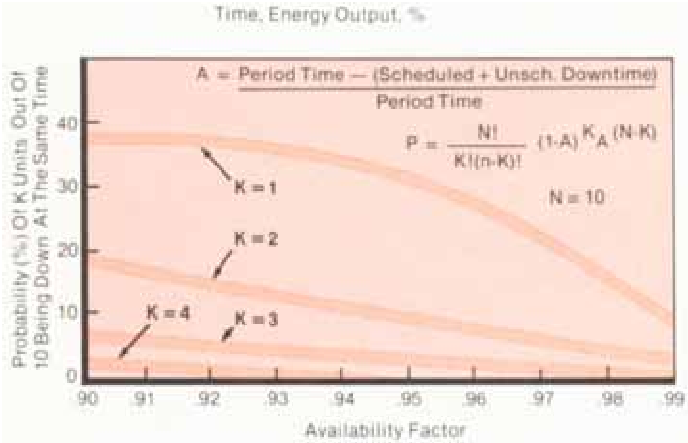


- A side benefit of simpler design is the **Ease of Maintenance**. TI's concept of utilizing 5MW modules employs smaller units, which uses much smaller handling equipment, and will reduce down time by a minimum of 30 percent. The modular concept and reduction in down time will provide a $^1/_4$ to $^1/_3$ increase in plant generating capacity. Maintenance expenditures and personnel costs are held at a minimum. Repair parts are "off-the shelf" items requiring lower inventory costs and shorter delivery schedules.

- A safety benefit results from the radial flow path of the fluid and custom disc design: **self - limiting overspeed protection**. Centrifugal forces acting on the fluid are overcome by the forces from the pressure drop across the rotor disc. Inertial forces (from the fluid velocity) overcome friction forces (boundary layer drag and resulting turbulence).

- The **nozzling arrangement** consists of specially designed toroidal expansion, phase separating nozzles with an integral system of flow guide vanes. This configuration directs the fluid into the drive discs uniformly around its circumference at the optimum angle. (Ed; Possell Pat. U.S. # 4,232,992)

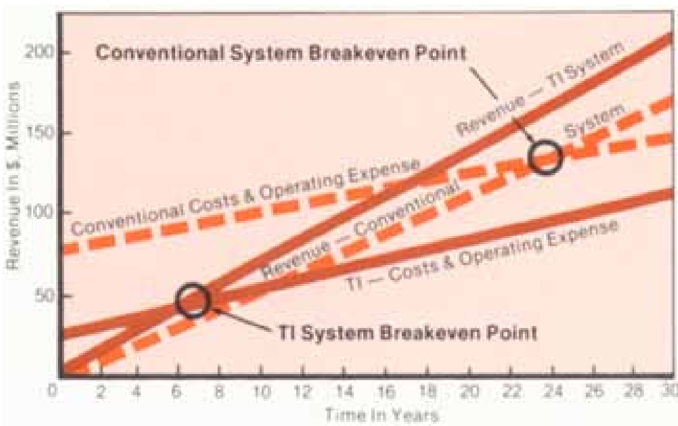
An integral regenerator section is employed to maximize the pressure drop across the drive discs as well as enhance the properties of the working fluid entering secondary stages.



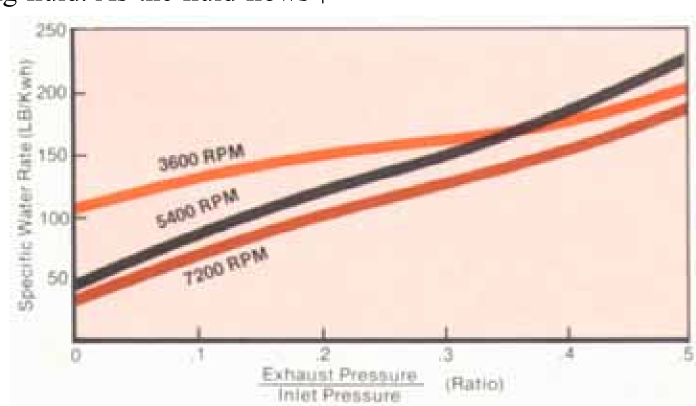
Operating Principle:

TI's turbine converts energy from the incoming fluid (gas, liquid or any mixture of the two) to rotating shaft power through the principle of boundary layer drag. This drag phenomenon is well known to aerodynamicists as a negative factor in aircraft performance.

In TI's turbine, boundary layer drag is utilized to achieve energy conversion by the fluid flowing between the rotor discs.



The working fluid enters the turbine housing tangentially and passes through a unique nozzle/flowguide system where it is expanded (and, for the two-phase fluids, separated) and then is guided to a near-tangential entry into the rotor section. This system imparts a high degree of kinetic energy to the working fluid. As the fluid flows in a spiral path between the surface of the drive discs to specially designed exhaust ports, it transfers energy to the discs due to the friction created by the boundary layer shearing with the fluid flowing thru the discs. This drag or shear friction causes the rotor to turn in the direction of the moving fluid.



By definition of the boundary layer, the velocity of the fluid adjacent to the disc is virtually the same as the velocity of the disc. Therefore, surface wear is eliminated since impingement is eliminated. The turbine, with no impinging surfaces, is not subject to the same limitations of input (i.e. clean, dry steam) as conventional equipment. So it functions comparably with all the common geothermal and geopressure effluents as the working fluid.

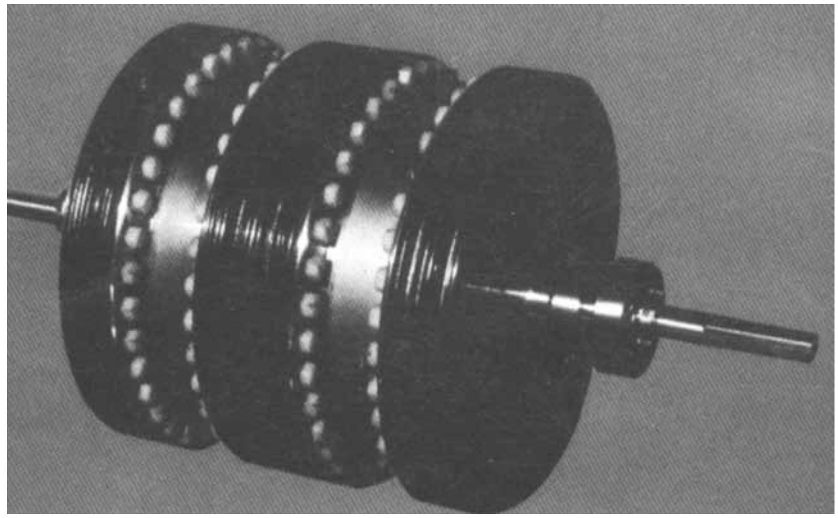
As the fluid exits the rotor section it spirals axially along the shaft through an internal crossover to the regenerator discs through inlet ports located near the shaft and continues in a spiral path thru the regenerator section where it picks up centrifugal pressure before exiting through the tangentially oriented exhaust ports in the wall of the regenerator housing. The regenerator is designed to control the exit pressure of the drive discs and thereby optimize the pressure drop across the drive discs.

At this point the spent fluid flows to a reinjection pump. In systems where all the energy is not extracted in a single pass thru the turbine, the working fluid may be directed to secondary stages for completing the energy transfer or auxiliary systems; such as space heating, air conditioning, etc.

Major Components:

- The housing consists of four castings made of alloys which resist corrosion, erosion and thermal fatigue.

1. Integral lower half,including base, inlet port and exhaust port.
2. Upper half.
3. Two (2) integral bearing and seal housings. Integral **nozzle / flowguide segments** made of high strength alloy to resist wear, corrosion and thermal fatigue.



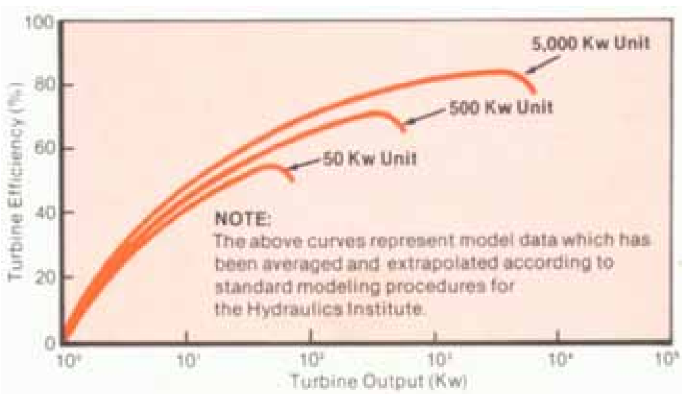
• Both the **drive discs** and the **regenerator discs** are made of a high strength alloy to resist thermal distortion and corrosion.

• Angular contact self-aligning roller **bearings** are designed for a B-10 life of 100,000 hours and are lubricated with a separate **forced lubrication system**.

• **Labyrinth seals** maintain a high degree of sealing between the casing and shaft.

• A **programmable microprocessor** controls the turbine speed through a feedback loop between the output frequency and the input control valve. Continuous monitoring of turbine and well conditions provides data for analyzing system and component performance. A troubleshooting program allows real time computer analysis of the turbine to pinpoint areas of difficulty for TI service personnel.

Applications



Electric Power Generation:

TI's turbine/generator units are particularly well suited for direct use on geothermal wells with low or varying quality steam. The elimination of cyclonic phase separators and long piping runs combine to provide more than 2.9 times more available energy to the turbine. Turbines for the geopressure zones (low temperature-high volume effluents) have been tested satisfactorily and promise to increase the potential energy output of those wells over 100 percent.

Other Uses:

By reduction gear coupling, the turbines can be used to drive pumps, compressors, fans, blowers as well as A-C and D-C generators.

TI's 5MW, modular concept, will reduce the initial cost of a 50MW power plant by 65 percent and will reduce lead time for installation by up to 75 percent. The accompanying system loss diagram shows how TI can achieve a power output 2.75 times greater than conventional systems for the same amount of available energy at the well head.

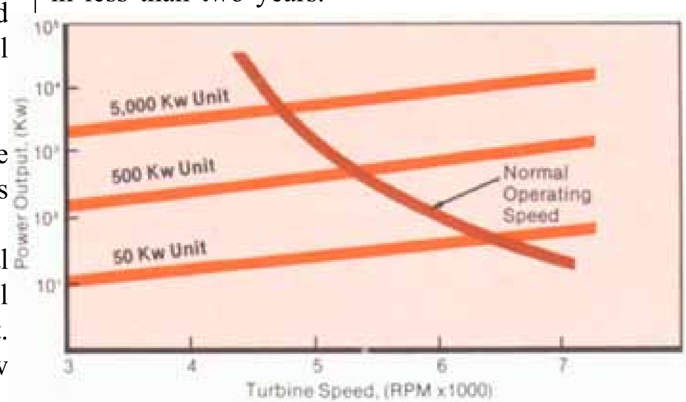
TI's system drastically improves the economics of power generation in the following six areas:

- Net power output increased 2.75 times
- Initial plant cost reduced 3.63 times
- Installation lead time reduced 3.25 times
- Plant capacity factor increased 1.26 times
- Availability factor improved 1.23 times
- Busbar price of electricity reduced 2.63 times

Economics

Several factors contribute to improved economics using TI's system.

Simplicity of design reduces manufacturing costs and shortens delivery schedules. Standard "off-the shelf" components, conventional-readily available steels and integrated design to reduce the number of components to be inventoried, all combine to keep manufacturing costs to a minimum. Since standard components and materials have relatively short lead times, the turbines can be manufactured, assembled, tested and installed in less than two years.

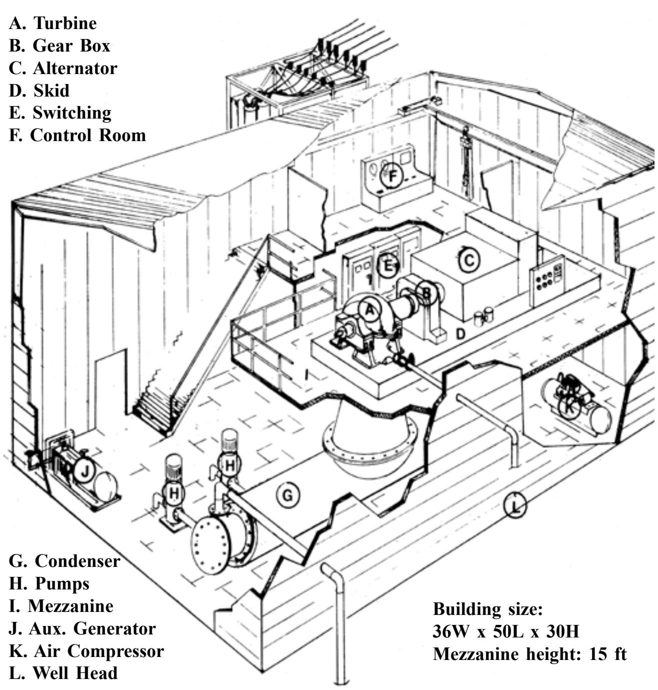


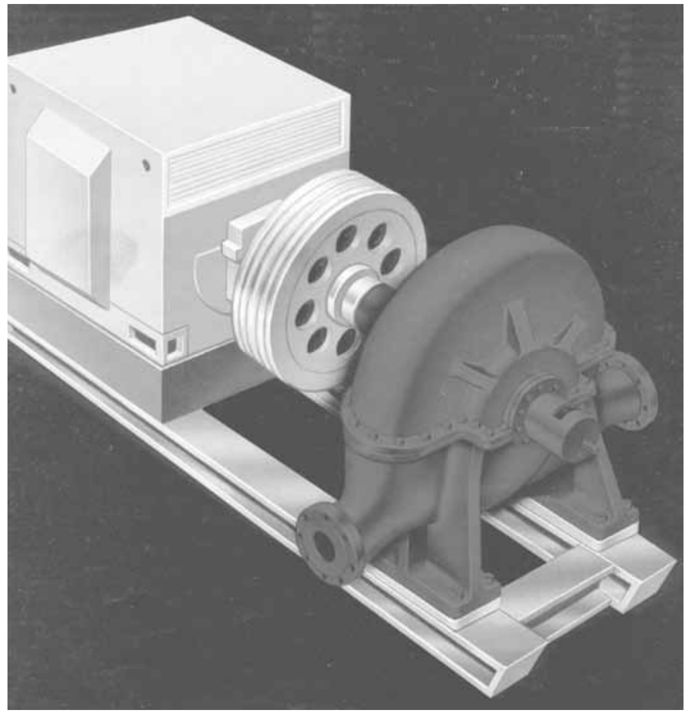
Tesla's Geothermal Solution

TI's one (1) turbine per well vs. the conventional multiple wells per turbine approach, points up even more economies in the system.

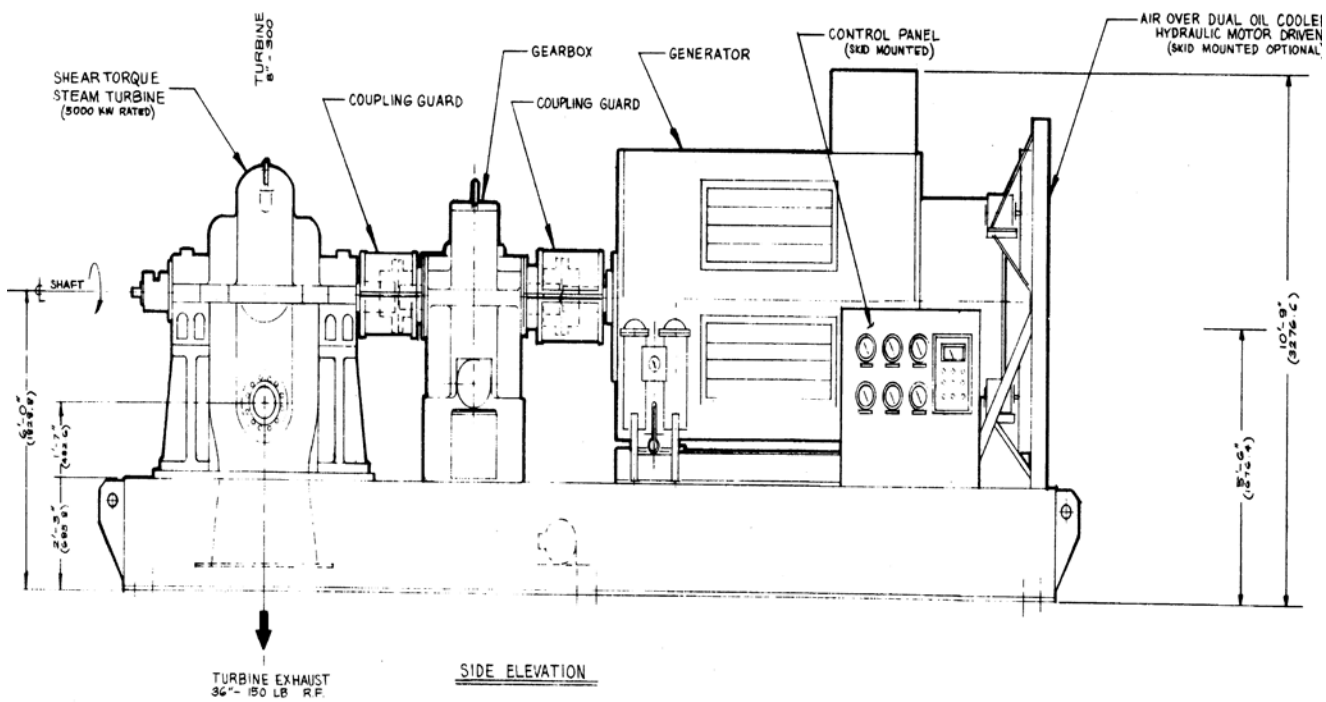
- Smaller units can be produced faster and more economically.
- Locating the turbine at the well head eliminates the long piping runs along with their inherent hydraulic and thermal losses.
- Having the ability to accept the total well effluent eliminates upstream cyclonic separators along with their inherent thermal and pressure losses.
- Turbine can be matched to the well characteristics to provide optimum utilization of the well thereby eliminating pressure regulating systems to balance the pressure of a group of wells to that of the lowest pressure well in the group.
- Maintenance on smaller units is faster and easier to accomplish and does not require large handling equipment.
- Turbine/generator units may be skid mounted to facilitate ease of initial installation as well as replacement in lieu of repair.
- TI's internal components are designed to be interchangeable and modular thereby reducing inventories, reducing assembly time and reducing maintenance down time.

The three factors of most significance to the end-user, when comparing TI's system to conventional systems, are (1) low cost; (2) short lead times; and (3) increased energy output vs. input. These factors

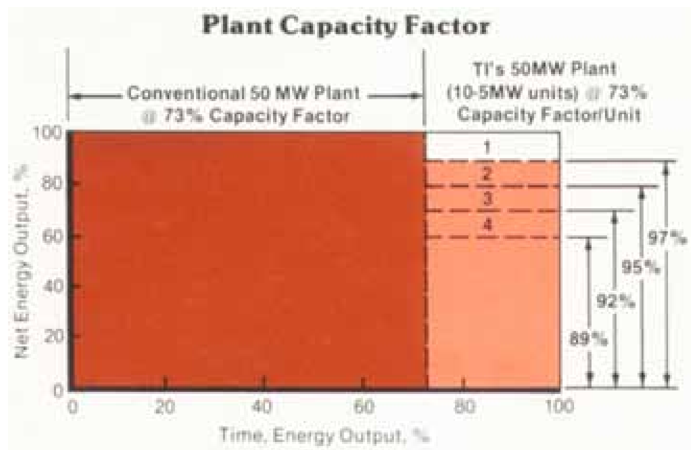


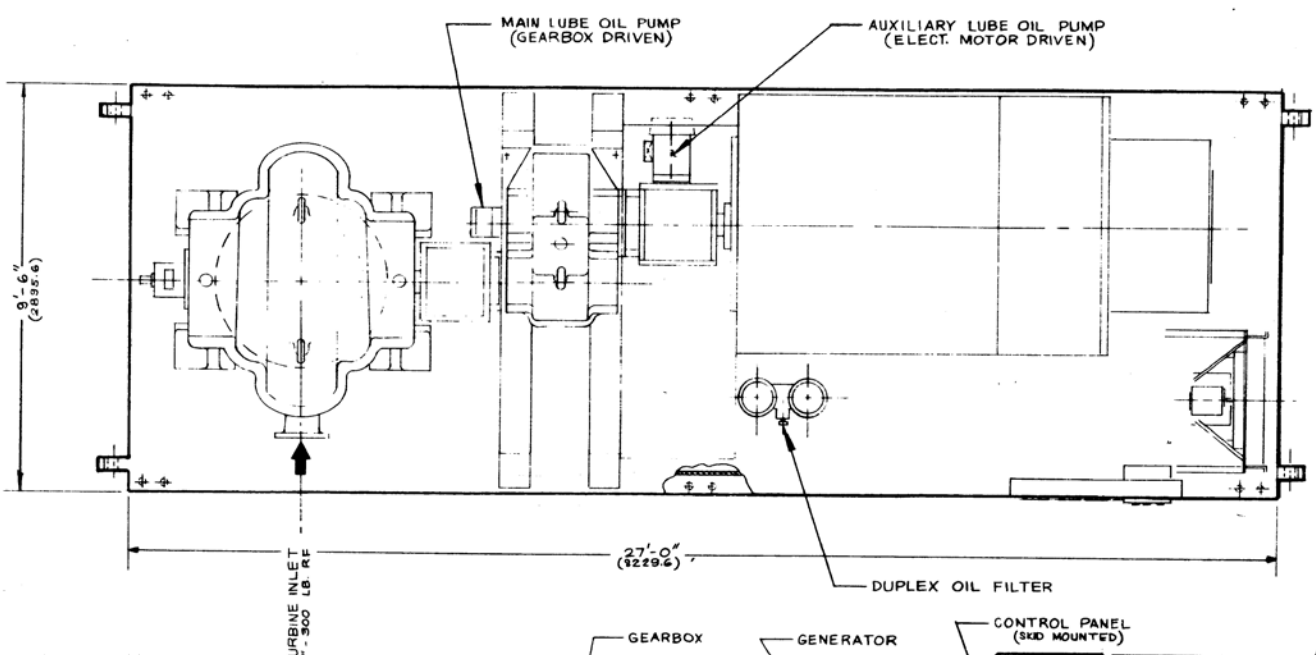


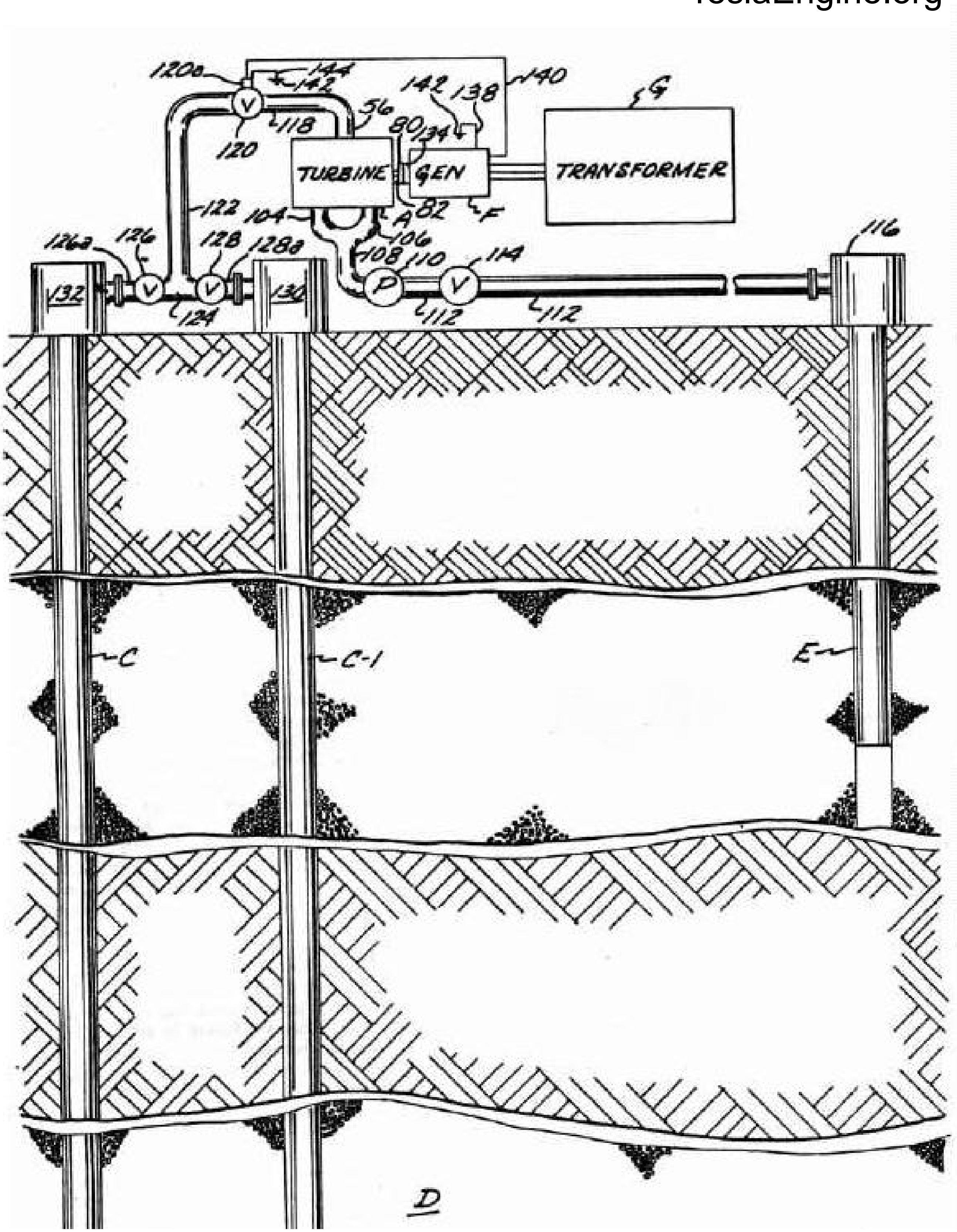
contribute heavily to an attractive rate of return in a short time span. The calculated breakeven of TI's system is approximately six years compared to a conventional system's breakeven of around twenty years. Of course, TI's system can be operational in less than two years compared to seven or eight years for conventional systems. So, from the beginning of a project, TI's system can be installed and completely depreciated in eight years while a conventional system will take 23 years to be installed and completely depreciated.



For more information on attempts to implement 'Tesla's Geothermal Solution' see: TEBA News #24.



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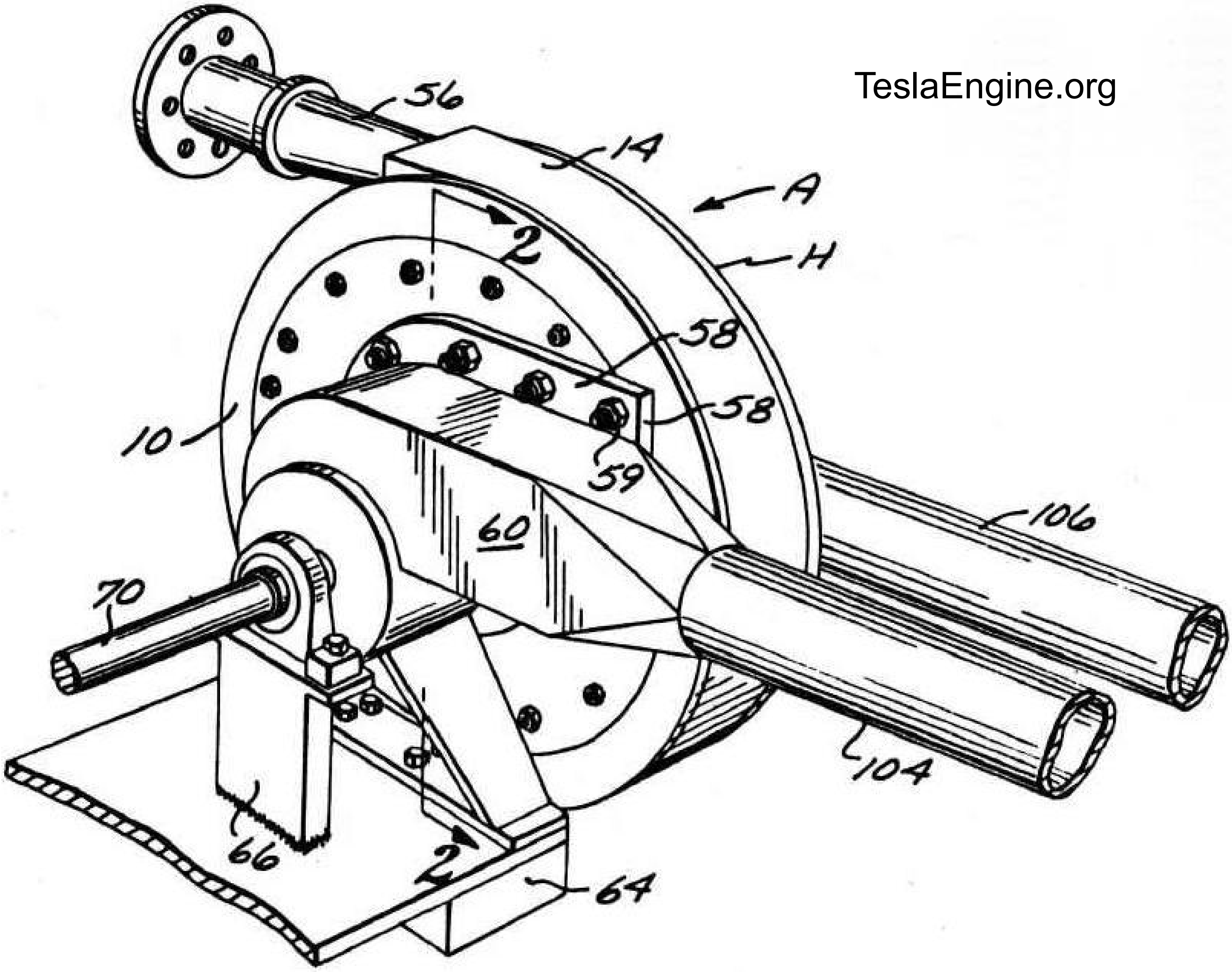

"My turbine is an advance of a character entirely different. It is a radical departure in the sense that its success would mean the abandonment of the antiquated type of prime movers on which billions of dollars have been spent."

Nikola Tesla