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A Concept for Subcritical Nuclear Electricity Production with Control of the Fuel - the "olive frame" Single-piece Core, a Simple Hydropump

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Abstract Fabricating an hydropump using nuclear power permits electricity production at community level. The subcritical nature allows a simple design. The core is built with as little pieces as possible (if possible a single ovoid core, that could be compared morphologically to a giant de-stoned olive, made of a single tungsten carbide frame, and, in addition, the tube for channeling the water that shall be inserted through the "olive" and welded so as to close the "olive" hermetically) and relies on, typically, helium for heat transfer; it is conceived with the purpose of being welded with the fuel in and let for heat production without reopening for several years until the whole machine is shelved after consumption of most of the fuel; in principle that design allows very limited staffing (or none at all, under electronic supervision at a distance). The increased diffusion of nuclear energy would be possible, with for instance community recollection of alpha-emitting nanoparticulates from draft water to recycle the pollution in electricity production for small communities (with fission possibly not even involved - solely alpha decay energy), with the idea that security services would, simply, regularly check the cores to make sure there is no "window" of any kind on the cores.

Keywords: *nuclear power, nuclear fission, electricity production, electronuclear, subcritical nuclear systems, accelerator driven systems, sustainability, nuclear waste recycling, fifth-generation nuclear reactors*

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1. Introduction

The design can be basically presented with an abstract scheme (Figure 1):

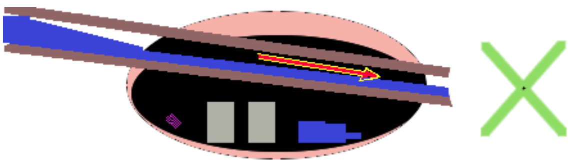


Figure 1.

The phenomenon is described in the following terms: acceleration of water thanks to heat where the heat delivered to the continuing water flow (no cessation of entry of water, top corner left, must happen or cooling of the core will be endangered and issues could possibly happen with the tube) produces a superpowered jet onto the wheel, from which mechanical & electrical power can be simply extracted.

The presentation of materials that have to be inserted into the core (made from tungsten carbide, for instance) is, from left to right a neutron source (for instance Am241 + Beryllium in a small fiberglass box), two repositories of hot materials with fissile included (calculations have to be made by the user depending on the available materials), and possibly some water (or solely helium), altogether it will naturally add energy to the waterflow. A pressure machine (compressor) can be used (and certainly has, to be used, at the beginning, especially if no water is used). More helium will be naturally provided by alpha decay over the years, making the depleted uranium inserted at the beginning progressively more and more useful. A single very small nozzle on the top of the "olive" frame will be used for both water injections into the nuclear core (to improve yield at the depends of depleted uranium use) and for, also, pressurization with a compressor and e.g. air or helium injections.

The design relies also on a setting of the fuel in which the most fissile part of the component is set close to the neutron source, so that the total K_{eff} of the core is well under 1 but *locally, in the area near the neutron source*, 1 is achieved. Depleted uranium has to be located on the outsides, with spacing, to replace progressively the fissile materials. The owners are of course the sole responsibles for finding the good set of materials for the fuel they have at their availability, so for instance:

- 20% of the core is at K_{eff} = 1,

- 60% at $K_{eff} = 0,2$
- and 20% at $K_{eff} = 0,05$

so the general K_{eff} of the core is of 0,33 (see [1] for demonstration of why this general result is the expected one).

As concerns metrology it is recommended to watch the working of the olive core in the atmosphere chosen for the energy production process while shutting down lights of the work area totally and taking also into account magmatic activity underground for comparison with precise gamma emission of the soil, the principles on small lights of Bose-Einstein condensation compression from gamma emission may help indeed, see the comparison with the example given in [2], this helps detecting nano-sized leaks of alpha-emitting materials laying on ground.

2. More Engineering Considerations

The stability of the design relies also on the building where it is set, strong supports and strictly no oscillation. It is advocated against systems of pumps to bring in and extract the water, the hydropump (the design) should be set along a river or waterfall and follow its flow (see example in next part). Indeed clogging may happen if the system is set with need for water extraction bringing it above the axis, should the extractive pump after the reactor fail. Permitting simple tube entry of water without anti-fish grid also seems more reasonable as, with a grid at the entry point, objects (clusters of tree leaves for instance) could clog and stop the water flow leading to some overheating at core-tube interface and possibly a leak if there is no rapid human intervention.

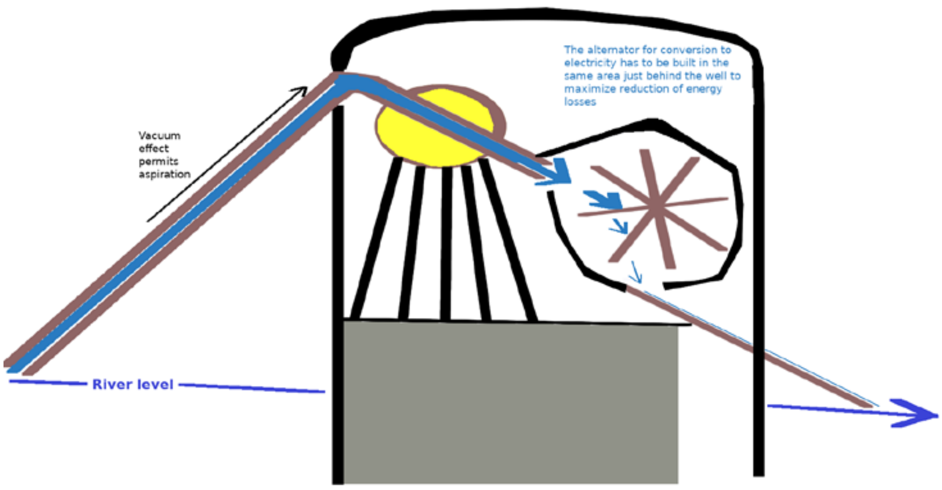
The design is akin to a subcritical pressurized water reactor, the acceleration under pressure *in descent* prohibits entry into boil state, *the water becomes partially supercritical however*, this is the basic principle of working of this subcritical nuclear power source, its energy is entirely channeled onto the wheel.

A crucial point is to take care of the thickness of the “olive frame” to avoid heat losses, ensuring all the heat output is directed onto the water passing in the tube [1].

3. A possible Application: Fessenheim

The Fessenheim nuclear plant (Figure 2 presents a rapid visual summary, the pipes plunging on the Rhin would not have the same angle as drawn on the summary) would simply require the construction of an upper floor in one of the concrete bunkers where the design would be laid. Preliminary pumping-up of water with a tube set and entrying from outside, reaching said upper floor, taking water from the Rhin allows feeding of the design and water elimination. In this application the main proposed use of the reactor is destruction of long-lived transuranics, with preliminary loading with important amounts of helium and reduction of water amounts. A particle accelerator for spallation onto a lead window could be used but a group of Am241 + Be neutron sources are nevertheless enough, with very slow taking off to be expected or, alternatively, inclusion of some more reactor-grade plutonium or highly enriched uranium to fasten take-off of the depleted uranium & transuranic fertile waste component of the fuel. Simply said, the design will become a natural pumper and can be managed with the single tool of e.g. air injection with a compressor onto the subcritical core to pressure it and increase yield (becoming a mix of air, helium and water vapor in addition to long lived waste).

To start the process, the “olive” frame should be welded with its tube, the fuel having been inserted already, no coolant however, some water will be injected through the top nozzle whereas, *at the same time (whereas some water is injected to prop up fission with thermal neutrons)* the initial pumping takes place so the fission yield rises progressively whereas water passes through the tube and initiates the vacuum effect at river drain point. As the pump is taken out when a sustained vacuum effect is achieved thanks to fission in the core, helium can also be injected through the same nozzle to a certain degree to create a water-helium mix and improve depleted uranium use.



The very strong magnetic field in the alternator (a magnetic field anteriorly decided based on the maximum power achievable with the accelerated water jet) is in itself the main cooling system. Derivative water channels with supplementary tubes and supplementary wells & alternators to collect more heat from the top of the subcritical core have nevertheless to be added to maximize thermal efficiency (they have not been integrated in this simple scheme).

Figure 2.

At a theoretical level, *the entire concept amounts to a rise of water if there are no leaks, i.e. if the entire tube from river drain point to wheel point is hermetical, so this amounts to the normal behaviour of water under heating even though the core part is in a descending direction, because the wheel itself is well above river drain level. The combination of the path of descent for the water before the core, and of the acceleration to that gravitational descent of the water that the core heat provides, produces a permanent aspiration process in the hermetical setting that allows both draining from the river and energy production with the wheel on the other side.*

A spiral design for the tube inside the “olive” would also allow for more heat capture, improving the efficiency of the machine. This is of course strongly recommended to demultiply the efficiency.

4. More Considerations

The electricity / energy output sees small variations depending on the conversion time between neutron capture by U238 and decay (U239 to Np239 to Pu239). It is reminded that insertion of neutron sources is the prime control of the core and that more such neutron sources can be inserted in case yield is too low.

This kind of design could be widely used, including by small communities, it remains that the use of depleted uranium involves plutonium-239 production and so, the essential point of a single frame core together with absence of window is that it allows for *recycling of depleted uranium into energy* without the risk that mischievous people would regularly open the cores to take the Pu239 and use it for e.g. terrorist purposes.

In community applications where the alpha emitters from e.g. draft water in areas of high natural radioactivity (after centrifugation) are used and only limited amounts of fissile materials are available (if any), it will be required to *isolate strongly the electricity production area (and distribution networks closeby) because of the strong accumulation of positive charges in the core*, to avoid capture of the electricity by the core itself. All forms of radioactive decay are energy and alpha decay (sometimes defined as a *quasi-fission...)* is particularly useful for electricity production because of its localized “effection” area (short Bragg curve) - the resulting vibrations, together, in a core, in combination thanks to the use of the tungsten carbide core that already is a pressurization system will be changed into energy by the tube system.

For tungsten carbide olive frame production, “lost wax” casting (with a sand equivalent of wax able to withstand the particularly high temperatures needed, a ceramic sand for instance) should allow the production of single piece “olive” frames without any welding on any side, for perfect long-term resilience.

It is reminded that the entire olive cores could be stolen at some time if badly managed and handled as dirty bombs after being surrounded by explosives, requiring utmost harshness of monitoring measures by security forces.

The water going out of the core and reentering the environment would certainly have some degree of higher temperature than the entrying water (1-2% accidentally) which is why the living fauna in the riversystems used for such installations is expected to learn spontaneously to live in the rejection area for water and avoid being caught and killed in wheel sector.

References

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[2] F Pirot, Alpha-Emitting Nanoparticulates and Their Various Physical Effects: More Case Studies in Laboratory Research and History. Applied Mathematics and Physics. 2020; 8(1): 1-7.