



# Electric machines with liquid metal working body

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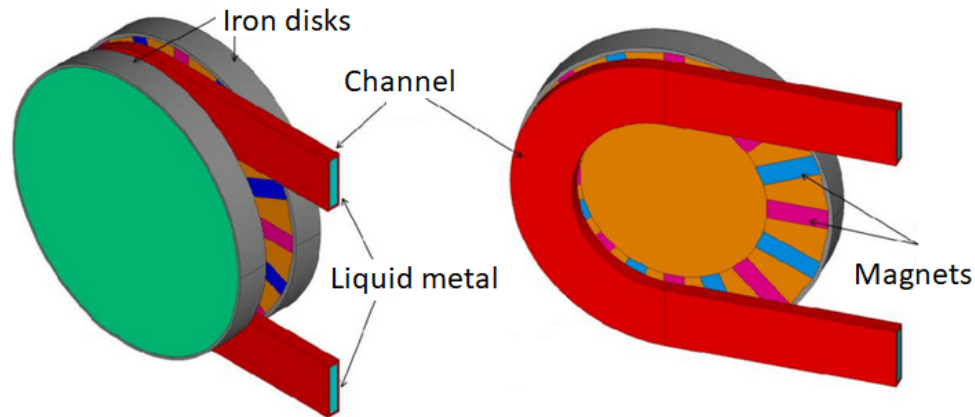
4th year Electrical engineering PhD student – RTU (Riga Technical university)

# Content of dissertation

- 1) Research of disk type electromagnetic pumps on permanent magnets for pumping liquid sodium
- 2) Thermoacoustic-to-MHD generator investigation

# Electromagnetic pumps

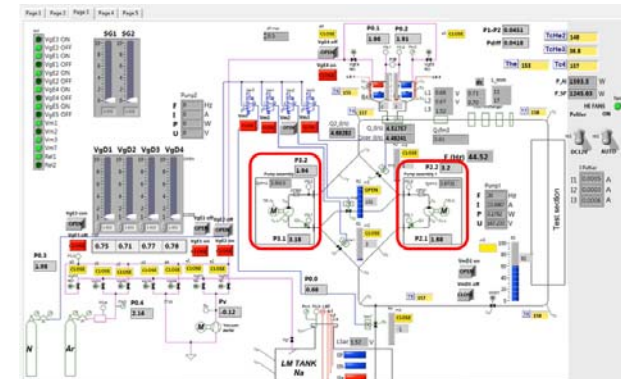
Investigated electromagnetic field configurations both numerically and experimentally.



Proved, that solid-body and inductionless approximation is acceptable to get a good p-Q characteristics, that fit well with experiments.

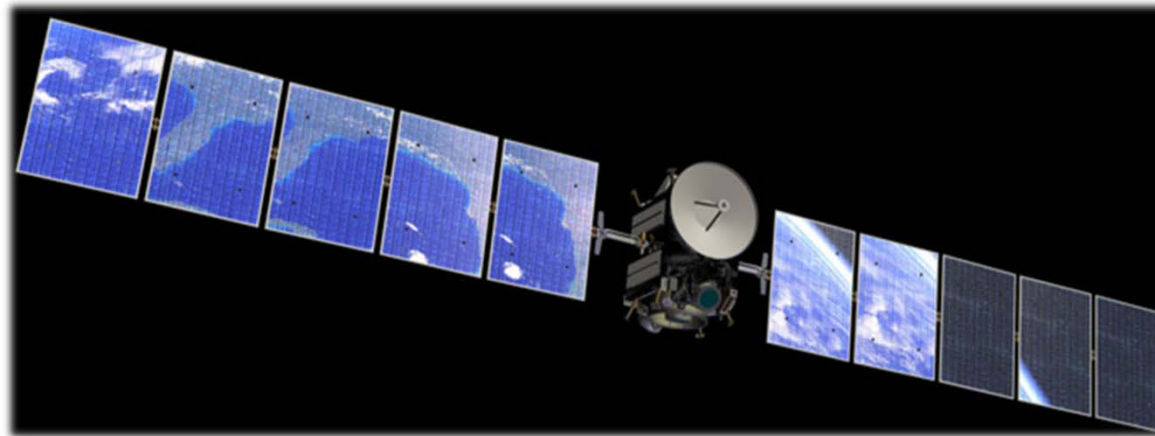


A new liquid sodium loop with intelligent pump control system built in IPUL during 2020



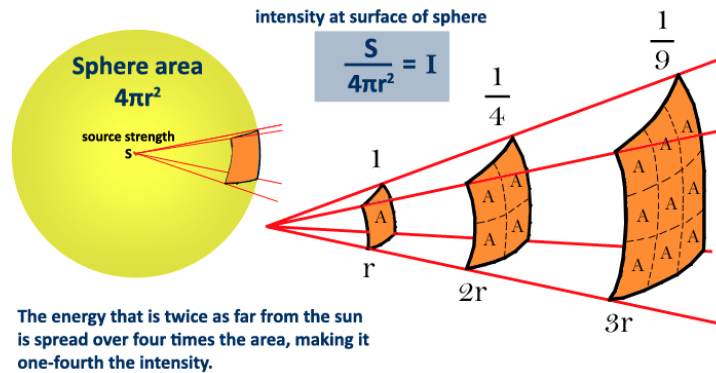
**Patent acquired!**

# MHD power generation



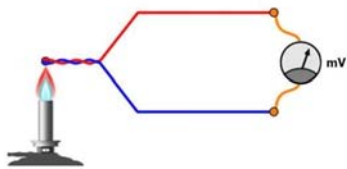
Now let's jump a little bit from Earth nuclear reactors to the Space exploration....

# Source of energy in Space



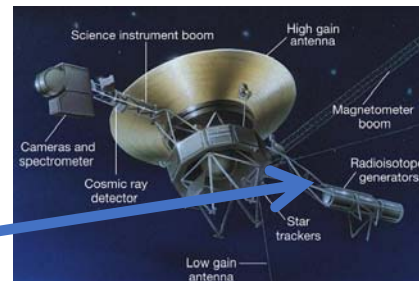
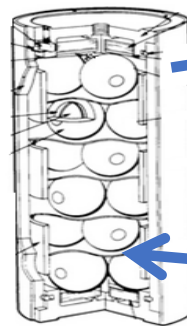
So, for example, in Jupiter orbit the surface area of solar panel would need to be enormous

Alternative – radioisotopic power source  
Advantage - high power capacity

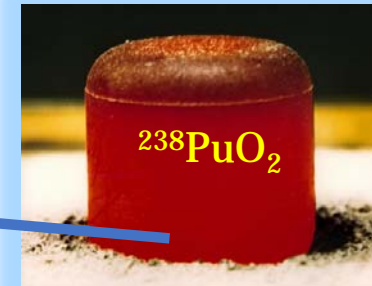


Used array of thermocouples

But efficiency of thermoelectric generator – less than 4 %



Voyager-1 (1977 start – and still operating)



# What does SpaceTRIPS propose?

To stay with nuclear energy!

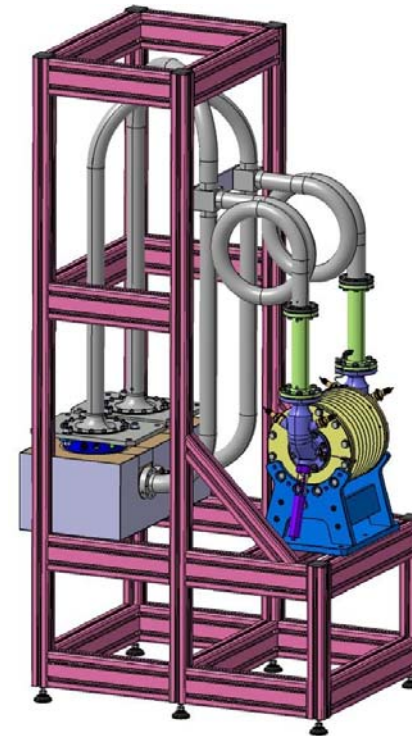
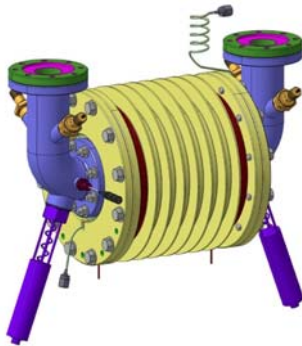


**Alternating current  
magnetohydrodynamical  
(MHD) generator**

+

**Thermoacoustic  
(TAc) engine**

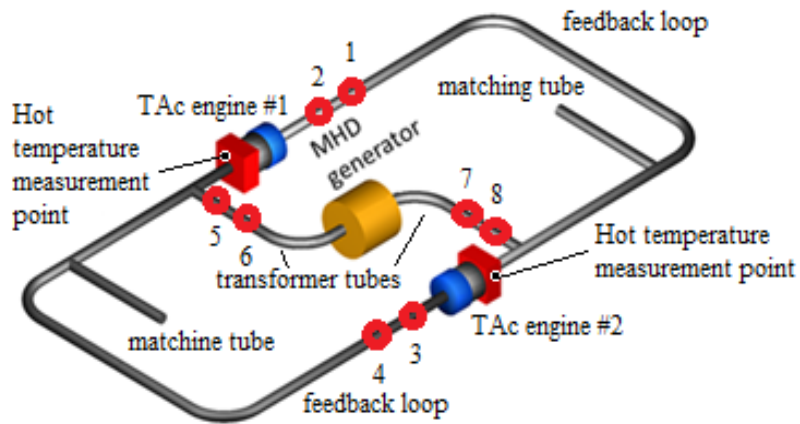
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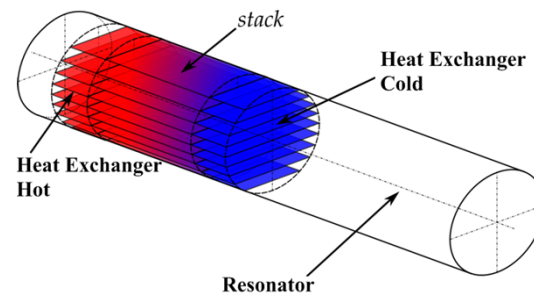
Potential use – satellite electrical power supply for deep Space flights far away from sun

Energy source in Space – radio-isotopic power source. Americium, 1200 °C.

# What does SpaceTRIPS propose?

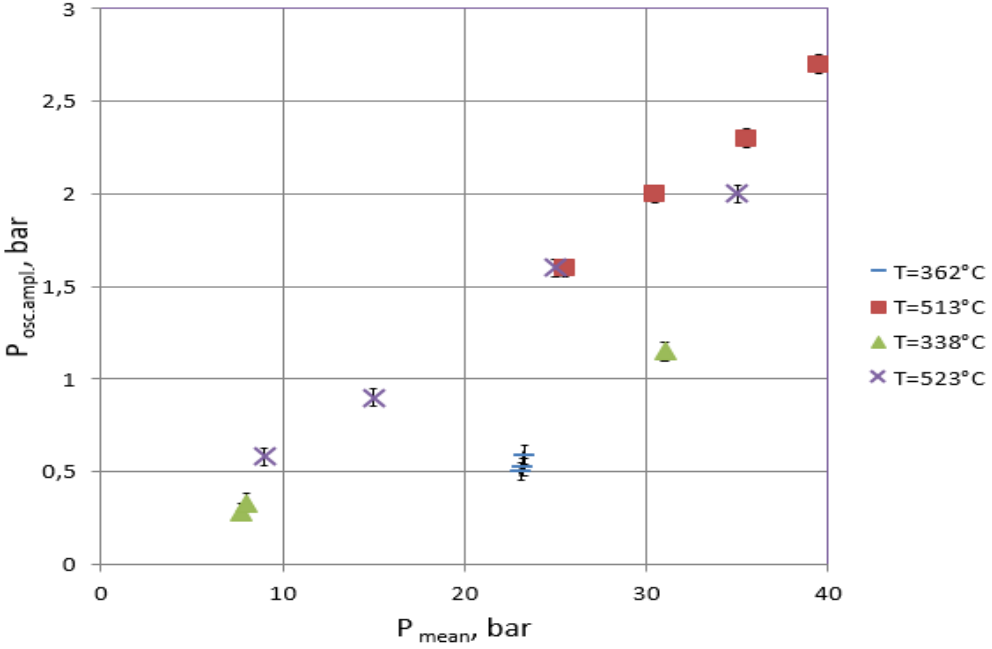


## Simplified design, but concept remained

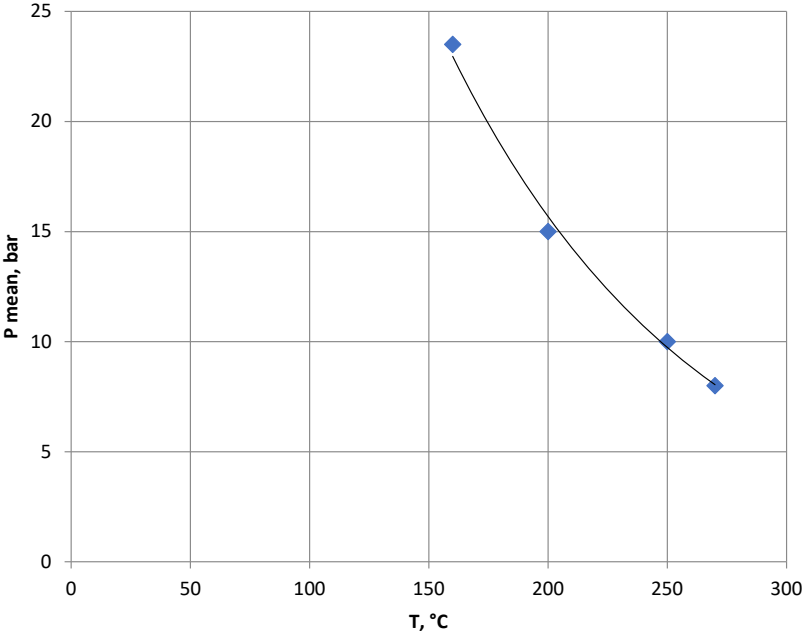


Thermoacoustic effect in a pipe with limited distance – induction of sound wave

# Thermoacoustic engine (TAc) experimental test results



Pressure oscillation amplitude as a function of TAc mean pressure



Critical excitation curve

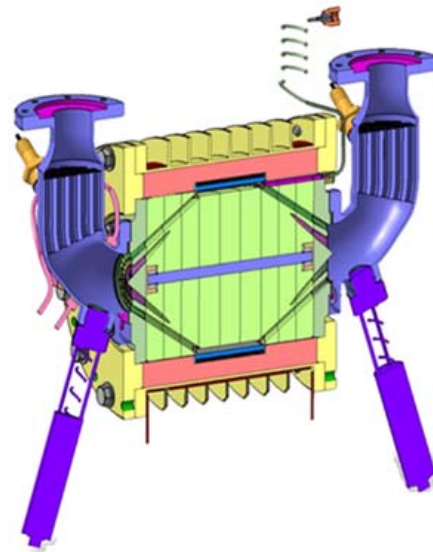


# AC current MHD generator

$$\eta = \frac{P_2}{P_1} = \frac{U \cdot I}{P \cdot Q \cdot \cos\varphi}$$

Liquid sodium oscillations in magnetic field induces currents, which creates secondary magnetic field, which induces an EMF in coil.

Axial symmetric construction



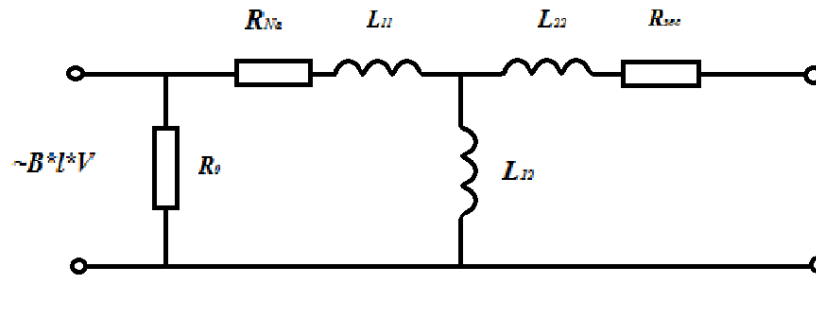
Diameter: 200 mm.

Characteristics:

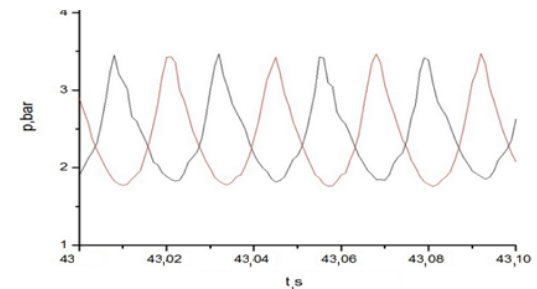
- Temperature of sodium: 150°C;
- Oscillation amplitude:  $\pm 25$ mm;
- Frequency: 45Hz;
- Input power (from TAc): 1 kW;
- Output power: 200W;
- Mass of sodium: 480 g.



Equivalent circuit:



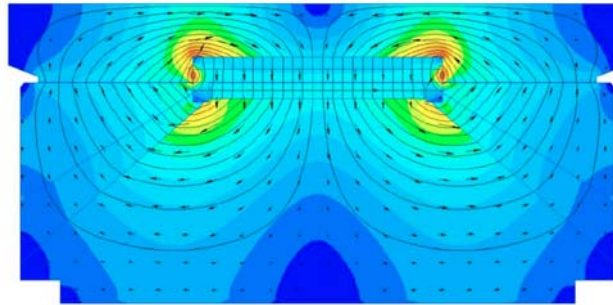
## Experimental pressure oscillations in liquid Na experiment:



# Two dimensional approach

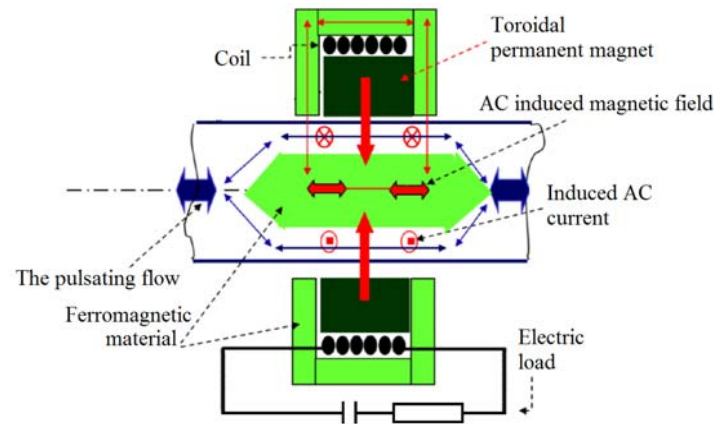
MHD generator magnetic field – complicated and consists of:

- 1) Permanent magnet magnetic field (DC)
- 2) Sodium current magnetic field (AC)
- 3) Transformer coil current magnetic field (AC)



$$j = \sigma[B(x) \times v - E_v(x) - E_U(x)]$$

Even more complicated - if take into account an armature reaction



# Conclusions

- Liquid metal free surface existence is present, that leads to hydrodynamic instability. However, some solutions are possible!
- Thermoacoustic-to-MHD generator is a quasi static solution so it can be a good energy converter option for applications where safety is prior. Not only in Space, but potentially in future also for implementation in Earth applications!
- In total – 7 publications published (4 in SCOPUS/WoS)

Thank you for your attention!