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Excess Energy from a Vapor Compression System

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Personal experience

- **Background**
  - Mechanical engineering (National Taiwan Univ, 1972)
  - Mechanical/chemical engineering (Case Western Reserve Univ/USA, ~1976): thermal/fluid sciences, aerospace engineering, transport phenomena
- **Research Interest [Energy Engineering after 1976]**
  - Before 1976: science of aerospace, heat transfer, fluid mechanics, transport phenomena [as a **Scientist**, first paper published in Nature (1976)]
  - Since 1976: Energy engineering. As an **Engineer** looking for new energies, including:

    (1)**High energy efficiency technology**: heat pumps, ejector technology, air conditioning and refrigeration, LED lighting etc

    [an ejector paper is cited 577 times which ranks No.1 in *Int J Refrigeration*]

    (2)**Renewable energy technology**: solar PV power, micro-grid, solar thermal

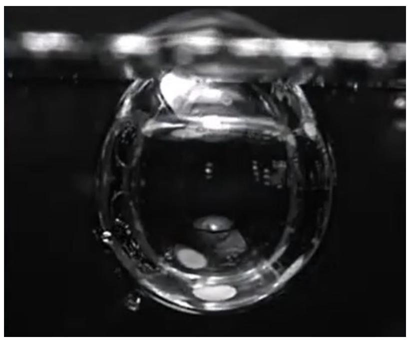
    [an PV/T paper is cited 478 cites which ranks TOP25 in *Solar Energy*]
- **New research interest (the last before retirement in 2021):**
  - **Cavitation-involved (or LENR) energy technology** (since 2018)

Content of presentation

1. Cavitation and cavitation-induced Low Energy Nuclear Reactions (LENR) – a review
2. Two Interesting Cases of COP > 1 in Commercial Equipment
3. Commercial aspects of vapor compression system with COP>1
4. Conclusion

1. Cavitation and cavitation-induced Low Energy Nuclear Reactions (LENR)

- **Cavitation Phenomenon**
  - the process of vaporization (at a pressure lower than thermodynamic vapor pressure) which generates bubbles and creates implosion with intense shock wave etc.



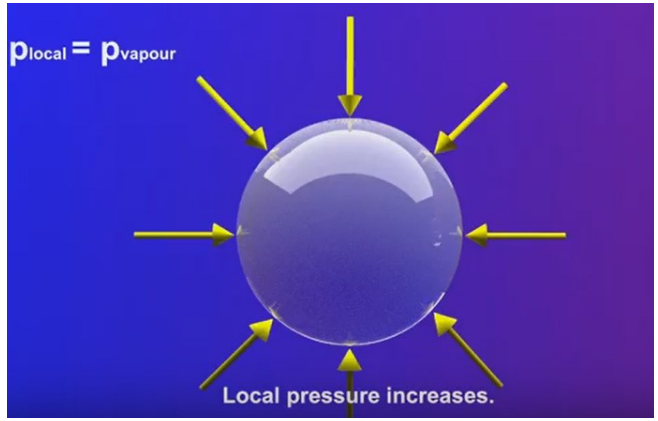
Vapor bubble formation and growth

No growth and Surface breakdown

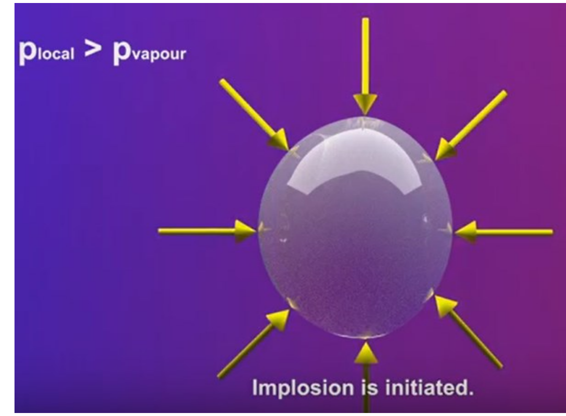
Bubble collapse with compression shock wave (Implosion)

IET Institute for Energy Technology, HSR, Rapperswil, Switzerland

Vapor bubble formation and growth

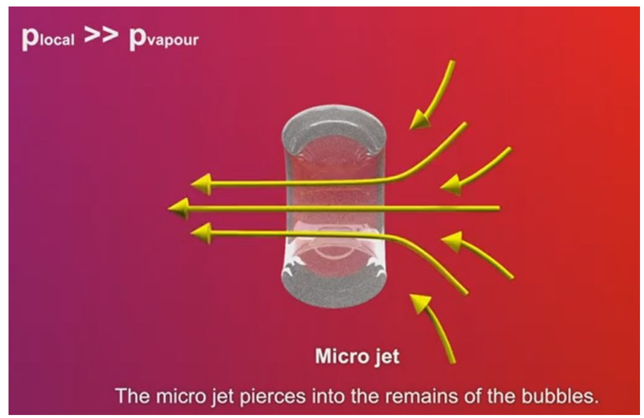


No growth



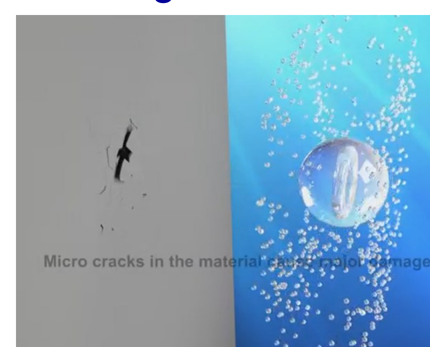
Surface breaks down at weakest spot

Water flows into the vapor volume



Micro jet

Damage to wall

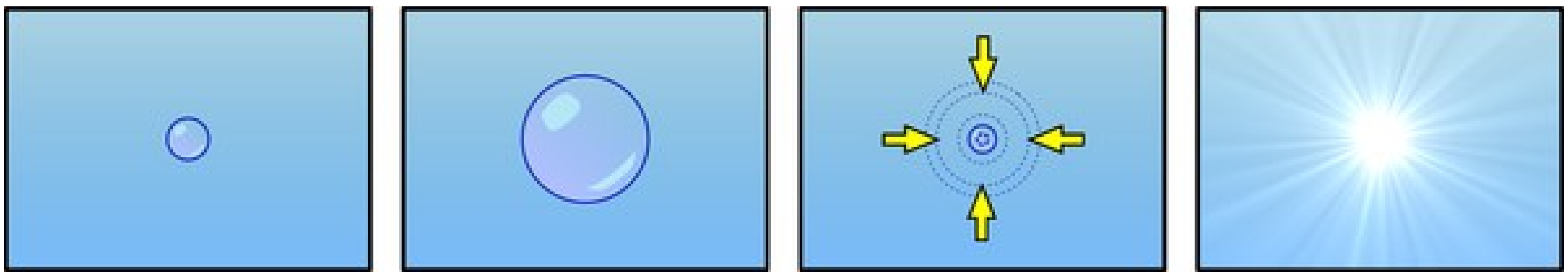


Ref: IET Institute for Energy Technology, HSR, Rapperswil, Switzerland

- **Cavitation-induced Low Energy Nuclear Reactions (LENR) ?**

  - **Sonoluminescence** (1934)
    - a LENR might occur inside extraordinarily large collapsing gas bubbles created in a liquid during acoustic cavitation.

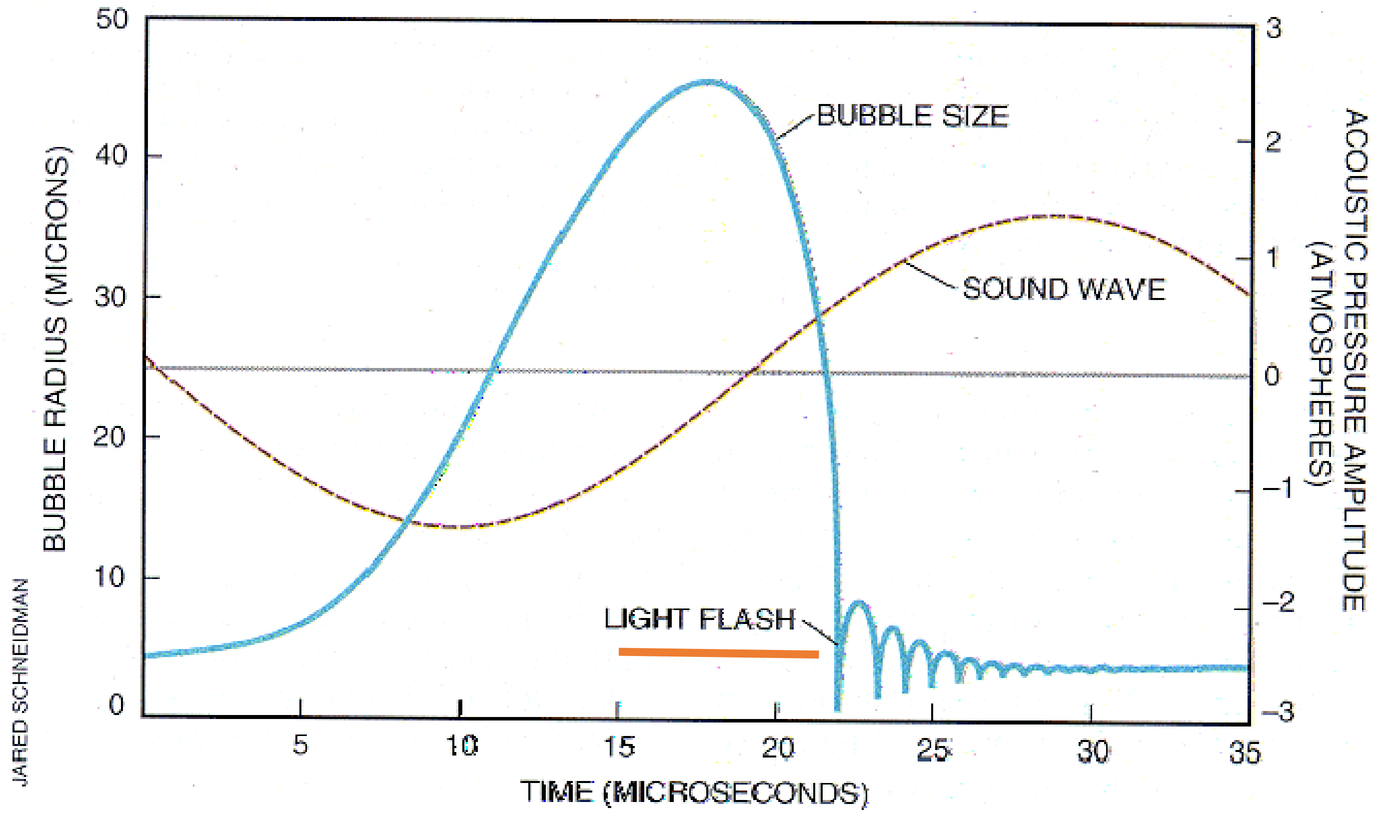
Alan J. Walton, Geo. T. Reynolds. Sonoluminescence. *Advances in Physics*, 1984, Vol. 33, No. 6, 595-660



formation of bubble	bubble growth	quick and sudden contraction (implosion)	**Sonoluminescence**

• Sonoluminescence

- first found by H. Frenzel and H. SchulteS, University of Cologne (1934)
- light flash generated by micro-bubbles
  - short time: 50 x 10^{-6} second, with low energy: 1~10mW at temperature 2.300-5.100K



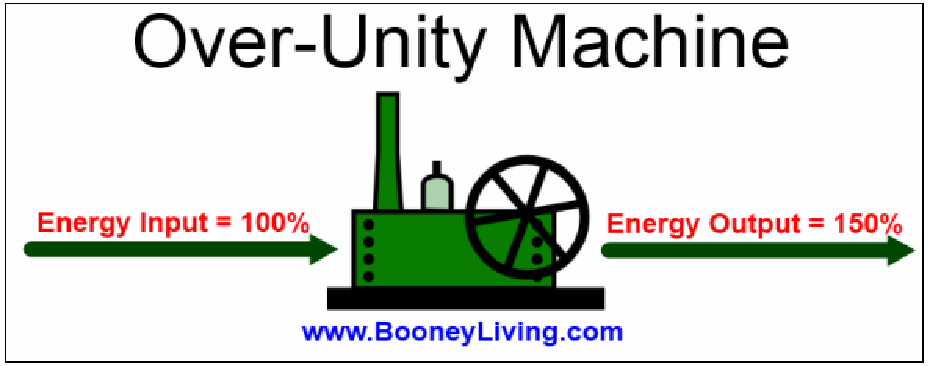
Fast growth of micro-bubbles up to 40 µm in 20 µs and then collapse

Pressure inside micro/nano-bubbles

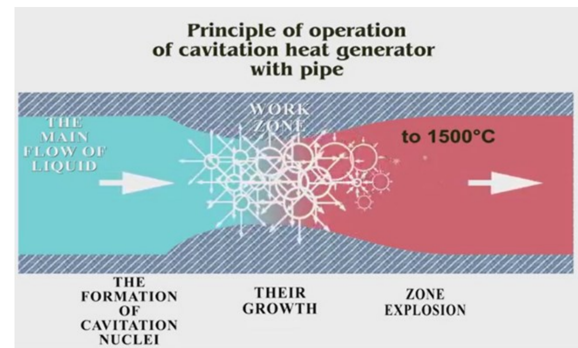
$$P_i - P_o = \frac{4\gamma}{r}$$

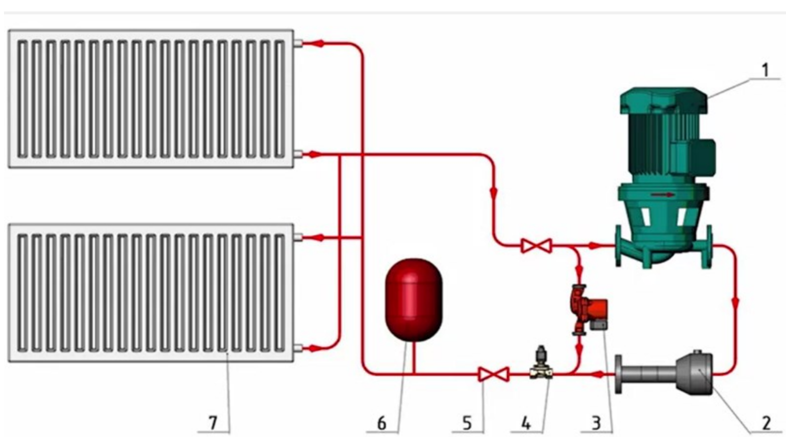
Diameter (2*r*)	△P (Pa)	atm
1mm	291.2	0.00287
500μm	582.4	0.00574
100μm	2,912	0.0287
50μm	5,824	0.0574
1μm	291,200	2.87
100nm	2,912,000	28.7
10nm	2.912×10^7	287
1nm	2.912×10^8	2,870

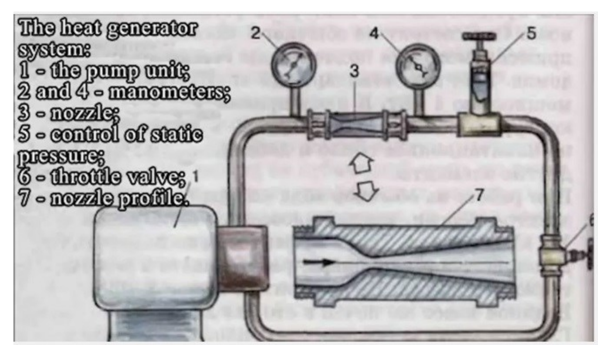
Some interesting phenomena found in internet



Ukrainian scientists



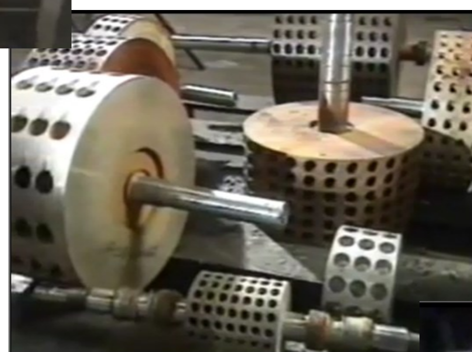


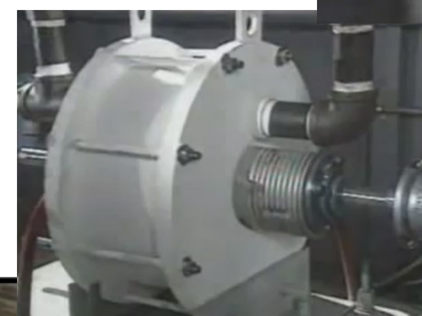


Cavitation heater

in high-vortex flow

COP=1.7



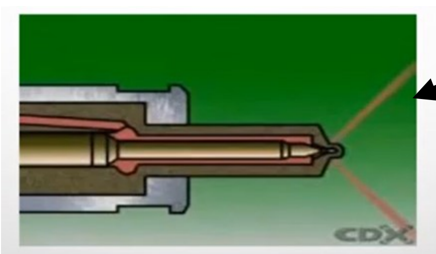

https://www.youtube.com/watch?v=Ji0GAt-q2EM&list=PLZk-jCLezj9hltBOsOUtri4W_71MbX8xU&index=14

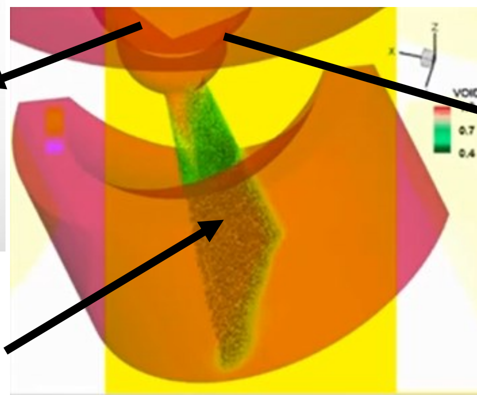
Cavitation engine

CONTROLLED CAVITATION ENERGY STEAM GENERATION (CCES)

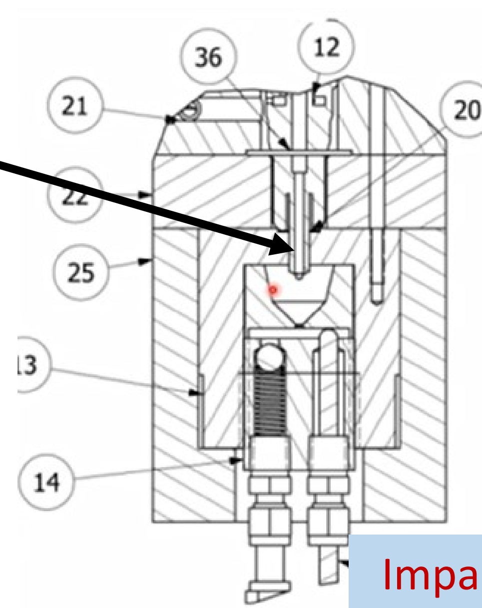
Cavitation Energy Systems, Inc.

- **Hydrodynamic cavitation: using conventional automotive fuel injector technology to inject a high-pressure water (20,000~25,000 psi) into a chamber to create LENR**

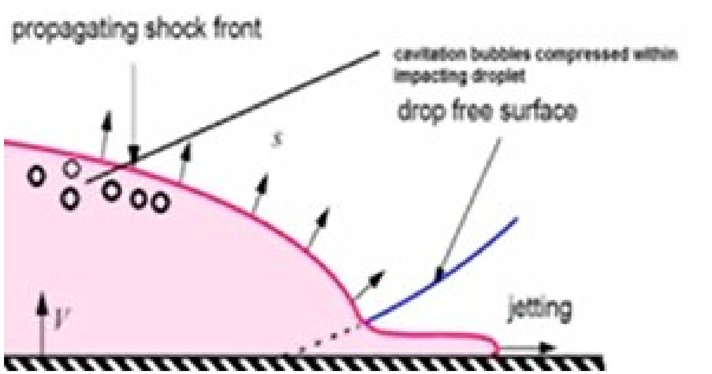


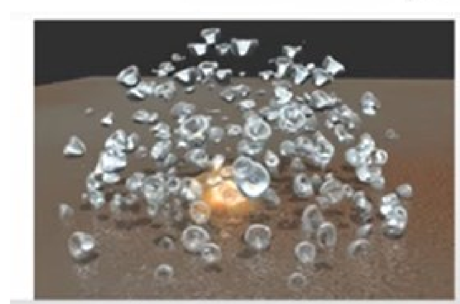


Ejection is saturated with cavitation micro-bubbles which collides with the wall.



Impact Chamber





Measured COP= 5.25 @388 ºC

Single Impact Chamber Energy Measurement

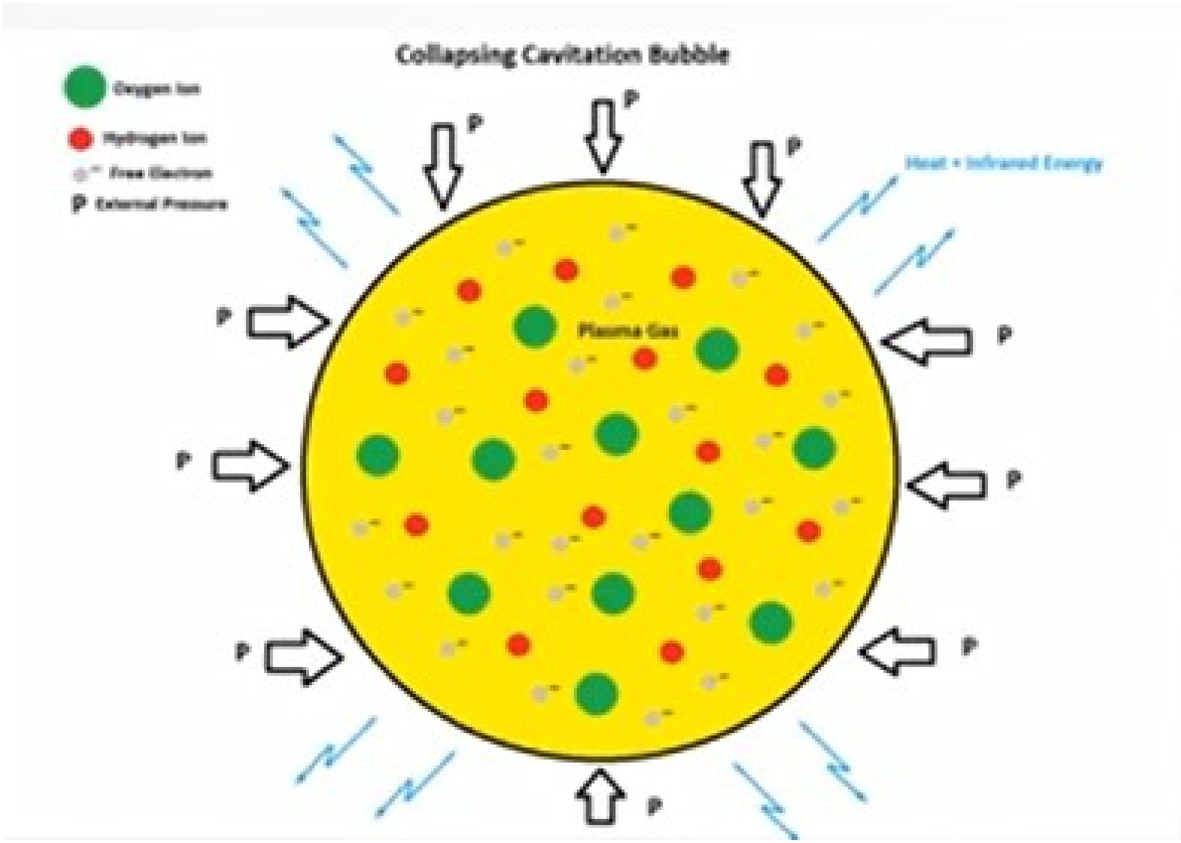
The following table summarizes the results.

Test Duration	Chamber Temperature	Heater	Volume (ml)	Injection Rate	Total Volume (L)	Total Steam Produced (lbs) @ 388
60 minutes	388 degrees	2 at 500 watts	0.275	5/sec	4.95	10.89

Component	Input Energy KWh	Output in BTU (1250 BTU/lb)	Output in KW	Steam Output/Electric Input Ratio
Water Pump	0.39			
Hydraulic Pump	0.19			
Heaters	0.21			
Electronics	0.0001			
Total Energy	0.791	14157	4.15	5.25

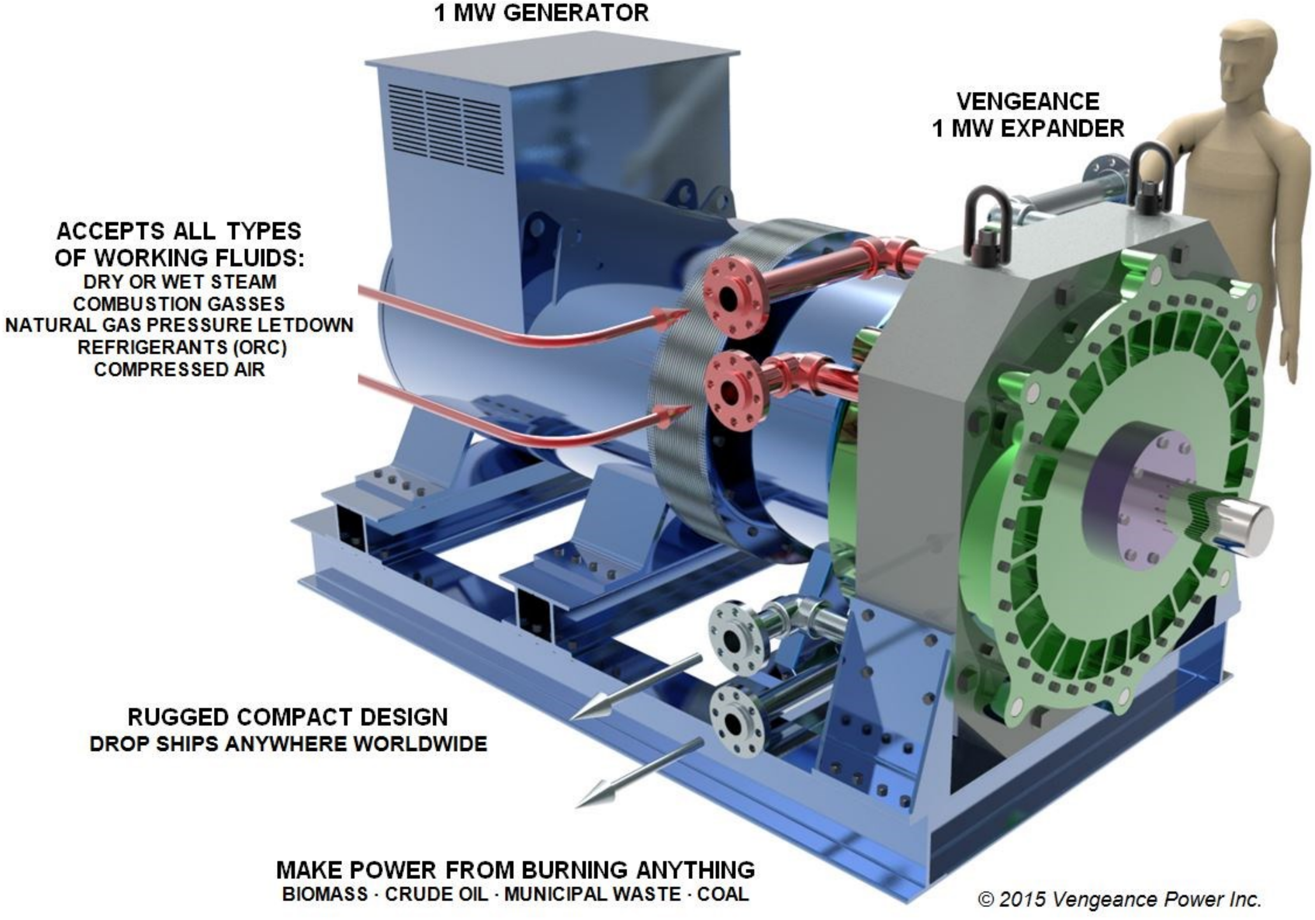
Two postulates of CCES:

1. thermolysis occurs within collapsing cavitation bubbles
2. plasma gas momentarily exists within collapsing bubbles. Hydrogen and oxygen ions surrounded by free electrons.



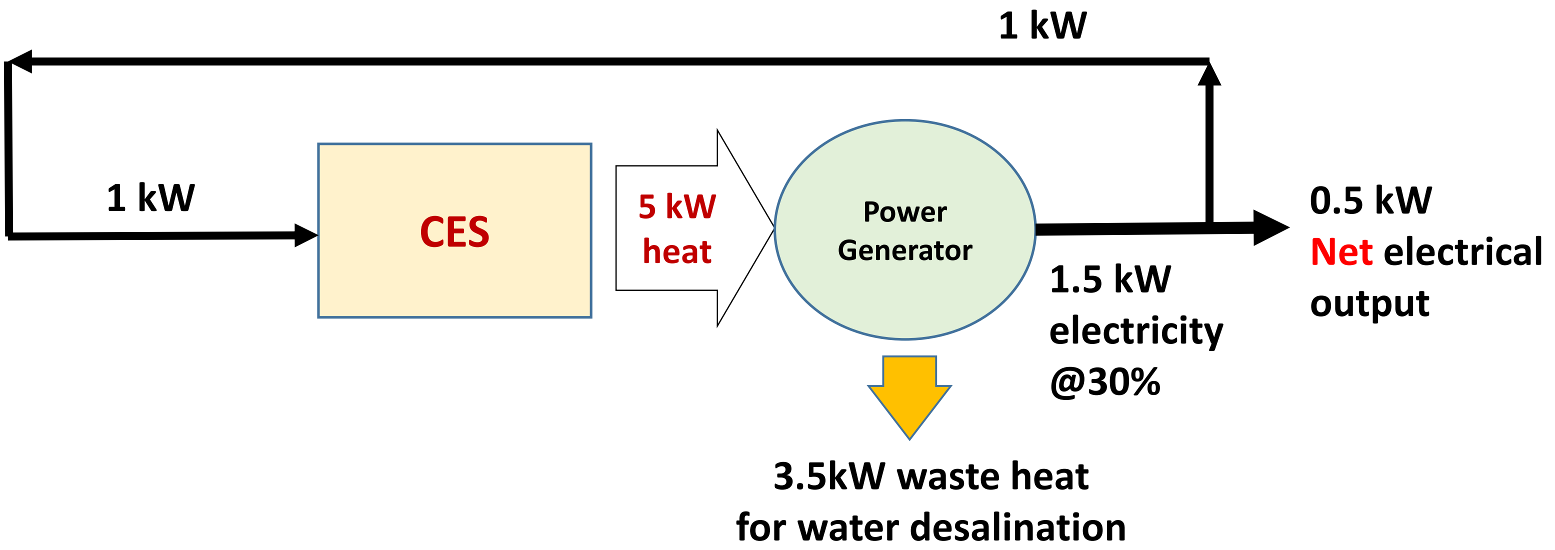
CES driven power generator

1 MWh Expander using 9,400 Lbs of steam/hour at 600 psi and 750 Degree Super Heat
Designed to run at 300 rpm and overdrive 5 to 1 to turn a 1MWh generator at 1500 RPM for 50 hz



An energy revolution with this result ?

COP= 5.25 @388 °C



- Doubts from common sense?
  - Energy Production Cost ($/kWh) ?
  - Need COP >>5 ?

2. Two Interesting Cases of COP > 1 in Commercial Equipment

(1) Pollution-control equipment

(2) Hydrogen-rich water making machine

Found COP > 1 just by chance

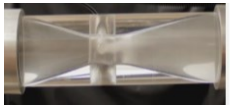
Case 1: Micro-bubble heater in pollution-control equipment (Company A)

Related to phenomena of cavitation, micro-bubbles

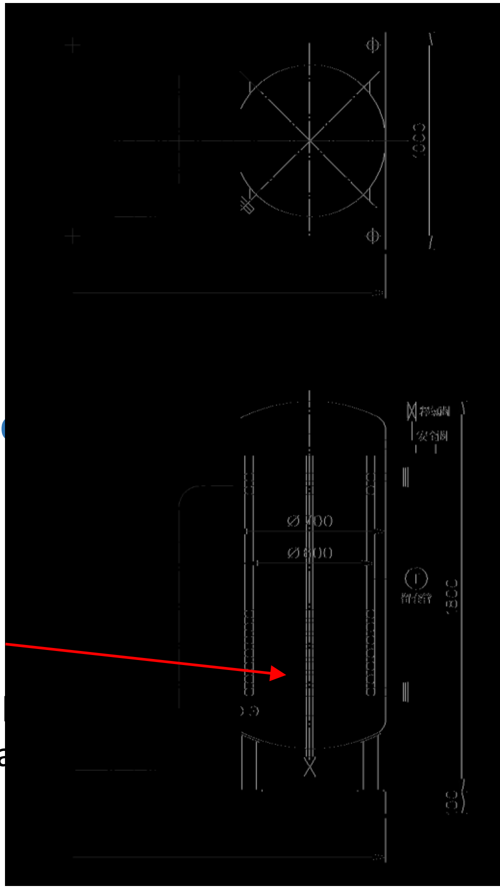
- Storage tank: 500L
- Power input:
  - Electrical heating power: @12KW x 3 = 36 kW
  - Hot water circulation pump: 2.3 kW
- Micro-bubble generator: Venturi Tube
- Output water temperature: 90°C
- Total heat output: 80,000 Kcal/HR (93 kW)
- Operating pressure: < 1 ATM (ambient)
- COP > 2.43

- Operating phenomena:
  - Noisy
  - Output temperature > 100°C
  - COP > 2.5

Electri

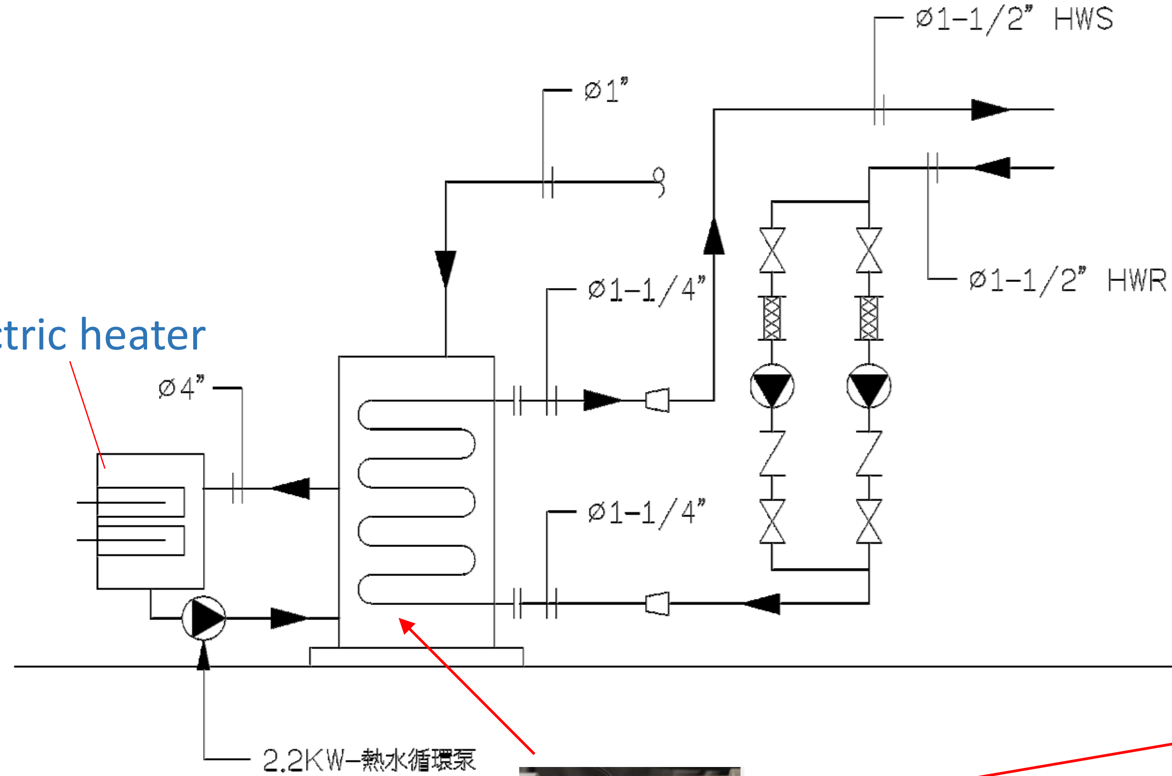


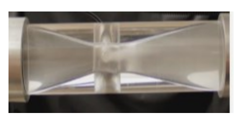
Cavitating Venturi Tu
(micro-bubble genera



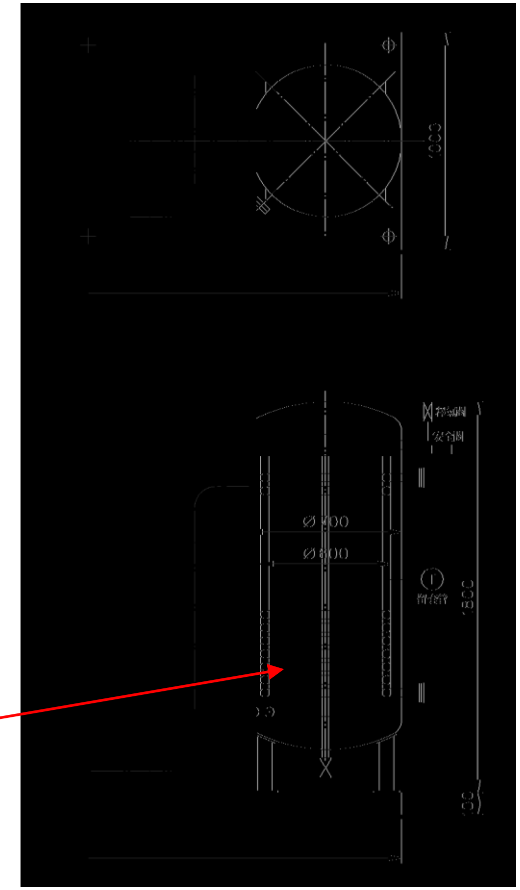
容氣式水加熱器

Electric heater

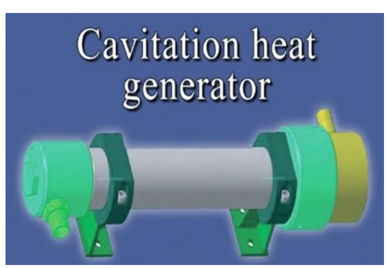


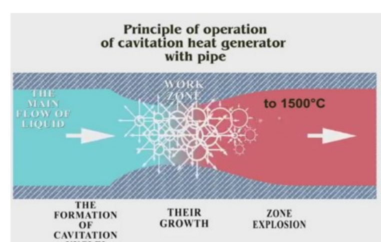


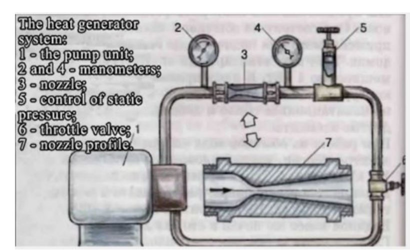
Cavitating Venturi Tube
(micro-bubble generator)

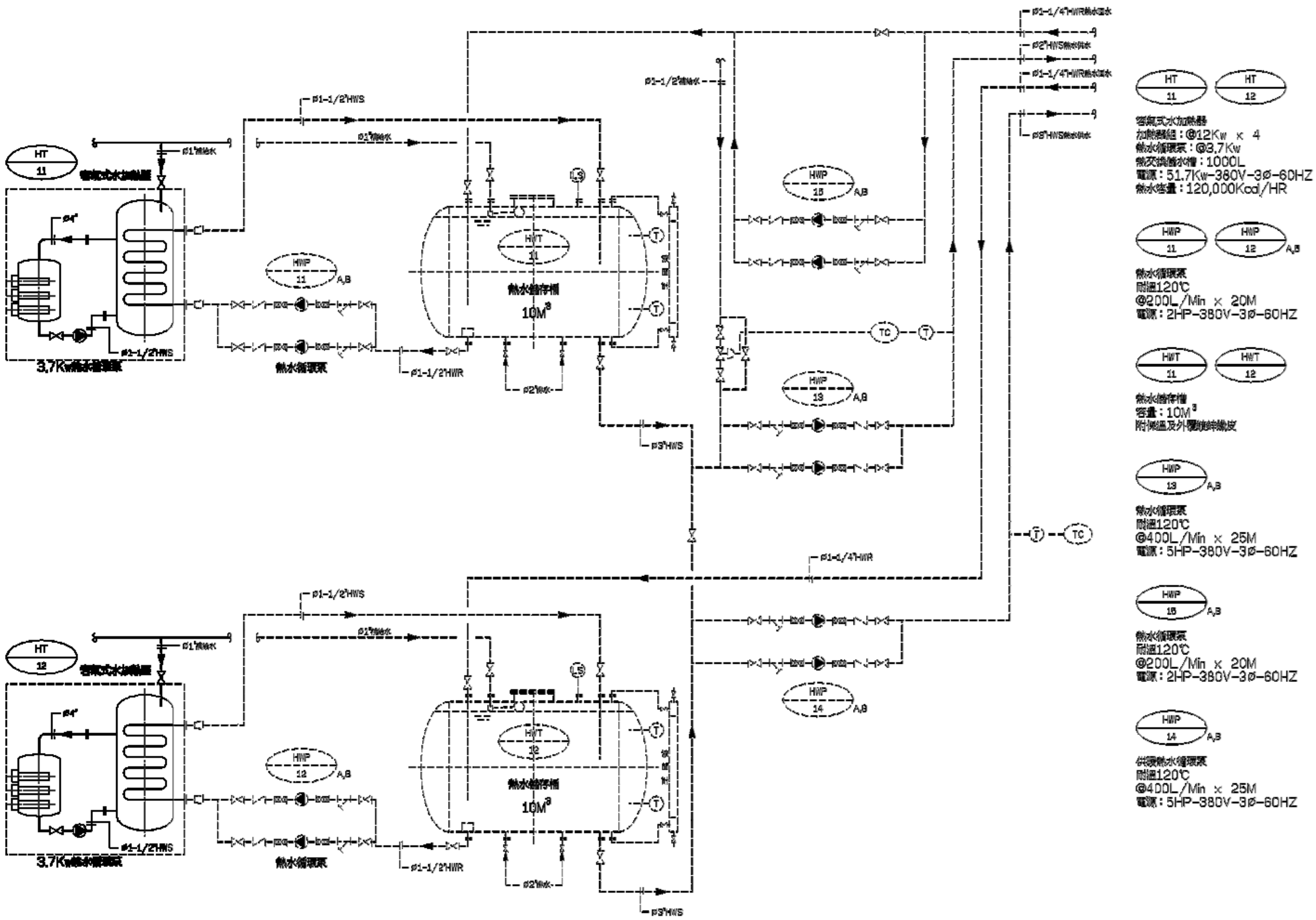


Similar to Ukrainian machine





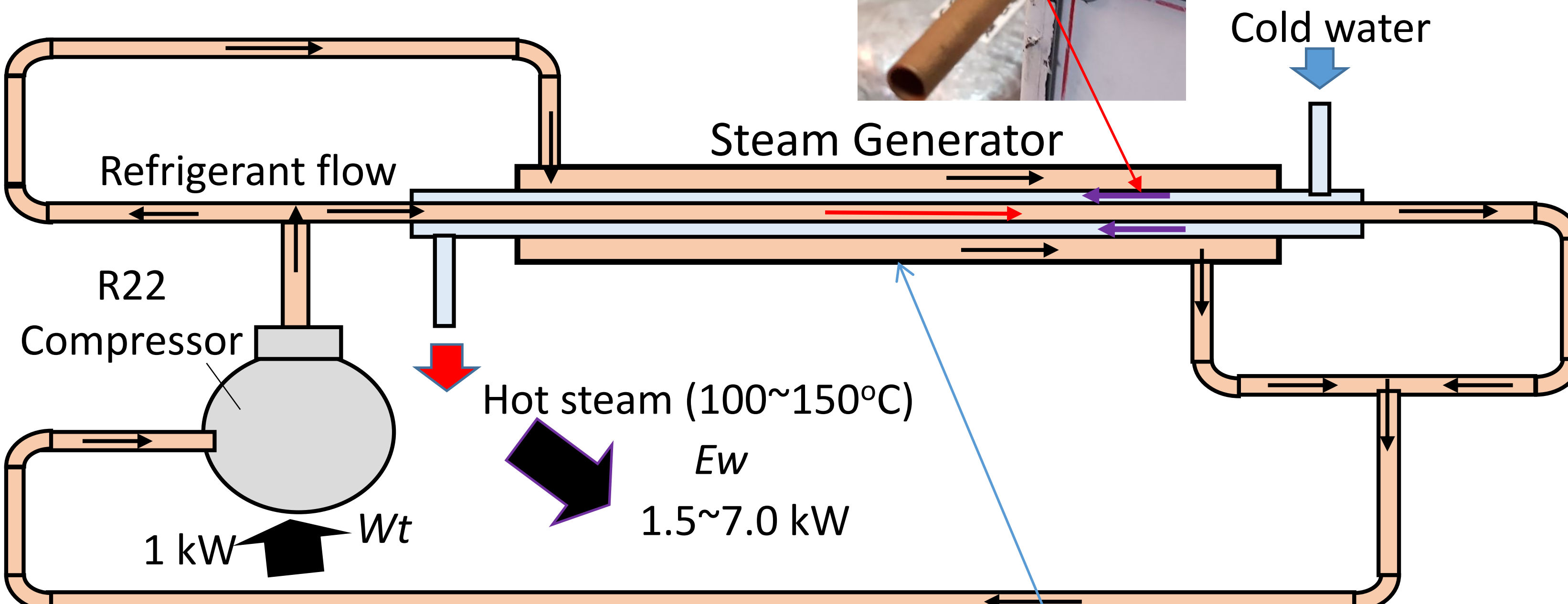




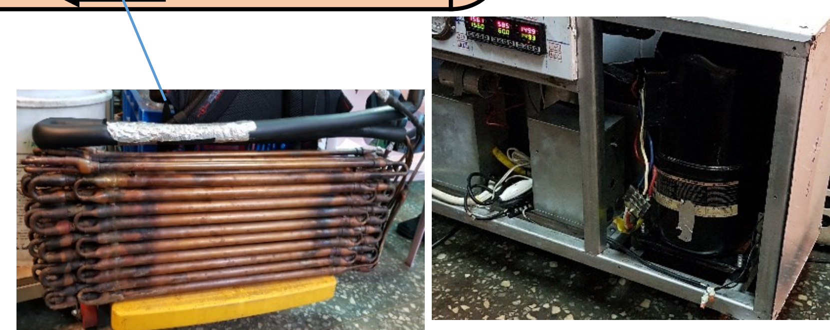
Commercial Water Heating Systems

Case 2: Hydrogen-rich water making machine (Company B)
(Vapor compression system without evaporator)

COP = Ew / Wt < 1
(thermodynamics of vapor compression cycle)

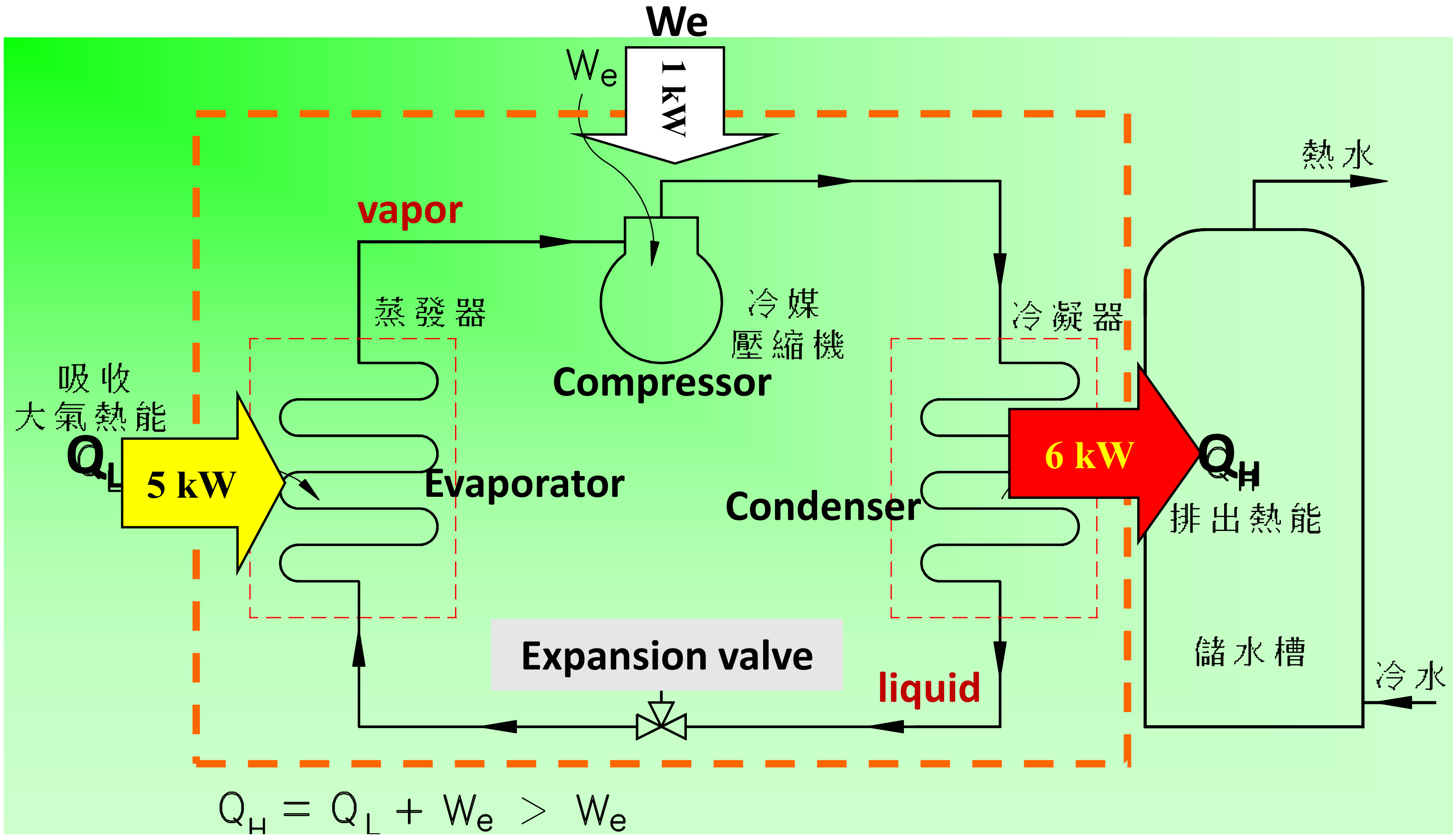


- Compressor: R22/2.75RT (3 kW input)
- **No evaporator** as in air conditioning system
- For making hydrogen-rich water (36 L/h, 360L/day)



Vapor compression cycle

(Thermodynamic Principle of Heat Pump)



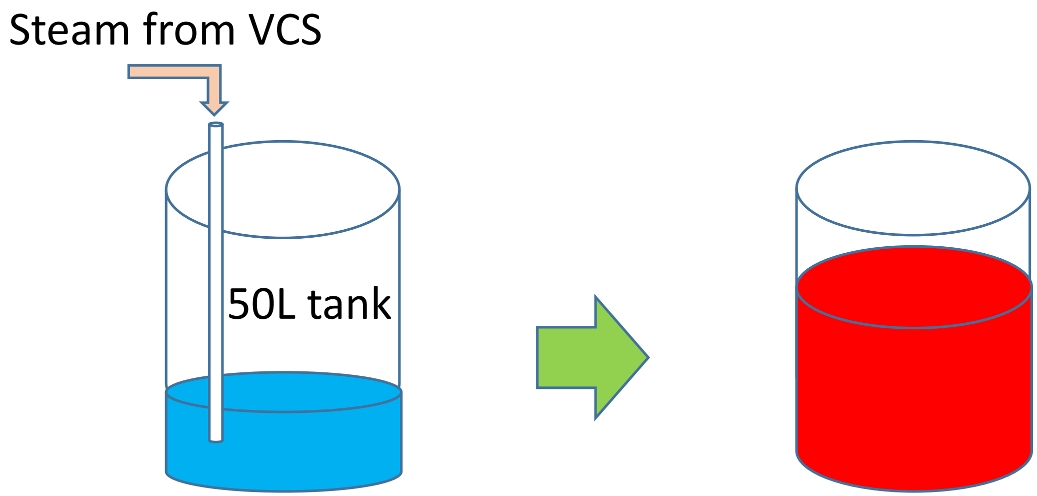
Energy balance: $Q_H = Q_L + We$

COP of heating: $COP_h = Q_H/We = 1 + Q_L/We$

For $Q_L=0$ $COP_h = 1$ (assuming no heat loss)

< 1 (with heat loss)

Energy-balance Measurement



Initial cold water mass M_i
Initial water temperature T_i
Initial internal energy u_i

Final water mass M_f
Final water temperature T_f
Final internal energy u_f

Energy released from hot steam: $E_w = M_f u_f - M_i u_i$ u: internal energy

COP = E_w (total heat released)/W_t (total energy input)

Test Results

Test date	2019/5/29	2019/6/1	2019/8/08
Maximum hot steam temperature (°C)	150	155	164
Initial water temperature in tank (°C)	41.1	44.7	44.5
Final water temperature in tank (°C)	**90.9**	**96.3**	**92.9**
Hot steam generation rate (kg/min)	0.61	0.60	0.42
Total electrical energy input (kWh)	2.4	2.7	3.1
Total heat released (including heat loss) (kWh)	3.74	3.94	4.1
Total running time at steady state, min	40	41	60
COP_{hL} including heat loss (measured)	**1.56**	**1.46**	**1.32**
COP_{h0} without heat loss (estimated 20%)	**1.87**	**1.75**	**1.58**
COP_{max} (assuming 100% dry steam output)	7.01	6.25	5.68

Violate thermodynamics ?

COP = Ew / Wt < 1

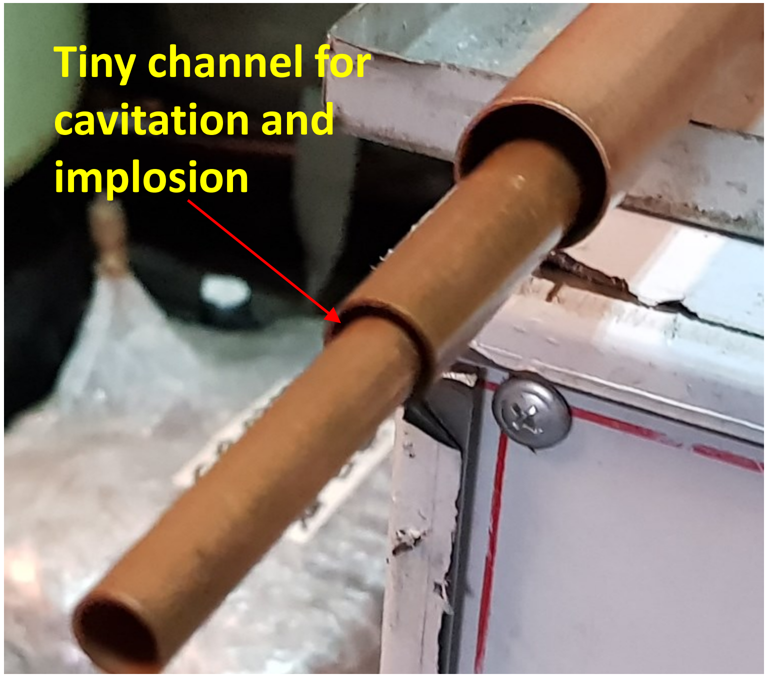
(thermodynamics of vapor compression cycle without evaporator)

Hypothesis for COP > 1 happened in two machines

- **Water cavitation within tiny channels**
- **Implosion from collapse of micro- or nano-bubbles (< 100nm)**

LENR ?

Something in common for machine of COP > 1 with unknown LENR:
(1) Cavitation phenomena
(2) Micro- or nano-bubbles
(3) Intense implosion



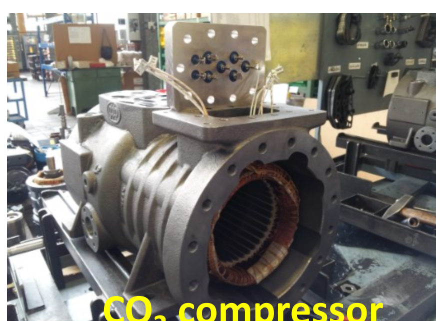
Business issue (Company B): Payback time for water business

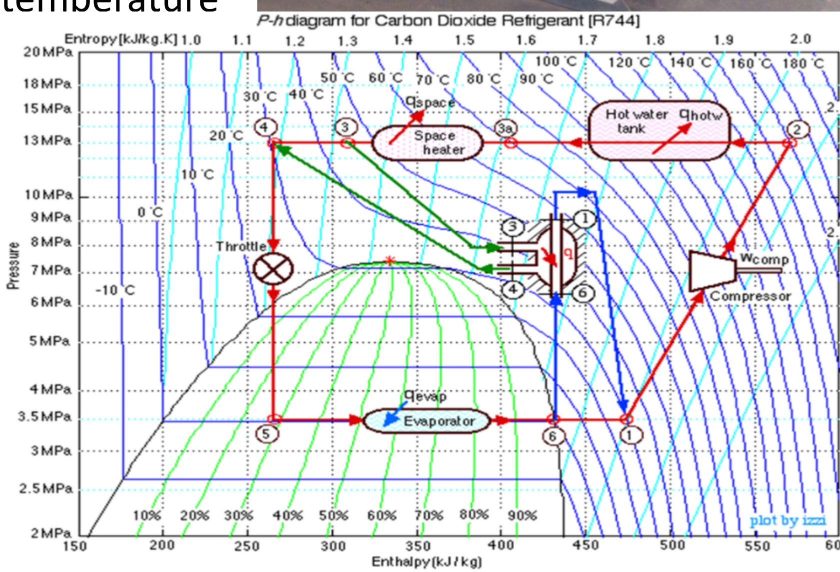
- Total system cost: 10,000 USD (3 kW input)
- Water production rate: 36 L/h
- Daily water production (10 h/day): 360 L/day
- Cost of energy consumption: 0.1 USD/kWh x 3 kWh/h x 10h/day = 3 USD/day
- Sale price of water: 1 USD/L
- Daily sales volume: 360 USD/day
- Daily gross income: 357 USD/day
- Yearly gross income: 357 x 22 day/mon x12mon/yr = 94,000 USD/yr
- Net profit (10~20%): 18,800 USD/yr
- Payback time: 0.53~1.06 yr (6~12 months)

3. Commercial aspects of vapor compression system (VCS) with COP>1 as a heat pump for space heating

LENR VCS compared to CO_2 heat pump for space heating

- **CO_2 HP:**
  - Using CO_2 as refrigerant
  - Trans-critical cycle with reasonable COP at low ambient temp
  - Suitable for space heating in cold zone areas
  - Key technology: high pressure compressor, gas cooler, expansion control technique, variable-frequency control, system optimization
  - Expensive
  - COP very low at ambient temperature below -10°C
- **LENR VCS as HP:**
  - Key technology: control of cavitation and micro- or nano-bubbles implosion, system optimization, lubricating oil return technique.
  - Machine is cheaper
  - COP is almost constant and not affected by ambient temperature





Performance comparison

	CO_2 HP		VCS LENR HP
Ambient temperature(°C)	7	-10	< -30
Heating rate (kW)	23.3	16.7	5~8
Water flowrate (LPM)	4.5	3.0	0.6
Water inlet temp (°C)	8.4	7.02	8~40
Water outlet temp (°C)	82.6	87.1	90~150
Compressor power input (kW)	7.7	7.20	**3**
COP (=Ew/Wt)	3.0	2.3	1.5~5
Installation Cost (USD)	**100,000**	**100,000**	10,000
(USD/kW heating)	**4,291**	**6,000**	**2,000~1,250**

4. Conclusion

- Many machines has shown experimentally the phenomena of COP > 1. Some of them are commercialized.
- The phenomenon of COP > 1 is related to cavitation, micro- or nano-bubbles implosion, and possible LENR.
- The test results of the present VCS HP shows that COP > 1 exists.
- The physics of COP > 1 in VCS HP still remains further researches.
- But the commercial application has big potential to compete with CO_2 heat pump.

Thank you

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