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A NEW CONFIGURATION FOR ORGANIC RANKINE CYCLE POWER SYSTEMS

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WHO

- EXERGY is a private-owned company: its mission is the development of ORC packaged systems in the 0.1 – 5 MW range and tailor made solutions up to 50 MW
- A number of EXERGY ORC machines are already in operation and under construction
- The Department of Energy of Politecnico di Milano is the largest energy university department in Europe, with a 40-year-long history of research activities in ORC development

THE MARKET

- For medium-high enthalpy applications, the market is oriented towards a technology with the following peculiar features, developed by one of the pioneers and now a standard:
  - Multi-stage axial turbine
  - Siloxanes as working fluid
  - Sub-critical cycle
  - Water-cooled condenser integrated with the recuperator

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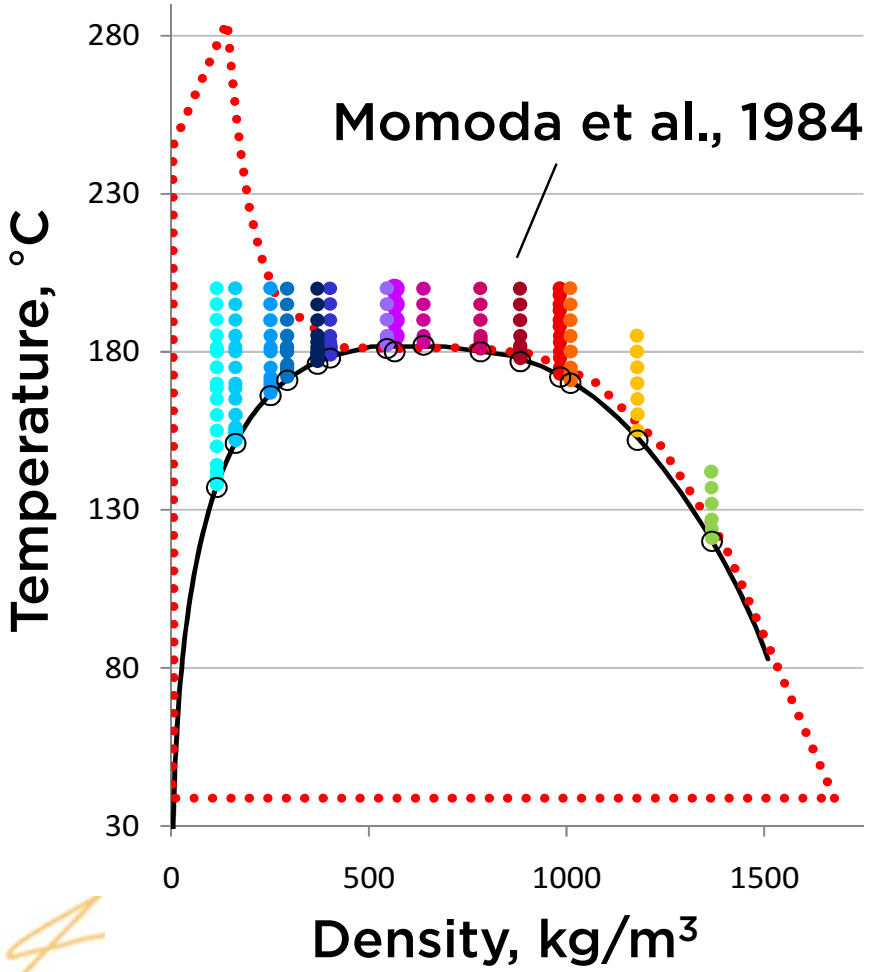
THE PROJECT

- Design and construct a 1 MW ORC package, first of the HEX series, based on the following concepts:
  - Multistage radial outflow turbine
  - Perfluorinated fluid
  - Supercritical cycle
  - Direct air-cooled condenser
- This is the first and only multistage radial outflow turbine with organic fluid existing

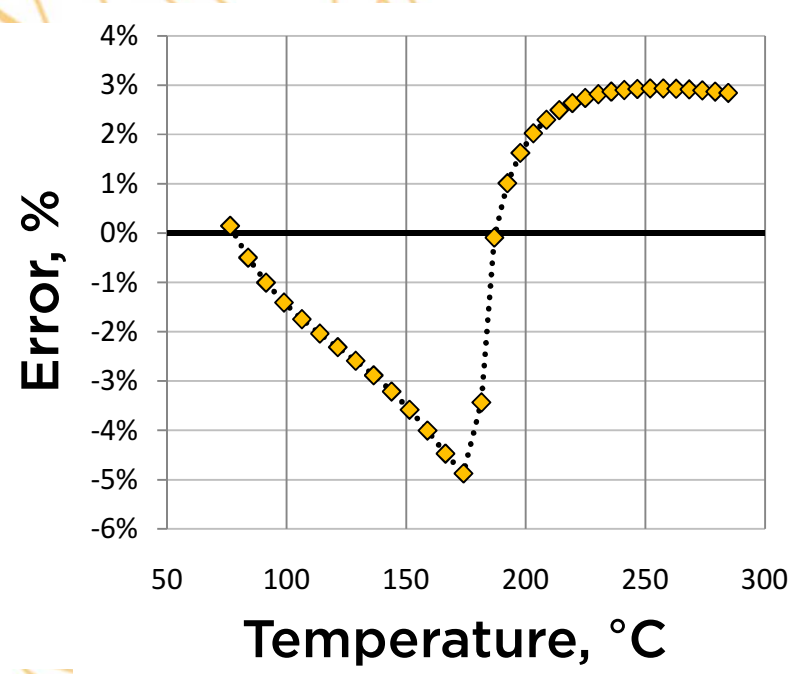
C_6F_{14}: PERFLUORO -2-METHILPENTANE

- High molecular weight
- Good thermal stability
- No flammability
- No toxicity
- Absence in the ORC market
- Availability on the market
- Affordable price

C_6F_{14}: PERFLUORO -2-METHILPENTANE



- Extended bibliographic review
- Peng-Robinson error evaluation
- Sat. Curve has been validated by various experimental data

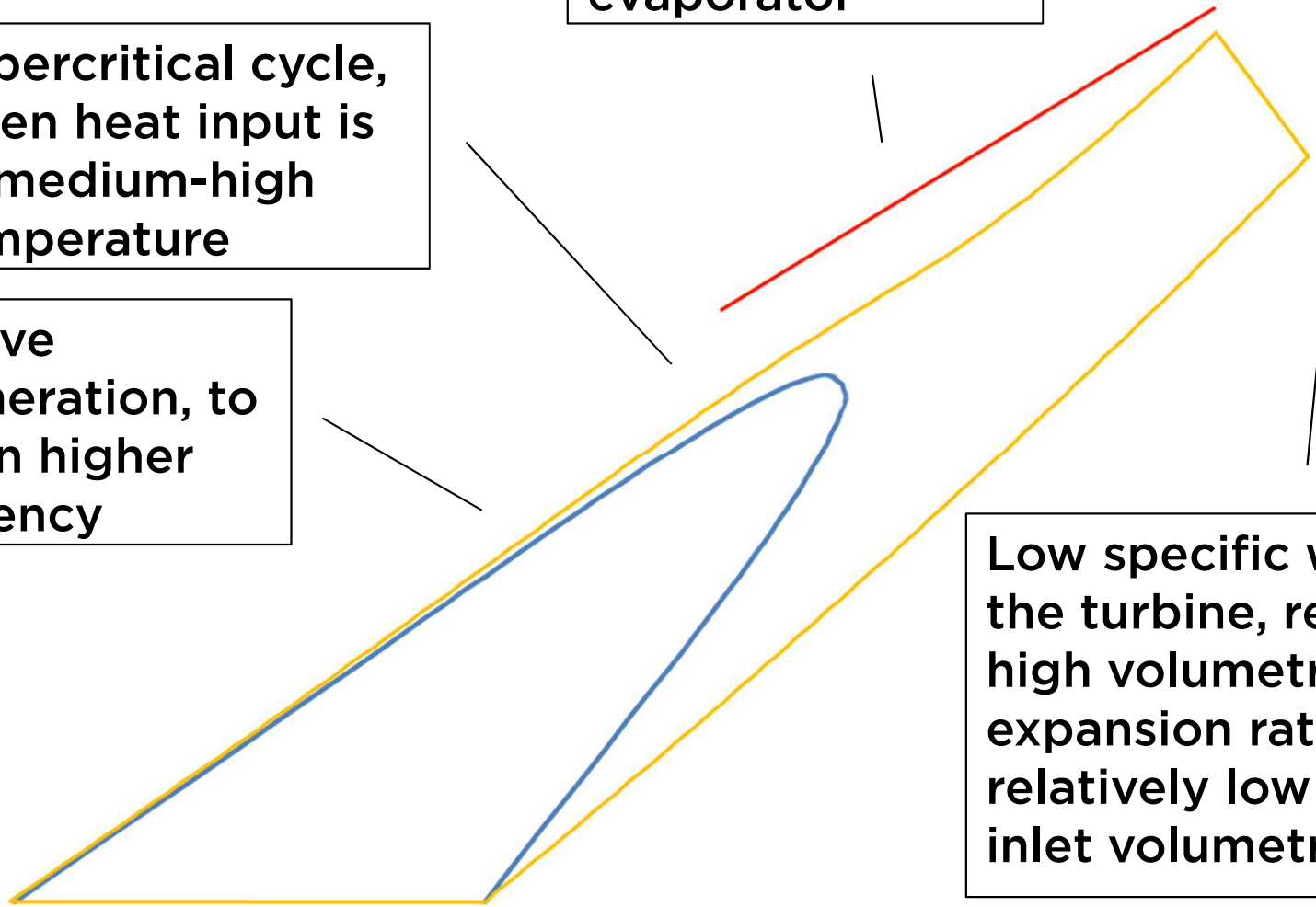


THE CYCLE

Huge thermal length: we choose a Hairpin evaporator

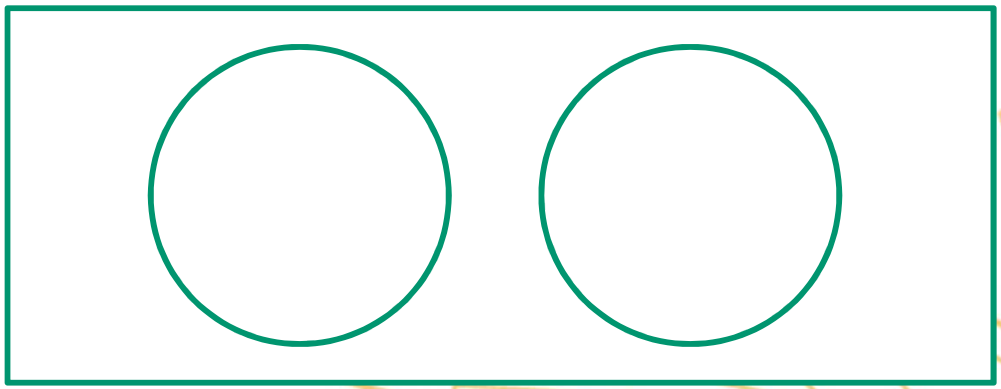
Supercritical cycle, when heat input is at medium-high temperature

Massive regeneration, to obtain higher efficiency

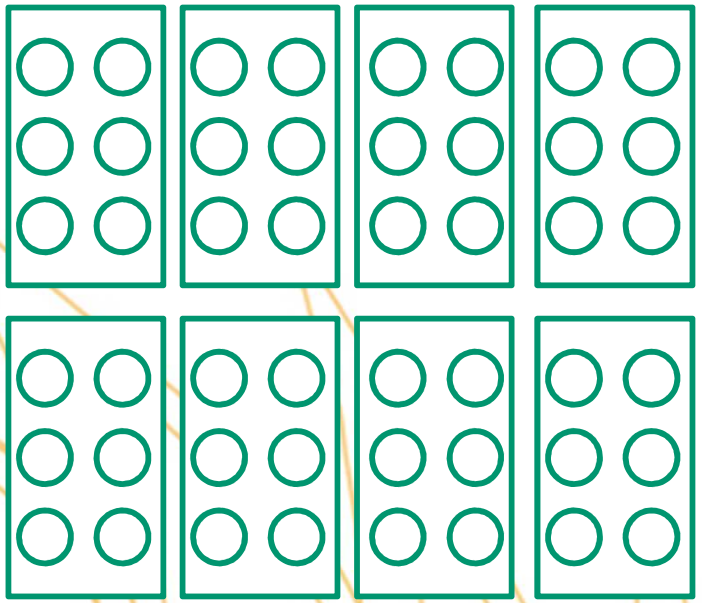


Low specific work of the turbine, relatively high volumetric expansion ratio and relatively low absolute inlet volumetric flow

THE CYCLE: COMPONENTS
AIR COOLED CONDENSER



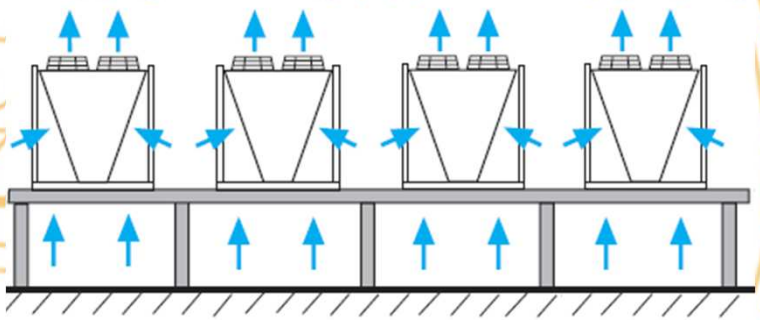
Present design (CS/Al finned tubes)



Advanced design
(Cu tubes OD 10 mm, Al fins)

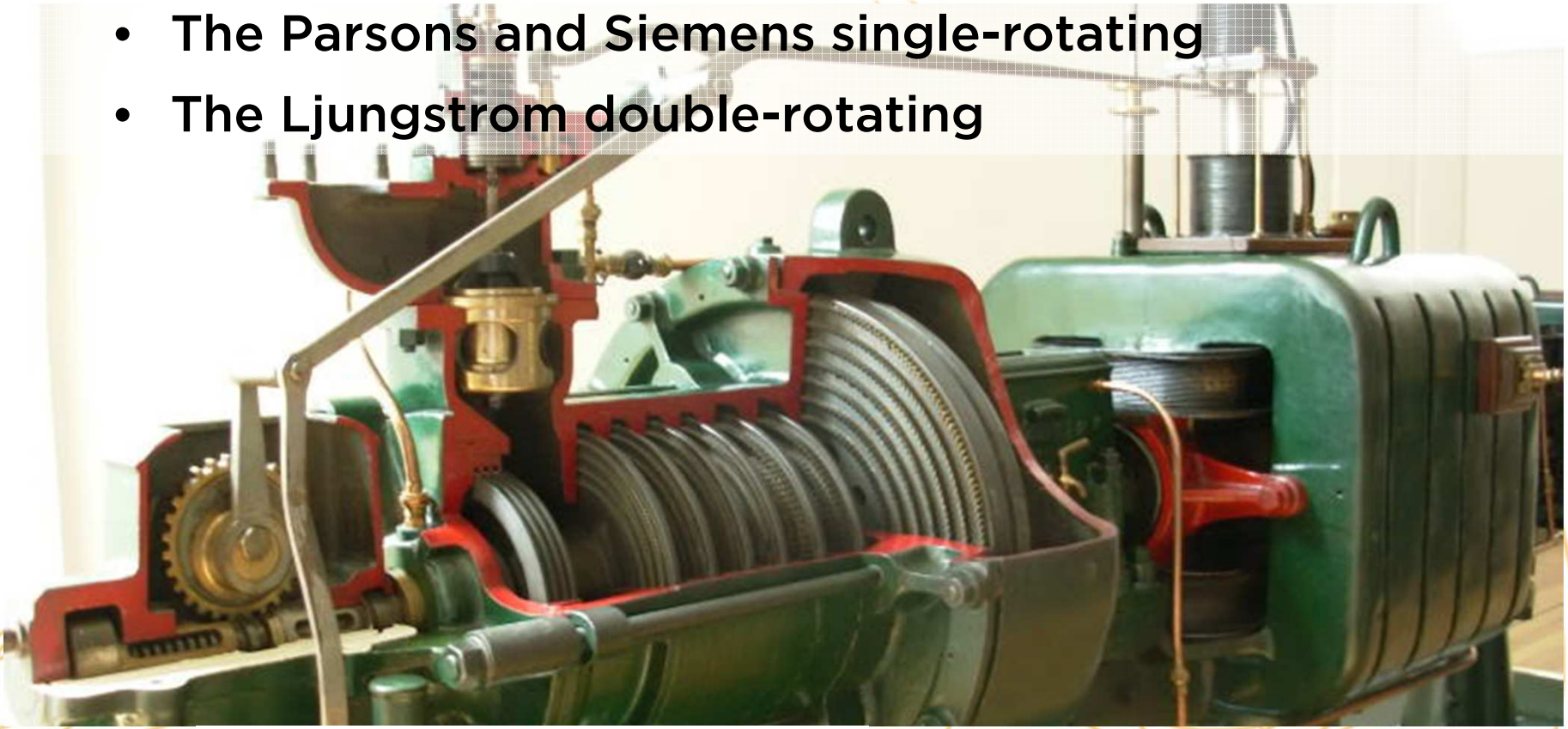
Advanced design:

- Footprint: +5%
- Weight: -80%
- Internal volume: -18%
- Electric consumption -16%



RADIAL OUTFLOW TURBINES

- Two kind of radial outflow expanders have been designed in the past for steam Rankine cycles:
  - The Parsons and Siemens single-rotating
  - The Ljungstrom double-rotating



THE TURBINE: FEATURES

- High inlet/outlet volumetric flow ratio well matches with the change in cross section across the radius;
- Compared to an axial turbine, the lower inlet volumetric flow is compensated by higher blades at the first stage thanks to the change in section available along the radius, so that there is no need for partial admission;

THE TURBINE: FEATURES

- Prismatic blade leads to constant velocity diagrams across the blade
- Minimum tip leakages and disk friction losses, due to the single disk multi-stage configuration;
- The limit of a radial outflow expander to develop high enthalpy drop is not relevant for this cycle, presenting itself a very low enthalpy drop;
- Tip speed is limited by the low speed of sound.

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AXIAL vs. RADIAL OUTFLOW COMPARISON

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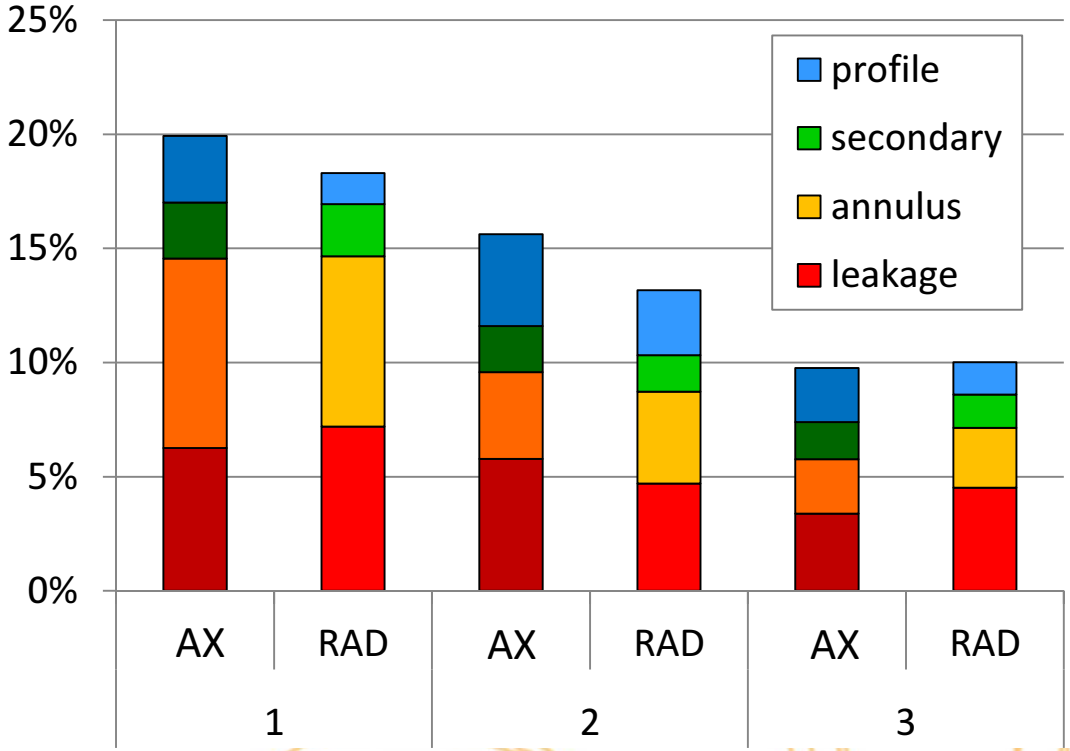
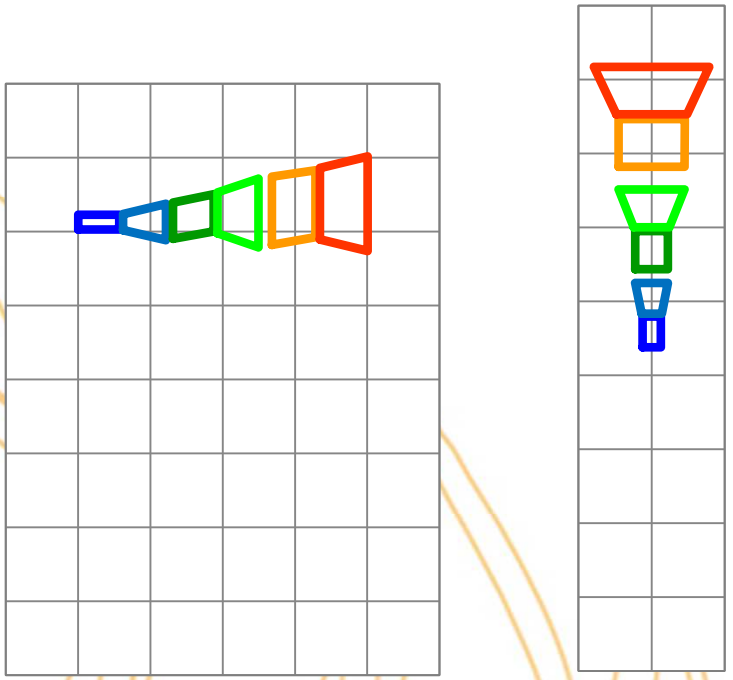
Stage losses breakdown



Δh	AX	RAD
1	31.9%	24.9%
2	31.9%	32.5%
3	36.2%	42.7%

η	AX	RAD
1	79.3%	81.3%
2	84.1%	86.4%
3	85.5%	89.1%



Efficiency gain +4.14%

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