Cryogenic Cooling of the ESS Cold Neutron Source

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European Spallation Source

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ESS Overview

ESS, the European Spallation Source, will be a major user facility at which researchers will investigate scientific questions using neutron beams.

Neutron methods are used for both basic and applied research, and provide insights about the molecular building blocks of matter not available by other means.

European nations are working together in order to build, in southern Scandinavia, this slow neutron source of unparalleled power and scientific performance.

ESS is planned to deliver its first protons to a solid, rotating tungsten target in 2019, which will in turn generate neutrons for delivery to an initial suite of seven neutron scattering research instruments.

ESS will reach its full design specifications in 2025, with a suite of 22 research instruments

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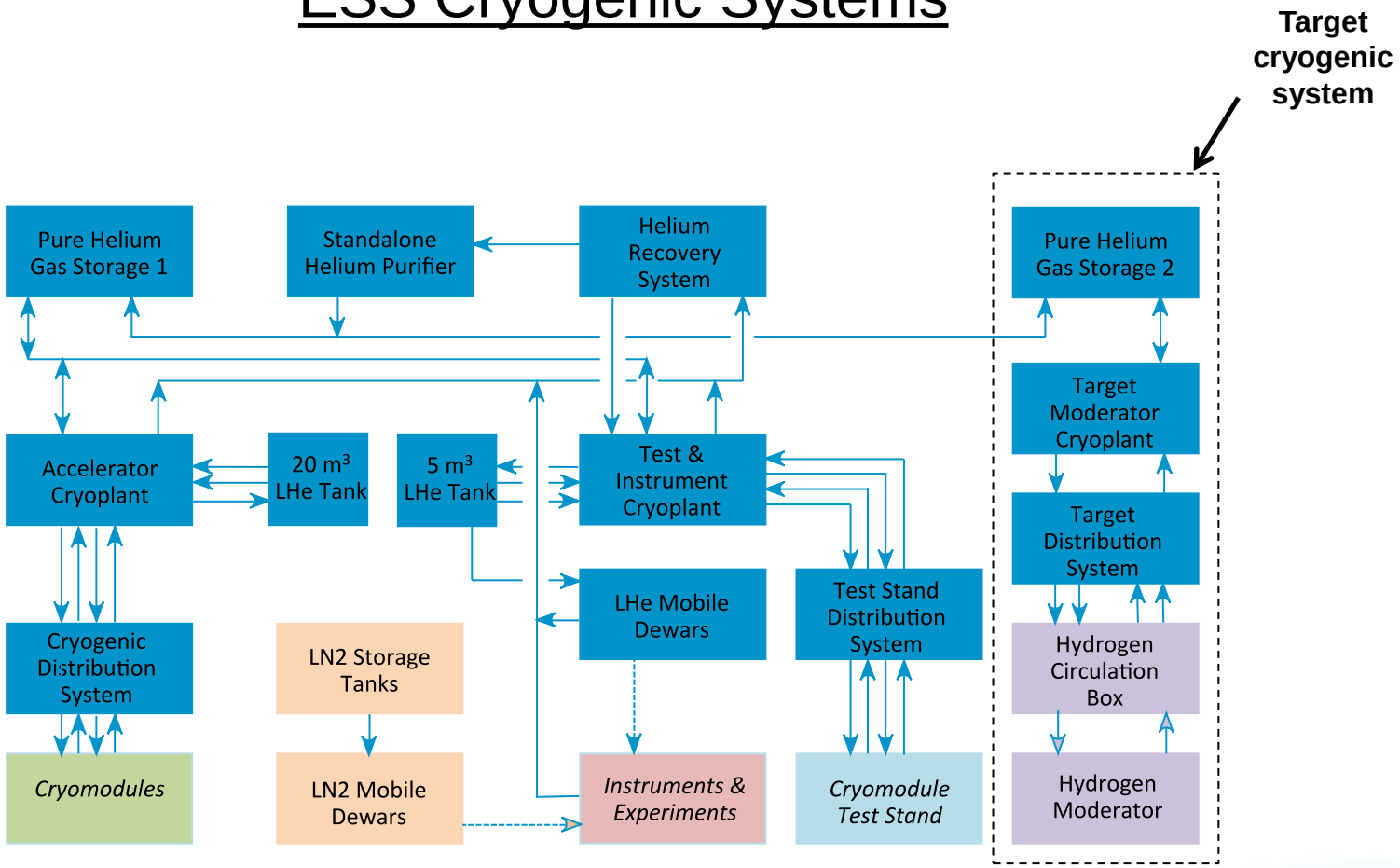
ESS Overview

- 482.5m long, 5MW, proton linear accelerator at 2.5 GeV, 5 mA
- 2.86 ms pulses, ≈14Hz (60 ms period)
- Solid tungsten metal target
- 22 neutron instruments
- To support a 5000-strong user community
- 450 staff

Photo - Henning Larson Architects

ESS Cryogenic Systems



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Supercritical Hydrogen cooling of moderators

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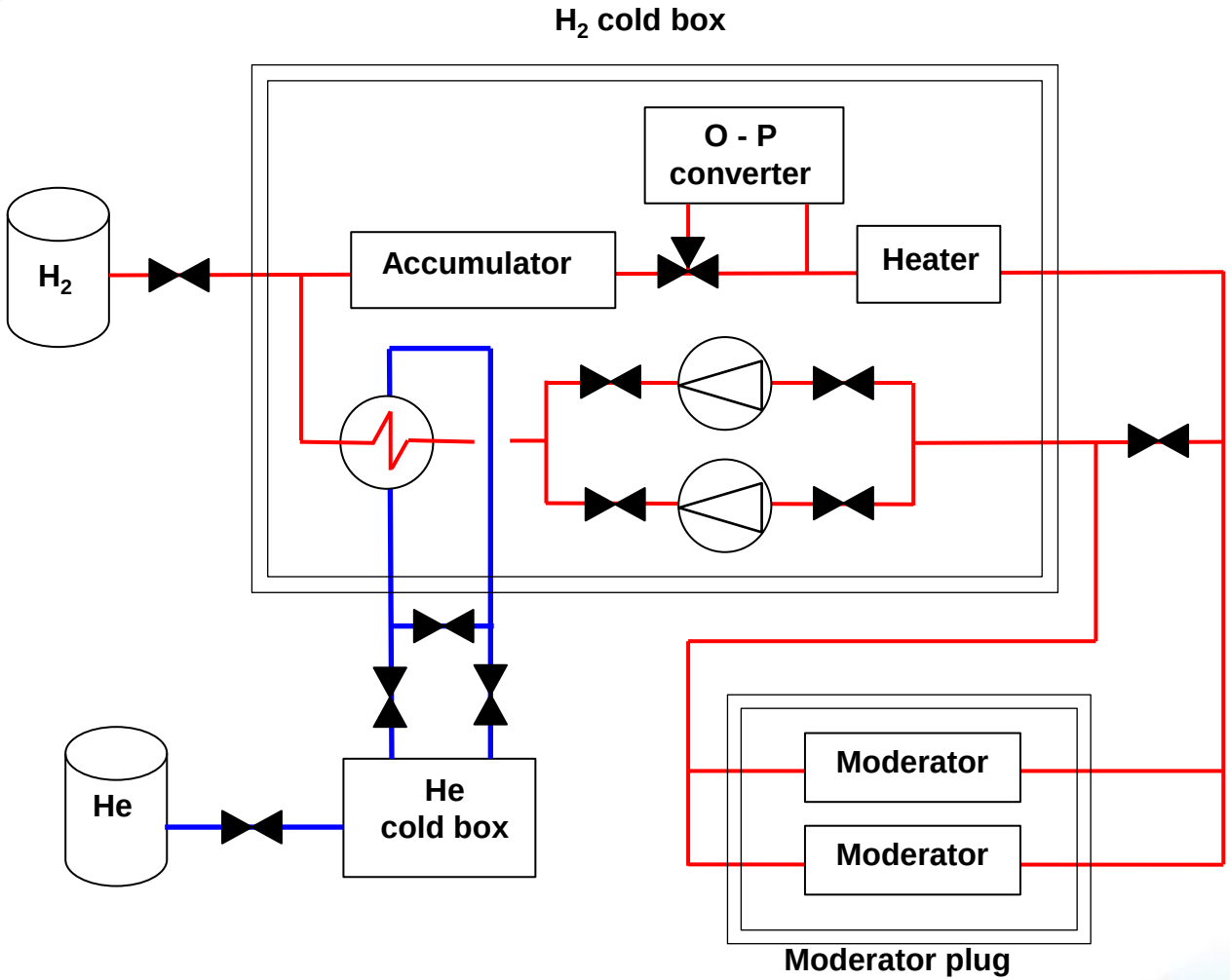
Spallation target cooling

A key feature of ESS is a ***tungsten target wheel***, which transforms high-energy protons via the spallation process to fast neutrons. A ***moderator-reflector*** system then transforms these fast neutrons into slow neutrons, which are the final form of useful radiation provided by the neutron source. A key feature of the target system are the hydrogen moderators,

- Use ***supercritical H_2*** at 17 K and 1.5 MPa to reduce the energy of the neutrons before they reach the instrument lines.
- Neutrons deposit significant energy into the H_2 that must be removed to maintain the H_2 at its nominal operating temperature of 17 K.
- The ***target moderator cryoplant (TMCP)*** provides cooling for the H_2 moderator cooling loop. The heat deposited into H_2 is removed via a heat exchanger in a ***H_2 circulator cold box***
- Heat from H_2 circuit transferred to a ***cold He circuit*** operating at 16.5 K which is connected to the TMCP

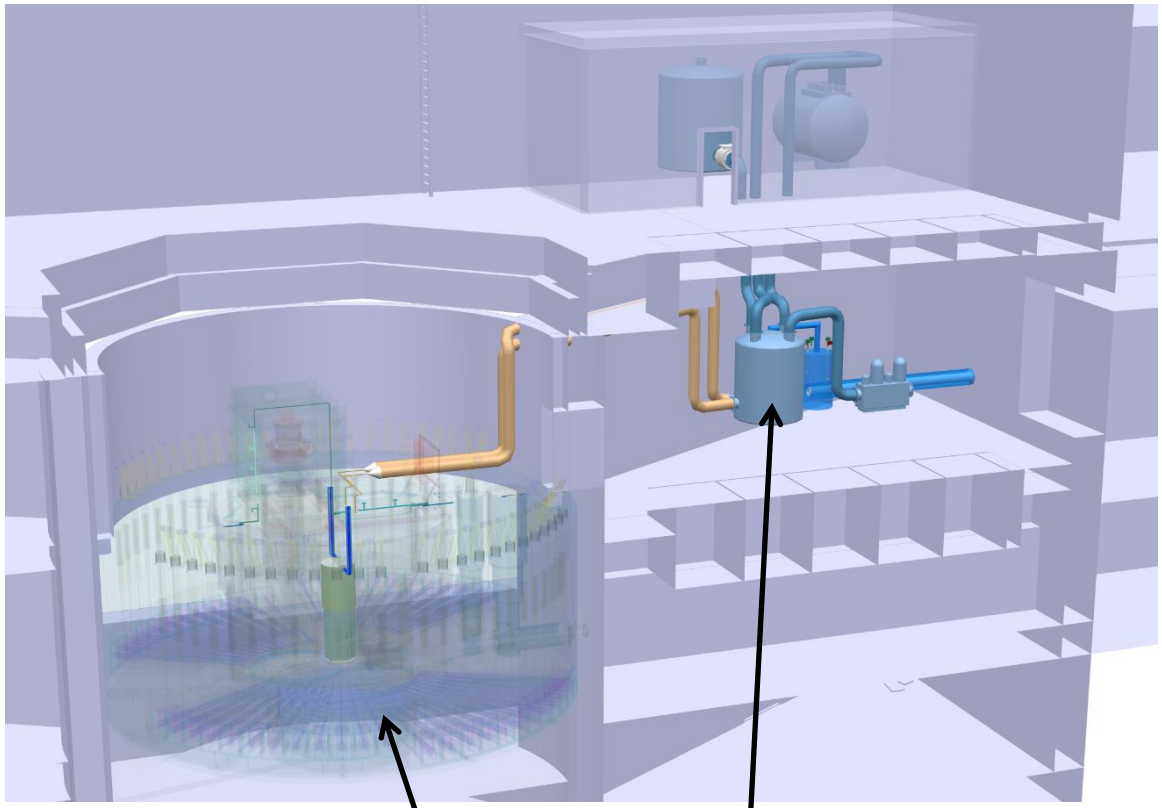

H_2 cold box
O - P
converter
Accumulator
Heater
H_2
He
He
cold box
Moderator
Moderator
Moderator plug

Supercritical H_2 design parameters

Parameter	Value
Heat load	
Moderators	10.8 kW
H_2 circulation pumps	4 kW
Hydrogen	
Moderator inlet temp.	17 K
ΔT @ 5 MW beam	3 K
Working pressure	1.5 MPa
Mass flow rate	0.8 kg/sec

Helium TMCP design parameters

Parameter	Value
Heat load (est.)	
H_2 system dynamic heat load	20 kW
Static load	5 kW
Helium	
HX inlet temp.	16.5 K
ΔT at 20 kW	3 K
Maximum pressure	2.0 MPa
Mass flow rate	~ 0.6 kg/sec



Target Wheel with hydrogen moderator

Supercritical H_2 cold box

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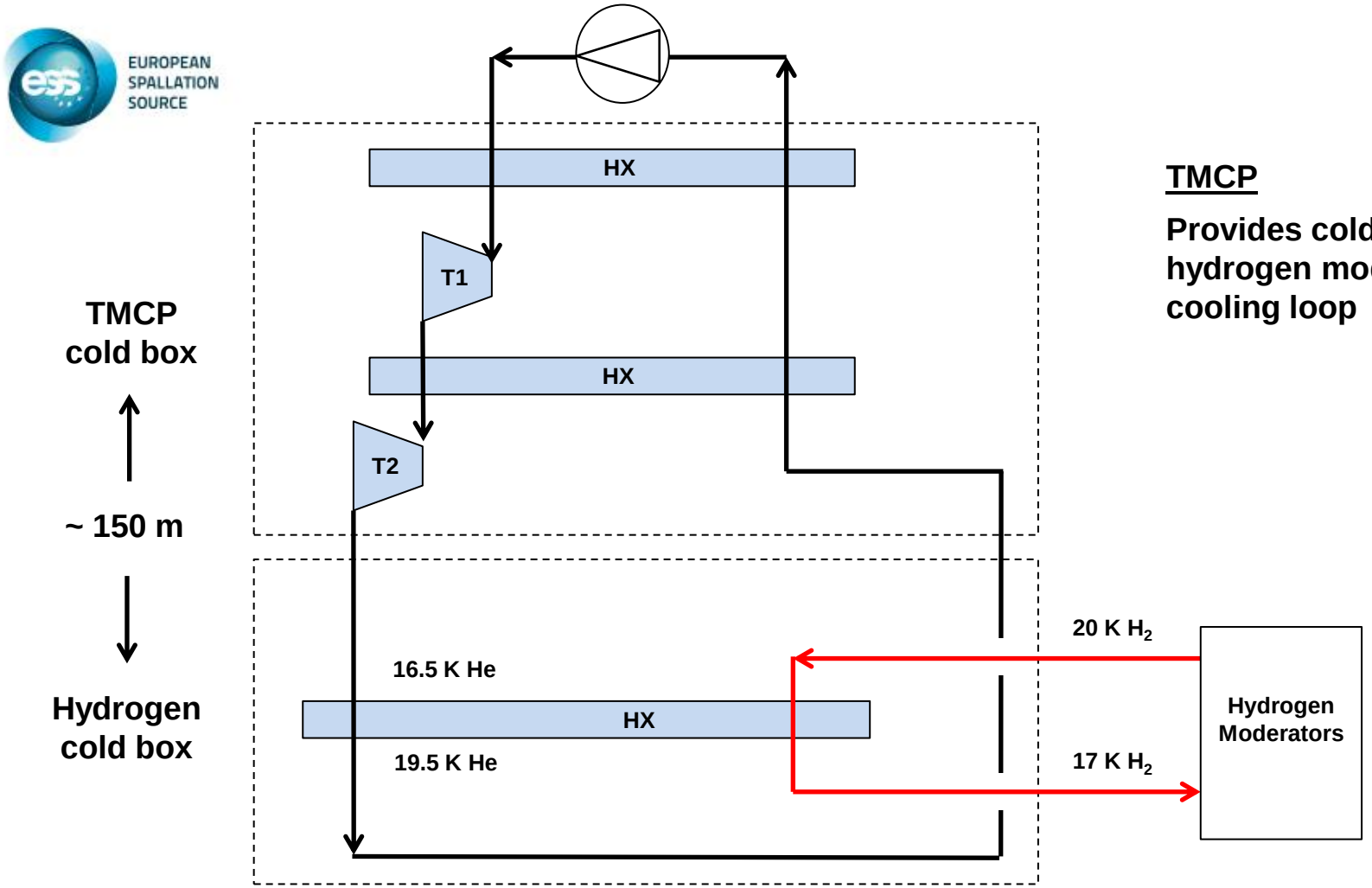
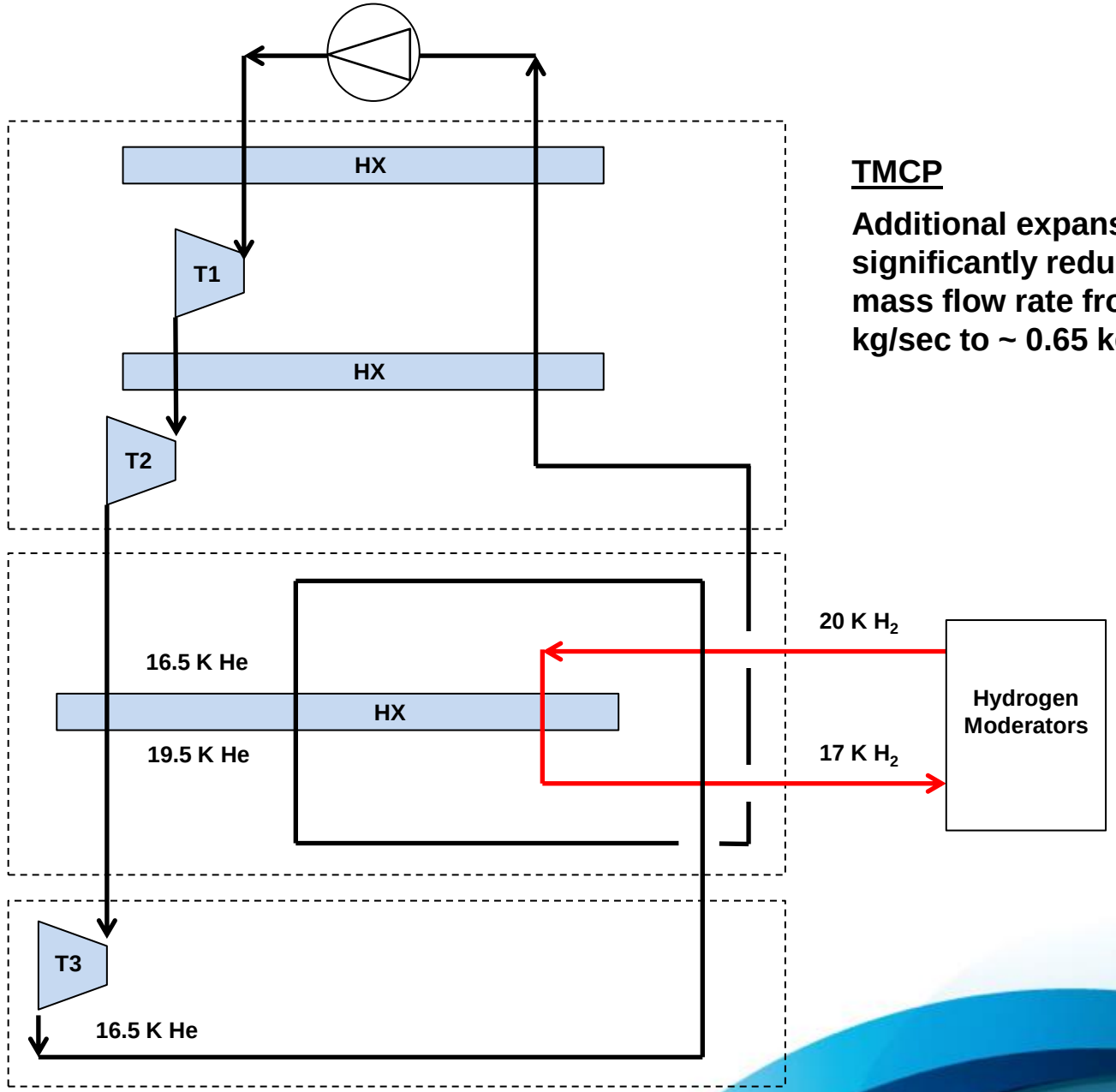
Target Moderator Helium Cryoplant



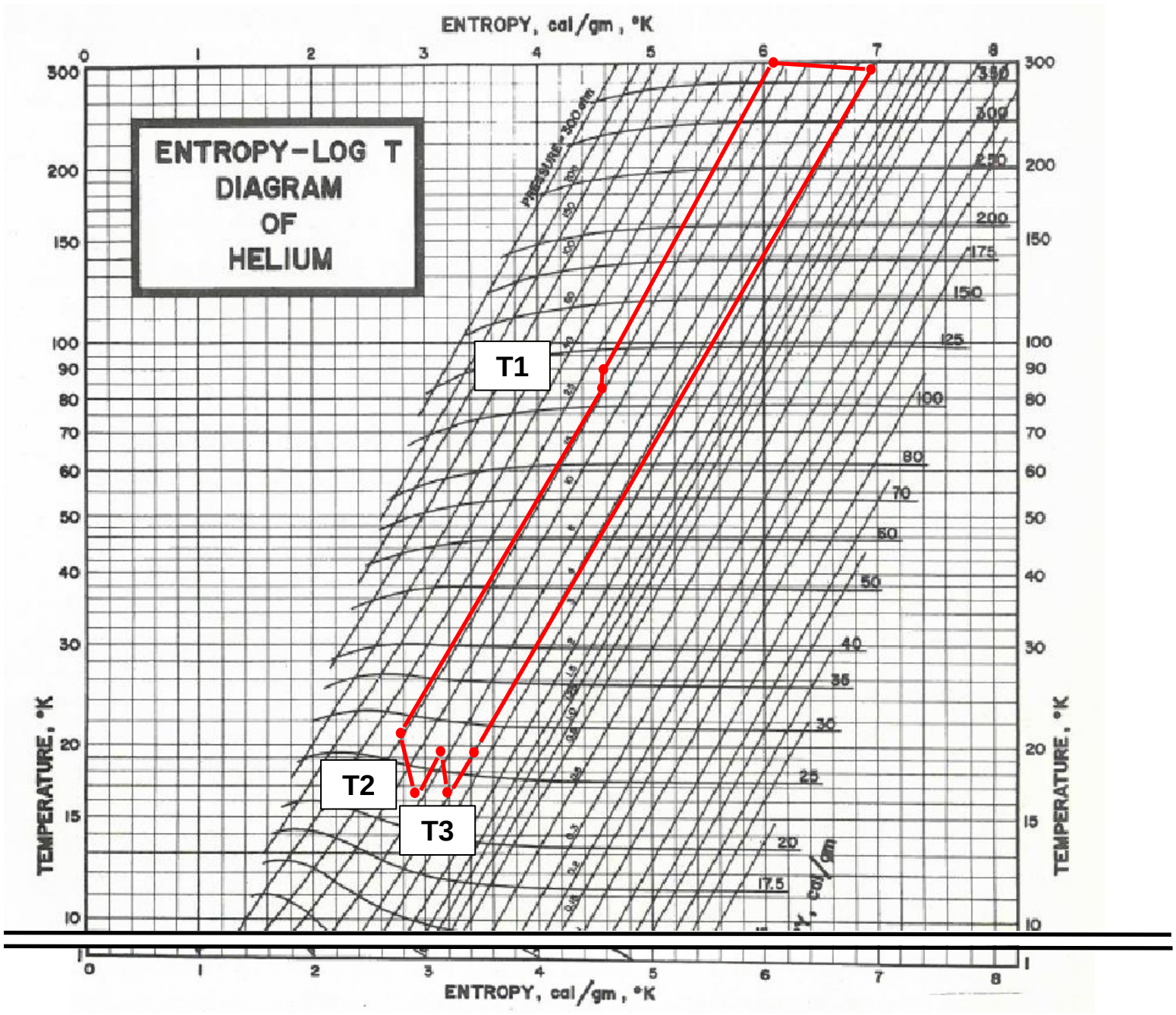
TMCP

Provides cold He to cool hydrogen moderator cooling loop



TMCP

Additional expansion turbine significantly reduces helium mass flow rate from ~ 1.4 kg/sec to ~ 0.65 kg/sec


ENTROPY, cal/gm, °K
ENTROPY – LOG T DIAGRAM OF HELIUM
T1
T2
T3
TEMPERATURE, °K
ENTROPY, cal/gm, °K

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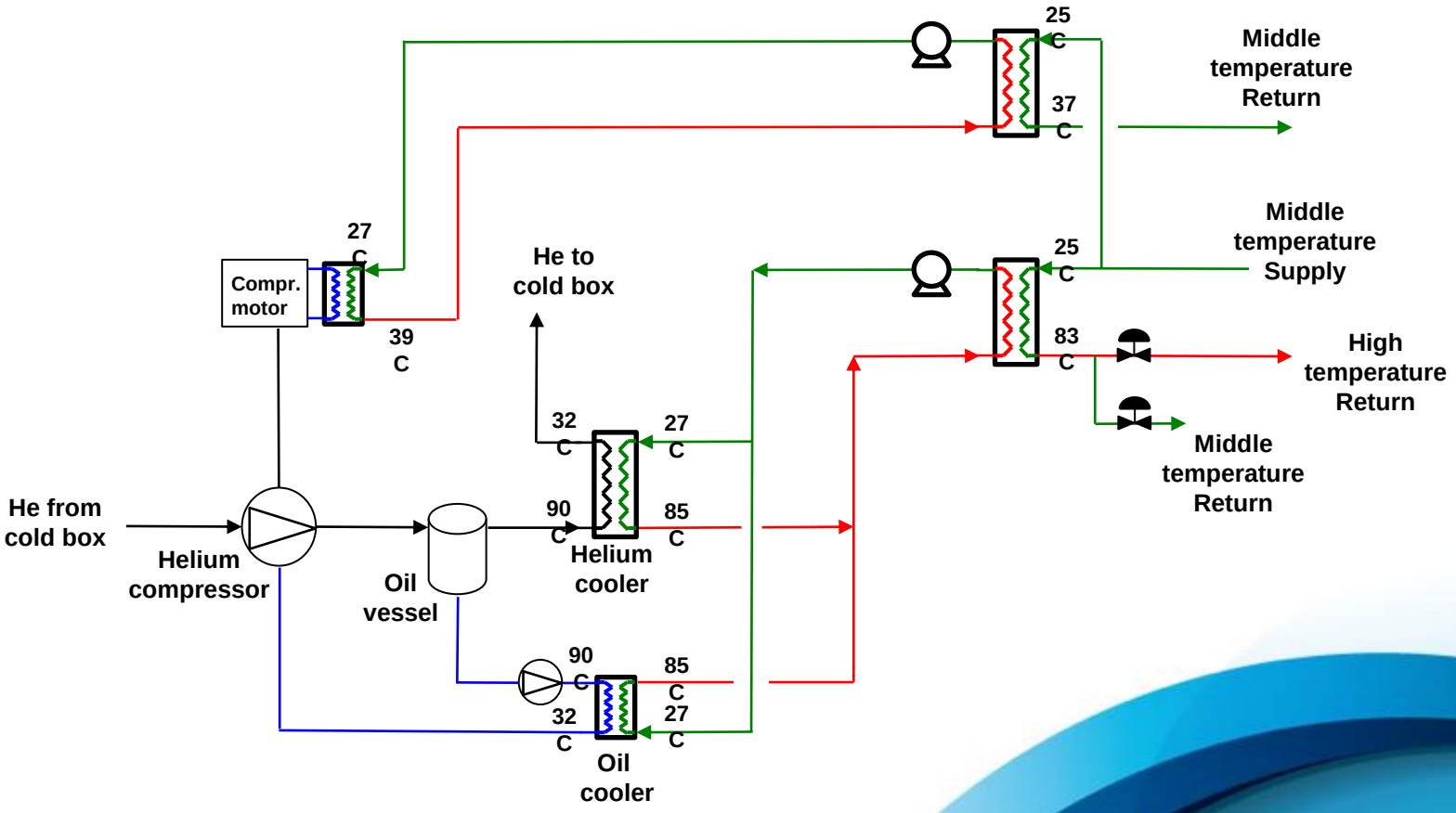
TMCP energy recovery

Energy Recovery

ESS has made energy management a matter of policy. One significant part of our energy management strategy is to to provide a cooling system that not only provides efficient cooling to all technical systems, but also recycles waste heat to the city of Lund district heating system and/or other potential customers.

ESS cooling system goal is to recover energy at as high a temperature as practical



Schedule

TMCP

- Technical specification complete, call for tenders – 1Q15
- Contract award – 3Q15
- Commissioning – 2Q18

Cryogenic moderator LH_2 system

- Design complete – 2Q16
- Award contract – 4Q16
- Installation complete – 2Q18
- Cold commissioning complete – 2Q19

Summary

- Target supercritical hydrogen moderator design options are still being considered
- Design parameters for target moderator should be fixed 3Q2014
- TMCP call for tenders 1Q15
- Challenges include:
  - Large variation in heat loads
  - Hydrogen system design, components, & fabrication
  - Maximize energy recovery from waste heat
- No “show stoppers”

http://europeanspallationsource.se

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Veel Dank