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CETC's Program on Thermally Activated Chilling

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Microturbine Applications Workshop

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Presentation Outline

- CETC's program on Microturbines
- Technology Gap "Thermally Driven Chilling"
- Technology Scan Results
- Ejector Chiller, Current Status and Future Plans
- Adsorption Chiller, Current Status and Future Plans
- Conclusions

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CETC Distributed Generation Program

- CANMET Energy Technology Center (CETC), located in Ottawa is one of the Canadian Federal Government's Research Laboratories
- DG program started in 1998
- **Rationale:** The utility sector contributes 15% of Canada's GHG emissions and gas flaring is a significant environmental issue
- Have supported the development of heat recovery systems (Mariah Energy Corp., Unifin International)
- Supported microturbine field demonstrations with gas and electric utilities
- New funding for DG (renewable and fossil) recently announced, C$30 million over five years

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CETC's CHP Program Vision

- To assist in the development of a packaged microturbine Combined Heat and Power unit that can be installed by a HVAC contractor with little or no consulting engineering requirement.

OR PUTTING IT ANOTHER WAY

- A commercial package boiler/chiller* that produces electricity

* Recent addition


Ottawa
Inuvik
Toronto
Canada
Montreal

What is the Potential of Thermally Activated Chilling?

- CETC’s program is focused on “low capital cost potential” rather than “highest technical performance”

- Simple cycles tend by their nature to be of low efficiency.
- Re examined “old’ concepts with new materials and design methods
- Focused on low cost concepts with the potential for high reliability

Thermally Activated Cooling Cycles

- In 2002 identified 10 thermal cycles and screened them primarily for three criteria.
  - Ability to produce ice
  - Simplicity- Minimum number of pumps and thermal circuits.
  - Required Driving Temperature
- Two candidate cycles and a reference LiBr Single effect absorber were identified
  - Ejector Chiller using new low boiling point refrigerants
  - Ammonia Adsorption Chiller

Thermally Driven Cooling Cycles

Ref Fisher and Labinov ORNL DE-AC05-96-OR22464 Feb 2000

Technology	COP	Quality of Thermal Input (120ºC)	System Complexity
Adsorption Zeolite/water	0.4-0.5	Low Temp	High
Vueilleumier	0.24	High Temp	High
Ammonia carbon Adsorption	0.7-1.0	Low Temp	High
Ammonia-Organic Compounds	1.0	Low Temp	Medium
Duplex Stirling	1.41	High Temp	High

Thermally Driven Cooling Cycles

Technology	COP	Quality of Thermal Input (120ºC)	System Complexity
Metal Hydride	0.45-0.7	Low Temp	High
Ejector	0.25	Low Temp	Low
Single Effect Absorption Ammonia	0.58	Low Temp	Medium
Ammonia Adsorption GAX	0.64	Low Temp	High
Li Br Double Effect Absorption	0.94	High Temperature	High

Ammonia Adsorption Chiller

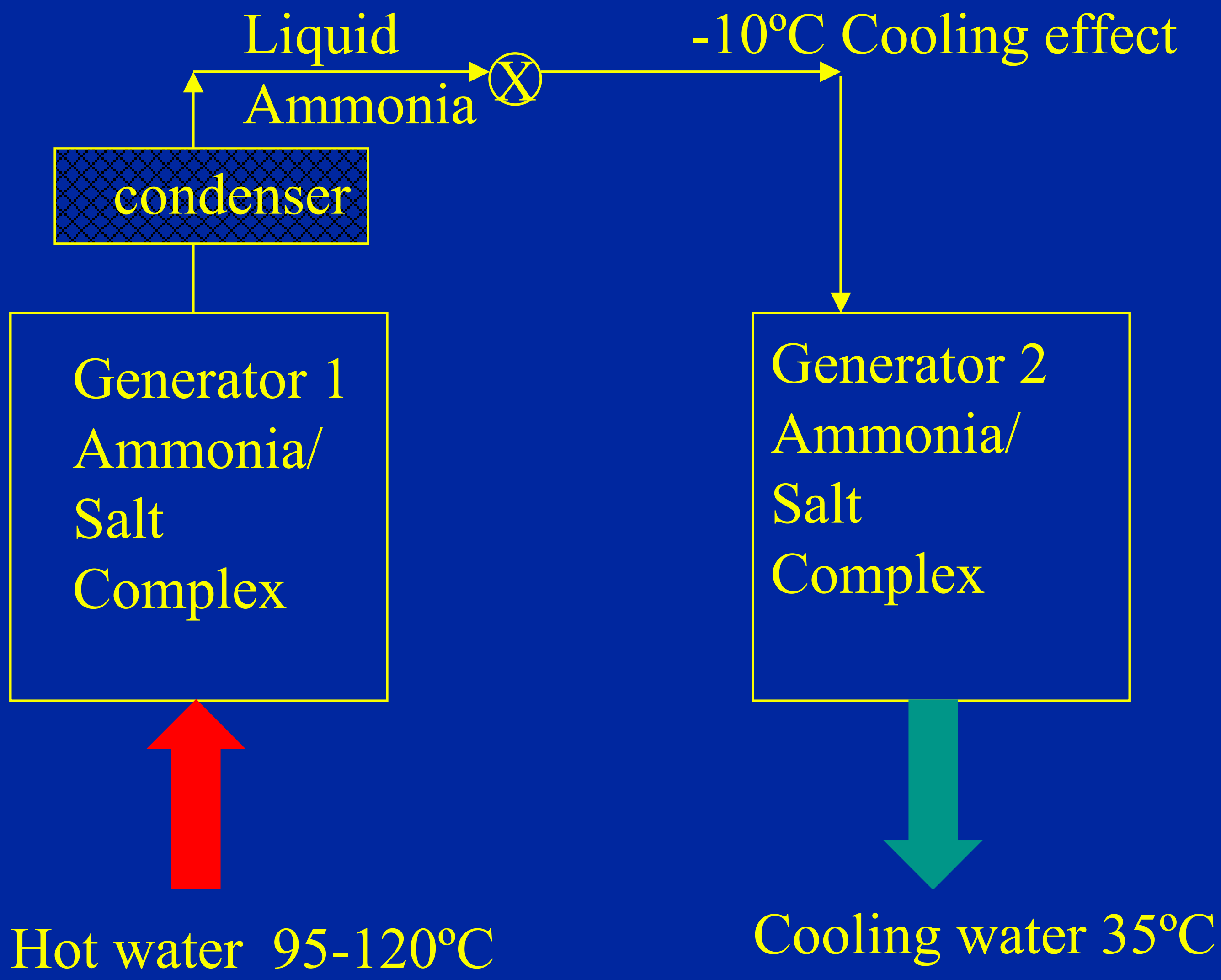
Advantages

- Able to produce below zero temperatures with hot water less than 100 deg C
- No pumping power required
- Scales down in size well
- No water means outside location possible

Disadvantages

- Ammonia requires outside location, special safety requirements
- Low efficiency means large condenser

Ammonia Adsorption Chiller
(Generators are alternately heated and cooled)



DY Refrigeration Prototype
DY Refrigeration, Changsha, China
0.7kWc (0.2 RT)


Hot Water
Heat Recovery Unit
30 kW
Microturbine
0.7 kW (0.2 tons)
Ammonia Adsorption Chiller

DY 0.7 kWc Chiller Current Status

- 0.7 kWc chiller installed in a test trailer at Calgary landfill site
- Capstone 30 kW turbine with Unifin heat recovery and DY chiller
- Chiller used to condense water and hopefully siloxanes from landfill gas
- Project status
  - Have had to certify Chinese electrical components to Canadian electrical standards
  - Has taken a long time to get complete system commissioned,latest problem have been mice building nests in electrical systems!!

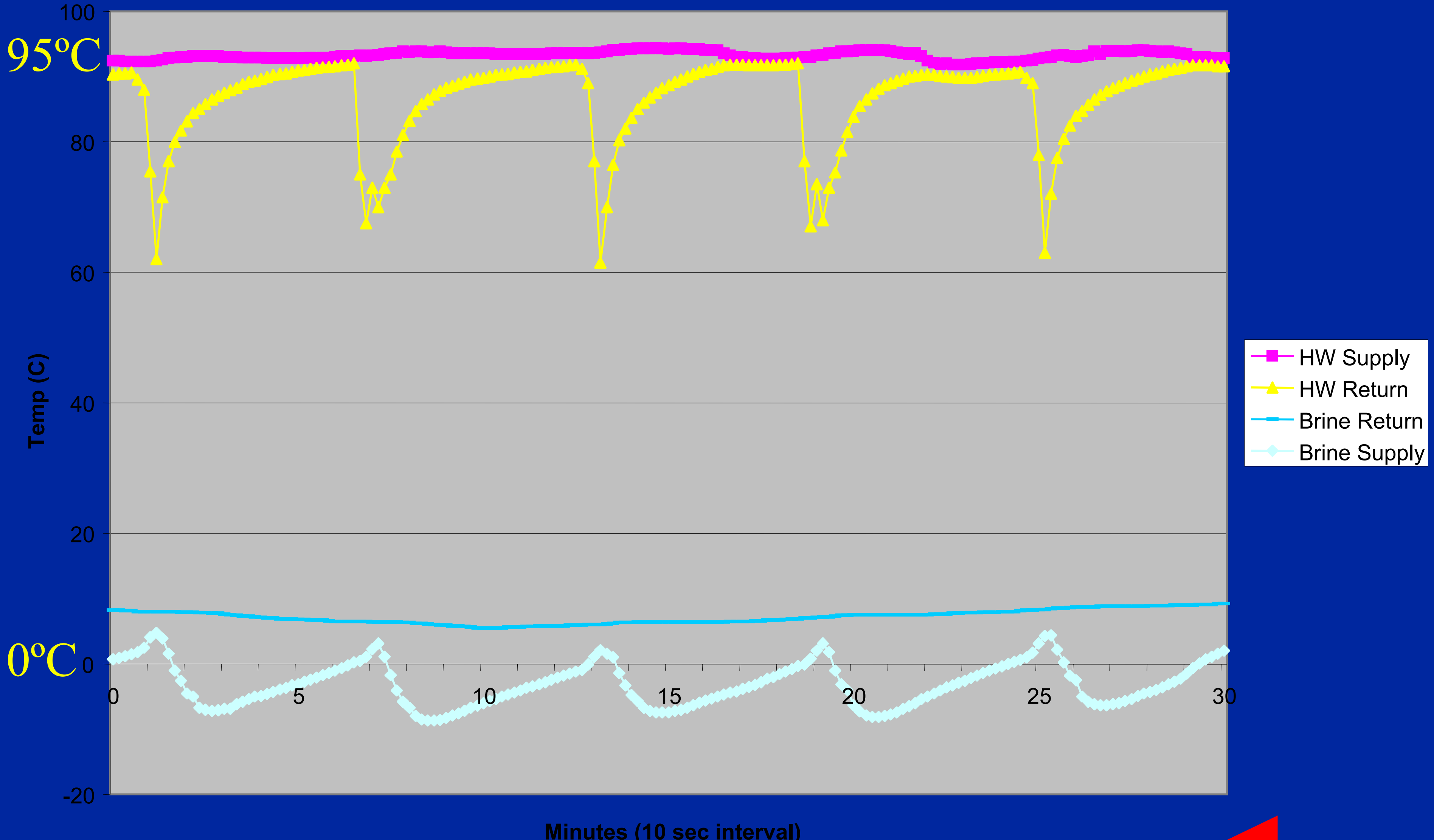
DY 14 kWc (4 RT) Chiller Status

- Unit undergoing test program in China, performance test witnessed by CETC in December 2003.
- COP with driving temperature of 95ºC and chilling temperature less than 0 ºC was 0.48.
- Operational hours in early December was 400 hours and 1000 hours of operation are expected by February.
- Delivery of unit to Canada for further evaluation is expected to be in March 2004

4 RT DY Refrigeration Chiller

- 14 kWc (4 RT) Chiller in Changsha
- Test Program under way in China
- System includes an ice store

DY 12000 COP Test Data



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14 kWc Generator Vessel
(2 per system)

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DY Chiller Future program

- Obtain performance map of 0.7 kWc unit
- Repackage 14 kWc unit to N American ammonia and electrical specifications
- Obtain performance map of 14 kWc unit
- Install the unit for field test late 2004

Ejector Chiller using low boiling point refrigerants

Advantages

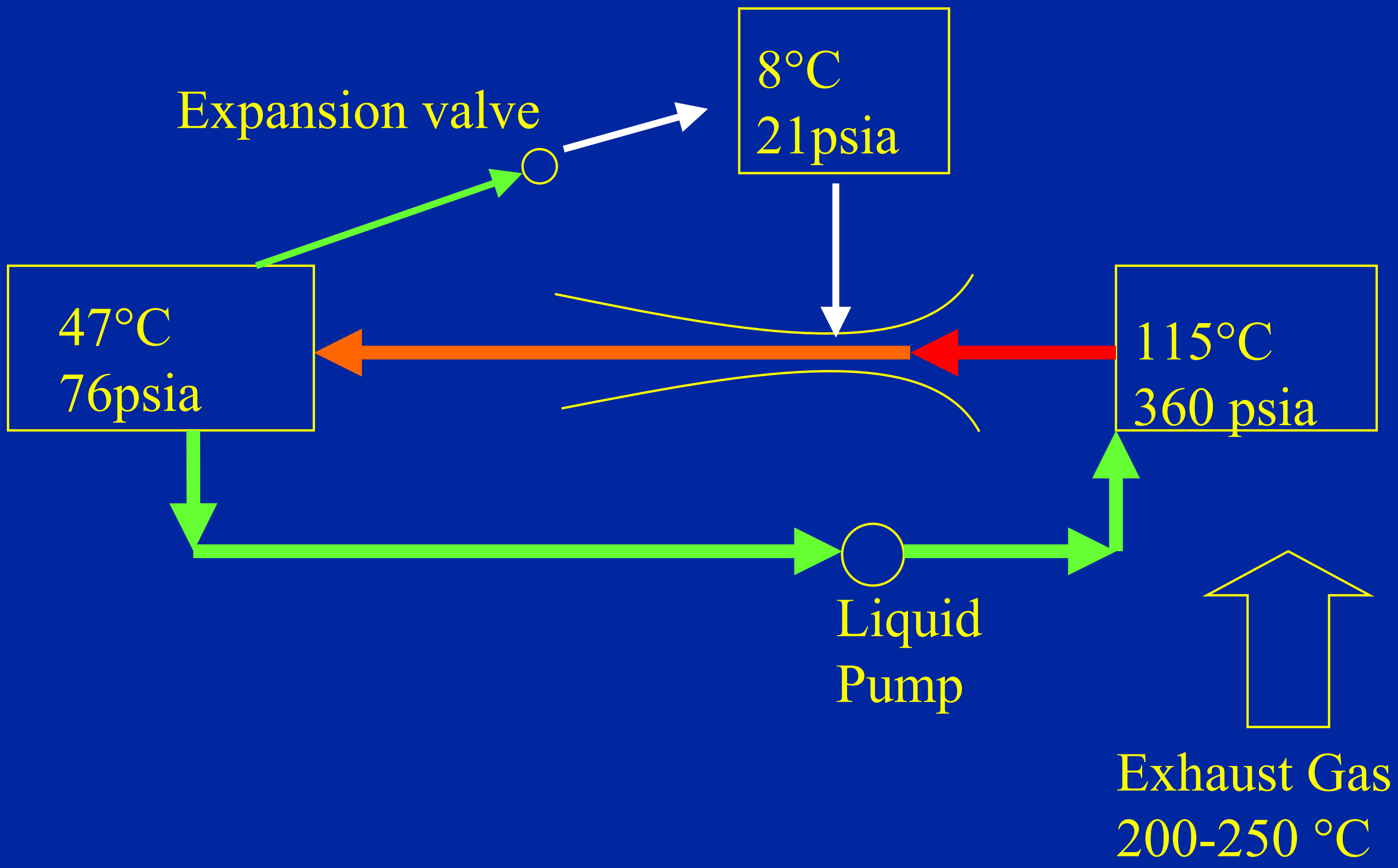
- Use of non toxic, non flammable refrigerant
- One moving part (feed pump) leads to high reliability and low maintenance costs
- Use of mass produced brazed plate heat exchangers reduces cost

Disadvantages

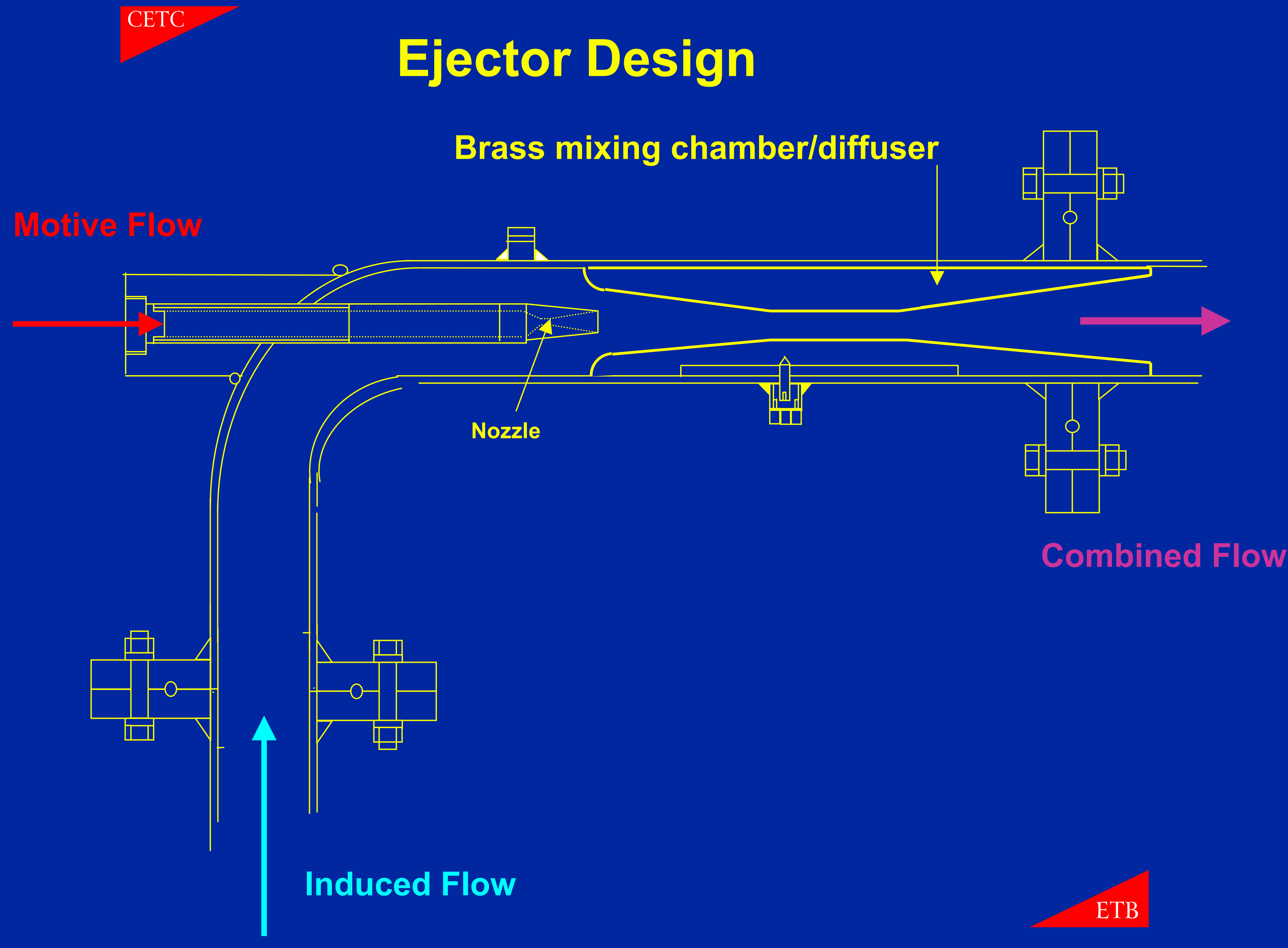
- Low efficiency means large condenser

Jet Pump Chiller

An “old “ concept using a new refrigerant HCF -236fa



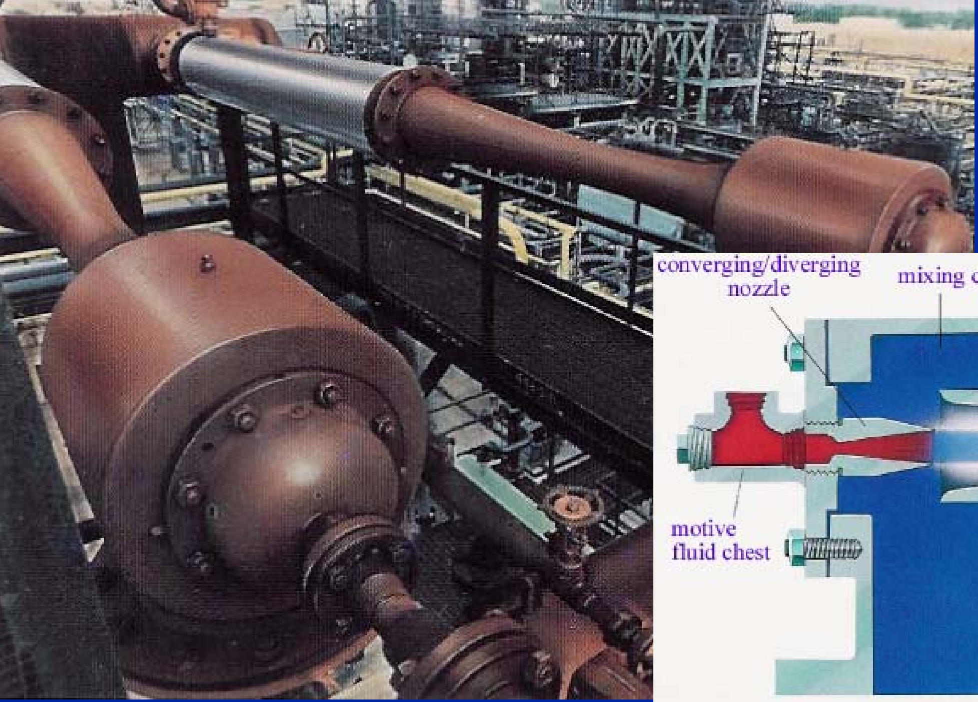
Ejector Design

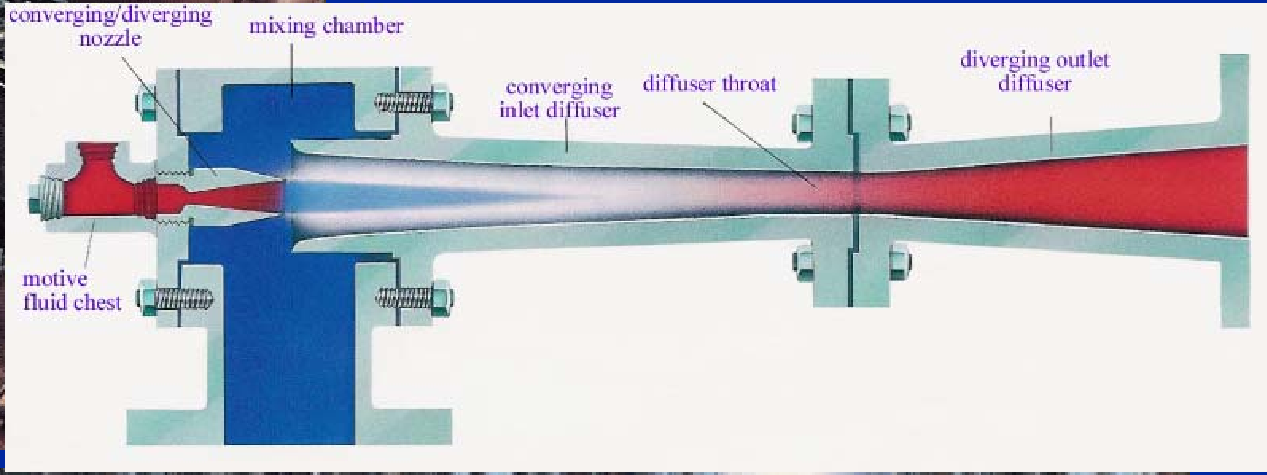


Ejector Program

- In order to be commercially viable it was decided at the start to only use refrigerants that were
  - Non flammable
  - Non toxic
  - Had zero ozone depletion potential
- Currently using 236 fa which is also used as a fire suppression gas
- Developing ejector internal profiles that it is hoped will raise the ejector coefficient of performance (COP) from 0.3 to 0.5.

Ejectors are not new devices
(images courtesy Dr Petrenko)





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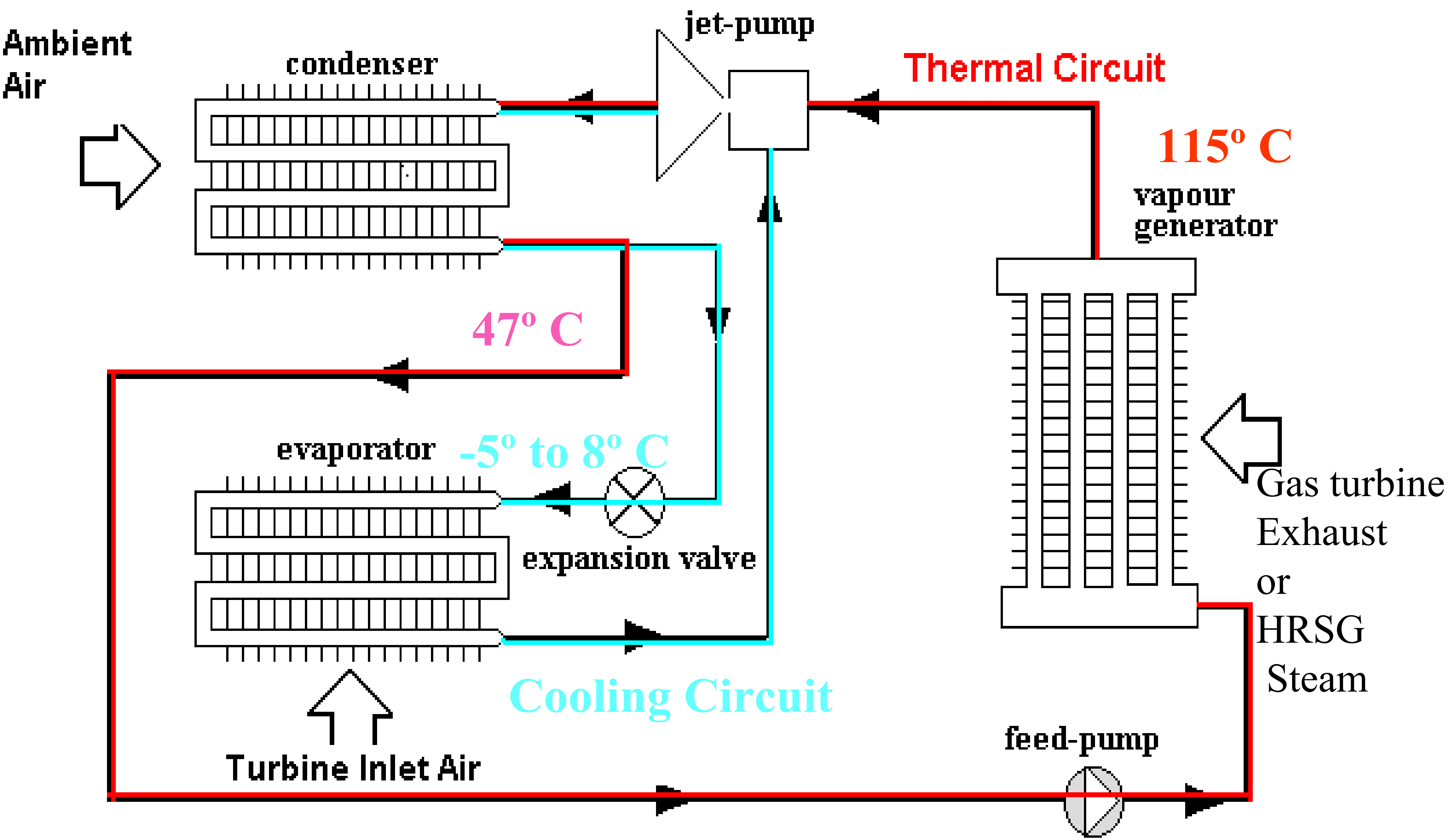
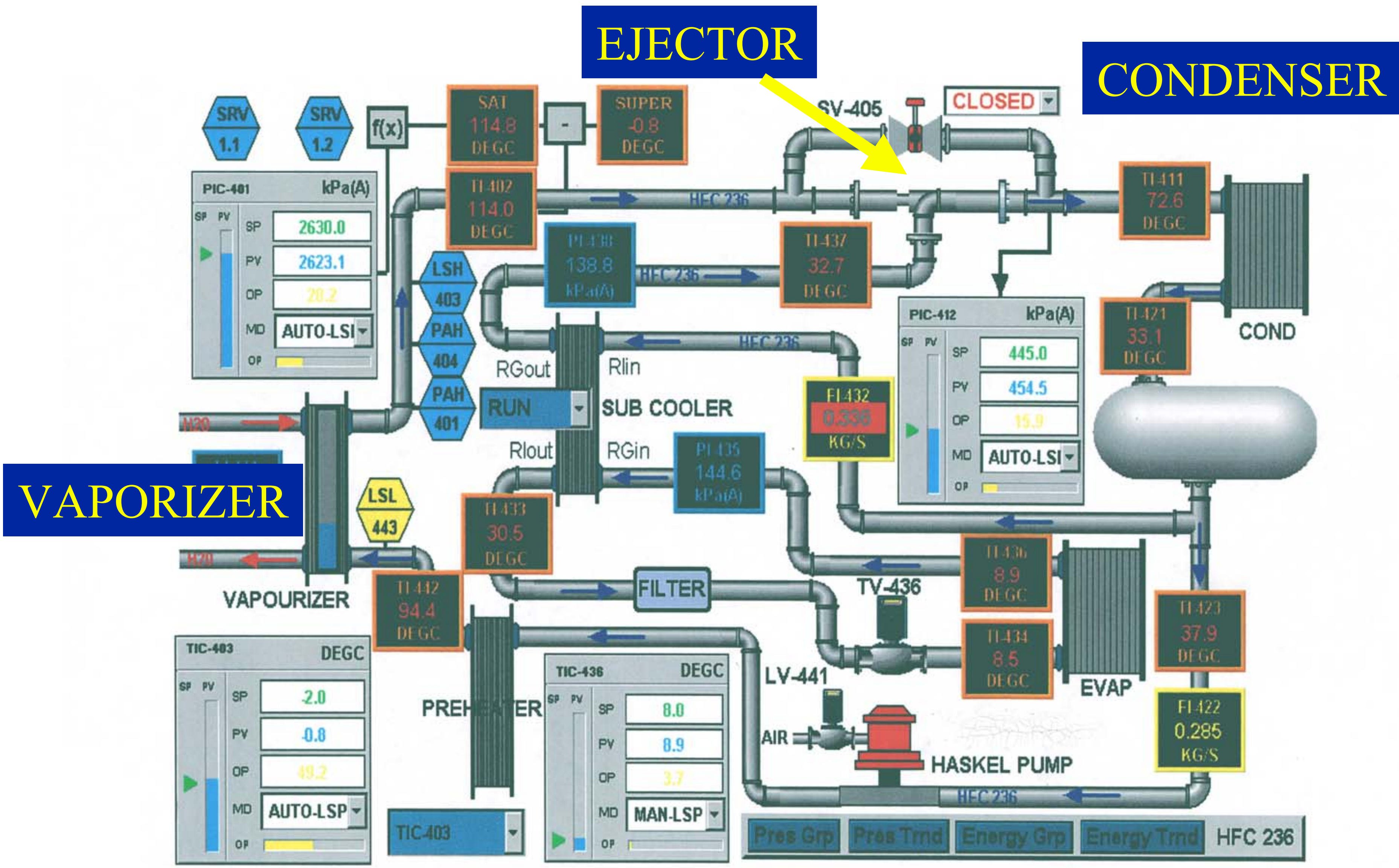
Ejector System




EJECTOR
CONDENSER
VAPORIZER
SRV 1.1
SRV 1.2
f(x)
SAT 114.8 DEGC
SUPER -0.8 DEGC
SV-405
CLOSED
PIC-401 kPa(A)
SP 2630.0
PV 2623.1
OP 20.2
MD AUTO-LSI
TI 402 114.0 DEGC
HFC 236
PI 438 138.8 kPa(A)
TI 437 32.7 DEGC
TI 411 72.6 DEGC
LSH 403
PAH 404
PAH 401
RGout
RIin
RUN
SUB COOLER
RIout
RGin
PI 435 144.6 kPa(A)
FI 432 0.336 KG/S
PIC-412 kPa(A)
SP 445.0
PV 454.5
OP 15.9
MD AUTO-LSI
TI 421 33.1 DEGC
COND
LSL 443
TI 433 30.5 DEGC
VAPOURIZER
TI 442 94.4 DEGC
FILTER
TV-436
TI 436 8.9 DEGC
TI 434 8.5 DEGC
EVAP
TI 423 37.9 DEGC
FI 422 0.285 KG/S
LV-441
AIR
HASKEL PUMP
TIC-403 DEGC
SP 2.0
PV -0.8
OP 49.2
MD AUTO-LSP
PREHEATER
TIC-436 DEGC
SP 8.0
PV 8.9
OP 3.7
MD MAN-LSP
TIC-403
Pres Grp
Pres Trnd
Energy Grp
Energy Trnd
HFC 236

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CETC Ejector Test Rig
14 kWc cooling capacity
236 fa Refrigerant

Ejector

Vaporizer

Test Ejector at CETC

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3 kWc ejector rig at the University of Nottingham

Dr Ian Eames
Dr V.A Petrenko

Project objective is to develop and test new ejector internal designs

Candidate Refrigerants

(Courtesy Dr V.A. Petrenko)

	R 245 fa	R 245 ca	236fa	R 141b	R 142b	R 123
Molecular Wt	134.0	134.06	152.04	116.9	100.5	152.9
Boiling Point	14.9	25.0	-1.44	32.2	-9.8	27.9
Critical Temperature ºC	154.05	178.4	124.92	208.0	137.1	183.8
Critical Pressure bar	36.4	38.6	32	43.4	42.0	36.7
Latent Heat at 8 ºC kJ/kg	200.5	210	155.4	234.0	208.4	177.4
ODP	0	0	0	0.1	0.06	0.02
GWP	Very low	Very low	Very low	0.126	0.36	0.024
Flammability limits	NF	NF	NF	7.3-16.0	6.7-14.9	NF

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Conclusions and Next Steps

- Plan to move beyond proof of concept testing and develop alpha field test unit
- Need to work on cost reduction concepts to reduce installed cost
- Still seen to be a market need for small thermally driven chilling systems in the 4-10 RT range
- Both concepts CETC is working with scale down well.
- Chilling system has to be “install and forget”, needs to have very high level of reliability to meet market needs

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Questions?

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