NGST COOLER TRADES

NRA PI Meeting

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Presented by
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OUTLINE

- **Introduction**

- **Regenerative versus recuperative coolers (a brief tutorial)**

- **Types of coolers considered**
  - Linear coolers (Stirling and pulse tube)
  - Turbo-Brayton coolers
  - Sorption coolers
  - Solid hydrogen cooler

- **Factors considered**
  - Availability
  - Reliability
  - Input power and mass
  - Residual vibration
  - Cost
  - Ease of system integration and test

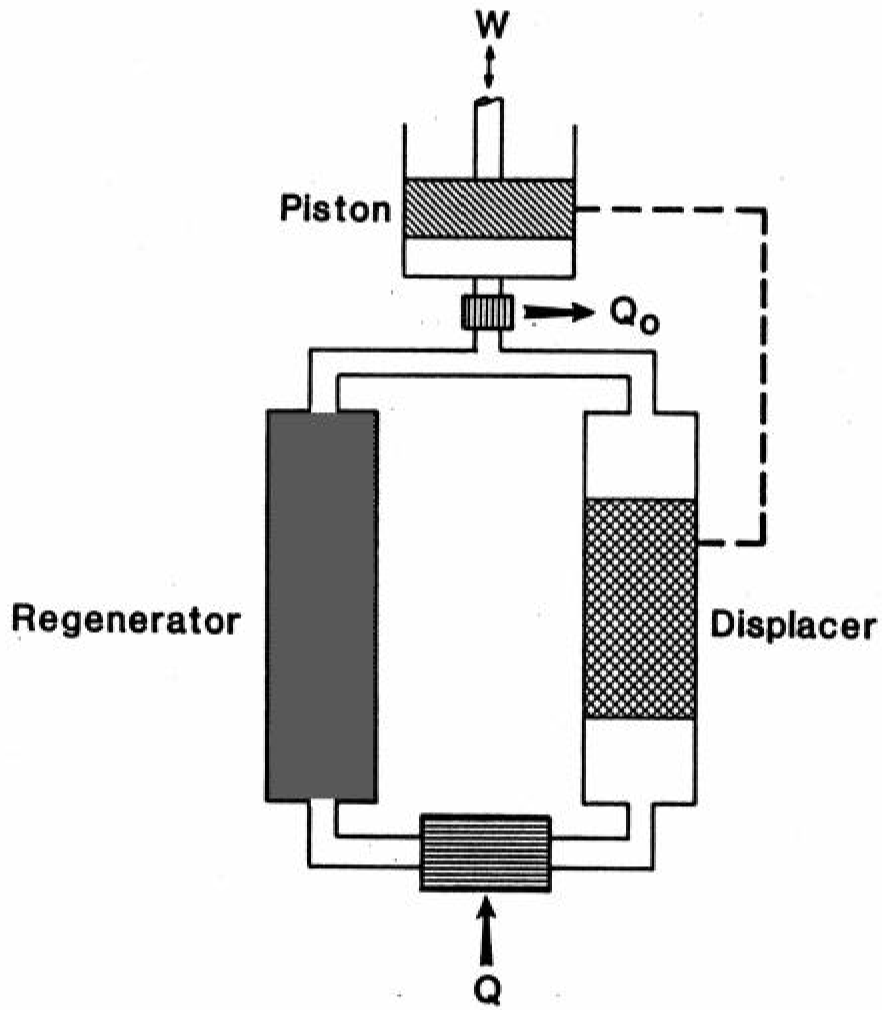
INTRODUCTION

- **NGST cooling for near IR could probably be provided by either a version of the HST/NICMOS turbo-Brayton cooler or a version of the PLANCK sorption cooler**
  - Turbo-Brayton cooler would need to be re-configured for helium
    - Input power of 30 to 50 watts for 250 mW at 25 K is attractive

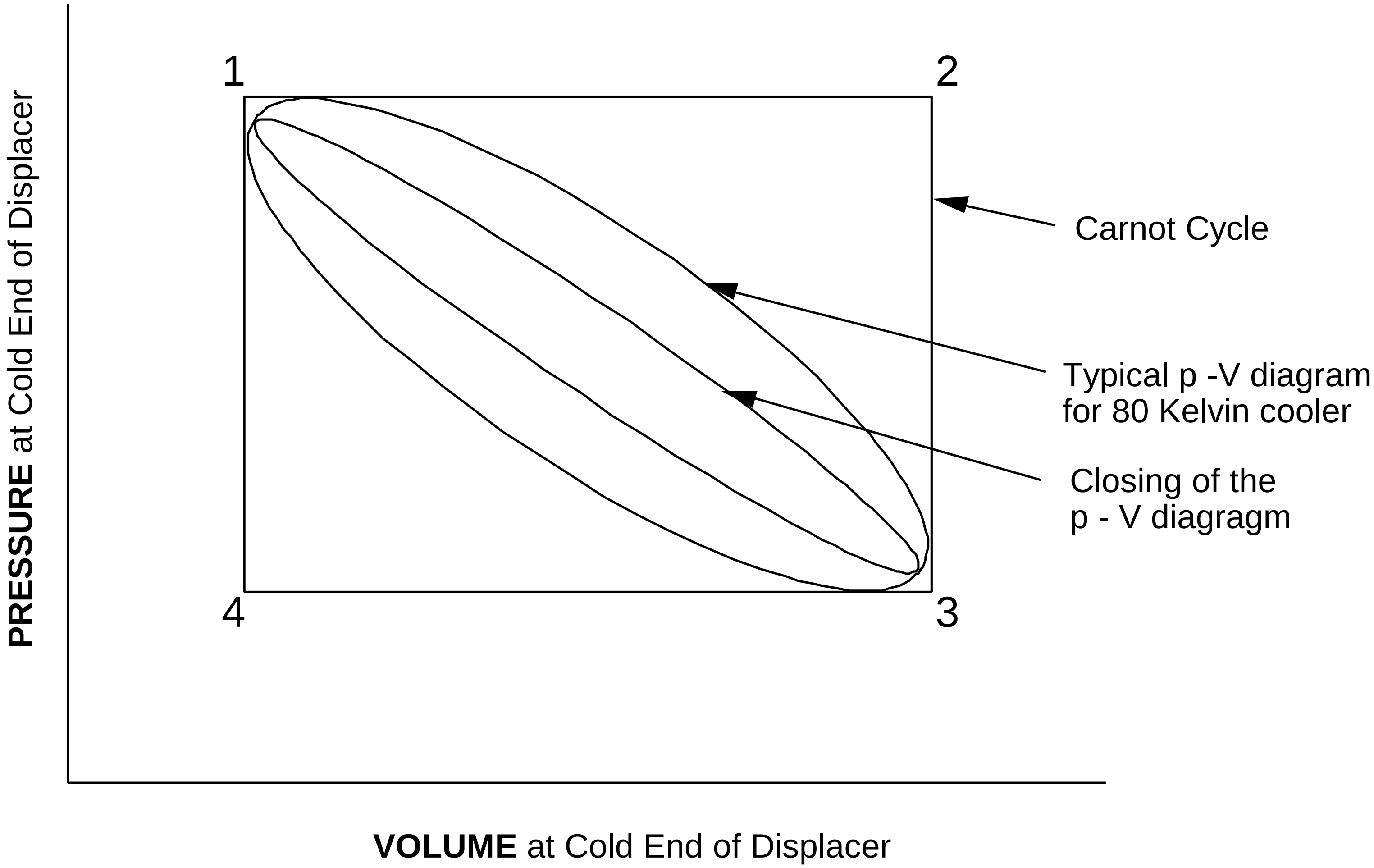
- **Cooling for mid-IR will require significantly more development**

- **This discussion will concentrate on the mid-IR cooler but many aspects apply to the near IR cooler as well**

STIRLING COOLER



Gross cooling power = Area within P-V diagraham



REGENERATIVE CYCLES

(includes Stirling and pulse tube coolers)

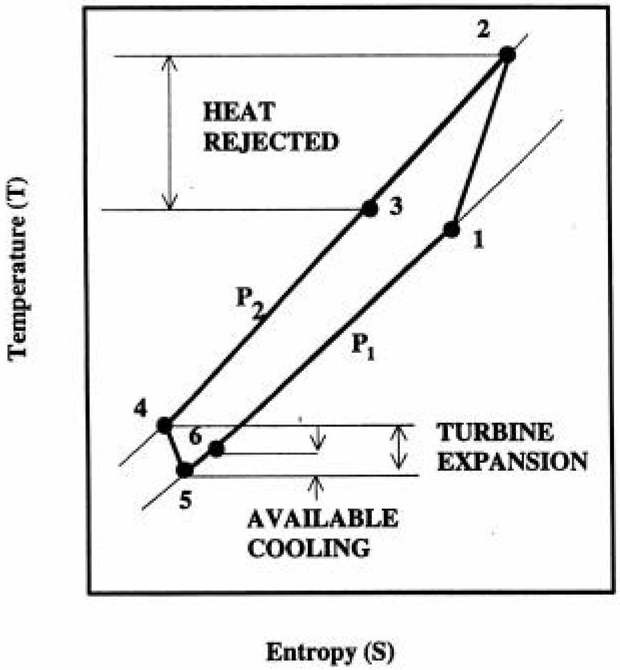
- **Regenerative heat exchanger**
  - Heat capacity decreases at low temperature

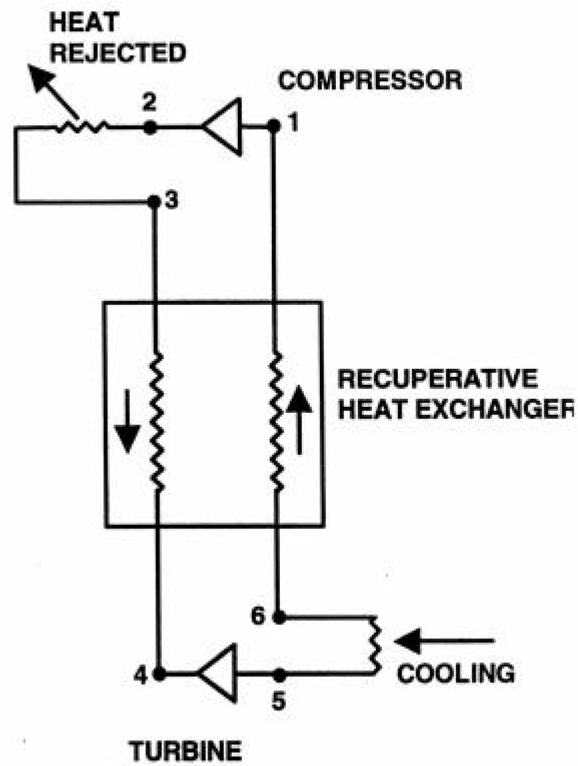
- **High cycle frequency**
  - Loss of regenerator efficiency at low temperatures resulting from poor heat exchange

- **Cyclic operation**
  - Linear compressors produce residual vibration
  - Efficiency susceptible to dead volume at cold end
  - Efficiency susceptible to density changes at cold end

- **High working fluid pressure**
  - Density changes at cold end aggravated below 10 K

Reverse–Brayton Cycle





RECUPERATIVE CYCLES

(includes Reverse Brayton and Joule-Thompson coolers)

- **Continuous operation**
  - Centrifugal and sorption compressors
  - Density changes at cold end does not effect working pressure
    - Quasi-steady-state flow
  - Void volume at cold end is not an issue

- **Recuperative heat exchanger**
  - Heat capacity at low temperature is not an issue

- **J-T cycle is not a Carnot cycle**
  - Irreversible expansion
  - High pressure accentuates non-real gas effects

SOLID HYDROGEN COOLER PARAMETERS
(0^{TH} ORDER APPROXIMATION)

Small solid hydrogen cooler to provide 3 to 5 mW of cooling

- **Concept: A heat switch and thermal strap could be used to cool the detectors and filter wheel from a "remote" solid hydrogen cooler**
  - May be required to accommodate instrument optical path
  - Decreases the size and mass of the pressure vessel enclosing the hydrogen tank

- **50 liters of solid hydrogen for 10 year life**

- **Mass of dewar TBD, perhaps 60 kg**

- **Dewar may be 80 - 90 cm in diameter and similar length**

- **May obtain nominally 6.5 K with 30K vent to space**

- **Major concerns: mass; volume; temperature; lifetime; integration and test with stored cryogens; safety**

REGENERATIVE VERSUS RECUPERATIVE COOLERS: PROS AND CONS FOR 6 KELVIN COOLERS

<u>Availability</u>

- **20 Kelvin (and warmer) linear Stirling and pulse tube coolers are available from several vendors**
  - Development of a 6 K version is not presently planned
- **70 K turbo-Brayton cooler is scheduled to fly on John Glenn flight, Oct. 29, 1998**
  - Scheduled for launch on HST Third Servicing Mission in May, 2000
  - Development of a 6 K version is scheduled for 2001
- **20 K sorption cooler under development for Planck at JPL**
  - Development of a 6 K version is under consideration

<u>Reliability</u>

- **Linear coolers mature and on life test**
- **Turbo-Brayton coolers rapidly maturing; key components on life test**
- **JPL is performing life test on sorption bed for 20 Kelvin sorption cooler**

REGENERATIVE VERSUS RECUPERATIVE COOLERS: PROS AND CONS FOR 6 KELVIN COOLERS
(CONTINUED)

Input Power

- **Linear Stirling and pulse tube coolers are inefficient at 6 Kelvin**
- **Turbo-Brayton cooler is relatively efficient at 6 Kelvin**
- **Efficiency of a 6 Kelvin sorption cooler is TBD but is expected to be lower than turbo-Brayton**

- **NOTE: To work around the inefficiency of Stirling and pulse tube coolers below 10 Kelvin, a hybrid linear cooler using a J-T lower stage is often used**
  - Improves efficiency but exhibits the residual vibration of the linear cooler

Mass

- **Mass is not a major discriminator**

REGENERATIVE VERSUS RECUPERATIVE COOLERS: PROS AND CONS FOR 6 KELVIN COOLERS

(CONTINUED)

Residual Vibration

- **Linear coolers have residual vibration on the order of 100 milli-Newtons**
- **Turbo-Brayton and sorption should have acceptable vibration**
  - Turbo-Brayton operates at 5,000 – 10,000 Hz
  - Turbo-Brayton exhibits pressure surges on start-up
    - Could be eliminated if desired
  - Sorption cycle includes periodic check valve operation

Cost

- **Linear coolers and turbo-Brayton cooler will have similar cost**
  - Cost will decrease with time but probably not significantly prior to NGST
  - Cost of sorption is TBD

REGENERATIVE VERSUS RECUPERATIVE COOLERS: PROS AND CONS FOR 6 KELVIN COOLERS

(CONTINUED)

<u>System Integration</u>

- **Linear coolers will need to be mounted on an additional stage of vibration isolation which may not function at cryogenic temperatures**

- **Linear compressors for regenerative coolers can not be remote from the cold finger**

- **It is preferable to operate the compressor of turbo-Brayton coolers at the lowest possible temperature**
  - Temperature limited only by radiator size
  - NICMOS circulator (a compressor) operates at 70 K
  - Eliminates need to have compressor on the warm module

- **Sorption compressors run warm (hydrogen bed over 400 °C)**
  - Can put in warm module since tubing from the compressors to the cold end is small diameter and should be flexible

NGST TURBO-BRAYTON COOLER:
LAYOUT OF MAJOR COMPONENTS

- **One possible layout of a turbo-Brayton cooler on NGST will be used to illustrate potential integration issues**

  <u>NGST "COLD" ELECTRONICS MODULE</u>
- **Gas bearing supported turbo-compressor**
  - Volume - 3 inch diameter by 4 inch length
  - Mount on 220 K (TBD) radiator near cold electronics to reduce input power
- **Warm heat exchanger between compressor and nominally 60 K radiator**
  - Volume - 8 inch diameter by 3 inch height
  - Could mount with compressor or on the radiator
- **Nominally 60 K radiator heat intercept**
- **Thin wall stainless steel tubing running from radiator to ISIM**

NGST TURBO-BRAYTON COOLER:
LAYOUT OF MAJOR COMPONENTS
(CONTINUED)

<u>NGST INTEGRATED SCIENCE INSTRUMENT MODULE</u>

- **Cold heat exchanger between 60 K radiator and expander(s)**
  - Volume - 8 inch diameter by 2 inch height
  - For cooling at both 30 K and 6 K, the cold heat exchanger would be split at 30 K
- **Gas bearing supported turbo-expanders at 30 K and 6 K**
  - Volume - 3 inch diameter by 4 inch length for each
- **Small diameter (nominally 1/4 inch) tubing loop from expander to near point heat sources and back to cold heat exchanger**
  - Heat exchangers for detectors, filter wheel, etc.
- **Flexible strap from heat exchangers to detectors and filter wheel**
  - Could be few inches to few feet in length
  - Recommendation: Electrically isolate both ends of thermal strap and ground electrically isolated thermal strap to instrument ground with a ground wire
    - Creates a Faraday shield between detectors and structure