Testing and Test Facility at Site

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Outline of Talk

- Introduction
- Various solar thermal devices
- Performance
- Conclusions

Solar Thermal Application and Devices

Applications

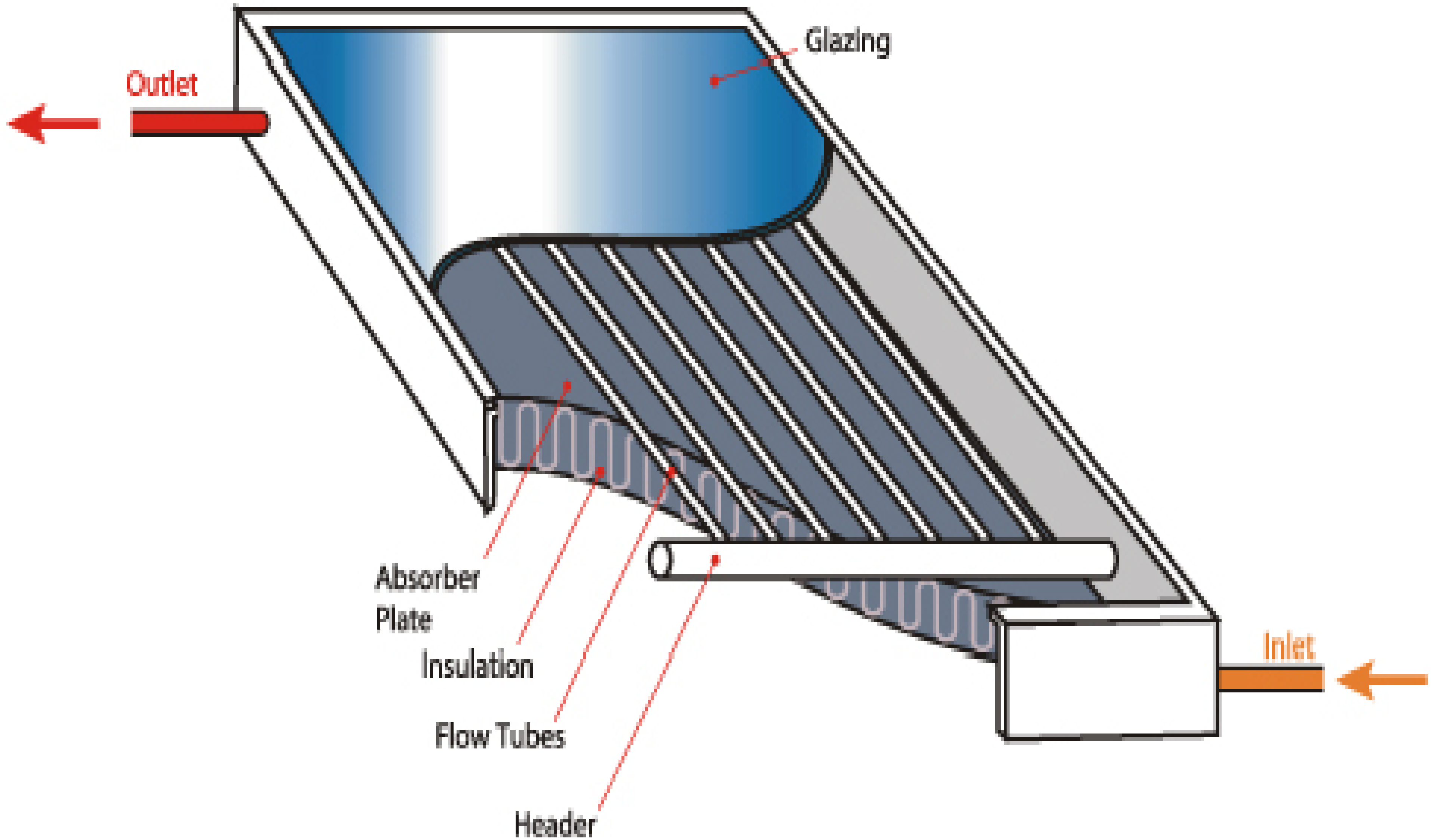
- Water heating
- Air heating
- Cooking
- Drying
- Distillation
- Process heat
- Power generation
- Space cooling and refrigeration

Devices

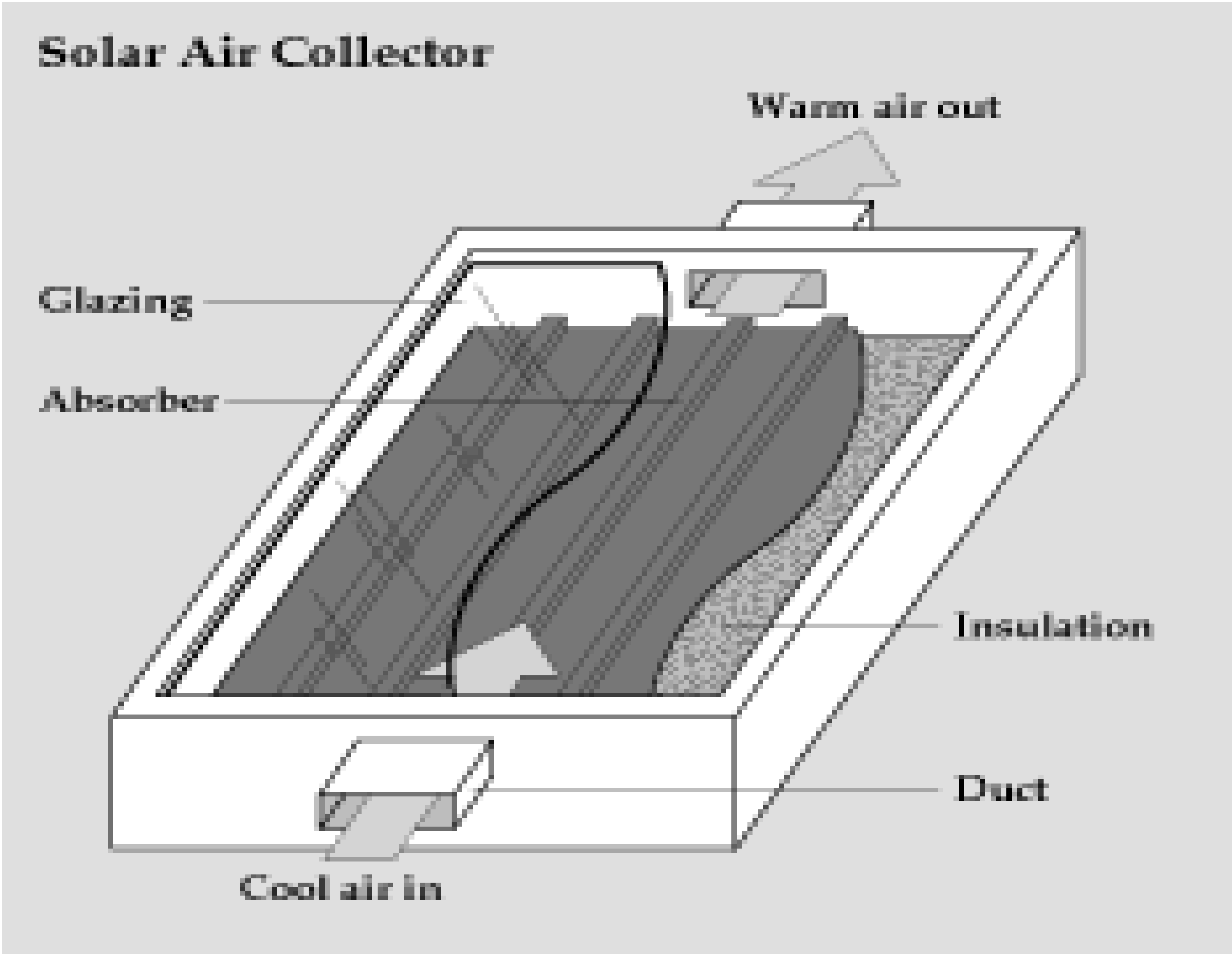
- Flat-plate collector
- Concentrator
- Cooker
- Still
- Solar pond

DEVICES

Flat Plate Collector

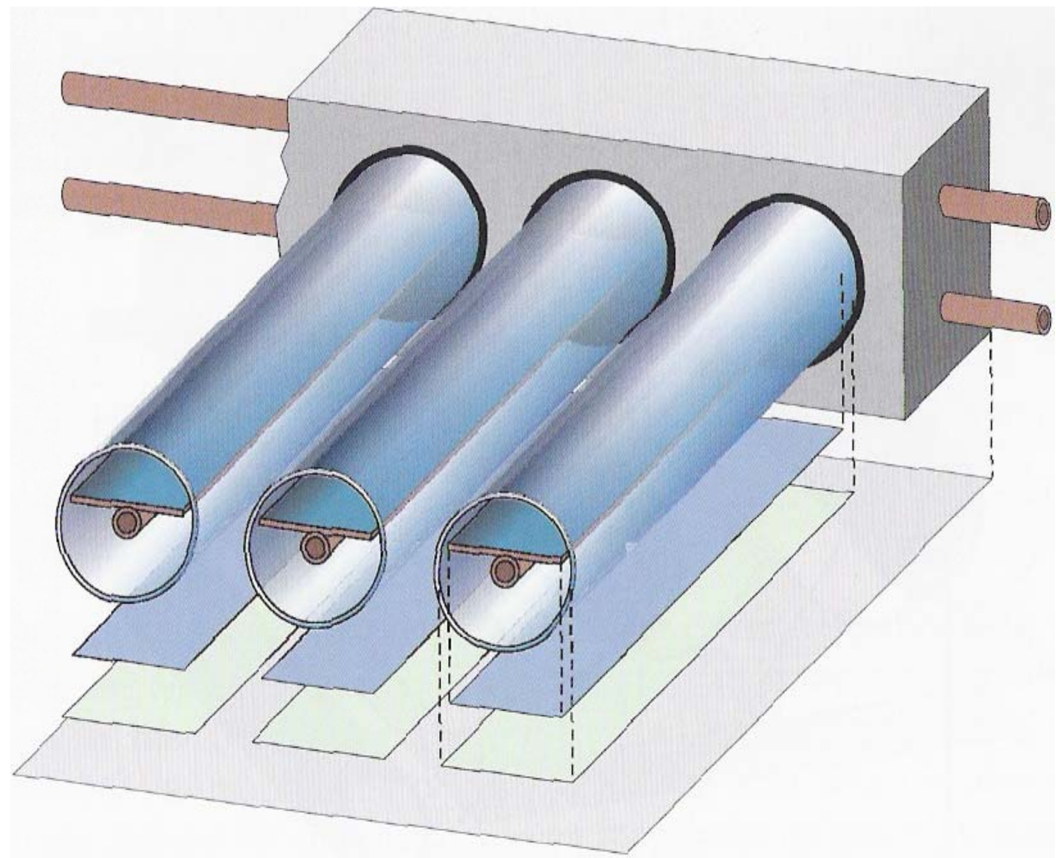


Solar Air Heater



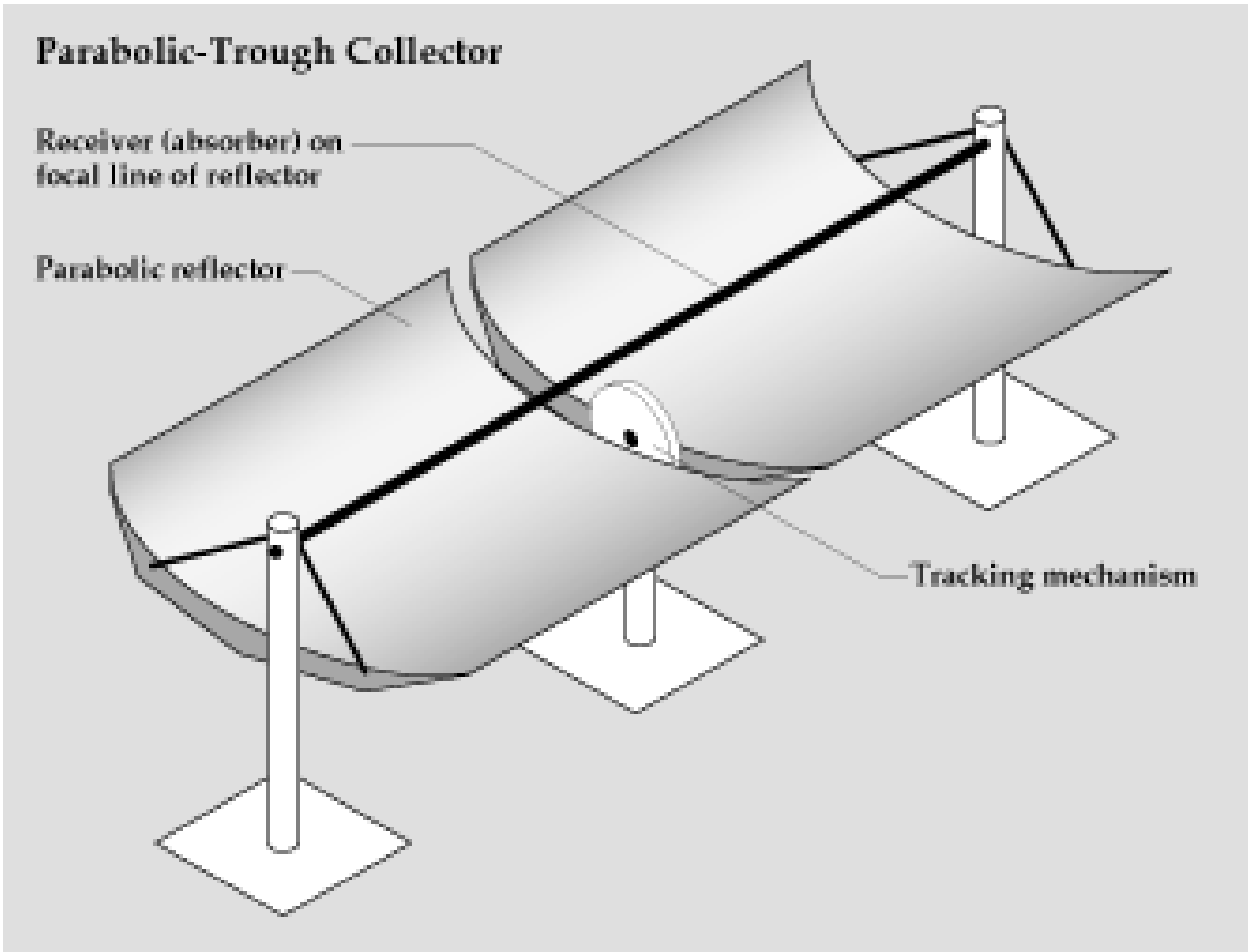
Evacuated Tube Collector

Collector

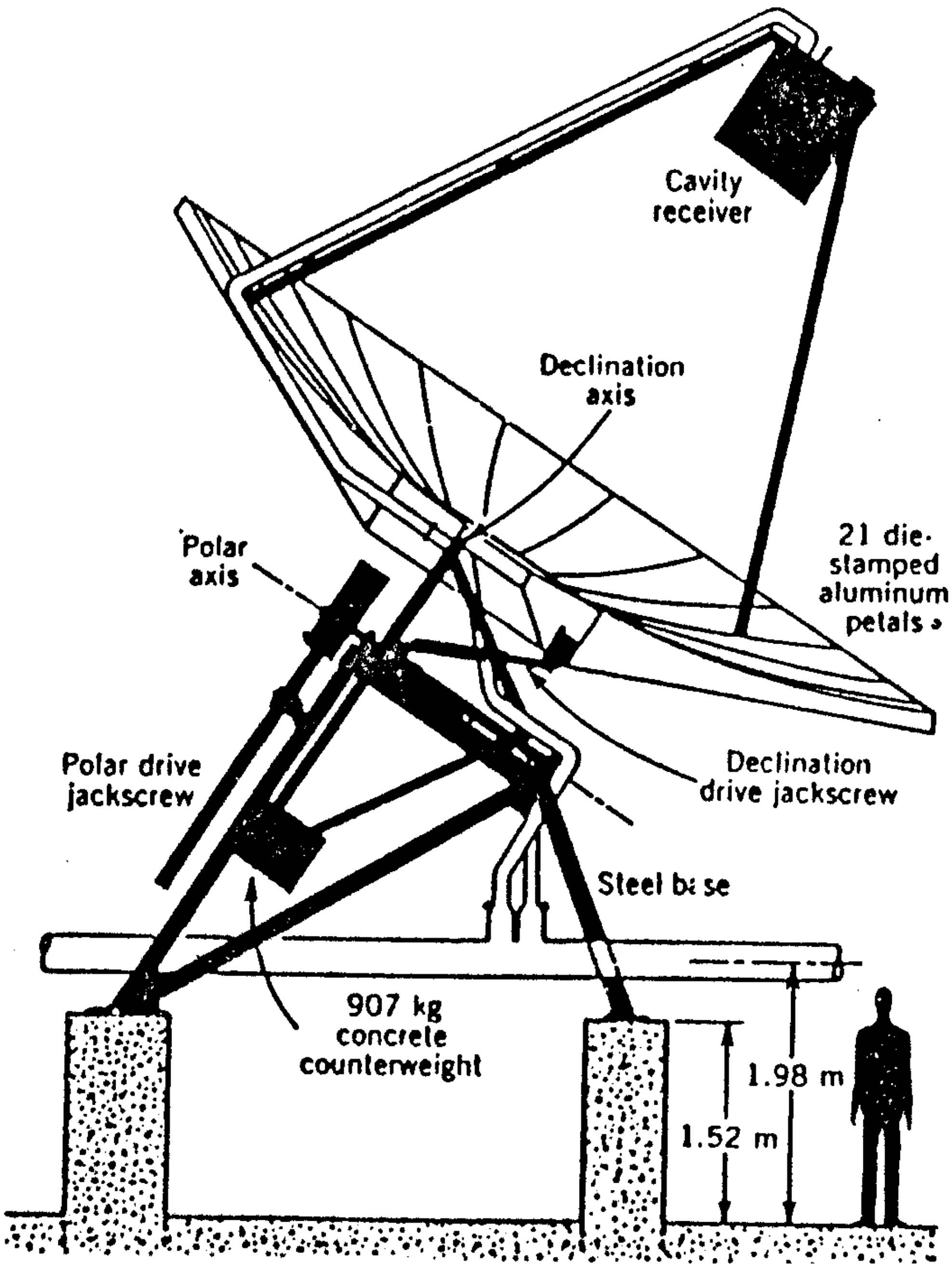


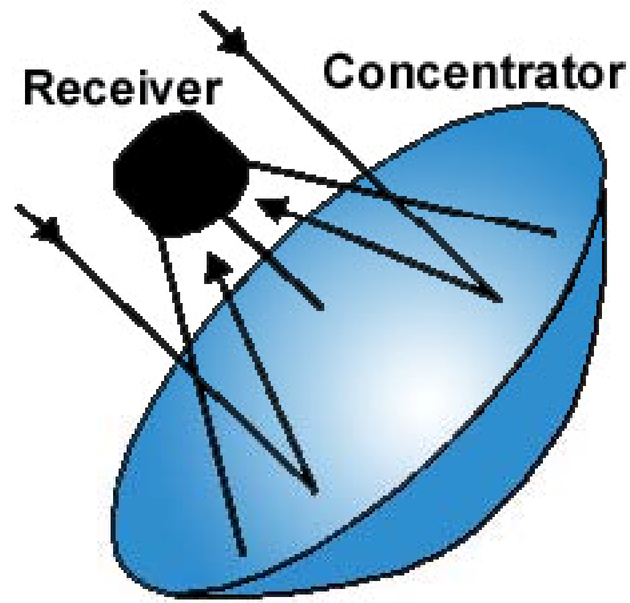
Collector Connection

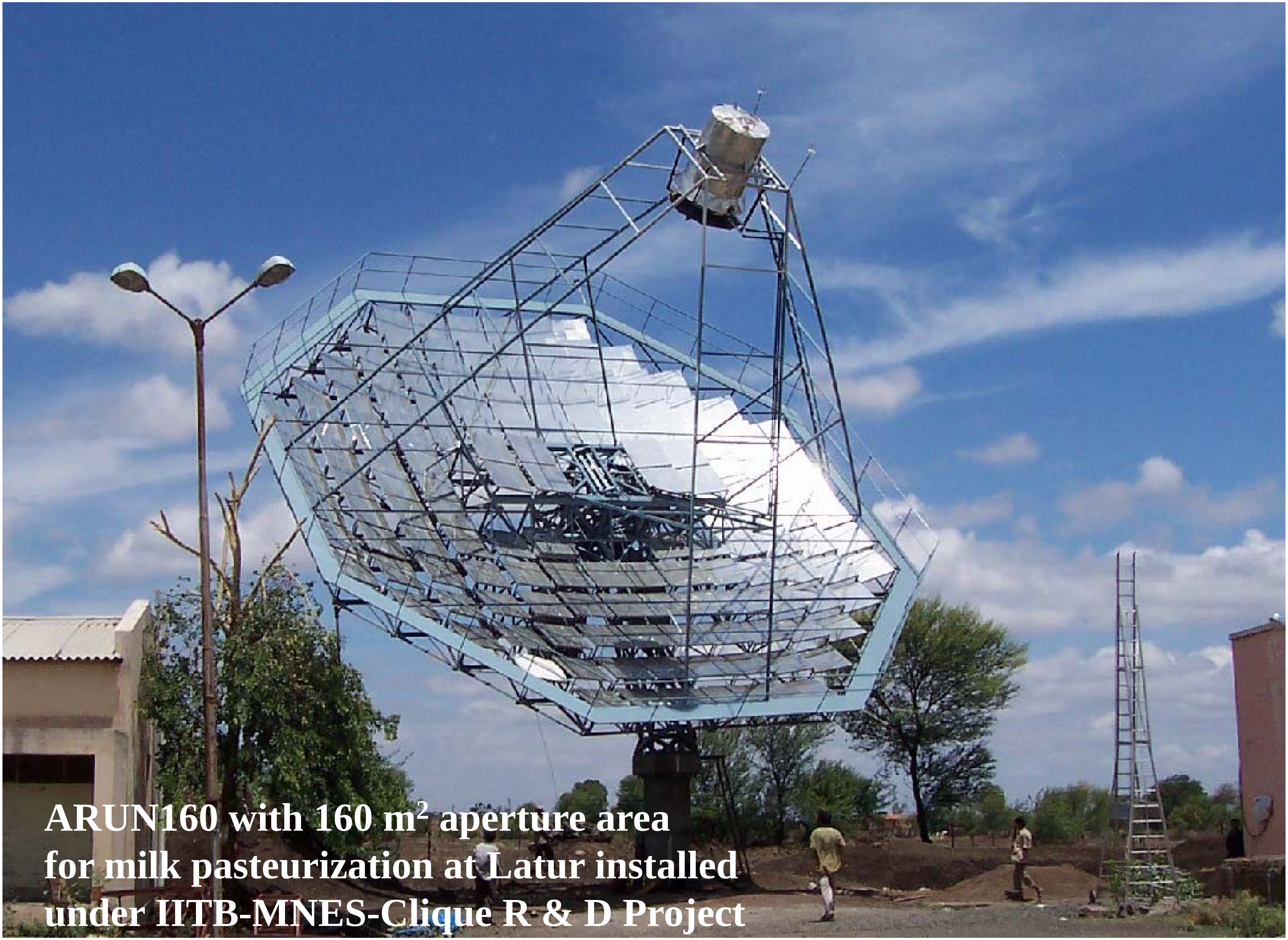
Cylindrical Parabolic Concentrator



Parabolic Dish Concentrator

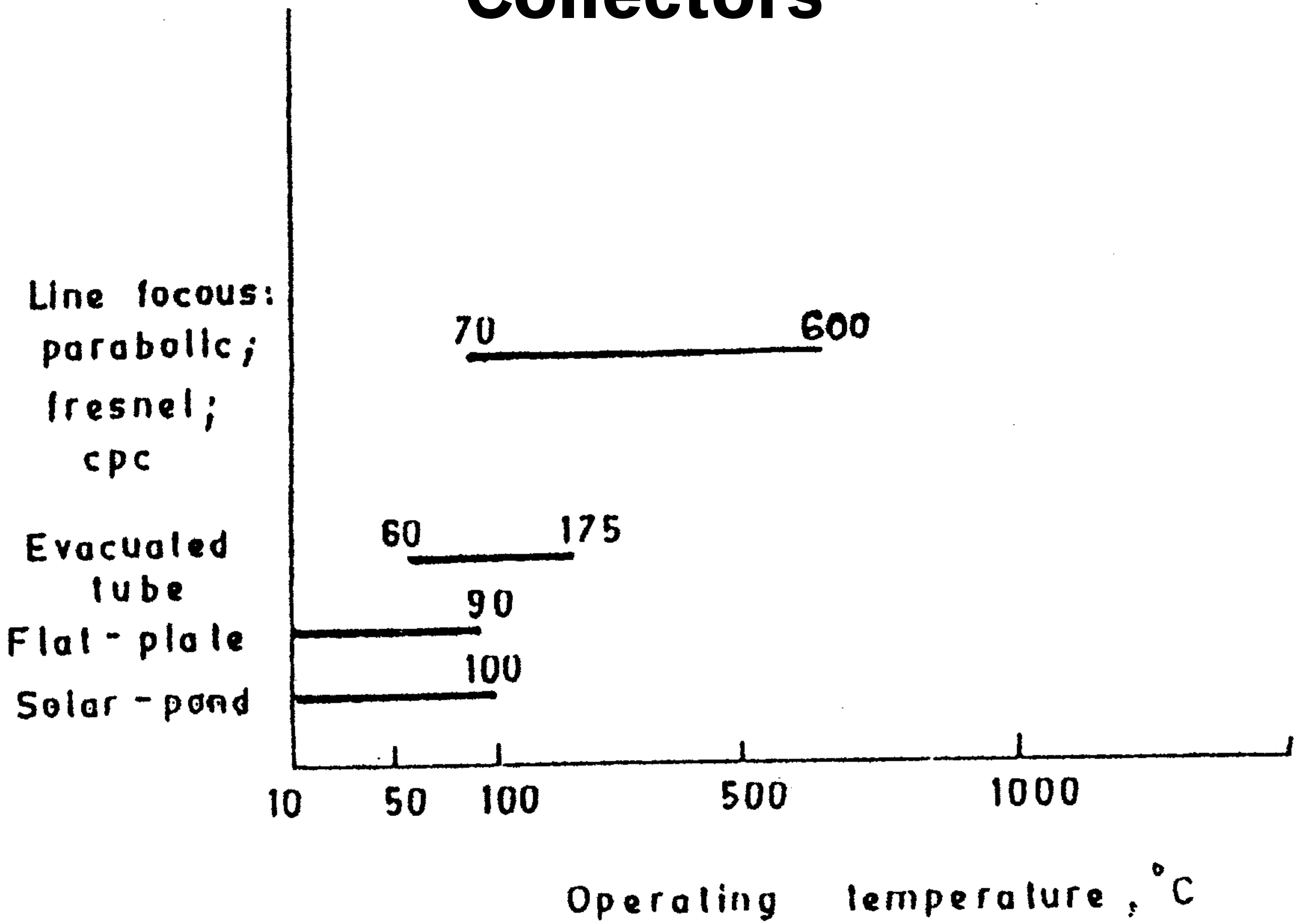






ARUN160 with 160 m^2 aperture area
for milk pasteurization at Latur installed
under IITB-MNES-Clique R & D Project

Operating Temperatures of Various Collectors



How does one know that a device is good, acceptable?

How to rate and compare?

Test

Testing of Collector

Why testing?

- Estimate certain characteristic parameters to
  - ascertain whether a product is qualified or not.
  - rate products
- Indoor

  realisation of actual sky temperature: an issue
- Outdoor: preferred
  - Quasi-steady state
  - Dynamic
- Accelerated testing: life, weather effect, etc.

Testing & Standardisation

Number of manufacturer of solar liquid collector :

70 (with BIS certification)

<u>BIS Standard</u> (outdoor test method):

1990 (revised in 1992) as

IS 12933 (parts 1-5)

Outdoor Test of Flat-plate Collector

- Endurance test
  - No flow exposure test
  - Static pressure leakage test
  - Internal thermal shock test
  - Rain penetration test
  - Impact resistance test
- Time constant measurement
- Thermal performance test
- Incident angle modifier test

Time constant:

$$\frac{T_{fo} - T_{fi}}{T_{fo,initial} - T_{fi}} = 0.368$$

Thermal performance

$$\eta = F_R \left[(\tau\alpha)_n - \left(\frac{U_L (T_{fi} - T_a)}{I} \right) \right]$$

Incident angle modifier

$$K = \frac{F_R (\tau\alpha)_{eff}}{F_R (\tau\alpha)_n}$$

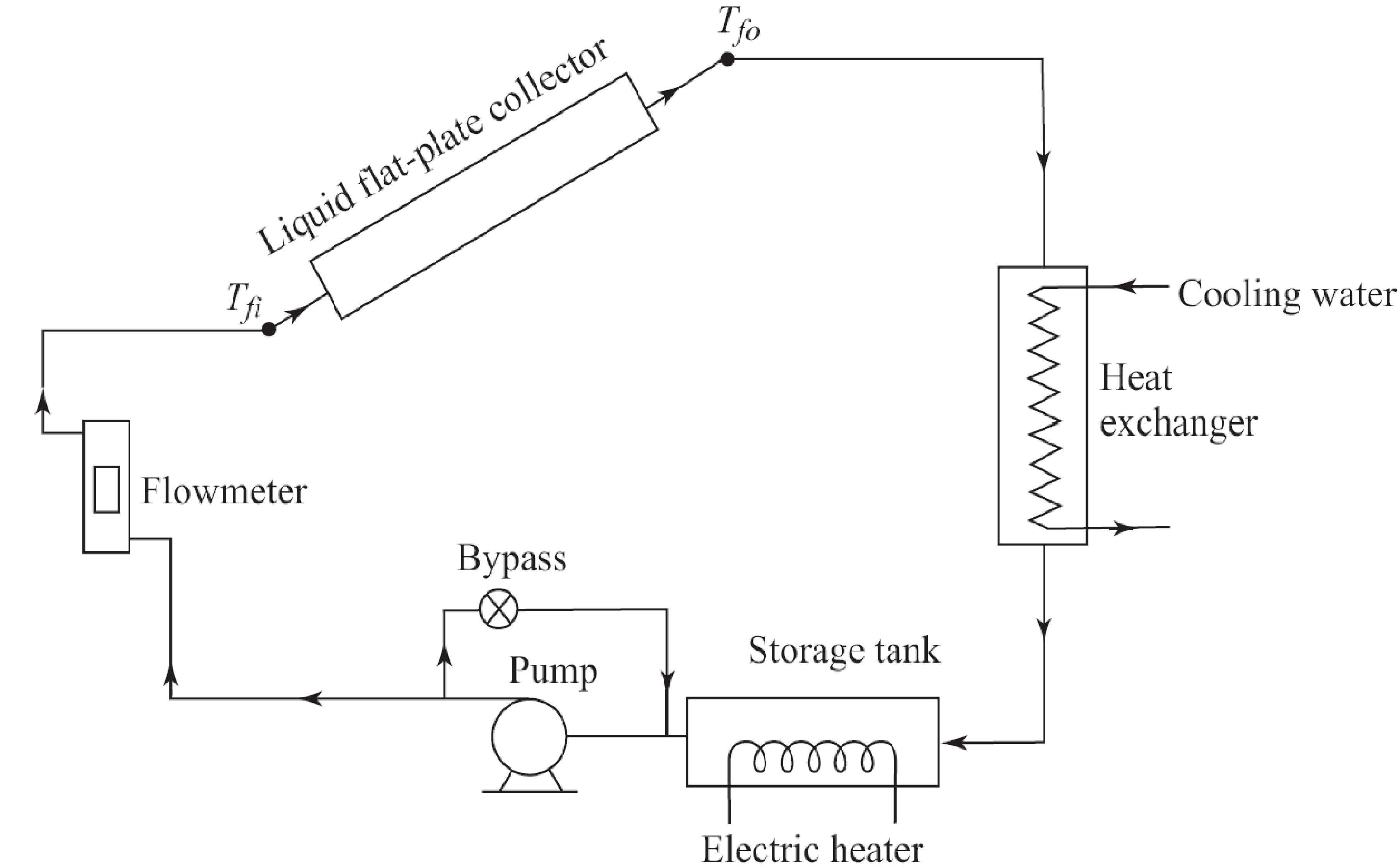


Fig. *Schematic diagram of a closed loop set-up for testing liquid flat-plate collectors*

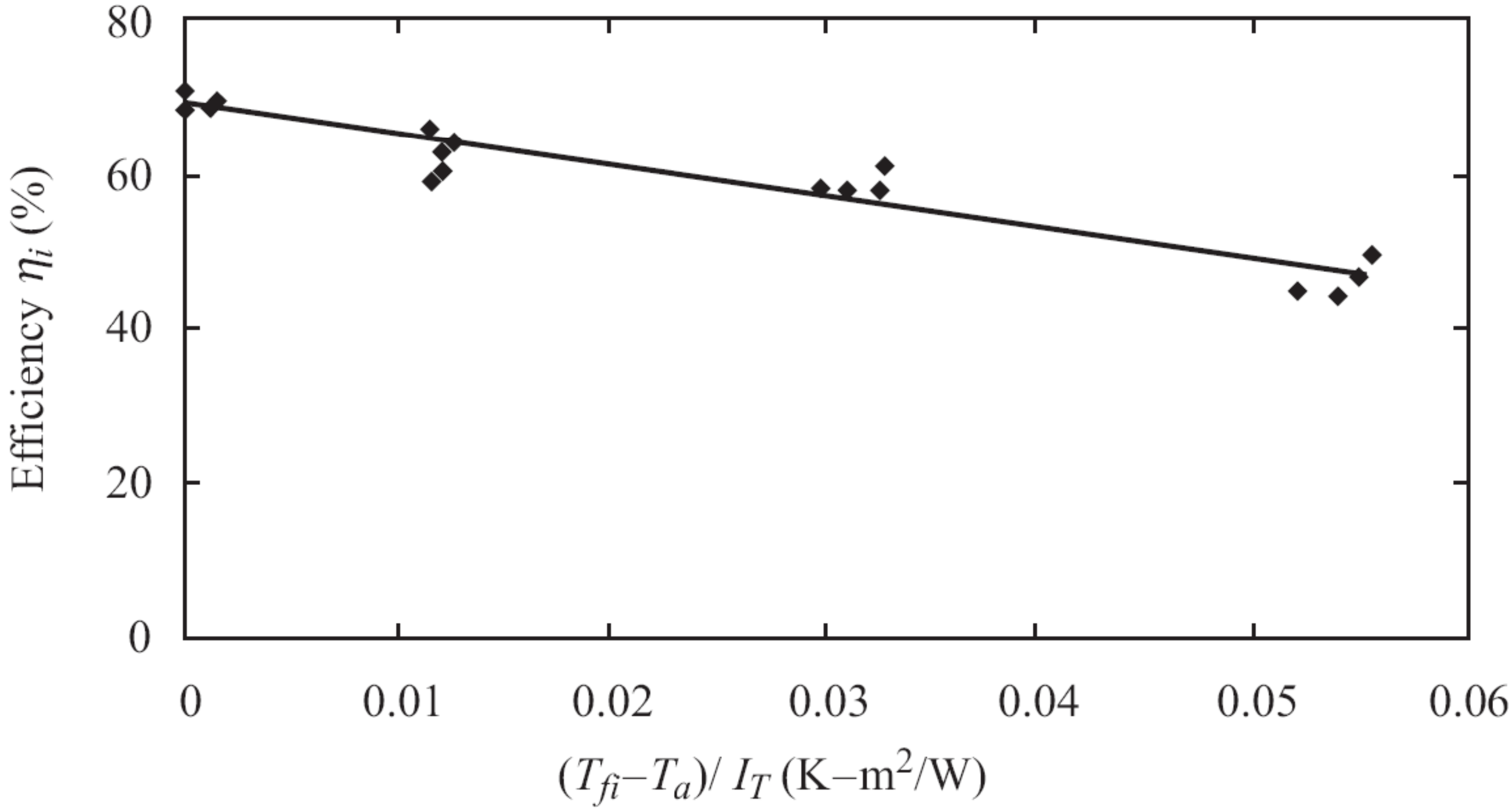


Fig. *Efficiency curve for a commercial flat-plate collector of the conventional type (single cover, selective copper absorber plate. $A_c = 2.270$ m^2; $\dot{m} = 0.0456$ kg/s)*

Efficiency curve does not remain a straight line at high temperatures, particularly for concentrators

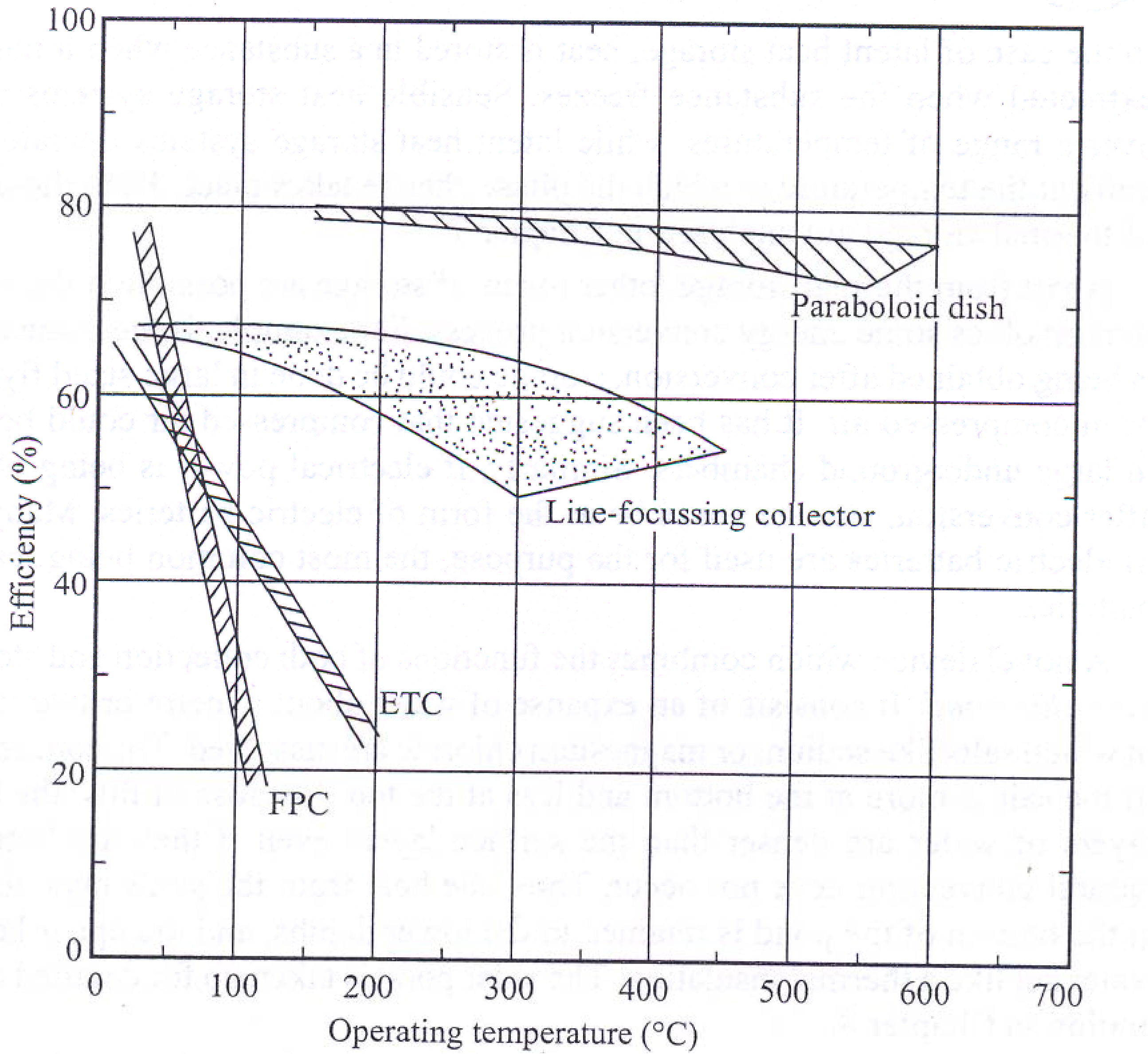


Fig. 2.6 *Efficiency of various types of collectors as a function of operating temperature (Adapted from Gehlisch et al. [1] and Rabl [2])*

Concentrator

ASTM standard E 905-87

1. Trough: Response time, Incident angle modifier, Rate of heat gain at near normal incidence

2. Point focus and linear two-axis tracking : Response time, Rate of heat gain at near normal incidence

No rating possible

Trough Concentrator

- Useful heat gain =

Reflectivity **Intercept factor**

$$I_{bn} \times \cos\theta \times K \times A_{ap} \times \rho \times \gamma \times (\tau\alpha)_{eff} \times F_m$$

Incident angle modifier **Collector efficiency factor**

$$- F_m \times [U_L \times (T_{mf} - T_{amb}) \times A_{rec}]$$

Receiver loss coefficient including convective and radiative losses

Useful thermal power delivered =

$$I_{bn} \times \cos\theta \times K \times A_{ap} \times \sigma \times \rho$$

Solidity (σ) **Reflectivity** (ρ)

Incident angle modifier (K)

Optical components

$$\times\ \gamma\ \times\ \alpha \times F_m$$

Collector efficiency factor (F_m)

Intercept factor (γ) **Absorptivity of the receiver surface** (α)

$$-\ F_m \times (U_L \times (T_{mf} - T_{amb}) \times A_{rec})$$

Receiver loss coefficient including convective and radiative losses (U_L)

Loss coefficient

- Trough:

$$U_L = U_0 + U_1 (T_{mf} - T_{amb})^p$$

- Dish:

$$U_L = U_0 + [U_1 + U_2 (\cos \theta_\nu)^n](T_{mf} - T_{amb})^p$$

Flux test

Flux distribution at the Receiver focal plane:

Optical efficiency
Focus size (receiver aperture size)

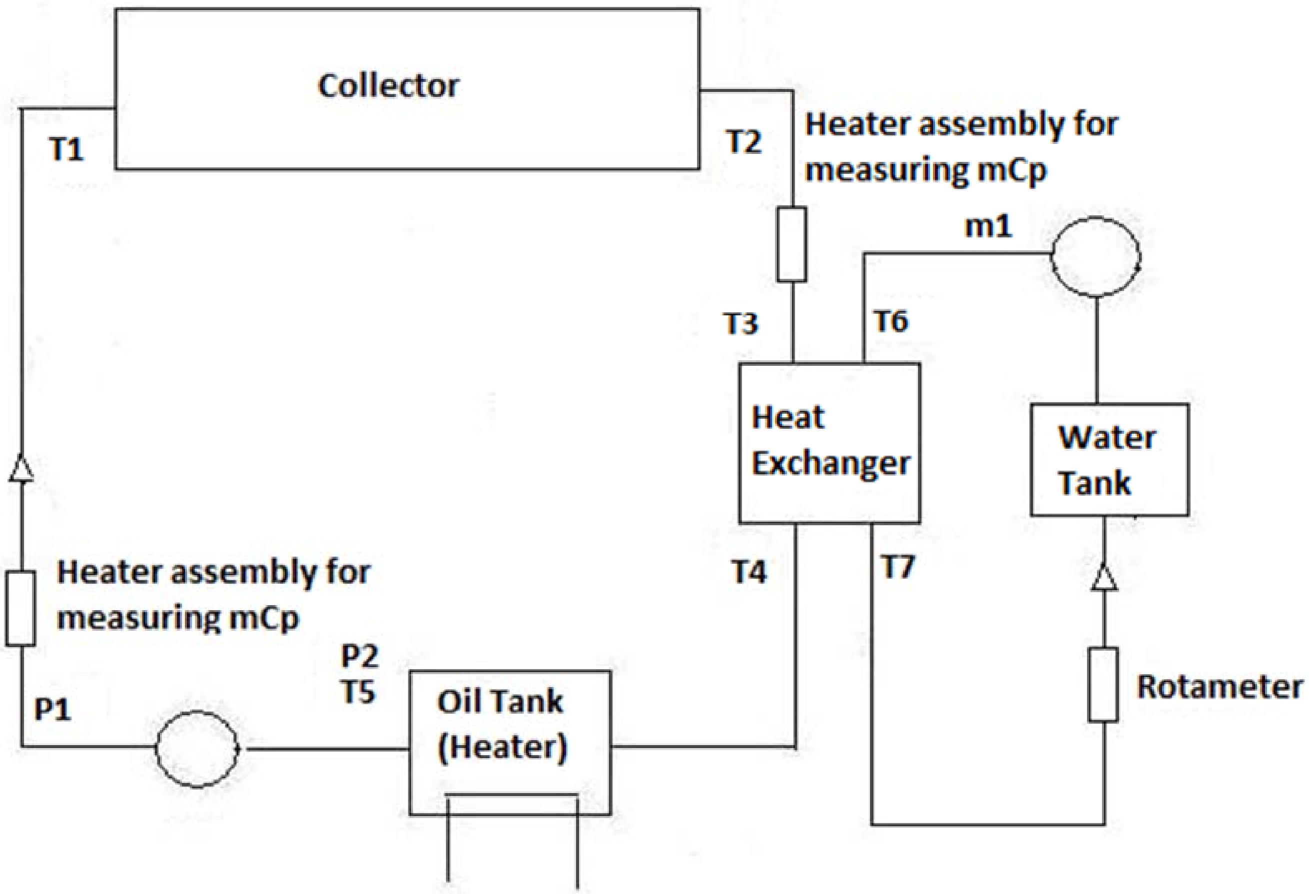
- **Other tests include**
  - **Reflector profile error**
  - **Reflectivity**
  - **Receiver absorptivity, emissivity and heat loss**

Test Description	DLR	Australian National University (ANU)	NREL	PSA	Sandia	Weizmann/ Ben -Gurion University
Methodology	Indoor/Outdoor	Outdoor	Indoor/Outdoor	Outdoor	Outdoor	Outdoor
System Performance Testing						
Central Receiver	No	No	No	Yes	Yes	Yes (W)
PTC	Yes	Yes	Yes	Yes (DISS)	Yes	Yes (BG)
Dish	No	Yes	No	Yes	Yes	Yes (BG)
CLFR	No	No	No	Yes	Planned	No
Solar Furnace	Yes (Cologne)	No	Yes	Yes	Yes	No
Component Testing **Optical testing (Mirror properties)**						
Flux Mapping	Yes	Yes	Yes	Yes	Yes	Yes
Slope Error	Yes	Yes	Yes	Yes	Yes	Yes
Accelerated Testing	Yes	No	Yes	No	No	No
Material Testing						
Coating	Yes	No	Yes	Yes	No	No
HTF	Yes	No	Yes	Yes	Yes	No
Storage	No	Yes	Yes	Yes	Yes	No

Scope of Test Facility

Particulars	Tests
Thermal performance	Efficiency, Heat loss, Response time and Incident angle modifier
Optical Performance	Flux mapping Intercept factor
Component Testing	Receiver: Heat loss, Absorptivity, Emissivity Reflector: Reflectivity

Schematic of the Proposed Test Rig



- Design and fabrication of a novel flux mapping system
- List of testing and calibration equipment needed within short term period (1 year) are being finalised

Test Rig

Dish Concentrator

Test Building

Rig

Conclusion

- Devices
- Performance parameters
- Testing
- Status

Thank you