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Temperature Precise Control in a Large Scale Helium Refrigerator

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Precise control of operating load temperature is a key requirement for application of a large scale helium refrigerator. Strict control logic and time sequence are necessary in the process related to main components including a control load, turbine expanders and compressors. However control process sequence may become disordered due to improper PID parameter settings and logic equations and causes temperature oscillation, load augmentation or protection of the compressors and cryogenic valve function failure etc. Combination of experimental studies and simulation models, effect of PID parameters adjustment on the control process is present in detail. The methods and rules of general parameter settings are revealed and the suitable control logic equations are derived for temperature stabilization.

2kW@20K helium refrigerator

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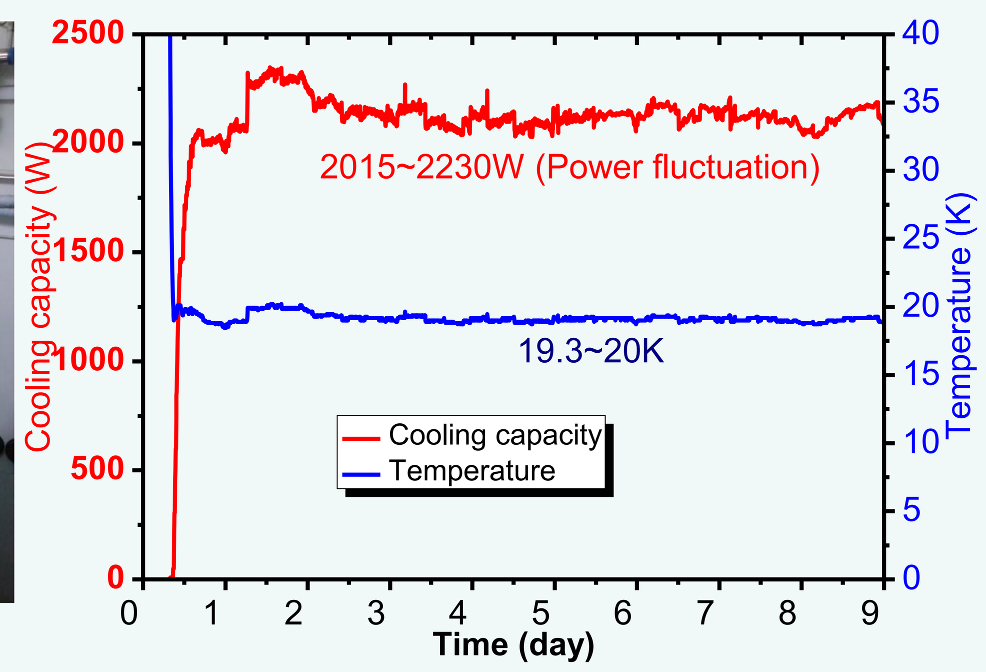


Performance test by long-term stable operation

➢Buildup of a set of 2kW @ 20K helium refrigerator (without LN2 pre-cooling)

➢Temperature adjust by means of auxiliary heater, turbine expander and compressor

The main temperature adjust components

Auxiliary Heater

Turbine expander

➢Turbine expander: speed 12krpm,efficiency over 70%

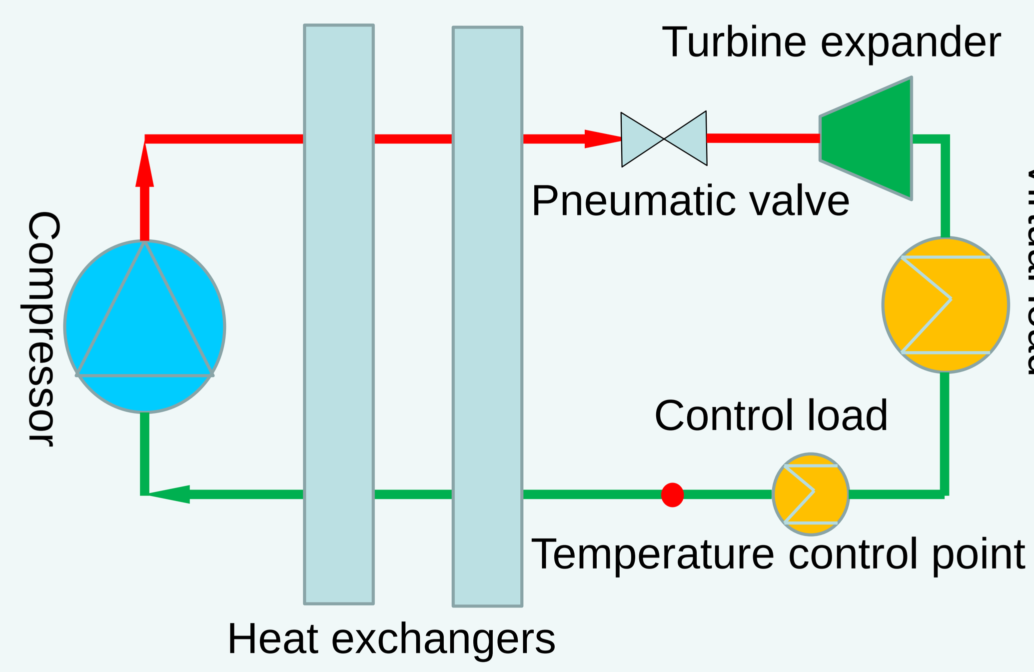
➢Auxiliary heater: leakage rate $10^{-9}Pam^3/s$

Outlook

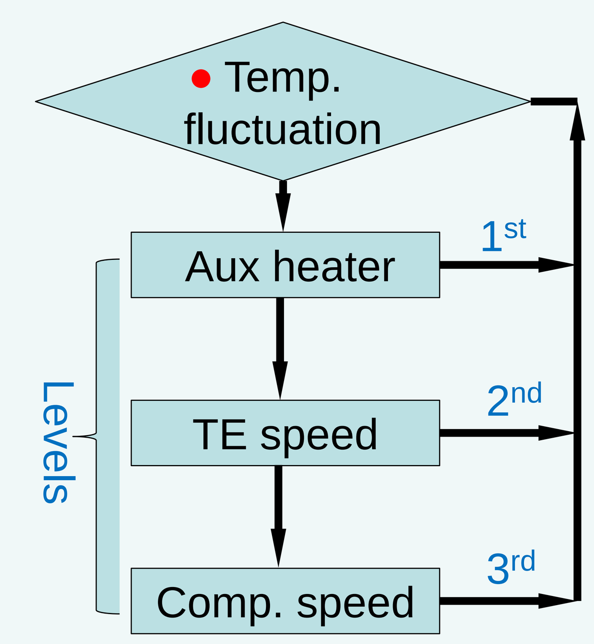
Further resolves of the temperature precise control by studying :

- dynamic response characteristics of the control load itself will be identified by model buildup and experimental measurement
- PID parameters are going to be set according to its response
- revise and validation of the related logic equations

Stable temperature-based control strategies

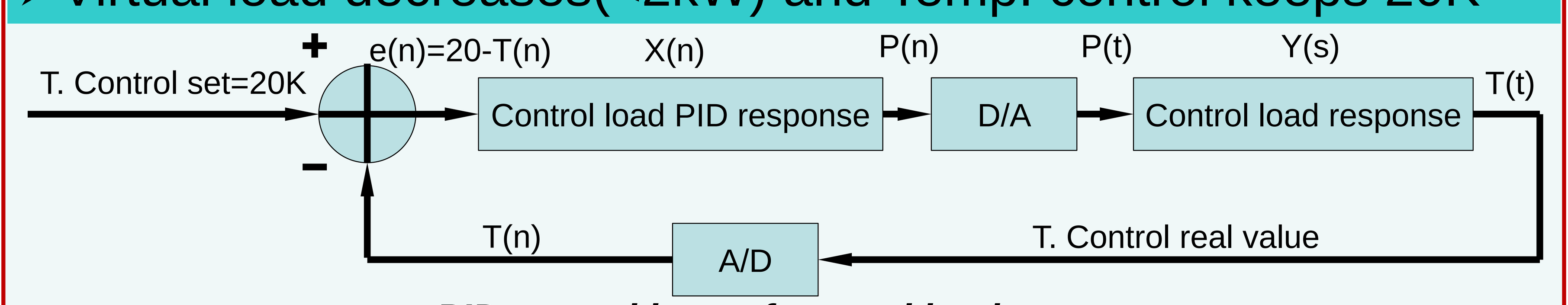


Schematic of system flow diagram

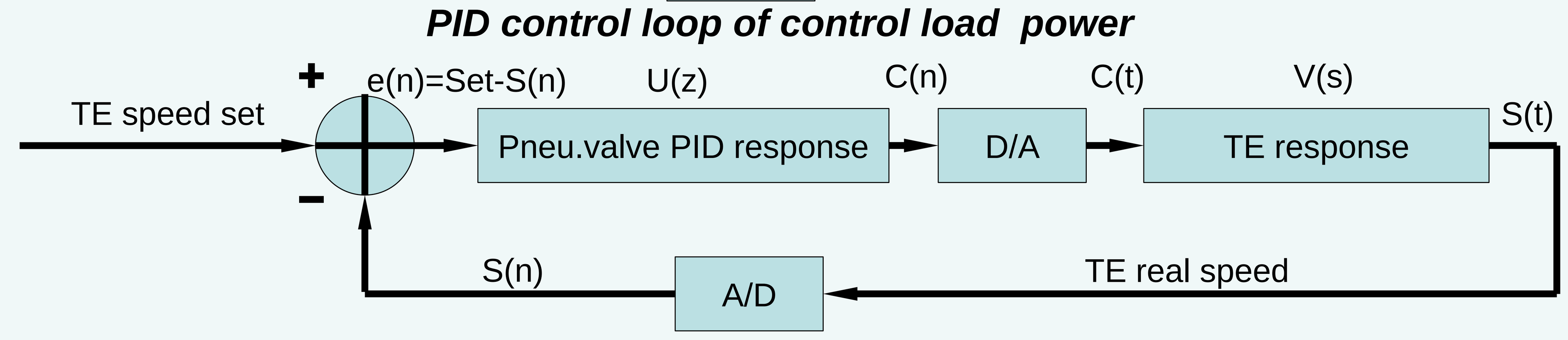


Temperature-based control strategies

➢Virtual load decreases(<2kW) and Temp. control keeps 20K



PID control loop of control load power

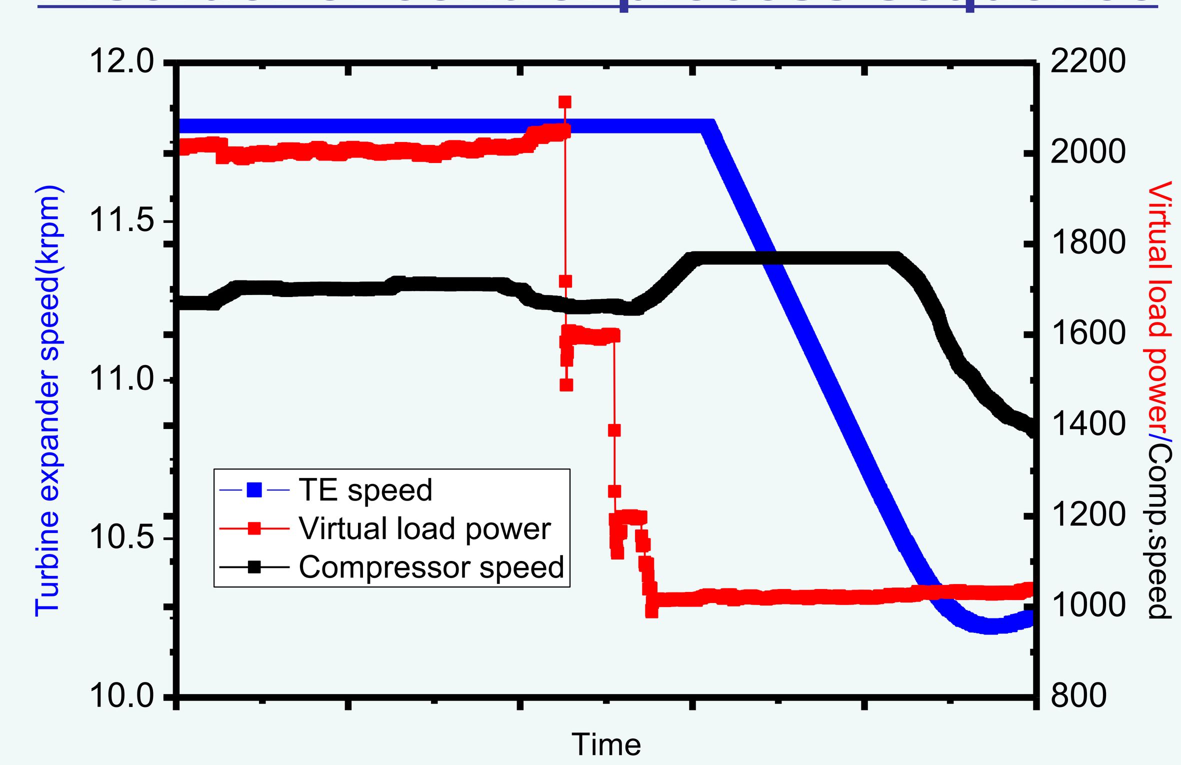


PID control loop of Turbine expander speed

$$P(n) \text{ or } C(n) = K_P \left\{ e(n) + \frac{T}{T_I}\sum_{i=0}^{n} e(i) + \frac{T_D}{T}[e(n) - e(n-1)] \right\}$$

$$\text{TE\_Speed}(n) = \text{TE\_Speed.set} \times [1 - K * f(Q_{control})]$$

Disorder of control process sequence



➢While virtual load power decreases gradually, the TE speed should drop down firstly, and then the compressor speed should decrease. Actually, the compressor speed increases firstly due to improper PID control and control equations etc.