New PLC for Turbines and Commission of PAT Refrigerator

K. C. Wu 12/23/03

- Introduction - PAT
- Overview - Air Liquide Turbine
- New Instrumentation and PLC
- Turbine Performance
- Liquefaction Rate

Introduction - PAT

- The PAT helium refrigerator was installed in B902 for Production And Testing of magnets in 1979.
- It is designed and built by CVI corporation using two Air Liquide turbines.
- The design capacity is ~ 1000 W at 4.5 K.
- It has provided reliable operation for more than a decade after minor problems were corrected in the beginning.
- Reliability of the turbines deteriorated in the 1990's and PAT became impractical to use.
- With the generally good condition of PAT, we believed an upgrade of instrumentation and control for the turbines will bring PAT back to reliable service.

Overview – Air Liquide Turbine

- Original condition
  - Original turbine pod and instrumentation are 20 years old and unreliable
  - Speed readout failed and some interlocks were disabled
  - Two failures occurred in 2001 and PAT was shutdown until recently
- Present condition
  - Upgrading efforts began in 2002 under auspices of BNL GPP grant for PAT helium compressor funded in 2001
  - Installed new instrumentation and PLC to better protect the turbines
  - Minor changes on operating parameters
  - Improve hardware along installation
  - PAT and turbines have been used for liquefaction routinely since 12/2/03.

New instrumentation for turbine

- 12 pressure transducers
  - Turbine inlet and outlet
  - Bearing inlet and outlet
  - Brake
  - Wheel
- 5 temperature sensors
  - Brake
  - Bearing outlet
  - Outlet of cold turbine
- 2 speed pickups

New PLC controllers

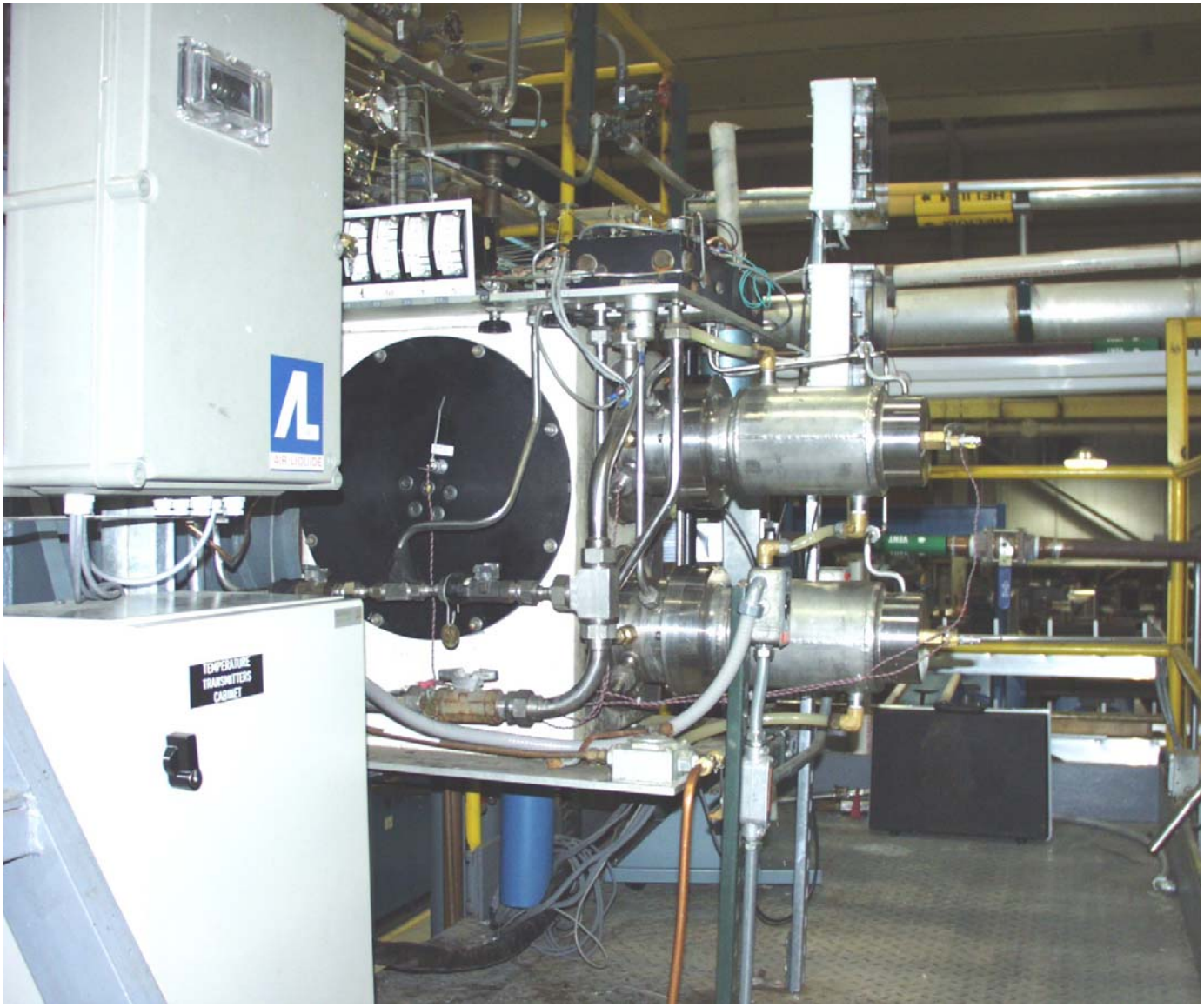
- Two PLC - One for each turbine with alarms and trips on
  - Turbine inlet and outlet pressure
  - Bearing gas inlet and outlet pressure
  - Bearing outlet temperature
  - Brake pressure
  - Brake temperature
  - Wheel pressure
  - Speed
  - Outlet temperature of cold turbine

Operating experience and performance

- Very stable
- No abnormally high temperature on brake housing
- No ice on bearing gas outlet
- No need to disable any interlock
- No leak of helium from bearing gas system to ambient
- No unreliable solenoid for Start/Stop control
- All parameters within Air Liquide specification

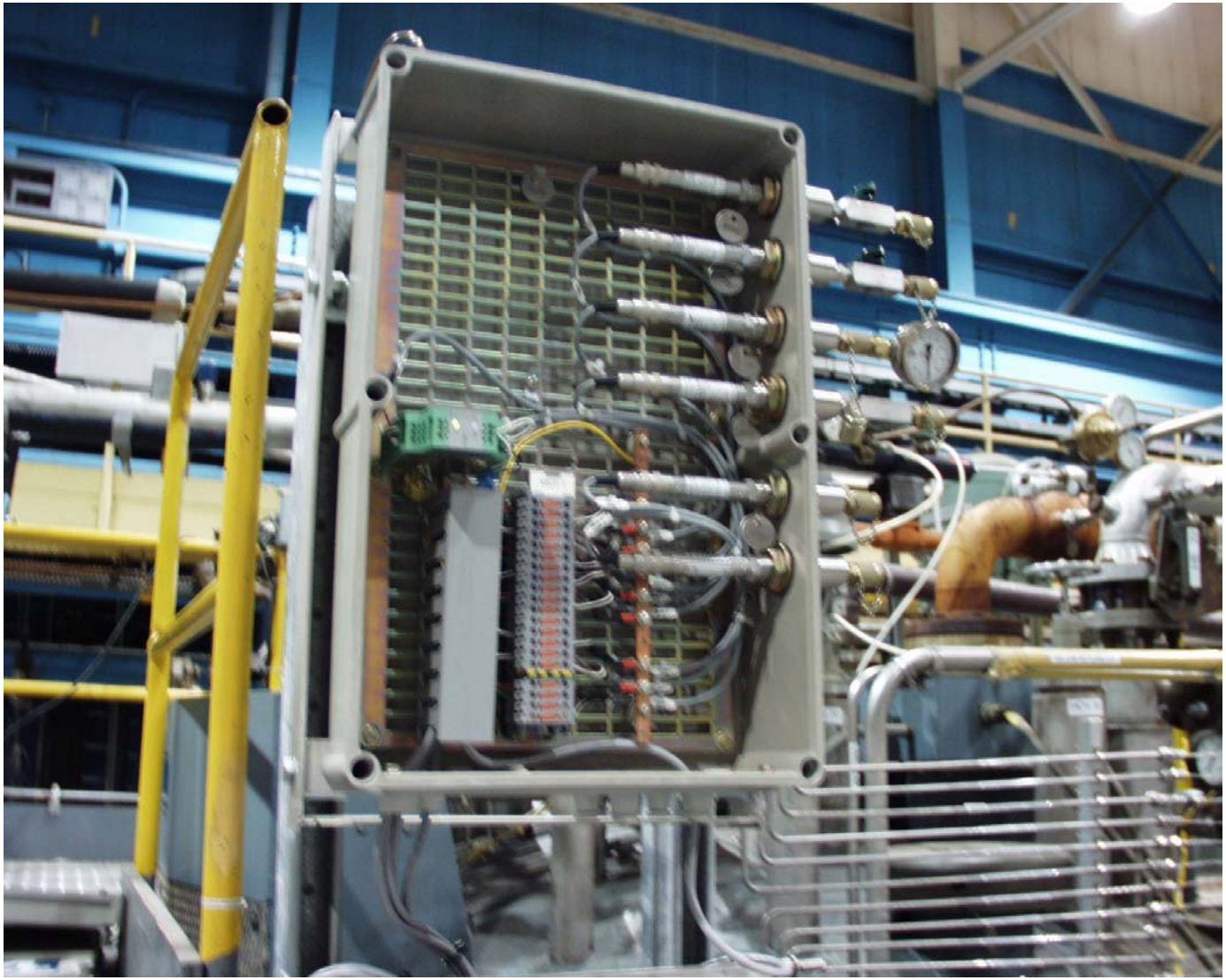
- Liquefy ~ 40 gallon per hour overnight

Turbine pod on PAT

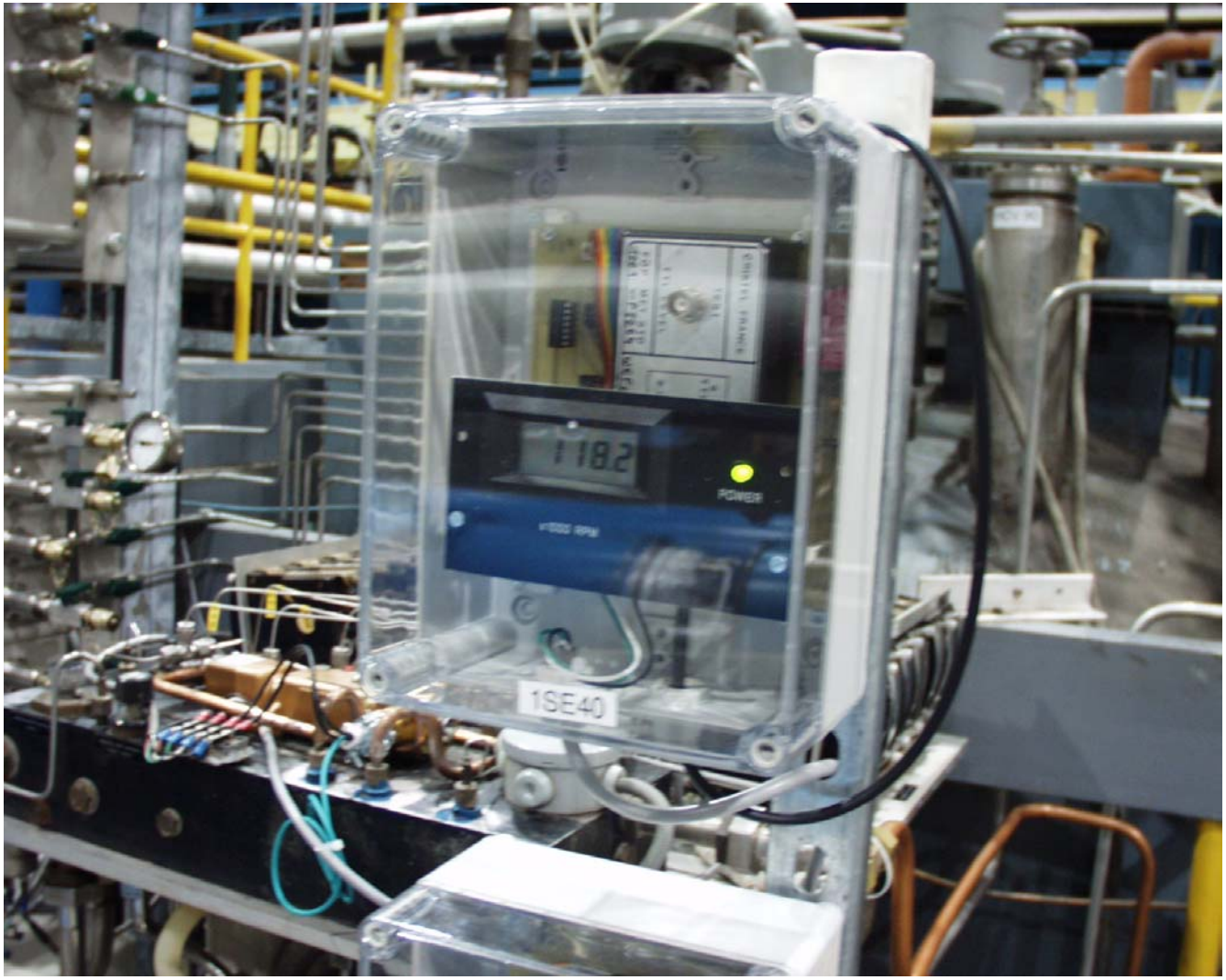


PLC controller and original control console of PAT refrigerator

New sensors for the warm turbine



Speed readout for the warm turbine

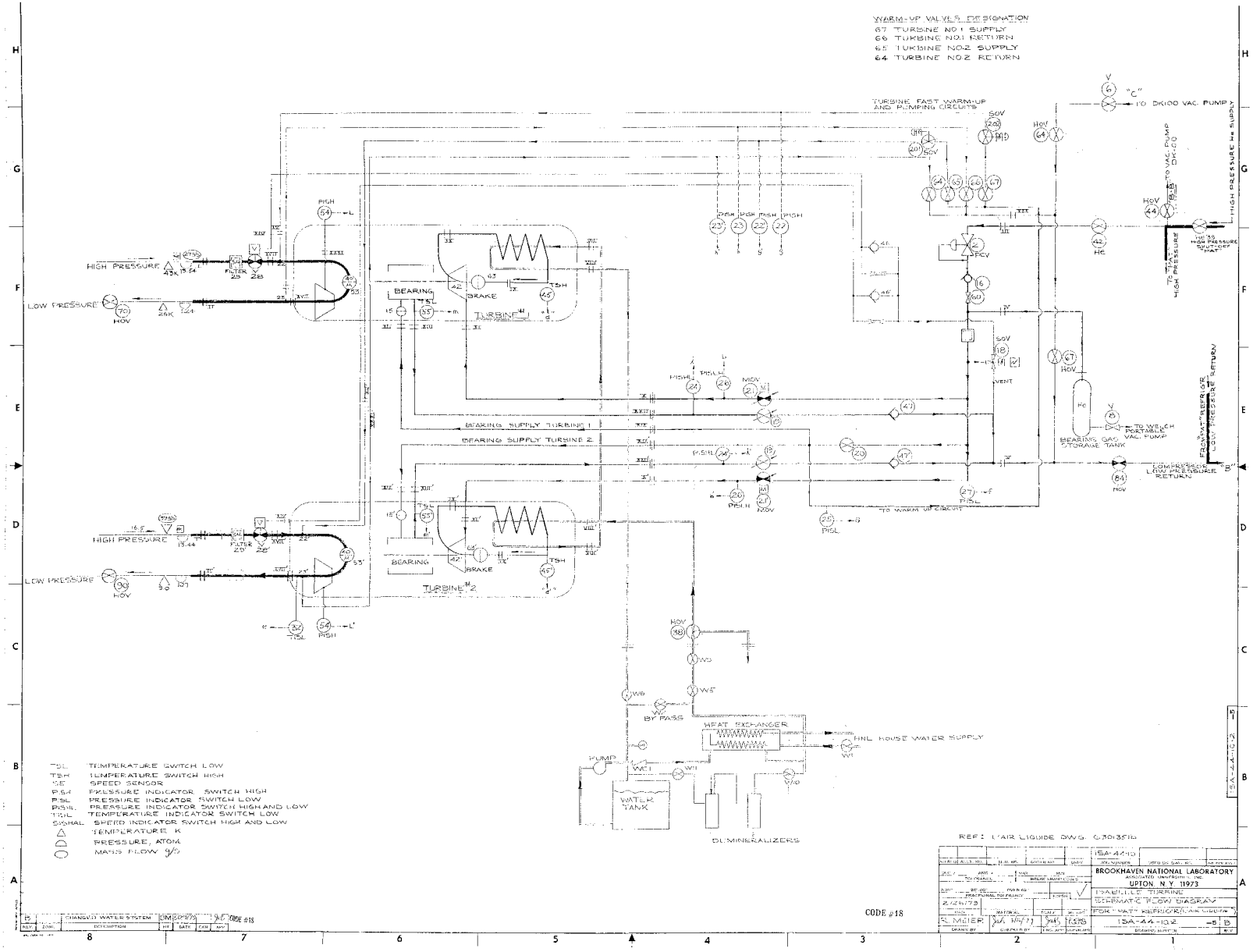


PLC for warm and cold turbines

New Start/Stop control for the turbines

Right button for start and stop, Yellow buttons for reset, Crash button on the left. Upper displays are for speed and temperature.

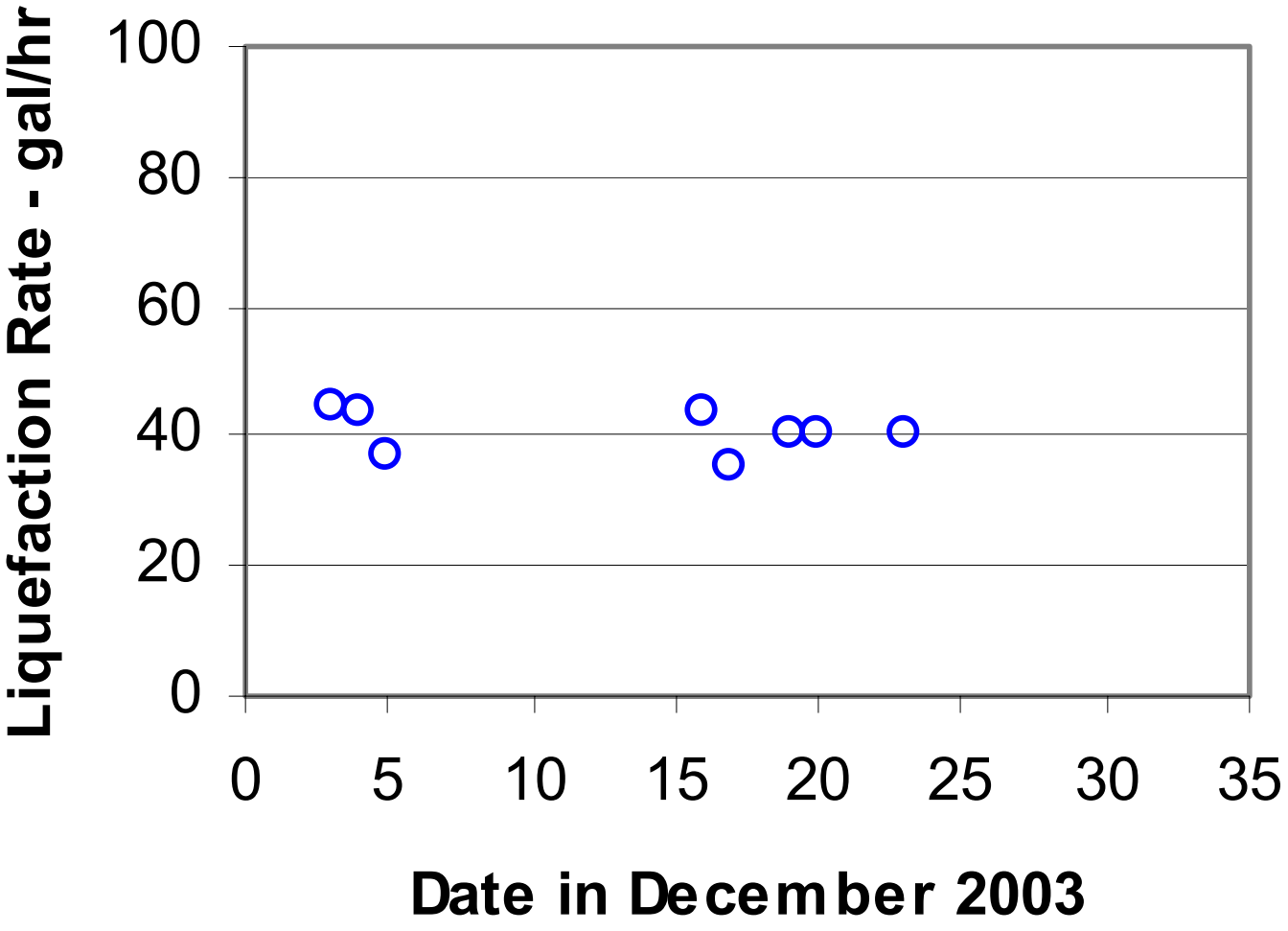
Flow diagram for Air Liquide turbine on PAT



Steady state condition of turbines on PAT

	Warm Turbine	Cold Turbine
Speed – 1000 x rpm	119	112
Bearing inlet pressure – bar	12.4	12.4
Bearing outlet pressure – bar	2.45	2.54
Brake pressure – bar	10.2	10.2
Wheel pressure – bar	2.42	2.88
Brake temperature – K	317	313
Bearing outlet T – K	295	295
Turbine inlet pressure – bar	13.4	13.4
Turbine outlet pressure – bar	1.2	1.2
Turbine inlet temperature – K	~ 50	~ 20
Turbine outlet temperature – K	~ 40	~ 13.5

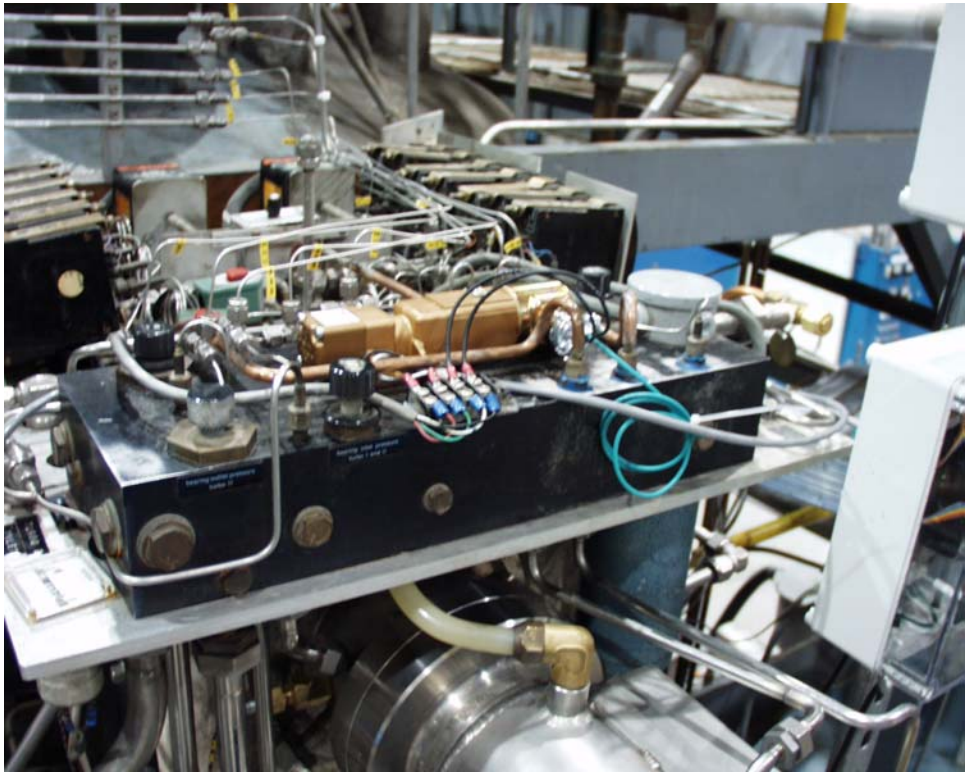
Overnight liquefaction rate of PAT

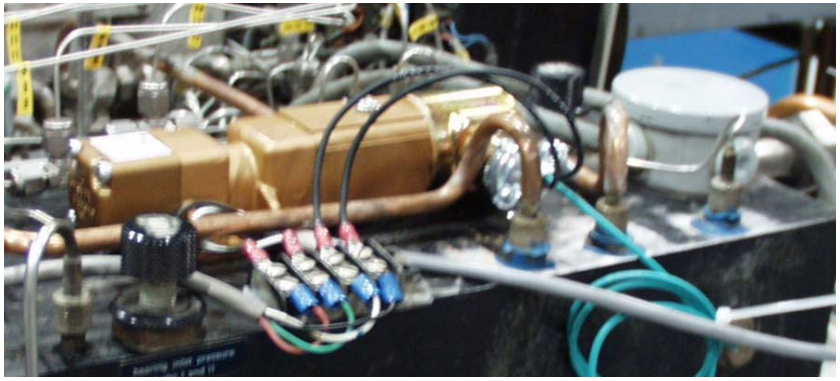


General Assessment

- Hardware and control of the turbines are in very good condition
- New instrumentation and PLC should be able to provide reliable operation
- PAT refrigerator is also in good working order. Heat exchangers and valves are very good. Valve actuators and some control operation requires minor improvements
- Will evaluate condition of PAT as we gain operating experience

Manifold on PAT Turbine Pod with new Start/Stop control solenoid and blue epoxy sealed joints to prevent helium leakage





Left side old controller for PAT turbine

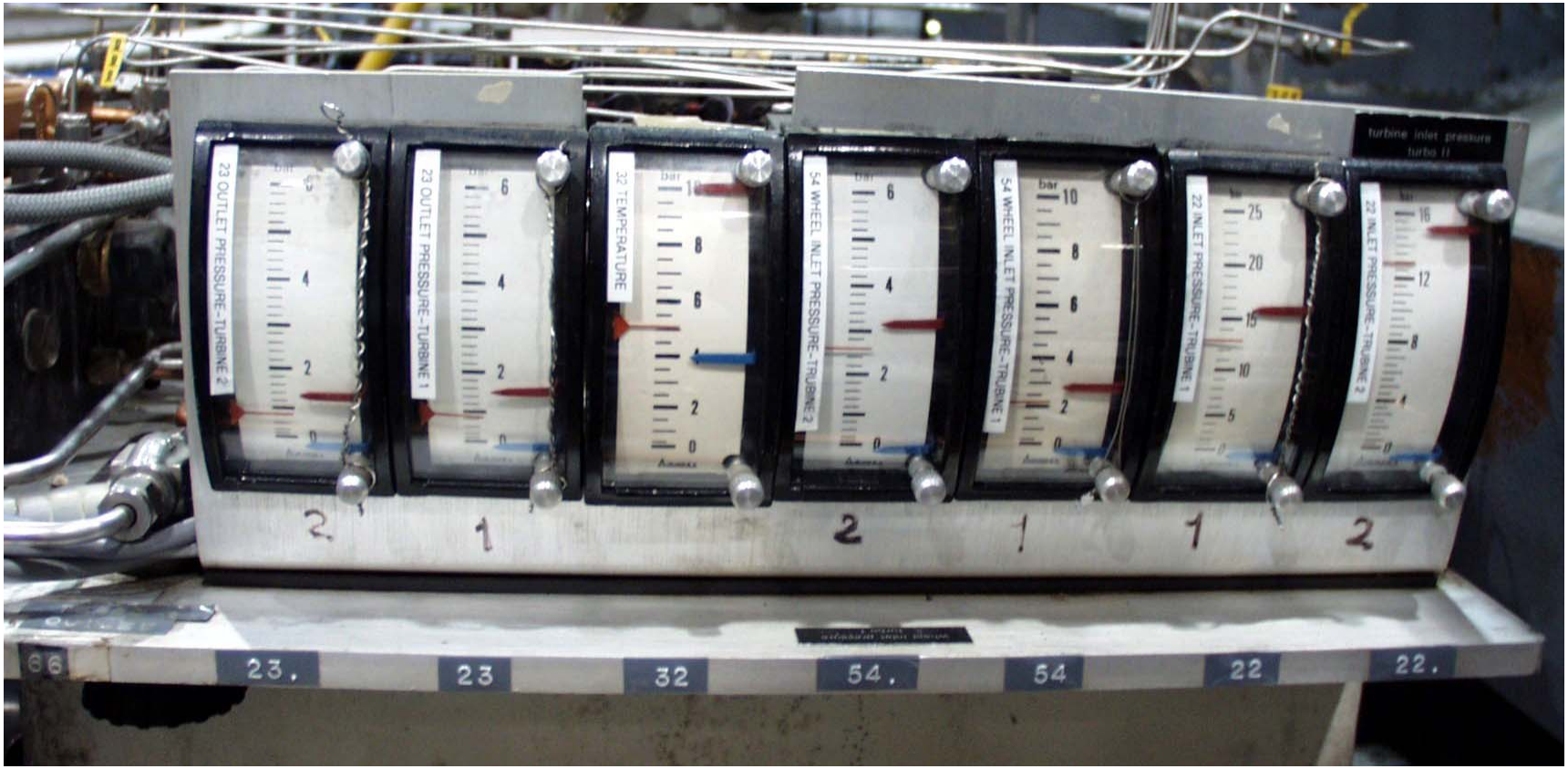
Pressures for bearing inlet and brake are within old ranges

Pressures for bearing outlet are set slightly above old values

Right side old controller for PAT turbine

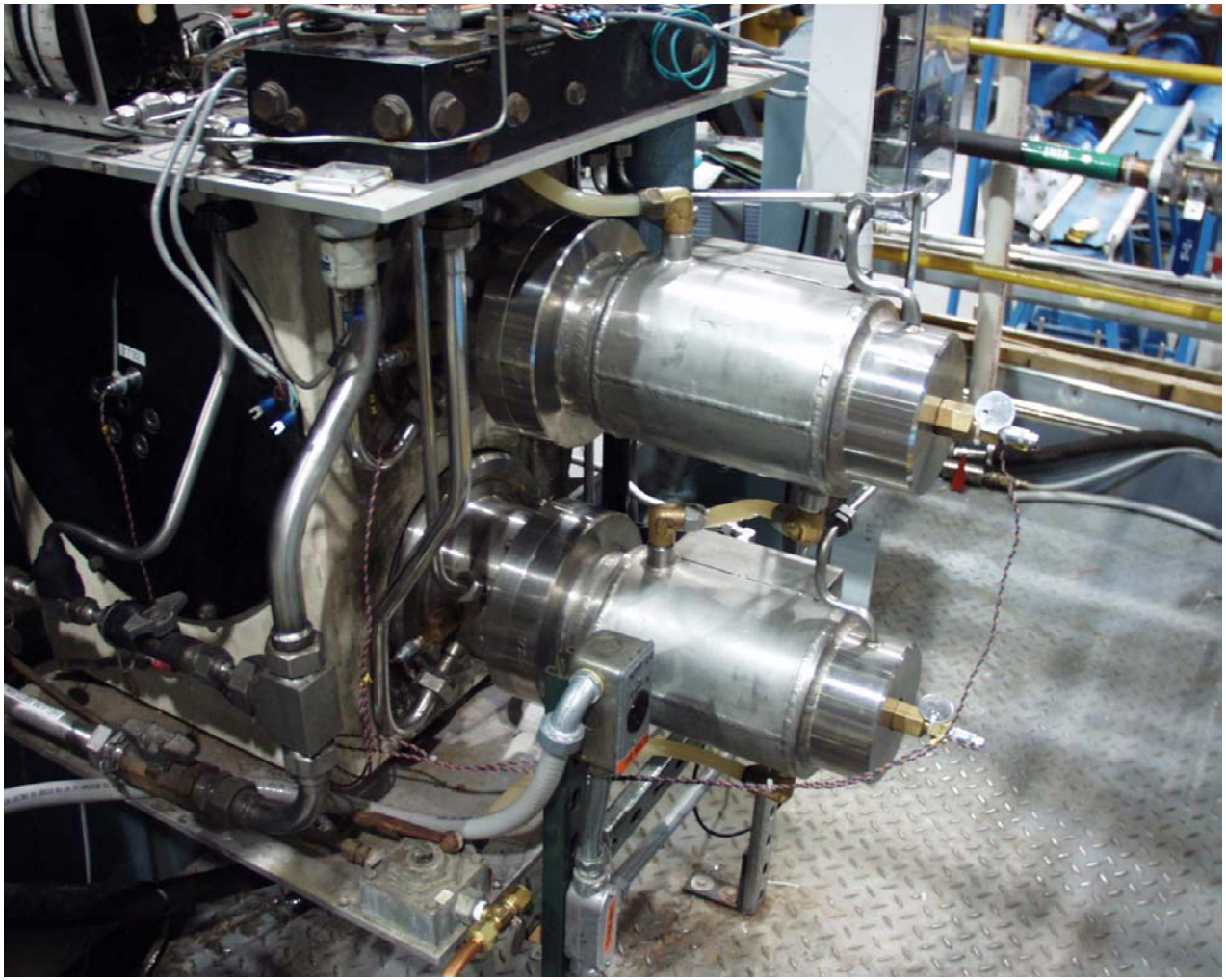
All pressures for turbine inlet, outlet, wheel are within old ranges

Pressures for temperature is also within old range

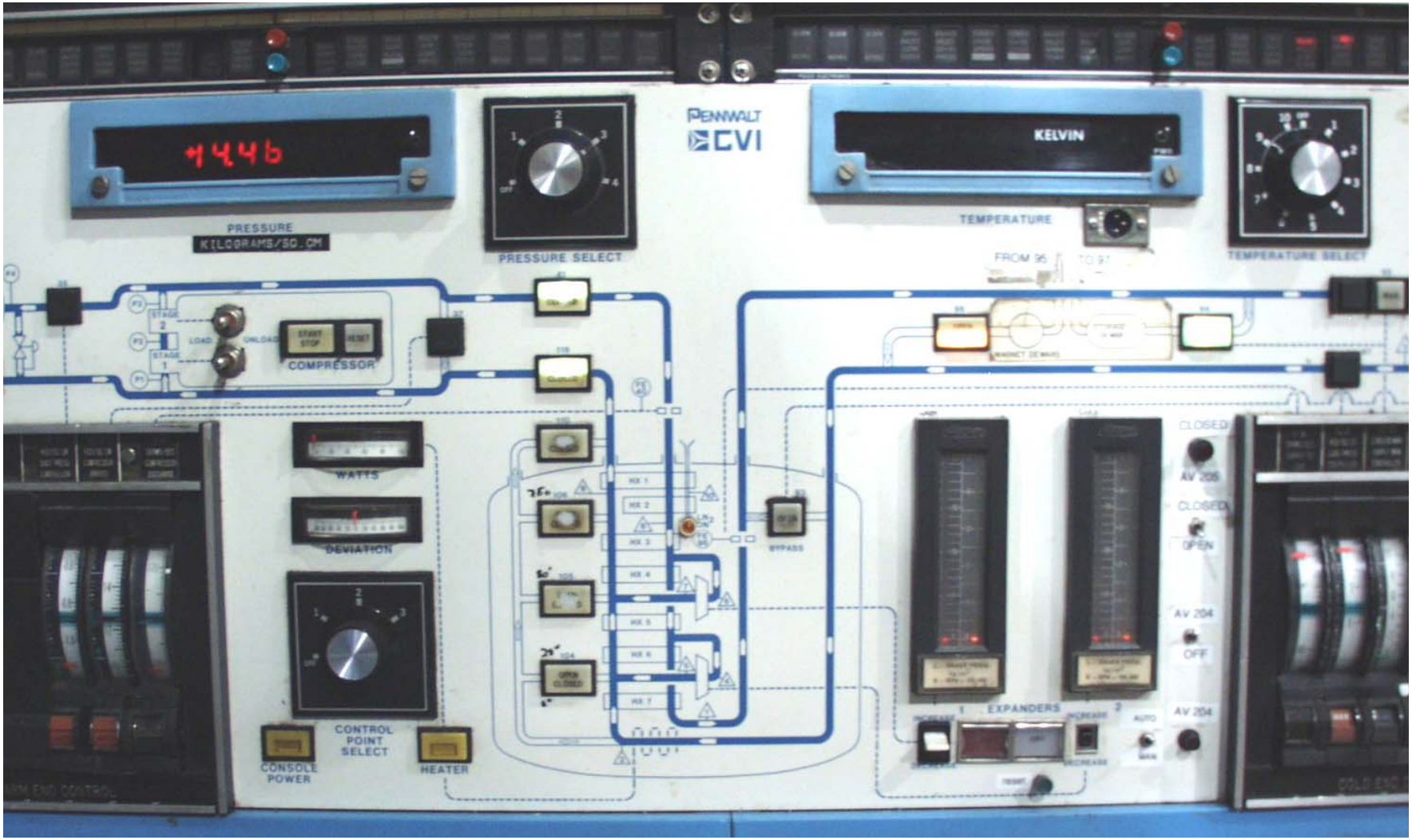


Water cooler has been cleaned to keep brake housing cool

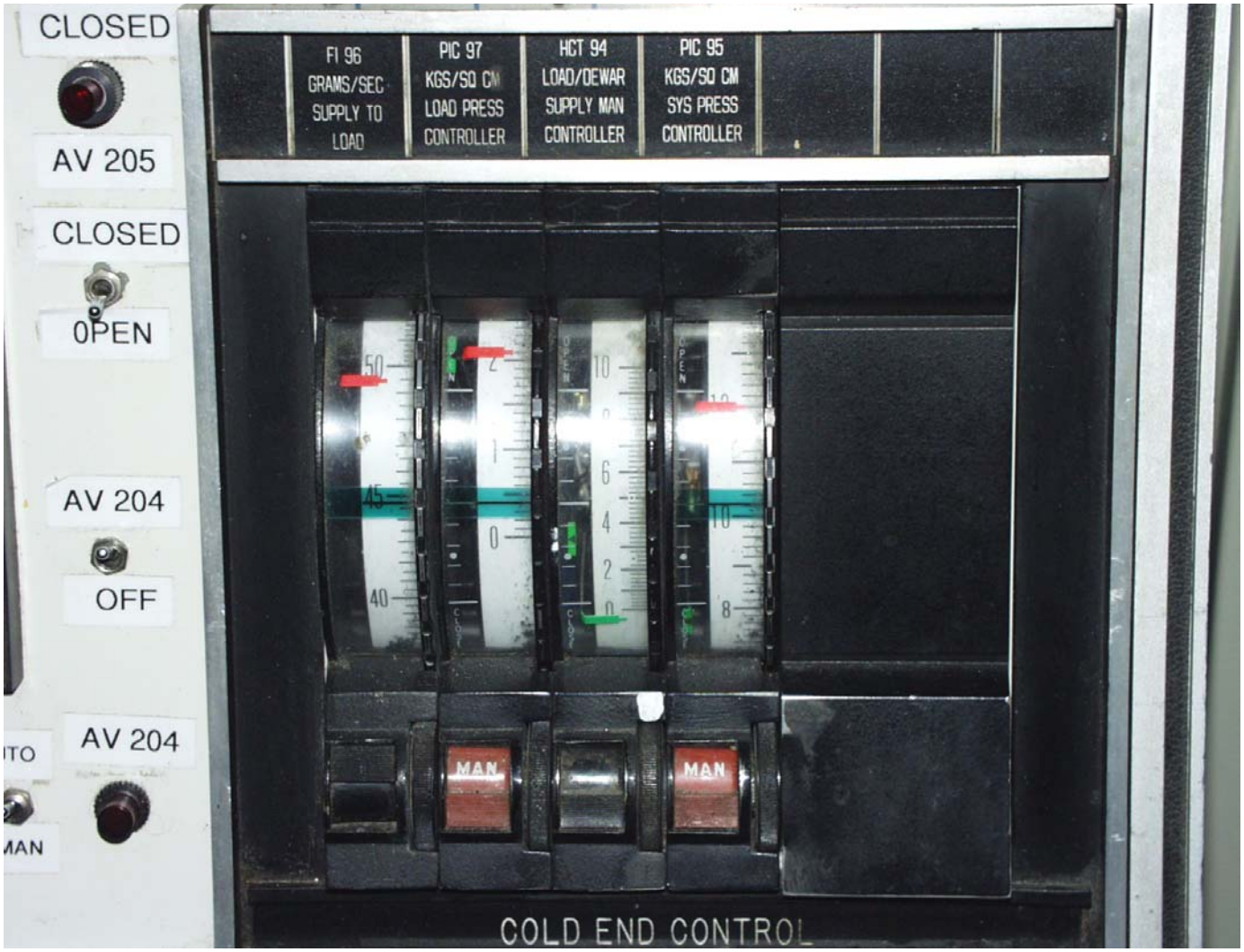
Brake housing (heat exchanger) with temperature sensor for overheat protection



By-pass control on PAT console



JT flow control on PAT console



Acknowledgment

- Successful upgrade of turbine control for PAT refrigerator substantially increase the liquefaction capacity in B902, and enhance our ability to meet tight test schedule.
- K. C. Wu would like to thank those contributing to the project, especially the excellent work and support from M. O'Donnell, W. McKeon and G. Herbst.

Areas for improvement

- Add an audio alarm for turbine trip
- Multiple display of temperature readings on PAT
- Replace failed temperature sensor TI 2 in PAT for better control on cooldown by-pass
- Inspect conditions for valve controllers on PAT
- Replace failed flowmeters for turbine flow
- Update Operating Procedure for PAT
- Investigate diode installation at the outlet of cold turbine
- Possibility of PC interface