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NOTES ON VISIT TO APD CRYOGENICS, 29 OCTOBER 1997

LRD 971030

People:

John Crowe, Product Manager (host and main contact)
Ravi Bains, Sales Rep (Advanced Research Systems)
Bruce Sloan, engineer
Steve Abush, Director of Sales
Peter Blanchet, Eastern Regional Manager
J.L. Gao, Senior Research Associate
Ralph Longsworth, senior scientist

All these people were present for a four-hour meeting, including lunch. Afterwards I got a 1 hour tour of the plant with John and Peter. Mentioning a potential order for >90 systems ($3M) seems to get their attention.

I was very impressed to learn (a few weeks prior to this visit) that Longsworth and Gao are on their staff. Longsworth is a co-inventor of the pulse tube refrigerator (Gifford and Longsworth, Trans. ASME, 1964). Gao is one of the foremost developers of pulse tubes, having written many recent papers (e.g., Cryogenics 34:25, 1994); he was previously at Nihon University in Japan, where much innovative pulse tube research continues to be done.

NRAO REQUIREMENTS

I gave them some very tentative numbers, while carefully explaining that we are just at the beginning of our design work and many things are still uncertain.

Loads:	4.0K	0.3 W	(SIS mixers)
	10-20K	2	(HEMT amplifiers)
	40-100K	20	(Cable & WG sinks; rad shields)

Stability: 4.0K stage -- 10 mK p-p in 1 min
100 mK p-p in 1 day
drift: never above 4.5K

15K stage -- 1K p-p in 1hr
never above 25K

Prioritized selection criteria:

1. Meeting load and stability requirements.
2. Minimizing power consumption.
3. Reliability (MTBF), time between overhauls, ease of maintenance.
4. Minimizing vibration (importance TBD, might be higher priority).
5. Minimizing capital cost.

DISCUSSIONS

Daikin 4K GM runs at 2Hz cycle rate, vs. Sumitomo 1Hz. This makes temperature stabilization easier. Predict unloaded p-p at cold finger will be 250mK, vs 500mK for Sumitomo, but APD does not yet have instrumentation for fast sampling of temperature so as to check this.

Demo:

All these refrigerators work best with cold end down. This is how it was oriented in test dewar that I saw in their lab. It was reading 3.1K on HVP gauge with no load (3.3K on Si diode gauge); and 18.5K on 1st stage (!). With loads of 35W, 0.7W the readings were 33K, 4.3K after 5 minutes (claimed 37K on 1st stage with 36W after equilibrium reached in about 30 min).
Compressor on 10m lines, each 1/2 in flex tubing (same as we use), 310 psig supply, 80-95 psig return at compressor; flow rate not measured. Compressor consists of 2ea 4 SCFM pumps in parallel, water cooled.

Explanation of load maps showing lower 2nd stage temperature when 1st stage is loaded: Higher 1st stage temperature produces less mass flow to that stage, allowing more mass flow to 2nd stage.

Longsworth presentation:

Properties of He at low temperatures cause the GM cycle to be inefficient. Need to expand to ~1 atm to get much cooling per cycle, rather like typical JT system; but GM expands only to ~6 atm. The same He properties make it impossible to get regenerator warm-end temperature the same for inflow and outflow. Therefore, outflowing gas from 2nd stage cools 1st stage, leading to low 1st stage temps and high 1st stage capacity.

Seal wear in 4K GM systems causes ~1K temperature rise over 1 year. This happens for all manufacturers. Capacity is strongly affected by leakage past seal, much more so than at higher temperatures. To achieve decent performance, considerable attention must be paid to minimizing parasitic losses; due to properties of He mentioned above, there is not much cooling available so a little loss could bring net capacity to zero. It's not only a matter of using a regenerator material with high enough specific heat.

All APD/Daikin GM expanders use pneumatic drive. So does Leybold, but Sumitomo uses mechanical (Scotch yoke) drive. Pneumatic drive is very much simpler, fewer moving parts, very quick and easy to disassemble and reassemble, no mechanical adjustments. This part of the technology belongs to APD, licensed to Daikin. APD claims highest reliability in the industry.

In JT systems, they have gone to considerable effort to control contamination. Biggest problem is H2O (*not* oil, which is well controlled by established methods of separation and filtering), because many expander components are hygroscopic. Contamination at a few parts in 10^9 is significant. They built a special RGA to measure such things.

APD compressors all use rotary pumps supplied by Daikin (more later). They can do 1atm::14atm in 1 stage, making a single-stage JT compressor possible.

Rule of thumb on PTs is that efficiency is 75% of that of similar-capacity GM system. New developments may make PT efficiency nearly same as GM, but for fundamental reasons it's not likely to be better.

Possible system for NRAO requirements:
APD 208L GM expander driven by HC4 compressor using 3kW:
40W @ 77K, 12W @20K
JT stage driven by separate HC4 compressor using 1.8kW:
0.5W? @ 4K
Total of 4.8kW, pretty good.

Gao presentation:

Concentrated on pulse tubes, discussing general principles and recent results. He provided copies of several papers that I didn't have. German group achieves 170mW at 4.2K with 1.7kW compressor.

Other:

Flex hoses -- I explained that these are our most frequent cause of leaks, especially when used in antenna cable wraps. APD has available hoses that are much more flexible than standard -- more convolutions per unit length. Like all others, there is no spec on flex life, but these should be better; they have smaller minimum bend radius, so they can be used much farther from there limit.

Daikin also has smaller 2GM 4K system, ~0.5W. Not yet available in US, but expected soon. Long available in Japan. --Crowe.

Pulse Tube Refrigerators -- APD expects to have a PTR on the market in about 1 year. This will probably be a 70K system with capacity of some 10s of watts. I said that I know of no commercial PTRs now, and they made no comment, making me suspect that some competitor has a product that I don't know about.

The Daikin compressor pumps are designed and spec'd for helium service. Earlier attempts to use pumps designed for freon led to lots of trouble. Helium has much larger heat of compression than freon, requiring more complex cooling; internal heat paths of freon pumps are usually inadequate. The deal with Daikin followed some very bad experience with GE pumps; these were the same ones that GE sold in huge quantities to the refrigeration industry and that tended to fail in those applications after 1 yr, causing a recall that cost GE $450M. They failed much faster in He service. Somewhat similar troubles caused NRAO to switch from freon pumps by Rotorex to scroll pumps by Hitachi, where the latter are intended for He. The Daikin pumps are not scroll type, but rather "rotary piston" types using a vane; in principle they are like the freon pumps, but they are very much beefed up internally, especially with respect to heat dissipation. They are therefore capable of very long lifetimes.

All the APD compressors are water cooled. I indicated that we prefer air-cooled compressors for simplicity, on the assumption that this implies lower cost and higher reliability. On the other hand, it was pointed out that air cooling requires reliance on the pump oil to remove a large fraction of the heat, thus requiring a separate oil circulation circuit with oil-to-air heat exchanger and more complex oil separation. All this is avoided with water cooling, at the cost of a separate water circuit.

PLANT TOUR

Compressors: Very nice production line. Starts with Daikin sealed pumps, in boxes; 3 sizes. They come with water cooling jackets. APD has exclusive rights to these in the US; this is the other side of their technology sharing agreement: Daikin gets APD's "Displex" expander designs (GM with pneumatic drive), and APD gets Daikin's compressor pumps. APD puts pumps into cases with controls, monitoring, plumbing, oil separation and filtering. Very long lifetimes achieved: 150000 hrs. Although the pump is plumbed in by brazing, a technician I talked to says they are no problem to remove and replace. Adsorber replacement is recommended at 15000 hrs, but studies show that this can probably be extended to 30000 hrs. (See

Longsworth and Slone 1993.)

Each compressor is run for several hours with gas passed through a LN2 trap, so as to ensure that it's thoroughly clean. I had trouble understanding the trap construction by inspection, and did not have time to ask enough questions. It's fairly big, with a horizontal steel cylinder about 6in dia and 24in long and a similar-sized vertical cylinder. The latter might just be an LN2 tank. After this cleaning, each compressor is "burned in" for 99 hours before shipping.

Expander construction techniques are also careful and precise. Special fixtures are used for packing regenerator material into pistons. They have a new CCM machine for checking cylinder dimensions.

They have a new sub-factory for a product line called "Cryo Tiger". It's for 70K cooling in a 1-stage expander similar to JT, but with some subtle differences that I don't understand. A key point is that it uses a proprietary mixture of gases as the refrigerant. They get 3W at 77K with small 520W air-cooled compressor, claiming MTBF>1e5hr with no maintenance for 5 yrs. This might be useful to us for some things.

GENERAL

I was generally quite impressed. They have some of the top people in the industry, and their good control of the manufacturing process makes their reliability claims believable. They are innovative, and they are willing to work with us to meet our requirements. They could even design some special versions to our specs; I indicated that we usually find such an approach too expensive, but with a project as big as the MMA it might be considered.

John Crowe presented a long list of radio astronomy facilities that are APD customers, and NRAO is conspicuous by its absence. I think this resulted from bad experience in the early 1970s, when APD was part of Air Products Inc (now they are separate). Air Products compressors were originally used on the VLA, and they had many early failures, causing them to be replaced by CTI equipment. In those days, Air Products and others (including NRAO) made helium compressors using rotary pumps originally designed for freon, and these proved inadequate. APD now uses the Daikin pumps, as noted above.

LocalWords: PT