Memorandum

ARUP

To	Josh Willhite	Date	14 August 2018
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From	Cillian Brown, Richard Potter	File reference	4-05-06
Subject	LBNF BSI FSCF Final Design - Chiller Plant and Spray Chamber Capacity		

Increase in Cooling Loads

FRA has added substantially to the cooling load requirements since the 100% PDR submission. In particular, the communication rack loads in the detector chambers and the CUC have increased by a factor of almost 2.5 and as such have become the dominant loads (approximately 55% of the total cooling loads). The net result is an increase of over 60% in the cooling capacity is now required. To accommodate this the chiller plant and the spray chamber capacities must be increased.

Previously the cooling loads could be accommodated during 100% operation with one chiller out of service. All chillers could be operated to speed up the cooling down process while charging the cryostats. The latest requirement to eliminate N+1 level of redundancy has allowed the design requirements to be met with 4 chillers, however when a chiller is down for maintenance or due to a malfunction, load shedding will become necessary. As the detector and communication rack loads are by far the dominant loads, it is inevitable that data collection will be stopped for one or two cryostats when a chiller is taken out of service.

Typically, there will be an annual shut down for each chiller to clean the condenser tubes and perform minor maintenance. Chillers typically require a longer shut down period every 5 years for more intensive overhaul activities. Assuming an annual shutdown of 24 hours for each chiller would result in a reduced capacity (i.e. load shedding) for 4 days a year. The 5-year overhaul is a more intensive exercise typically taking 2-3 weeks per chiller.

The 100% PDR design was based on 170,000 CFM air flow through the spray chamber. The 30% FD design is based on 230,000 CFM air flow through the spray chamber. The spray chamber as designed for the 100% PDR submission provided for a heat rejection capability of 12,450 MBH. The experiment's cooling requirements have since increased this to 19,300 MBH, an increase of over 60%. Even with the spray chamber air flow increase from 100% PDR, the spray chamber heat rejection capacity margin is reduced from 22% to 15%. While this is within the capacity of the spray chamber as currently designed, at this stage of the design a margin of 20% would be appropriate. In addition to the reduction in spray chamber heat rejection margin, with the current chiller selection, the margin to the water flow limit through the spray chamber is reduced from 15% at 100% PDR to 3% at 30% FD.

Note that the other experiment loads have not been updated since 2015, and therefore any increases in these loads will further erode the margins.

Table 1 – Comparison between 100% PDR and 30% FD Chiller Plant and Spray Chamber Capacities.

	100% PDR	30% FD
Total Cooling Load [MBH]	9,620	15,435
Chiller Plant Cooling Capacity [MBH]	9,960	16,320
Chiller Plant Cooling Capacity Margin	3% *	5%
Spray Chamber Air Flow [CFM]	170,000	230,000
Chiller Plant Heat Rejection [MBH]	12,450	19,300
Spray Chamber Capacity [MBH]	15,965	22,845
Spray Chamber Capacity Margin	22%	15%
Condenser Water Flow Rate [gpm]	2,490	3,860
Spray Chamber Water Flow Limit [gpm]	2,950	3,990
Spray Chamber Water Flow Margin	15%	3%

* 3% margin refers to (2) chillers operating with (1) chiller available in standby

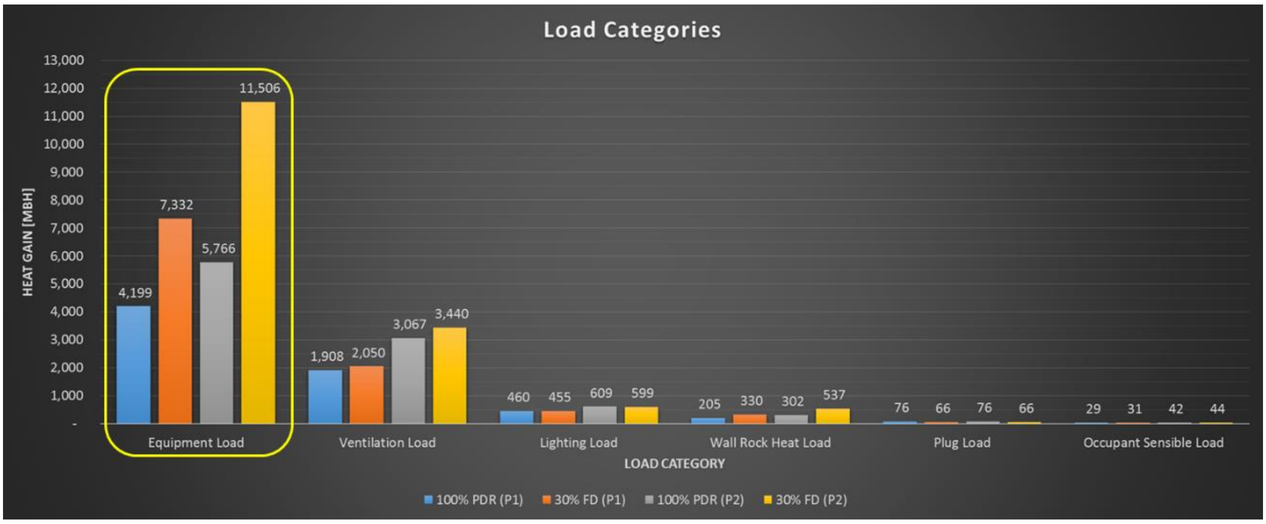

Figure 1 – Comparison of loads between 100% PDR and 30% FD by category and phase

(Note that 100% PDR had four phases; 30% FD has combined Phase 1 and 2 into Phase 1 and Phase 3 and 4 into Phase 2; in the legend, P1 = Phase 1, P2 = Phase 2)

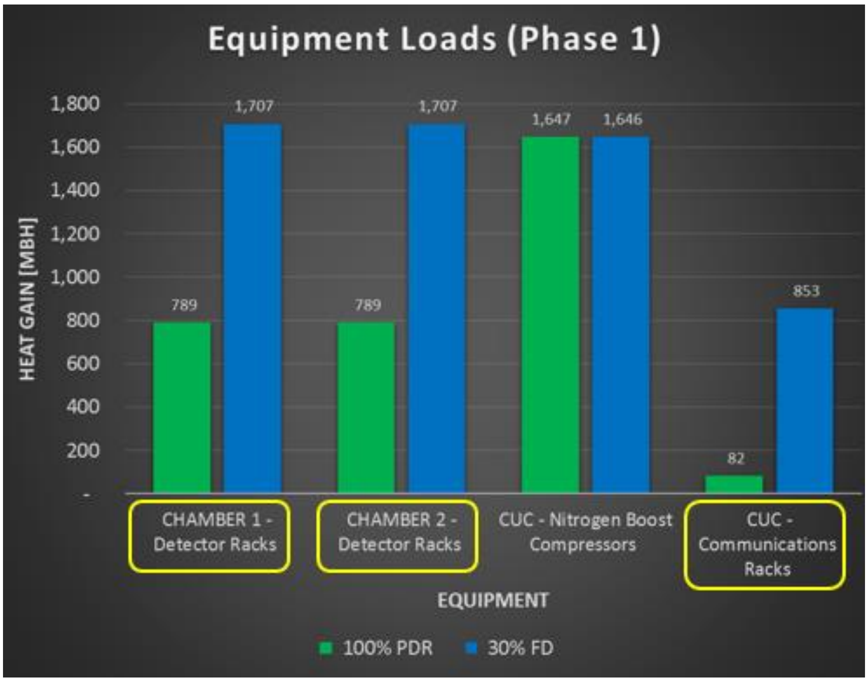

Figure 2 – Comparison of equipment loads between 100% PDR and 30% FD (Phase 1).

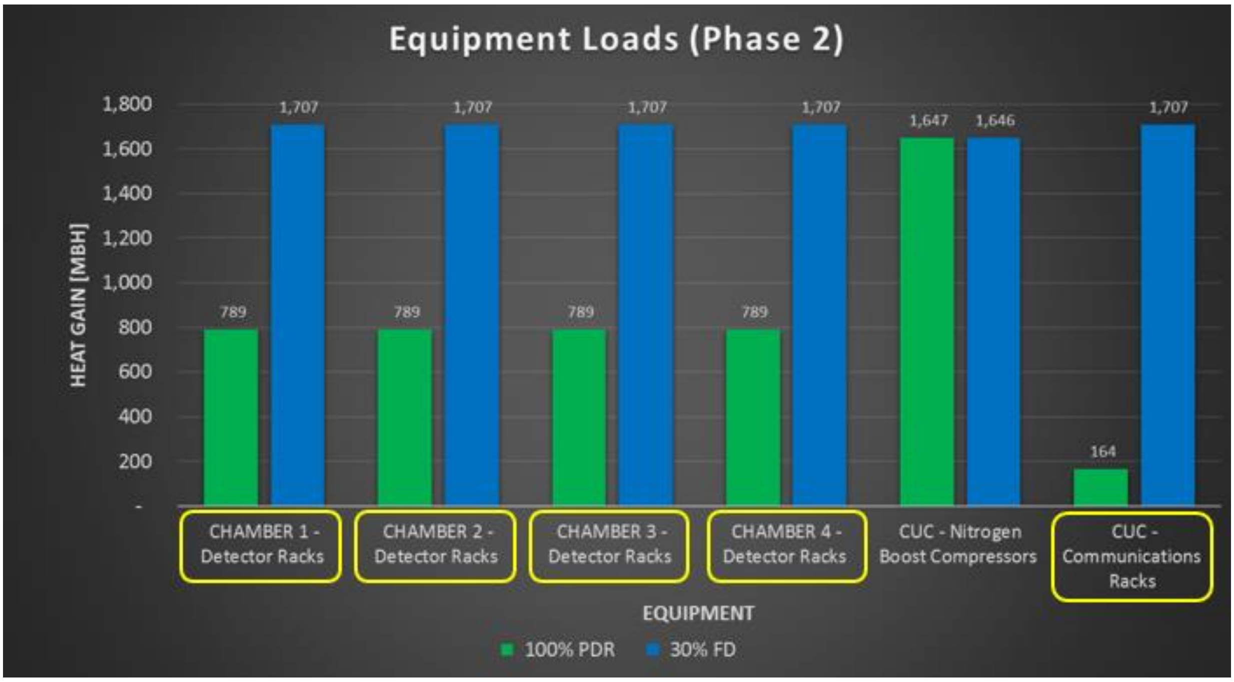

Figure 3 - Comparison of equipment loads between 100% PDR and 30% FD (Phase 1).

Conclusion

The increase in cooling loads has reduced the margins to below prudent levels. Further increases are limited by absolute limitations on the spray chamber heat rejection capacity and water flow limit at the design air flow. Furthermore, if the loads as currently estimated increase due to, for example, installation of equipment with a lower efficiency, the margin will further decrease.

As noted the lack of redundancy in the chillers will result in likely a weeks' worth of downtime each year where data collection will have to be suspended for at least one cryostat. In addition, the 5-year overhauls will likely require a total of 1-2 months downtime. In view of these outages and any unscheduled outages that may occur, the need for N+1 redundancy should be evaluated by FRA. While rotary chillers are in general very reliable if annual cleaning is forgone there will be a drop in the capacity of the chillers.

Additional to the downtime required by the chillers, the spray chamber will also require downtime for maintenance. The spray chamber tanks will need to be drained and cleaned in addition to the cleaning of any clogged spray nozzles. The spray chamber is divided in half along its length, allowing one side to be taken out of service for maintenance. During this time, the spray chamber capacity will be reduced by 50%. The expected downtime for 50% of the spray chamber is likely for one week every 6 months, based on OSHA recommendations to clean cooling towers twice a year.