Negative Pressure Laboratory Heat Exchanger Design Document

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I. INTRODUCTION

Common practice for providing cooling to high power output devices is to provide some form of a chilled water loop. This is typically more efficient than convective cooling systems. Generally this can be supplied on either a facility scale system that is designed to provide cooling for a number of devices throughout an area, or alternatively on a bench-top scale to provide cooling for a single device. The coolant can be any variety of fluids designed for this purpose and can be either cooled through a heat exchanger with the ambient air or actively cooled by some form of refrigerant. Most common circulation schemes drive the water through some circulation loop using a circulation pump. The pump generates a positive head pressure, above atmospheric, to drive the coolant through the loop. In some applications even with a low probability for a leak forming the risk is still high due to the severe result from such a leak. In these applications one can employ a system that is operated below the atmoshperic pressure throughout the entire circulation loop. In the event of a leak, air is drawn into the system instead of coolant being pushed out. Such a system is commonly referred to as a negative pressure circulation loop.

The detectors commonly employed in heavy ion and collider physics generate a heat output that must be removed from their confined spaces through some form of a coolant. Due to the severe consequences of a leak in these coolant loops it is desired in the design of the sPHENIX MVTX vertex detectors to utilize a negative pressure circulation loop to provide the cooling. On the facility scale, circulation loops are commonly custom designed to meet the facility requirements. As such designing the system to circulate on a negative pressure is straight forward. However at the bench-top scale, there seem to be no commercially available devices off-the shelf to provide negative pressure. Perhaps this is because the details of the circulation loop that is being driven play an integral role to the design of such a system.

Here we explore the possibility of modifying a commercial bench-top scale heat exchanger to provide the needed negative pressure coolant loop to operate a small scale LDRD project. The goals of this project are to study the ALICE detectors being planned for use as the vertex detectors in the sPHENIX upgrade. One aspect that is planned to be explored is the use of a negative pressure system with these detectors.

II. CIRCULATION SYSTEM REQUIREMENTS

The circulation loop requirements are driven by the conditions of the individual MVTX detector systems. The benchtop system is planned to operate four to five detector staves, 1.5 cm x 27 cm, that are comprised of 9 MAPS detector chips, 1.5 cm x 3 cm each. Based on measurements each chip is expected to dissipate 130 mW, however the maximum expected dissipation with a 50% safety factor is 0.15 W/cm^2 or 675 mW per chip. For optimal detector operation, the maximum temperature must be less than $30\,\mathrm{deg\,C}$ with a temperature non-uniformity of $< 5\,\mathrm{deg}\,C$. A coolant loop is provided for each stave that is made from 1.02 mm ID tubing, see Fig. 1, and is expected to be roughly a meter in length once connections are made to the chiller system. Water will be used as the coolant. Using the Pipeflow procedure built into the EES software we estimate the required flow rate through the stave coolant loop to drop the pressure by a desired .3 bar is roughly 1 gph. This program also calculates a bounds on the heat transfer coefficient $2410 < h < 3124\mathrm{W/m^2 \cdot K}$.

Specification	**Requirement**	**PolyScience 3700**
Cooling Power	> 30 W @ < 30 deg C	500 W @ $\Delta 2\,\mathrm{deg}$ C
Max Flow Rate	> 5 gph	2.4 gpm
Absolute Pressure	< 11.5 psia (.8 bar)	< 100 psia

The requirements for the system to drive the circulation loop for five staves in parallel are summarized in Table II. Given the relatively low power consumption of the detectors these specifications are not beyond the

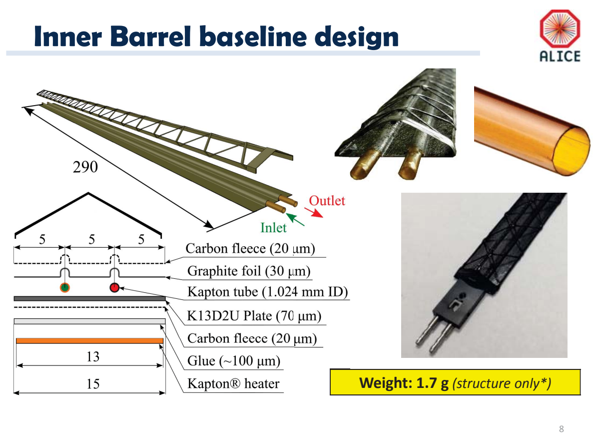


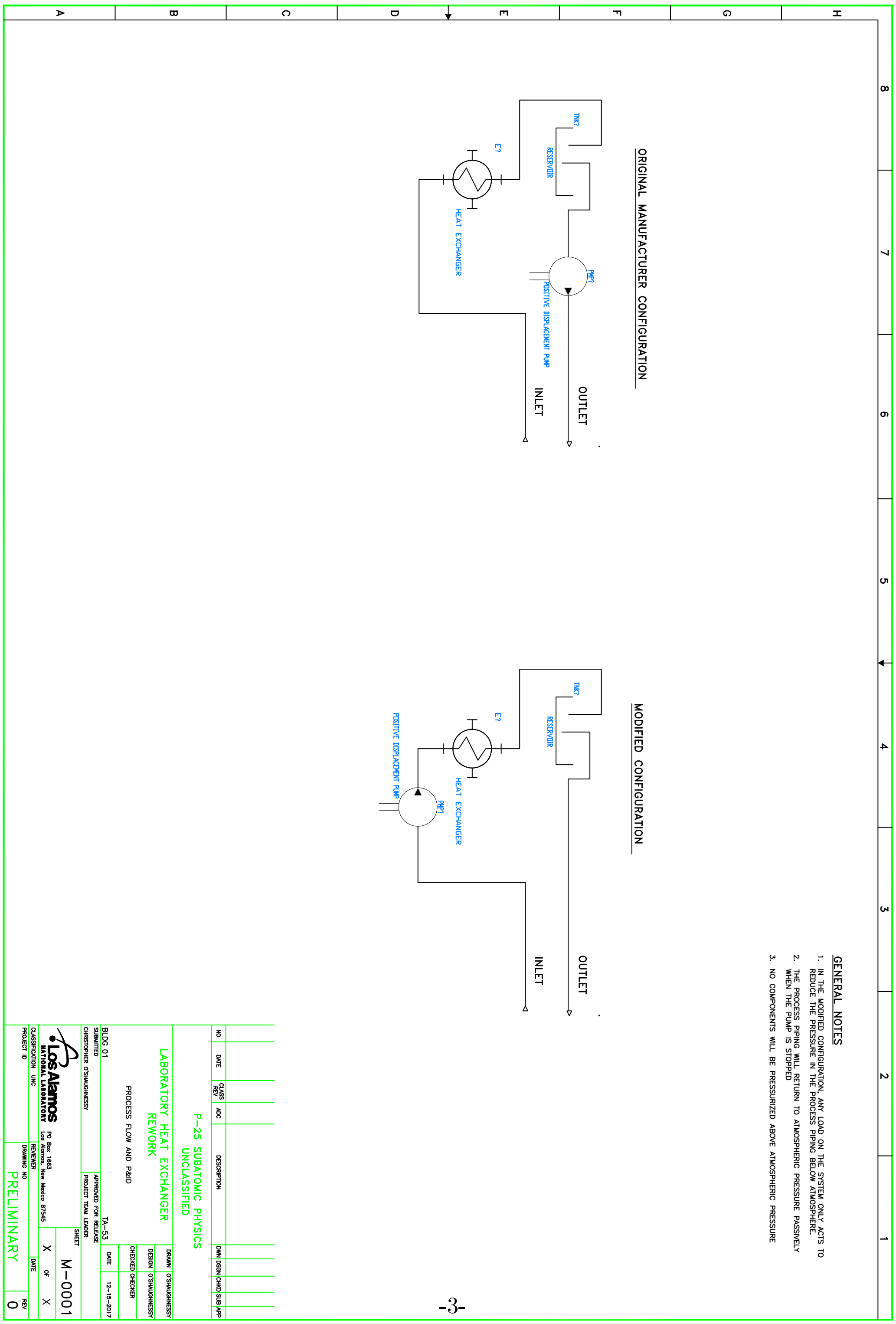
FIG. 1 Mechanical design of a single stave with coolant loop.

standard laboratory chiller system. The most challenging specification to meet is the negative pressure aspect. This however can be achieved by utilizing the pressure drop through the small diameter tubing of the stave circulation system. For this to work however one must move the circulation pump past the load so that it is drawing water through the piping while still forcing it through the heat exchanger. In doing so however one must avoid dropping the pressure in the piping to the vapor pressure of water, 0.03 bar (0.5 psi), in order to avoid cavitation of the circulation pump. While more than an adequate flow rate to drop the pressure to .7 bar in the piping, the flow rate through the polyscience 3700 heat exchanger is high enough to cause cavitation. Therefore the stave circulation loops must be bypassed with large enough piping to allow the bulk of the flow rate directly into the pump. A flow controller can be used in each stave loop to adjust the flow rate to the desired rate of 1 gph. Both process and instrumentation diagrams for the heat exchanger modification and the control panel are included at the end of this document.

III. CONCLUSIONS

While off-the-shelf solutions for a negative pressure cooling system aren't readily available, a simple modification to off-the-shelf heat exchangers can produce the desired specifications. We have outlined the modifications and the required control to convert the Polyscience 3700 system into a negative pressure cooling system. Since the pressures are all sub-atmospheric and the reservoir is opened atmosphere, no pressure safety hazards are created and the system will passively return to atmospheric pressure when de-energized.

IV. APPENDIX


ORIGINAL MANUFACTURER CONFIGURATION
TNK?
RESERVOIR
E?
HEAT EXCHANGER
PMP?
POSITIVE DISPLACEMENT PUMP
OUTLET
INLET
MODIFIED CONFIGURATION
TNK?
RESERVOIR
E?
HEAT EXCHANGER
PMP?
POSITIVE DISPLACEMENT PUMP
OUTLET
INLET
GENERAL NOTES
1. IN THE MODIFIED CONFIGURATION, ANY LOAD ON THE SYSTEM ONLY ACTS TO REDUCE THE PRESSURE IN THE PROCESS PIPING BELOW ATMOSPHERE.
2. THE PROCESS PIPING WILL RETURN TO ATMOSPHERIC PRESSURE PASSIVELY WHEN THE PUMP IS STOPPED
3. NO COMPONENTS WILL BE PRESSURIZED ABOVE ATMOSPHERIC PRESSURE
P-25 SUBATOMIC PHYSICS
UNCLASSIFIED
LABORATORY HEAT EXCHANGER REWORK
PROCESS FLOW AND P&ID
BLDG 01
TA-53
CHRISTOPHER O'SHAUGHNESSY
DATE 12-15-2017
M-0001
PRELIMINARY
REV 0

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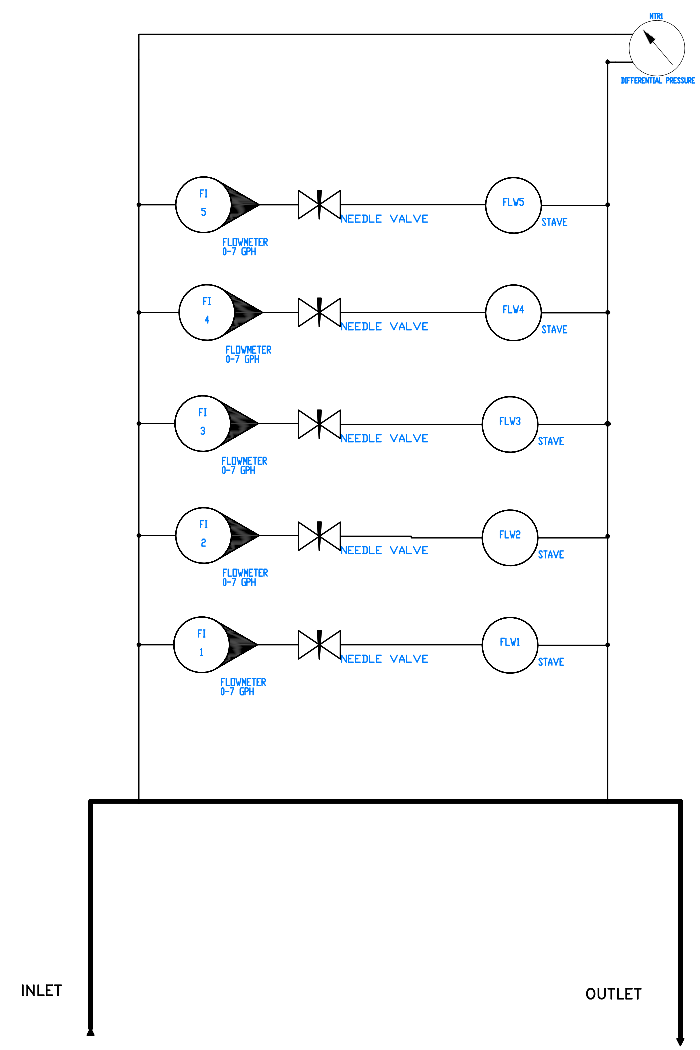

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P-25 SUBATOMIC PHYSICS
UNCLASSIFIED

STAVE COOLING
CONTROL LOOP

PROCESS FLOW AND P&ID

DRAWN	O'SHAUGHNESSY
DESIGN	O'SHAUGHNESSY
CHECKED	CHECKER
DATE	12-15-2017

BLDG 01 TA-53

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