ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-TUPMP045

THE PROTECTION INSTRUMENT FOR CRYOGENIC PHASE SEPARATOR PRESSURE RELIEF VALVE OF TPS BEAMLINE

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Abstract

TPS (Taiwan Photon Source) beamlines have operated for three years after the successful commission in 2015. Recently, the electromagnetic activated pressure relief valve of cryogenic phase separator of beamline had malfunction due to the rust of its control circuits. After on site observation and temperature records, the water was found to be condensed around the outlet area due to fast temperature dropping near the valve as it was activated. Such situation would cause the rust of metal components due to humidity after a certain period of time. To avoid such event, fan is used to blow the condensed water and silicone heat belts are added to increase the local temperature with unique designed clamp for fixing the fan, sensors and safety circuit breaker. Via the temperature control system, the temperature monitoring, setting and the abnormal situation can be access on web page through Ethernet to make sure the proper operation of the protected devices. The instrument has been operated since Dec. 2018. After four months of operation, the moist situation has been improved and the relief valve is no longer frosted.

INTRODUCTION

In a part of TPS beamlines, the cooling system of DCM (Double Crystal Monochromator) includes several valves, a cryocooler (chiller) and a phase separator

A cryocooler (chiller) has an internal LN_2 closed loop for cooling DCM. As the LN_2 level of chiller becomes too low to be refilled, LN_2 would come from phase separator to chiller then the LN_2 of phase separator would also be refilled by TPS surrounding LN_2 pipes. The flow of LN_2 is shown in Figure 1.

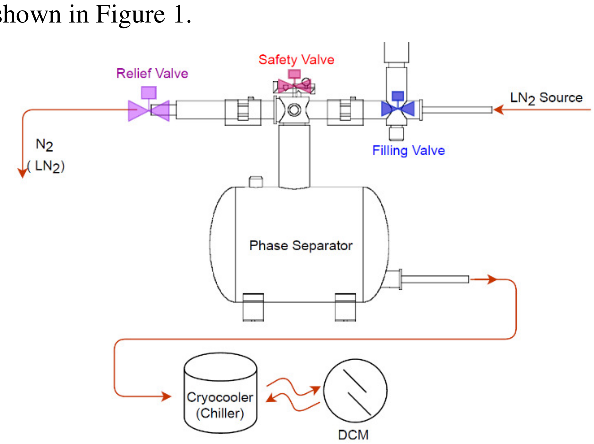

Figure 1: LN_2 flow schematic. [1]

After observation, LN_2 would fill the cryocooler in every 6 hours. During filling period, the internal pressure of phase separator would be higher than the gas release setting of 1.5 bar. The pressure relief solenoid valve would be opened continuously till pressure drop below the setting level. In this period, part of LN_2 would flow out through gas release valve to cause the fast dropping of the temperature in this area. The -100° Celsius would remain 25 minutes at the outside of the valve. Such low temperature condition would freeze the condensed water and increase humidity outside the valve. After 1-2 years, the control circuit of the pressure relief valve would be corroded till failure. The corroded PCB is shown in Figure 2.

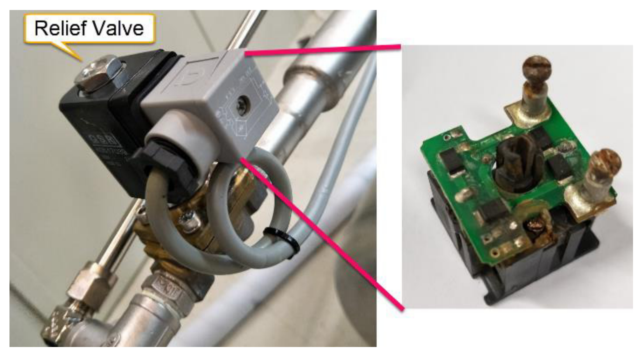

Figure 2: Pressure relief solenoid valve and the corroded PCB inside.

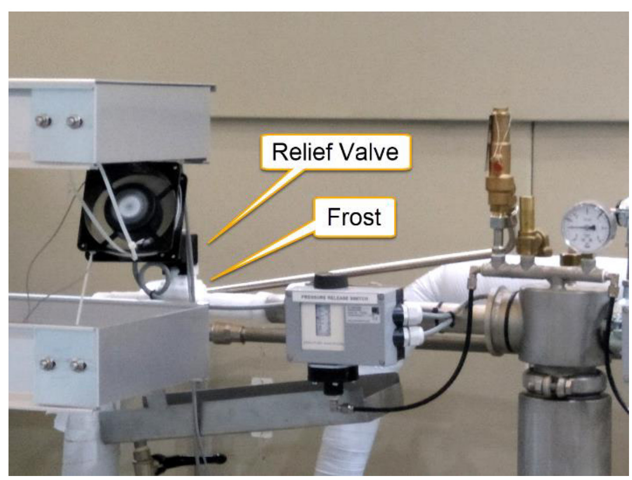

Figure 3: Frosted situation at TPS 25A relief valve.

The failure of pressure relief valves had interrupted the cryogenic system 3 time within 3 years and are located separately in TPS 05A, TPS 25A and TPS 09A. During system construction, the isolation of pipe and air was done by thermal insulation material, but it cannot eliminate thermal

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conduction completely. The condensed water and ice could accumulate within the gap. Our group started to learn such condition in TPS 25A and try to improve such situation. The first step was to remove the thermal insulation material and install a fan to reduce the frosted condition as Figure 3. But with fan is not enough, using heating components to control local temperature was adopted to eliminate frost and reduce humidity.

HEATING POWER ESTIMATED

The thermal analysis module of Solidworks [2] was used to calculate the required heating power that can resist the temperature dropping when the pressure release valve outflows N_2 during continuously filling. The estimated value of 400W heating power shall be just enough to prevent local frost. The simulation result with a simplified model is shown in Figure 4.

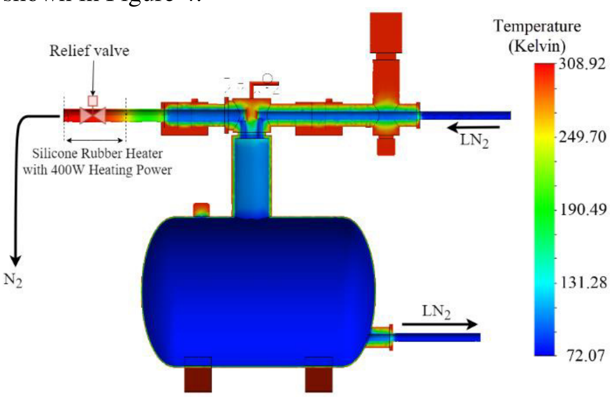

Figure 4: Thermal simulation for 400W heating power around the pressure relief valve.

HARDWARE AND INSTALLATION

Including water resistance, heating efficiency and integration, a piece of 400W Silicone rubber heater was designed to cover the valve. A clamping tool was also designed to fix k-type thermal sensor on the flange of the valve. An 8cm 12W AC fan (Fulltech UF80A11BWH) was installed just at the upside of the valve.

Averaging heating shall be achieved by using aluminium foil for cladding. With the continuous blow of the fan, the humidity surround there could be reduced. The temperature controller (DTB 4824) from Delta and SSR (Solid State Relay) are used to ensure high current.

The Silicone rubber heater was fixed by stainless steel hose clamp and the sensor clamp is fixed on the flange of the valve. After that, the fan and the k-type thermal sensor were fixed on it as shown in Figure 5. The aluminium foil was clad over the above parts.

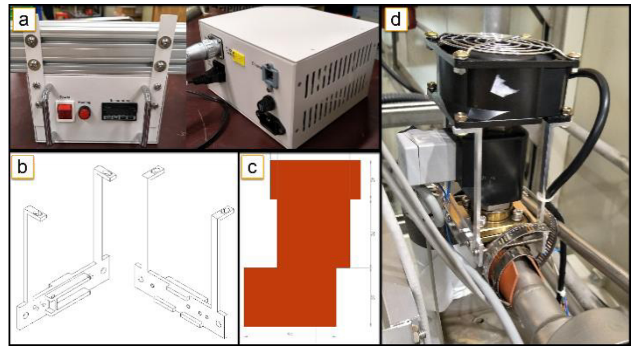

Figure 5: (a) The instrument chassis. (b) Clamp design. (c) Heating silicone rubber design. (d) Complete assembly.

ALM (alarm) function of DTB 4824 was used to control the temperature. The setting temperature is 20° Celsius. As the measured temperature lower than the setting value, heating would start. PID function is not used for heating efficiency and easier maintenance. The setup of the heater with DCM is shown in Figure 6 and the schematic of the wiring is in Figure 7.

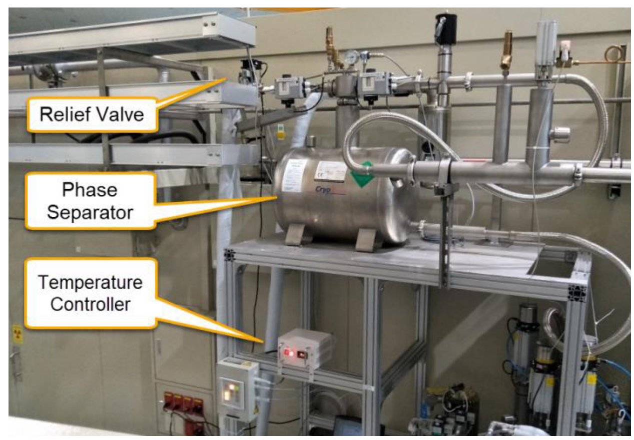

Figure 6: Protection instrument.

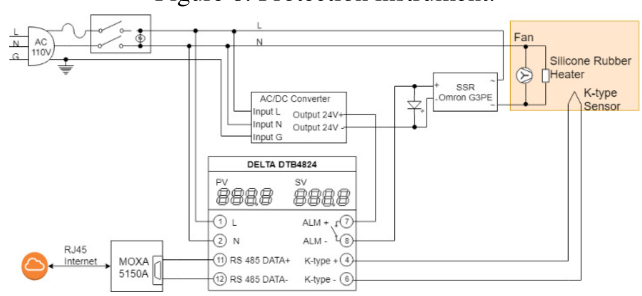

Figure 7: Circuit wiring schematic of the protection system.

SOFTWARE SOLUTION

The protection system can avoid frost and to remain low humidity surround the pressure relief valve. The accompany software can monitor the status in any time to inform failure actively.

The monitoring software is coded by LabVIEW [3] to provide three services: Management program, webpage, and EPICS IOC as shown in Figure 8.

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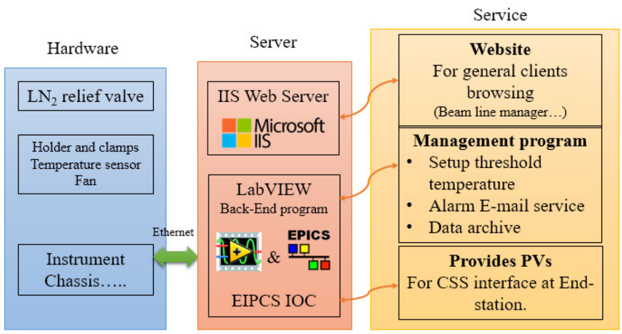

Figure 8: Services provided in software.

The Back-End management program can be used to adjust setting value, monitoring and record the operation data including temperature, error and error massage. Besides, E-mail message would be sent to notify the administrators. After the system is recovered, a message would also be sent. The software can also announce the operation status to webpage for internal monitor by the relating staffs and the generated page is shown in Figure 9.

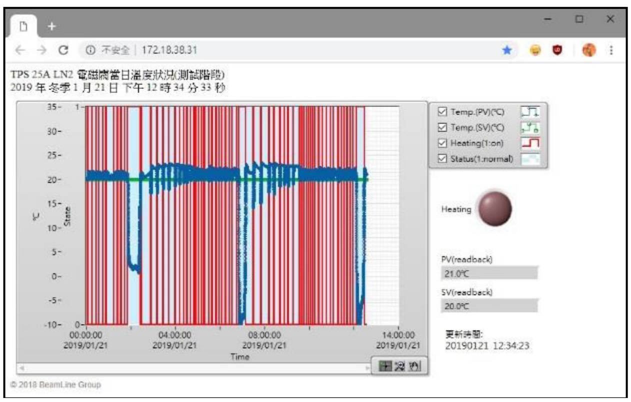

Figure 9: Web page for monitoring. Blue line: temperature (degree C). Red line: Heating state.

RESULTS AND CONCLUSIONS

The temperature variation curve of the same probing position before and after the protection instrument under single filling event is shown in Figure 10.

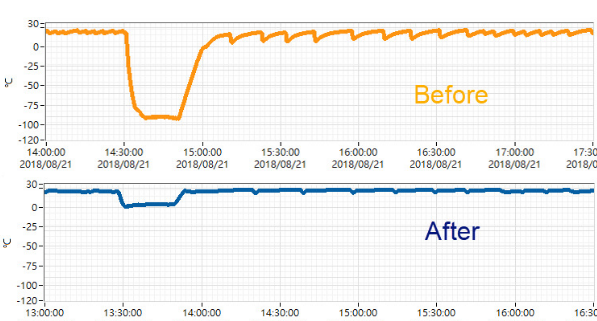

Figure 10: Single filling event, the temperature monitoring records before and after installation.

Before install protection instrument, the temperature would drop down to -110~100 ˚C during LN_2 refilling. After install the protection instrument, the lowest temperature would be -15~0 ˚C. In such range, the moist situation has been reduced and no longer frost exist around the relieve valve. The picture during refilling is shown in Figure 11.

Figure 11: After install protection instrument, there is no condensed water or frost surround the relief valve (foil covered) at LN_2 refilling period.

In long term temperature log data of 96 hours before and after installation as shown in Figure 12., the refilling period would not have obvious change due to the added system which indicating that no apparent heat loss was added by the heating system.

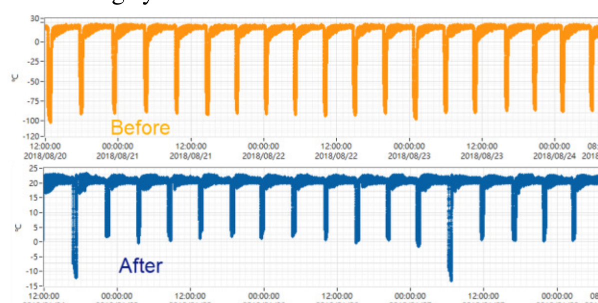

Figure 12: 96 hours before and after the installation of the new protection system, the LN_2 refilling period did not have obvious variation

After 4 months of observation, the protection instrument can remain stable temperature of the pressure relief valve to avoid frost surround the valve to effectively reduce the corrode of the PCB.

Further improvement is also applied by adding one more thermal sensor and thermal switch to have better system protection.

This new instrument would be installed to TPS 05A and TPS 09A in next TPS long term shut down period to avoid corrode of controller PCB of the pressure relief valve and also the failure period of cryogenic system.

REFERENCES

[1] Provided by RI, https://research-instruments.de

[2] Thermal analysis of Solidworks, https://www.solid-works.com

[3] LabVIEW, http://www.ni.com