# Operation-Readiness Clearance of the Slow-Control Rack for the SpinQuest Experiment at NM4

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**Abstract**

The SpinQuest experiment at NM4 requires superconducting magnet and cryogenic system to polarize the target. Various instruments involved in the polarized-target system are housed in several electronic racks: Magnet rack, slow-control rack and NMR rack. This document describes all instruments in the slow-control rack including the power requirement, cables and connections. The magnet rack and NMR rack are described in separate documents.

This document consist of five sections. The first section provides the introduction, scope and purposes of the document. The second section gives the layout and general description of the system. The third section provides the information for each instruments and the power consumption. Section four provide the load distributions on the Power Distribution Unit (PDUs) and section five provides the summary.

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# Contents

# 1 Introduction, scope and purposes of the document

The polarized target is one of the critical system for the SpinQuest experiment at NM4. Many electronic instruments are required to polarize, maintain and measure the polarization degree of the target and to monitor and control the cryogenic environment. Those instruments are organized in several electronic racks: Magnet rack, NMR racks and slow-control rack. Figure 1 shows the location of these racks along with the Root pumps and the target cave.

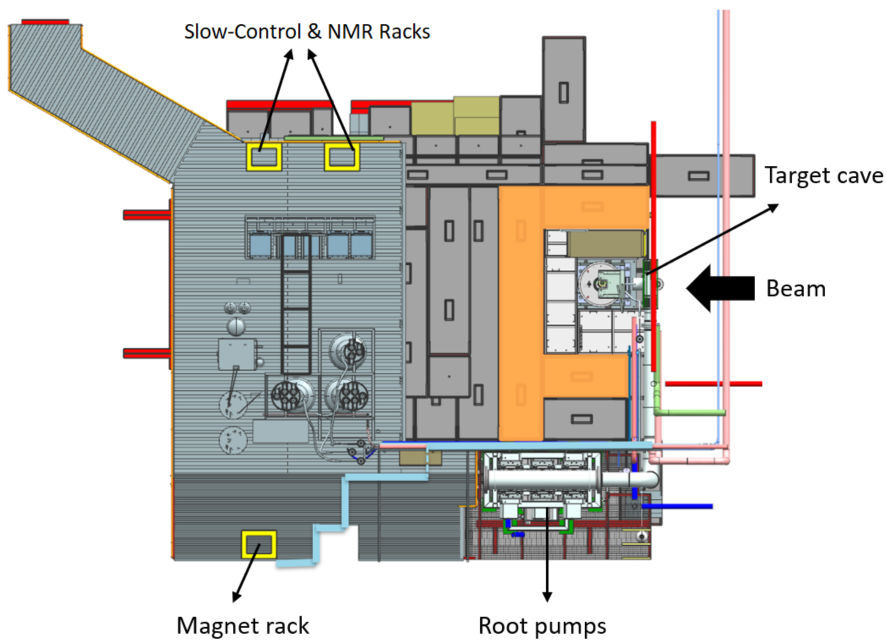


Figure 1: Top view of the cryo platform showing the location of the magnet rack, NMR rack, slow-control rack, root pumps and target cave.

This ORC document provides the description of the slow-control rack which include the layout, description for each instrument and power consumption. The NMR rack, magnet rack and other subsystems of the polarized target are described in separate documents.

There are various instruments that will be housed in the slow-control rack. Those instruments are organized into several subsystems:

1. Cryogenic-control subsystem.
2. Target-lifter and Outer-vacuum subsystem.
3. Microwave subsystem.

The purpose of this document is to obtain permission to turn on the instruments for testing prior to the experiment and during the experiment.

## 2 Layout and General Description of the System

The layouts for each subsystems of the slow-control rack are shown in figure 2, 3 and 4 . All instruments except the microwave power supply work with single-phase 120 VAC input. The microwave power supply (CPI VPW 2838) needs 240 VAC with no neutral and connected directly to the wall outlet via an isolation transformer. The 120 VAC input is drawn from the wall outlet and distributed to the instruments via three power distribution units (PDUs).

Most instruments are commercial product. Target-lifter box is a custom product with an approve ORC (the target lifter ORC will be attached to this ORC). The instruments housed in the slow-control rack are organized into three subsystems:

1. Cryogenic-control subsystem. This subsystem is responsible to monitor the cryogenic environment. The cryogenic-control subsystem consist of several readouts for the pressure sensors, temperature sensors, liquid-level sensors and flow meters. Those sensors are located at various places in the target cave and Root pumps area. The instruments are communicated via RS232 or GPIB protocols. The data then transferred to the counting house via Ethernet cable.

   Two Lakeshore 218s will be used to monitor the temperature in the fridge and target stick which is inside the target dewar. There are three pressure-sensor readouts that monitor the pressure value of the outer-vacuum shield and helium vapors. The level of the liquid helium that cool the target will be measured via American Magnetic Inc. (AMI) 1700.

   Teledyne THCD 401 is a multi channel instrument to monitor and control the flow of the fluids. We will use this instrument to control the flow of the pumps used to pumping out the helium vapor from the magnet dewar and separator volume. We will also use Teledyne THCD 401 to monitor the helium vapor flow out of the target nose.

   All instruments are communicated via RS232 or GPIB protocol. We will convert the communication connections to USB, and then to Ethernet before transmitting the data to the control room. Therefore, there will be several RS232 to USB cables and GPIB to USB cable. Those communication cables are connected to USB hubs and then to USB to Ethernet converter.

2. Target-lifter and Outer-vacuum subsystem. The target polarization will decays due to the radiation damage from the proton beam. Therefore, the target needed to be heated (annealing) to restore the polarization by lifting the target up to the annealing plate. Target-lifter subsystem is responsible to control and monitor target cup positions. This subsystem consist of a

custom lifter control box and ADC box in the rack that connect to stepper motor, position switches and potentiometer in the cave. The target lifter subsysem has a separate ORC that has been approved. There is also a camera that transmit the data via Ethernet to the control room.

The magnet dewar is protected from thermal contact by the outer-vacuum chamber. This high vacuum is achieved using a Turbo-Molecular pump that controlled from the rack via DCU 600. The vacuum pressure then monitored using a pressure readout (TPG 361) from the rack.

3. Microwave subsystem. The target will be polarized using Dynamic-Nuclear Polarization technique (DNP). This technique require a 140 GHz microwave generated from an EIO tube. The tube is located in the target cave. The power supply for the EIO tube (CPI VPW 2838) connect directly to the 220 VAC wall outlet with no neutral. The frequency generated will be monitored using EIP frequency counter placed in the rack. An interlock will monitor the EIO temperature and turning off the power supply if the EIO temperature exceed a certain value. There is a separate and approved ORC for the microwave setup and will be attached to this document.

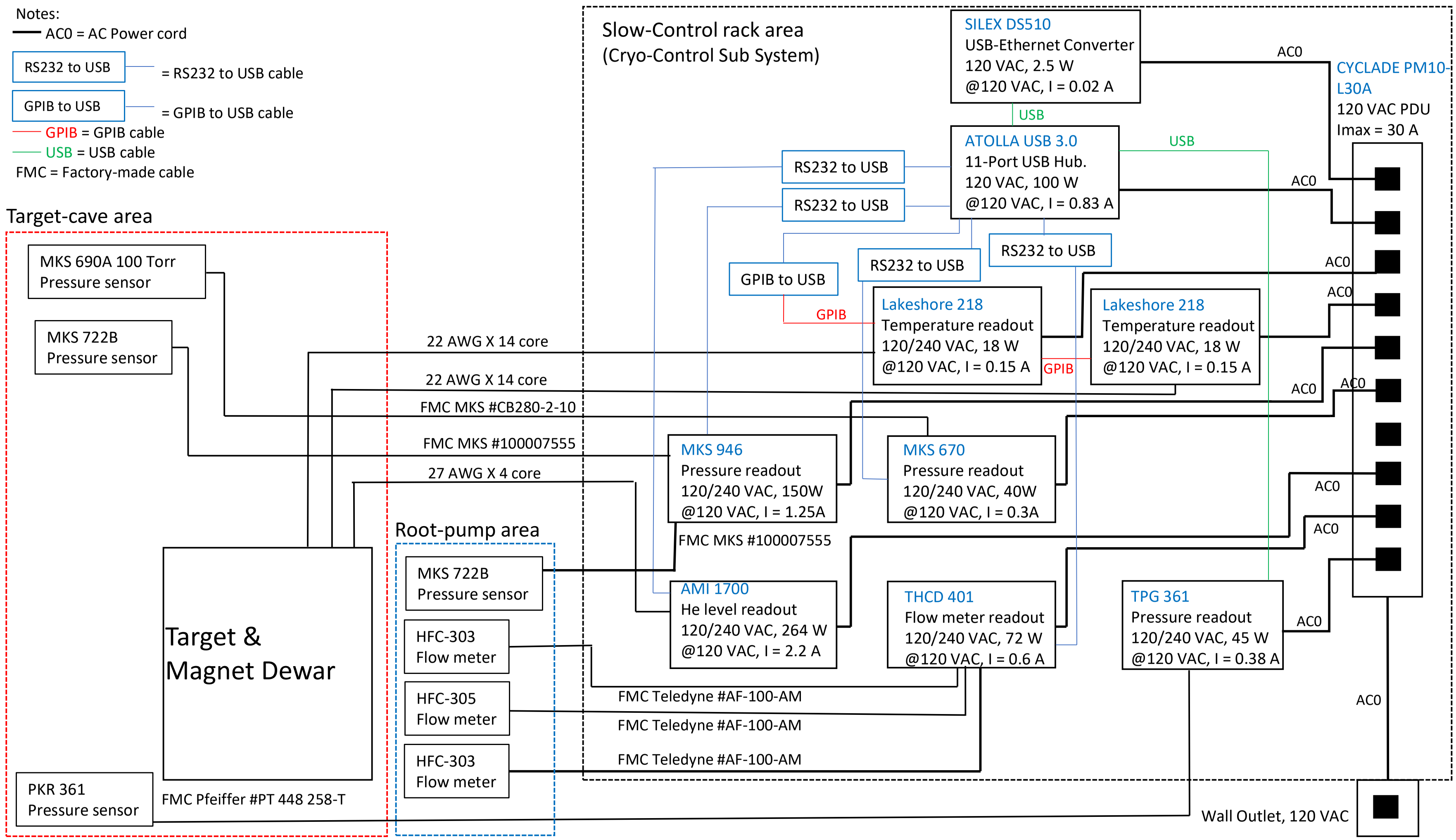


Figure 2: The layout and wiring scheme of the cryogenic-control subsystem.

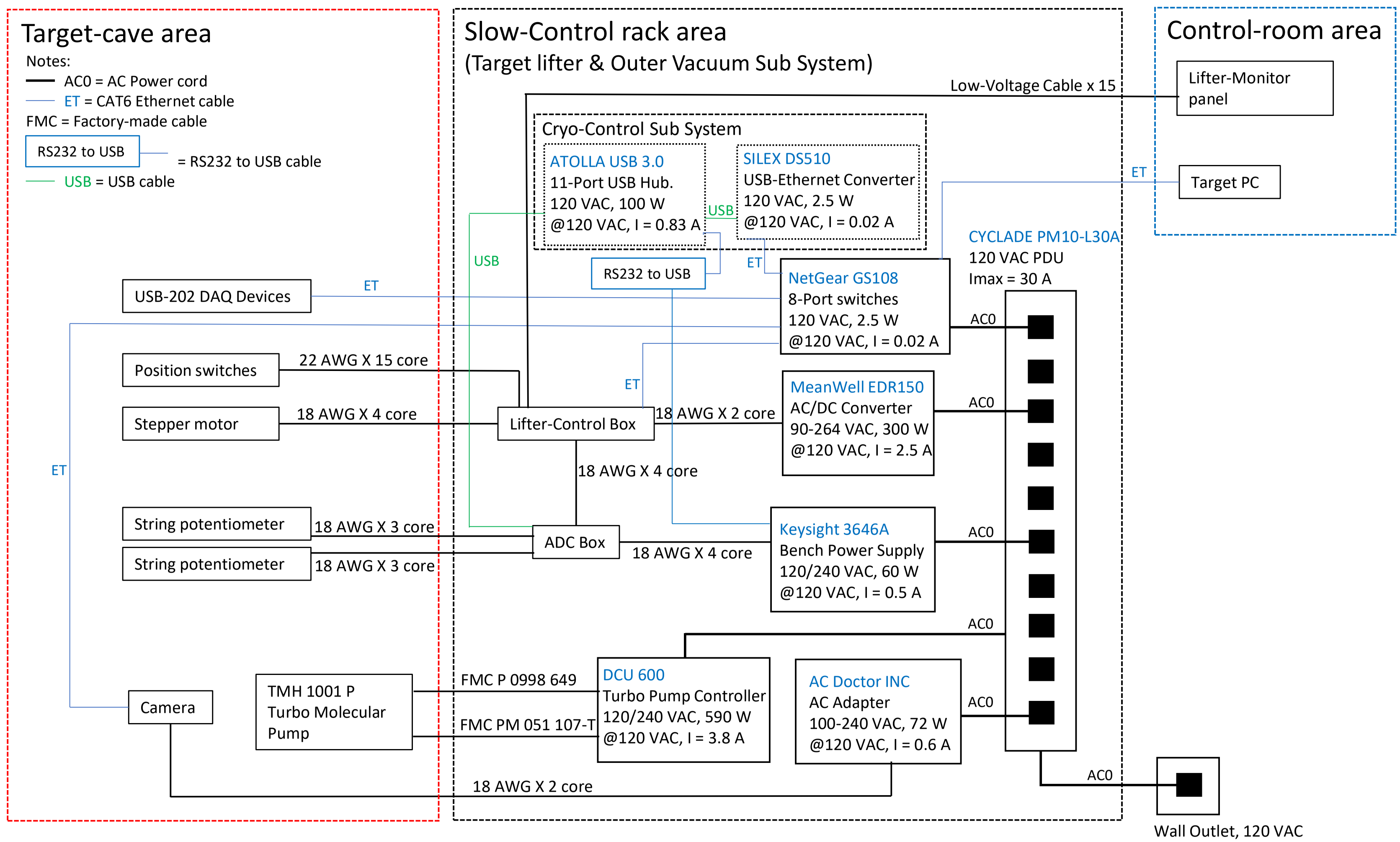


Figure 3: The layout and wiring scheme of the target lifter and outer vacuum subsystem.

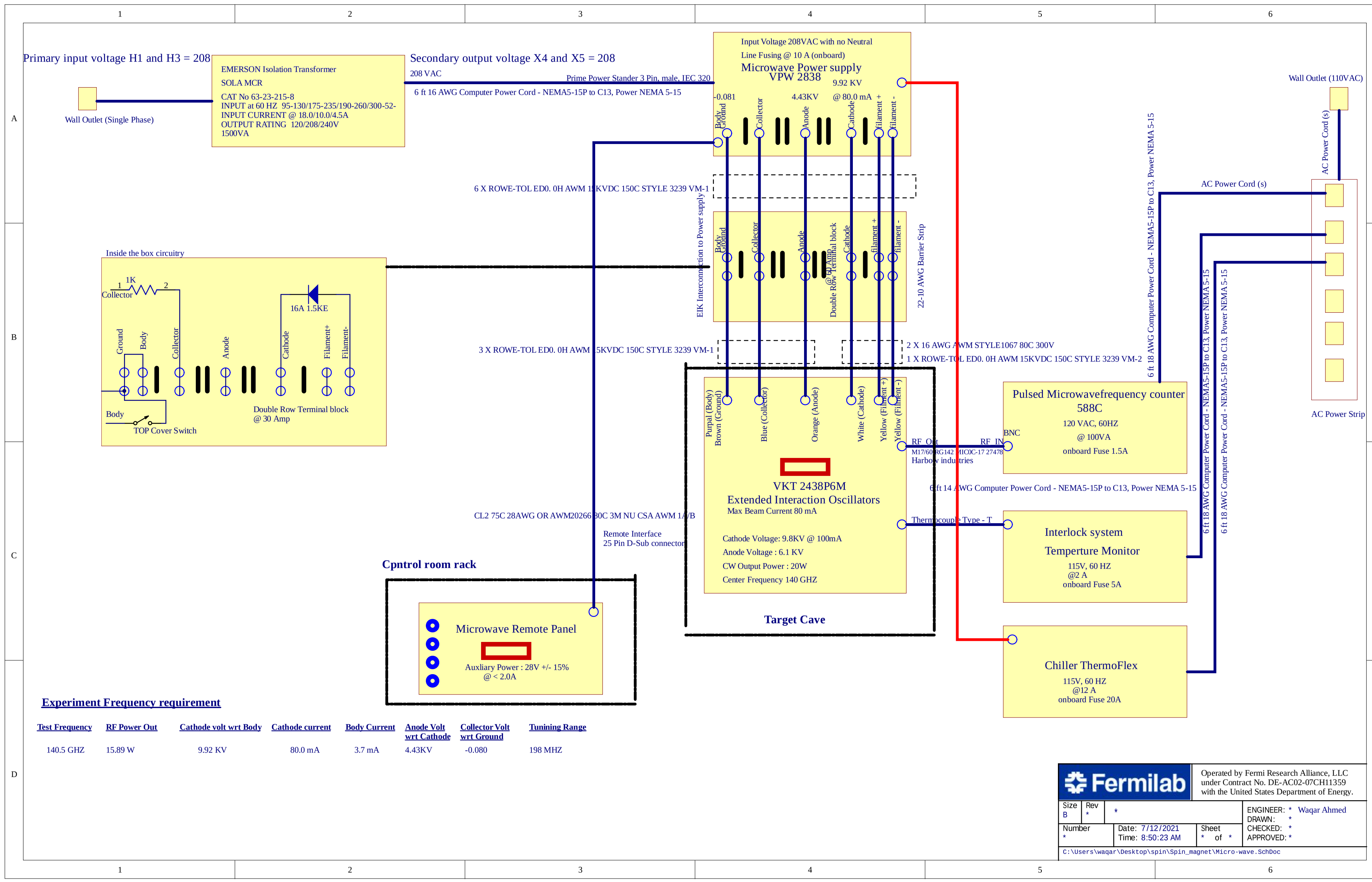


Figure 4: The layout and wiring scheme of the microwave subsystem.

## 3 Instruments and Power Consumption

This section provides all instruments housed in the slow-control rack and their power requirement. The information will be organized in separate tables based on the rack subsystems (cryogenic control, target lifter and outer vacuum and microwave subsystems).

| Instrument | Note | Power (Watt) | Current (Amp) |
|---|---|---|---|
| **Cryo-control subsystem** | | | |
| Lakeshore 218 | Temperature-sensor readout | 18 | 0.15 |
| Lakeshore 218 | Temperature-sensor readout | 18 | 0.15 |
| MKS 670 | Pressure-sensor readout | 40 | 0.3 |
| MKS 946 | Pressure-sensor readout | 150 | 1.25 |
| Pfeiffer TPG361 | Pressure-sensor readout | 45 | 0.38 |
| Teledyne THCD 401 | Flow-meter readout and controller | 72 | 0.36 |
| AMI 1700 | Liquid-Helium level readout | 264 | 2.2 |
| ATOLLA USB 3.0 | USB hub | 100 | 0.83 |
| SILEX-DS 510 | USB-Ethernet converter | 2.5 | 0.02 |
| | | | |
| **Sub total** | | **709.5 Watt** | **5.4 A** |

Table 1: List of instruments and power consumption of the cryogenic-control subsystem.

| Instrument | Note | Power (Watt) | Current (Amp) |
|---|---|---|---|
| **Target lifter & Outer Vacuum Subsystem** | | | |
| MeanWell EDR 150 | AC/DC converter | 300 | 2.5 |
| Keysight 3646A | Bench Power supply | 60 | 0.5 |
| Pfeiffer DCU 600 | Turbo Pump controller | 590 | 3.8 |
| AC Doctor INC | AC Adapter | 72 | 0.6 |
| NetGear GS106 | Ethernet switch | 2.5 | 0.02 |
| Lifter-control box | Motor-controller system | - | - |
| ADC box | Analog/digital converter | - | - |
| ATOLLA USB 3.0 | USB hub | 100 | 0.83 |
| | | | |
| **Sub total** | | **1124.5 Watt** | **8.35 A** |

Table 2: List of instruments and power consumption of the target lifter and outer vacuum subsystem.

| Instrument | Note | Power (Watt) | Current (Amp) |
|---|---|---|---|
| **Microwave Subsystem** | | | |
| Connect to the 120 VAC PDU: | | | |
| - EIP 588C | Pulse microwave counter | 100 | 0.5 |
| - Temperature-Interlock box | Temperature monitor | 240 | 2 |
| **Sub total** | | **340 Watt** | **2.5 A** |
| | | | |
| Connect to the 220 VAC with No neutral via isolation transformer: | | | |
| - VPW 2838 | Microwave-power supply | 1650 | 10 A (Max) |

Table 3: List of instruments and power consumption of microwave subsystem. The microwave-power supply (VPW 2838) will be connected to a special outlet which is 220 VAC with No neutral via an isolation transformer. The chiller will also be connected to the separate outlet near the cave.

# 4 Load Distributions on PDUs

There are three single phase, 120 VAC Power Distribution Units (PDUs) in the slow-control rack. It is very important to distribute the load (current) equally among these PDUs. Table 4, 5 and 6 show the instruments connected to each PDUs to achieve a uniform load among PDUs which is around 5.5 A. Table 7 shows the current load for each PDUs and the total current consumed by all instruments connected to the single phase, 120 VAC outlets.

| Instrument | Note | Current (Amp) |
|---|---|---|
| **Connect to PDU 1** | | |
| Pfeiffer TPG361 | Pressure-sensor readout | 0.38 |
| SILEX-DS 510 | USB-Ethernet converter | 0.02 |
| MKS 946 | Pressure-sensor readout | 1.25 |
| DCU 600 | Turbo-Pump controller | 3.8 |
| | | |
| **Sub total** | | **5.45 A** |

Table 4: List of instruments connected to the first PDU.

| Instrument | Note | Current (Amp) |
|---|---|---|
| **Connect to PDU 2** | | |
| Keysight 3646A | Bench Power supply | 0.5 |
| Teledyne THCD 401 | Flow-meter readout | 0.36 |
| Temperature-Interlock box | Temperature monitor | 2 |
| AC Doctor INC | AC Adapter | 0.6 |
| ATOLLA USB 3.0 | USB hub | 0.83 |
| ATOLLA USB 3.0 | USB hub | 0.83 |
| Lakeshore 218 | Temperature-sensor readout | 0.15 |
| Lakeshore 218 | Temperature-sensor readout | 0.15 |
| NetGear GS106 | Ethernet switch | 0.02 |
| SILEX-DS 510 | USB-Ethernet converter | 0.02 |
| | | |
| **Sub total** | | **5.46 A** |

Table 5: List of instruments connected to the second PDU.

| Instrument | Note | Current (Amp) |
|---|---|---|
| **Connect to PDU 3** | | |
| AMI 1700 | He-level readout | 2.2 |
| MeanWell EDR 150 | AC/DC converter | 2.5 |
| EIP frequency counter | | 0.5 |
| MKS 670 | Pressure readout | 0.3 |
| | | |
| **Sub total** | | **5.5 A** |

Table 6: List of instruments connected to the third PDU.

| Power Distribution Unit (PDU) | Total Current (Amp) |
|---|---|
| First PDU | 5.45 |
| Second PDU | 5.46 |
| Third PDU | 5.50 |
| | |
| **Total** | **16.41 A** |

Table 7: Current consumed by each PDUs and total current consumption

## 5 Summary

Slow-control rack houses many instruments which are important to polarize the target and monitor the cryogenic environment. The rack consists of three subsystems: Cryogenic control, target lifter and outer vacuum and microwave subsystems. Most instruments are commercial product. Target-lifter box is a custom product with an approved ORC.

Cryogenic-control subsystem monitor cryogenic environment such as temperature, pressure and liquid helium level. Target-lifter subsystem control the position of the target cup, outer vacuum subsystem maintain the vacuum level through a Turbo molecular pump. Microwave subsystem is responsible for polarizing the magnet using the Dynamic Nuclear Polarization (DNP) technique. A 140 GHz wave is generated via an EIO tube. The tube is powered by a high-voltage power supply connected to the 240 VAC with no neutral outlet via an isolation transformer.

Most instruments are powered by single phase, 120 VAC input via three Power Distribution Unit (PDUs). The maximum current drawn from those instruments is 16.41 A. Microwave power supply will be connected directly to 240 VAC outlet with no neutral via an isolation transformer.