BGC Automated Process

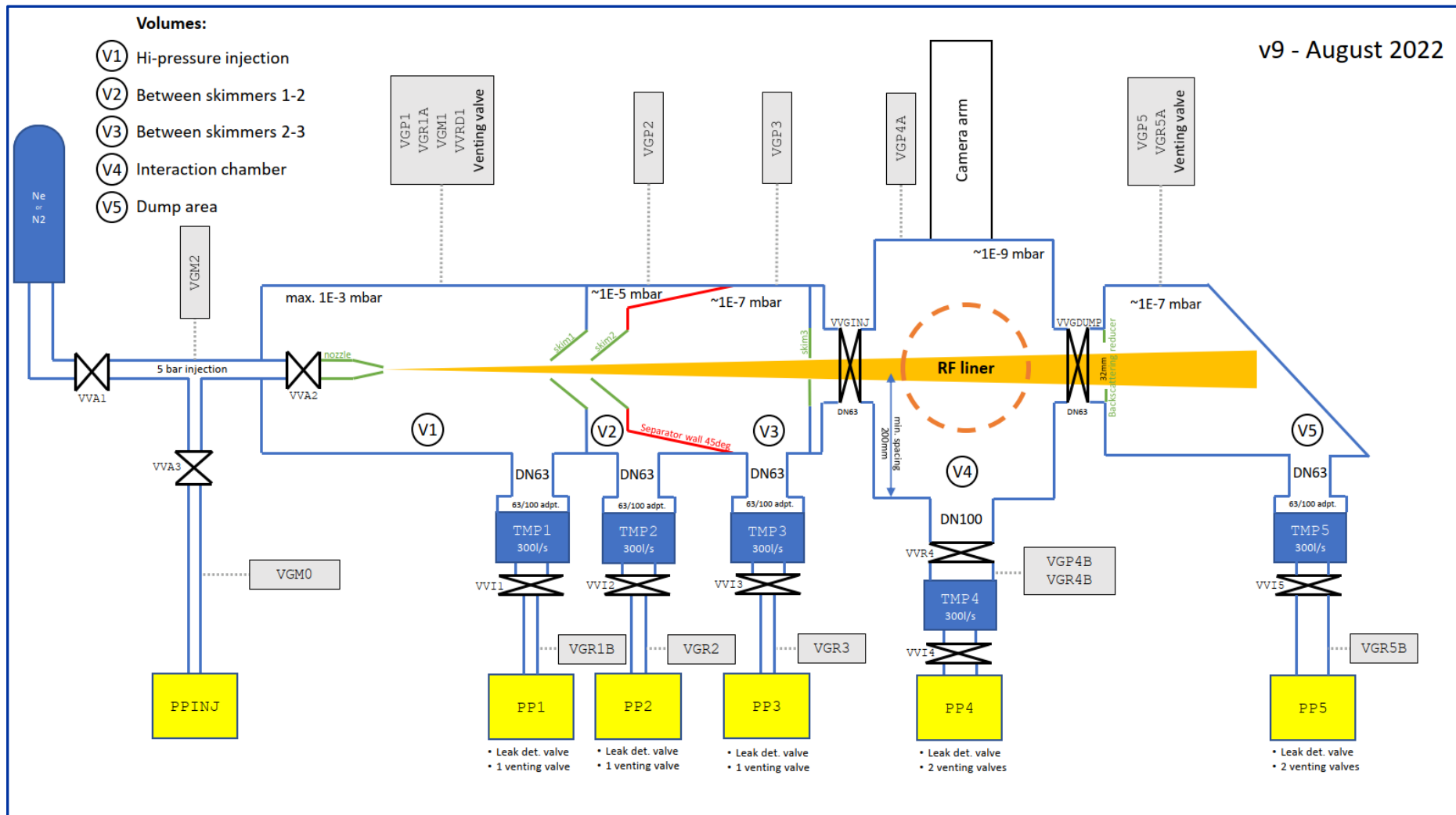**Liam Luigi Cantu**

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Contents

Introduction

**Current operation and Motivation for Automation**

BGC vacuum equipment

Current operation

- The BGC is currently operated fully manually (using the SCADA) following a detailed procedure

- Must be operated by expert users only

- There is a need to automate the process so that non-experts can safely operate the instrument

- Reliability and safety also increase with an automated process
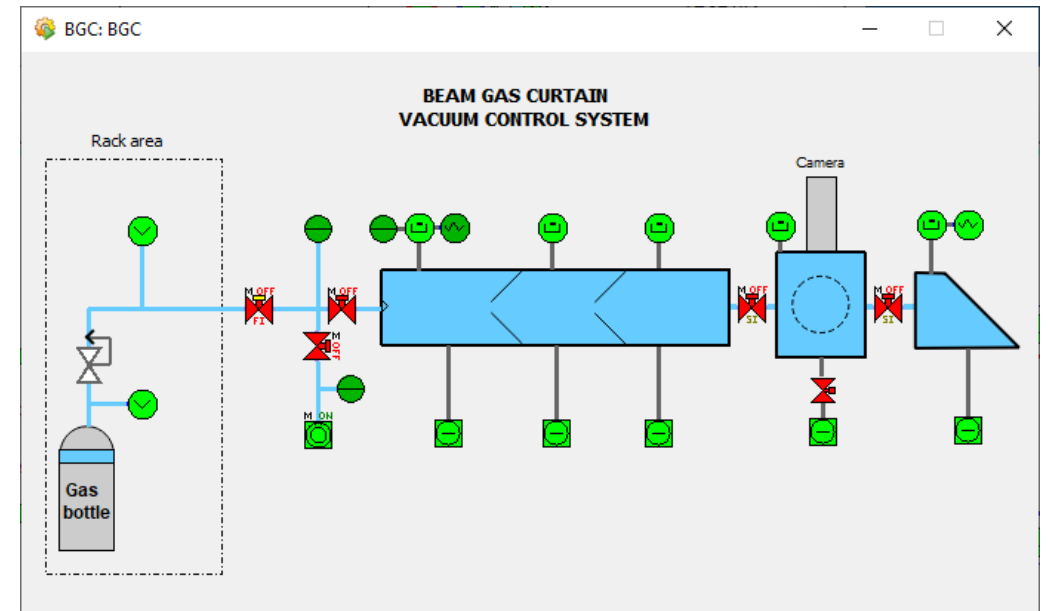
Scope of the process

- Automate preparation and injection sequence of the instrument based on experience operating it in the last year

- Returning to initial state after an injection

- Recovery from failures in the process

- Excluded:

  - Pump down/preparation of the instrument after venting

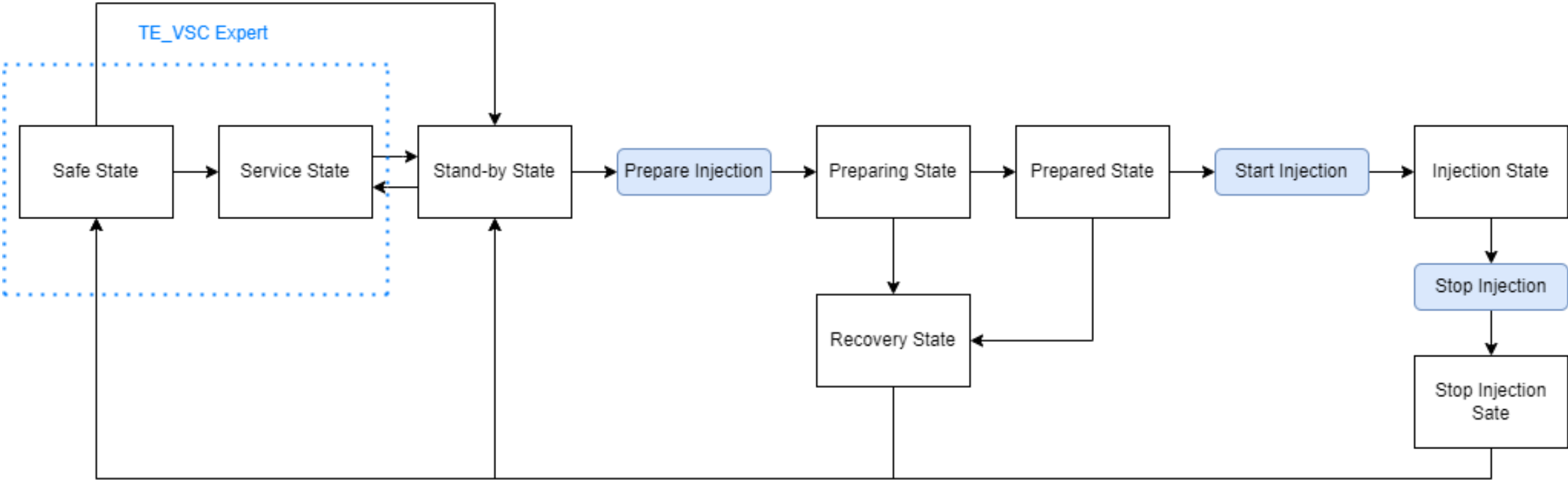 - Other specific tasks not related to injection
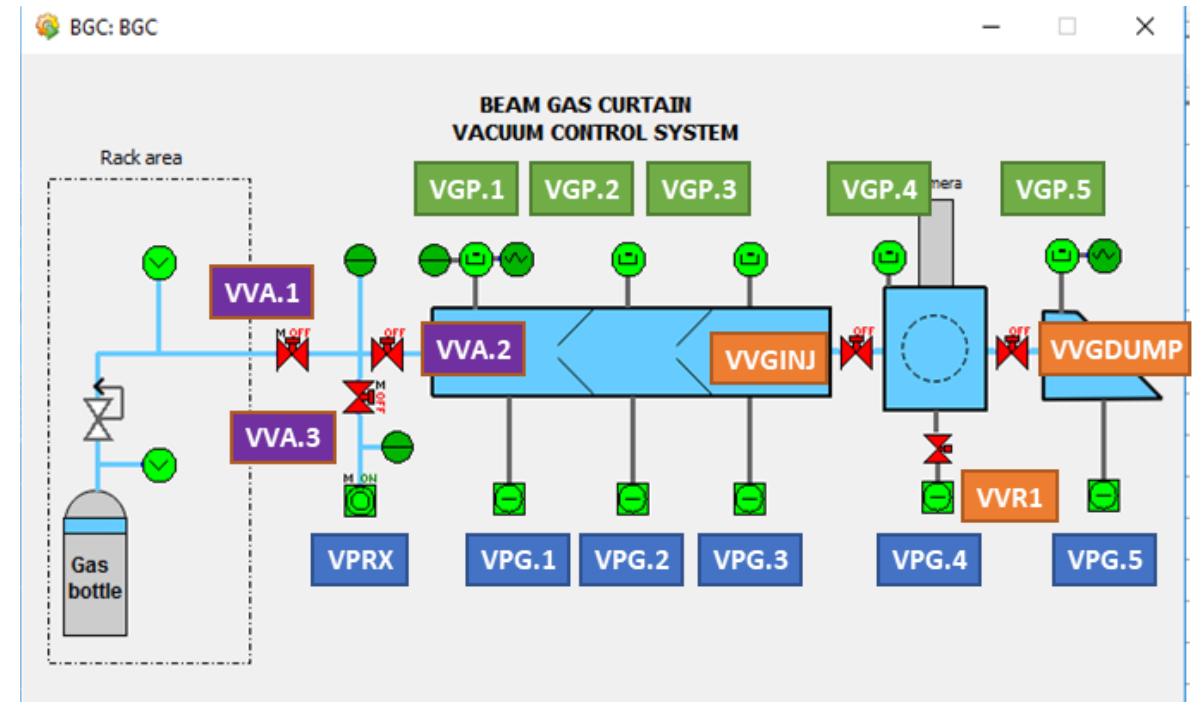
Process Control

Process Flow and Machine Safety Measures

General process flow

Technical Specification and User Manual: https://edms.cern.ch/document/2757469/5

Machine Safety Hazards

- ## No VVRs on pumping groups:
  - Possible backflow from the VPGs
  - Could pollute BGC and beam vacuum

- ## No VVR and a VVT on VPG5:
  - VVGDUMP could fail in open state and VPG5 could vent
  - Venting of the beam pipe

- ## Issues with injection causing pressure spike in beam pipe:
  - Could cause beam dump

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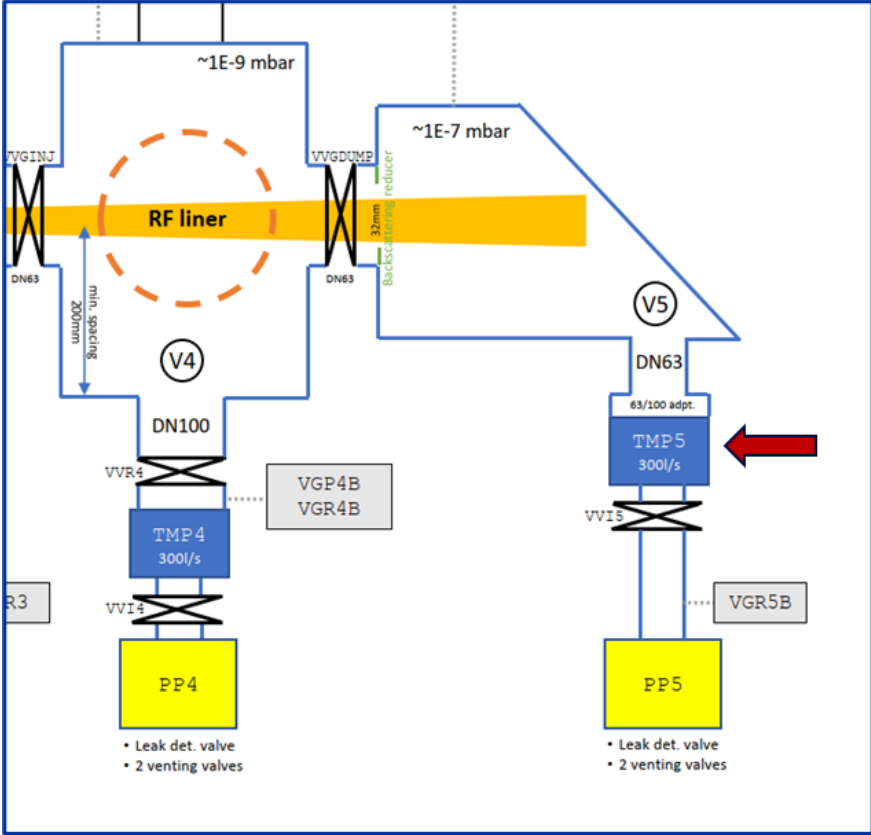
Process conditions and device Interlocks

- Two safety measures:

  - Device Interlocks:

    - Can be START or FULL Interlocks

    - Maintaining same interlocks as when process was manually operated

    - Baseline safety that protects the machine

  - Process Conditions, when breached:

    - In Stand-by state will not allow process to start

    - In Preparing, Prepared and Injection states, will move to the safe state in a controlled manner

    - Different values depending on the state

Device Interlocks

- Will always be acting and override the process, baseline safety

- Consist in:

  - Open and full ITLs on Gate valves

  - Start Interlocks on the VPG processes and Open Interlocks on their VVIs (avoid back-streaming)

  - VPG5 VVT Full ITL

  - Injection valve open and full ITLs

  - PPINJ full ITL

- If disabling of ITLs needed for operations on the BGC, will be done manually by controls expert
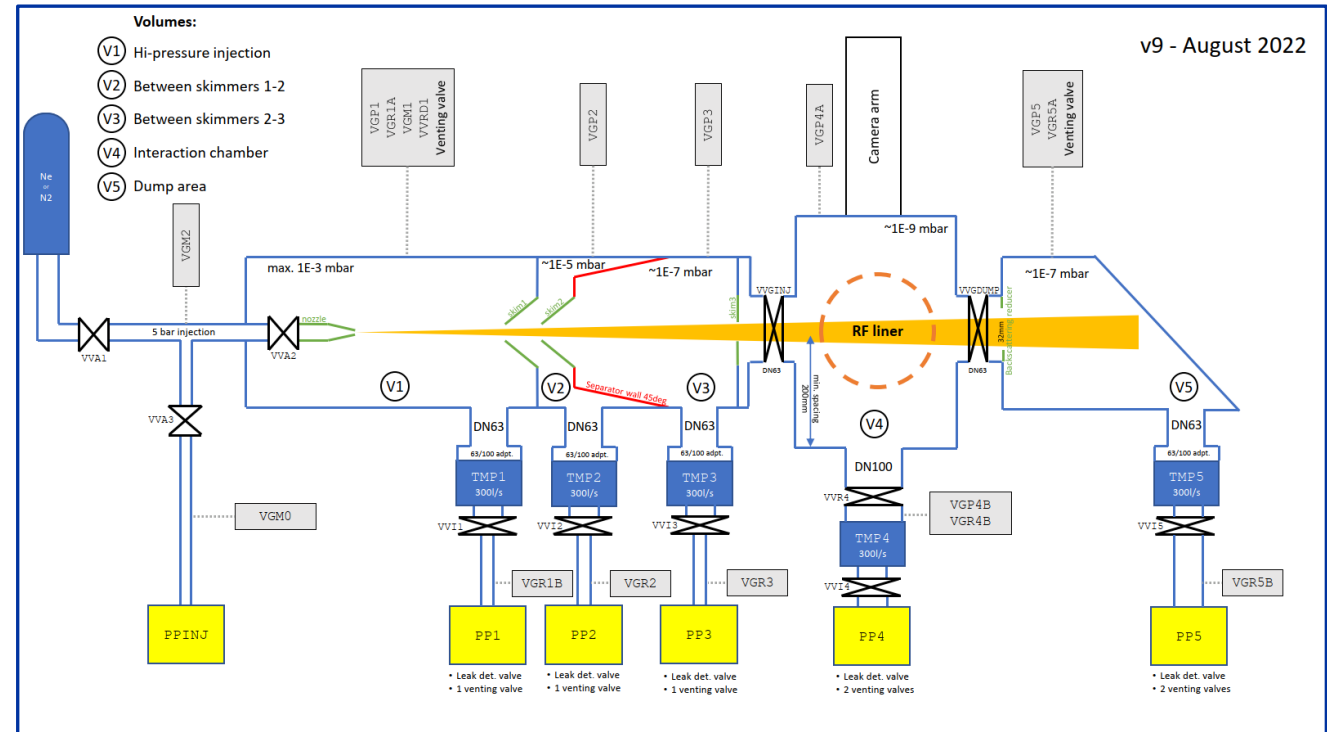
Process Conditions

Start Conditions

- Pressure values from all gauges
- Pumps in nominal state
- Valves closed and valid

Prepare Conditions

- Slightly less stringent pressure requirements
- Pumps in nominal state
- Valves valid

Injection Conditions

- Higher value pressure limits (injecting)
- Pressure requirement for gas at injection
- Pumps in nominal state
- Valves valid
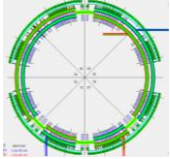
User Interface

New SCADA panels and Alarms

SCADA Layout – Main Panel

SCADA Layout – ITL panels

SCADA Layout – Main Panel

SCADA Layout – State detailed steps panels
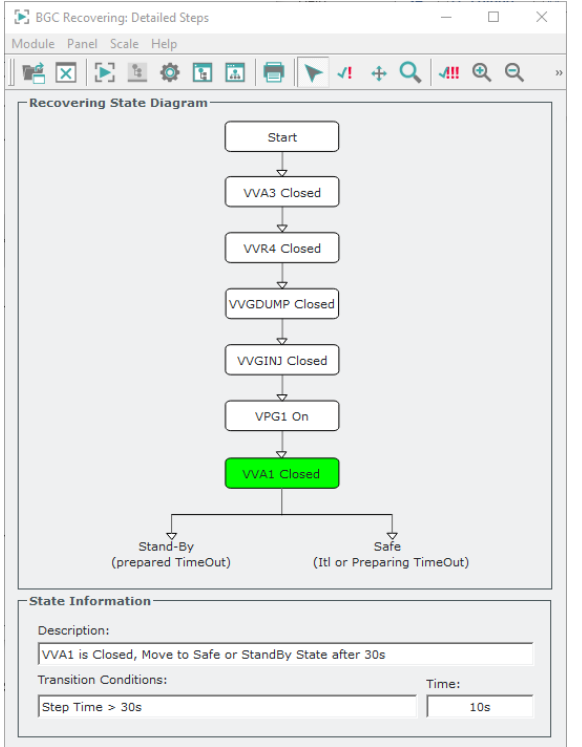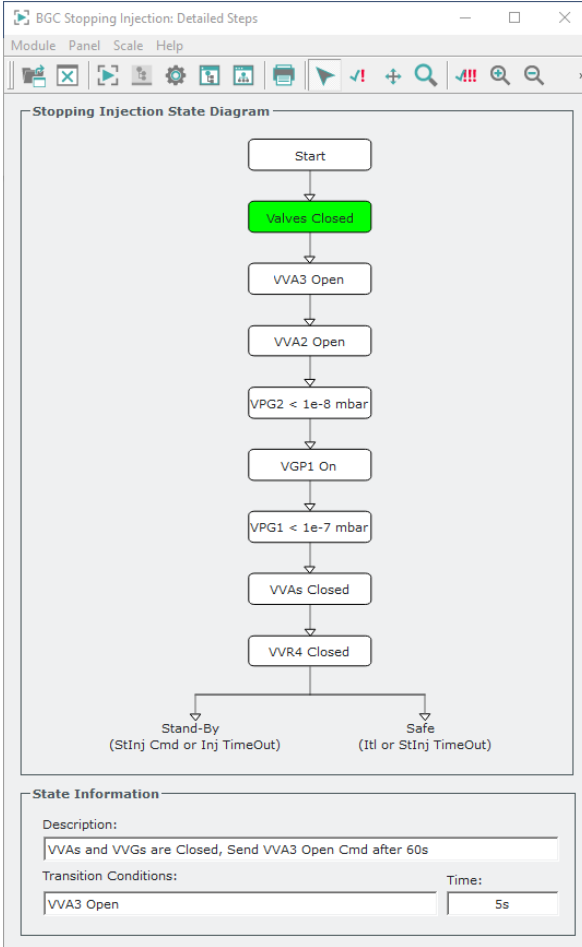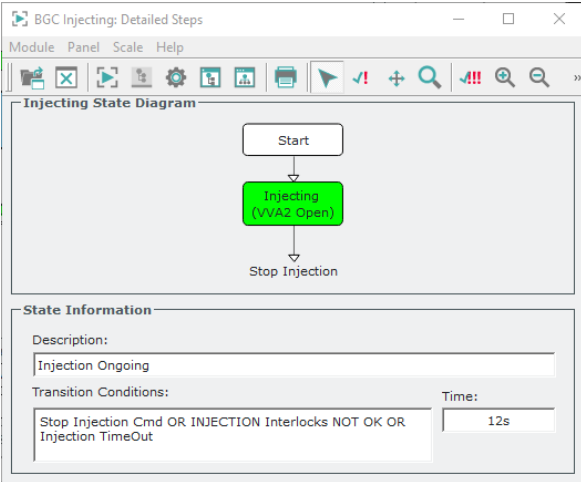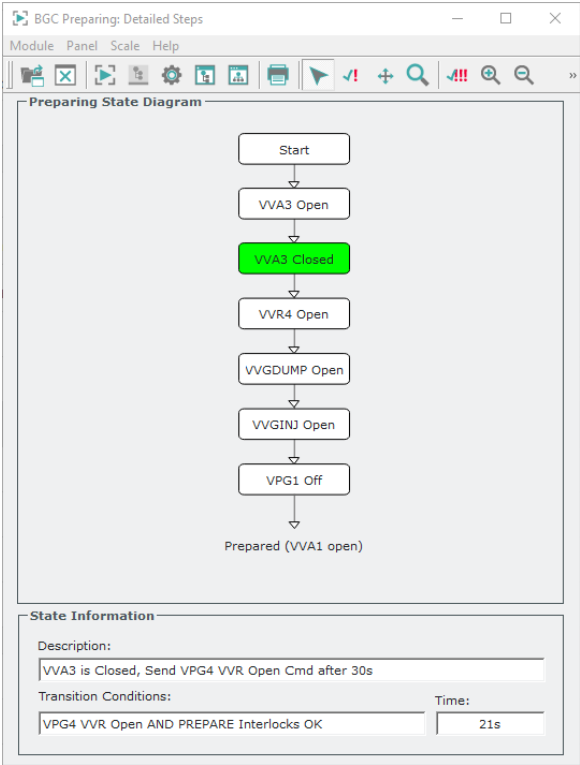
Alarms

Name	Description
VVGs NOT VALID	Invalid status on one or more of the BGC gate valves
VVAs NOT VALID	Invalid status on one or more of the BGC injection valves
SAFE STATE	The BGC has entered the safe state
ACT FAIL REC	BGC equipment could not be actuated to the expected state during one of the recovery steps
ACT FAIL STINJ	BGC equipment could not be actuated to the expected state during one of the stop injection steps
PRESS ITL TRIG	A pressure process interlock has been triggered on the BGC during the preparing, prepared or injection states
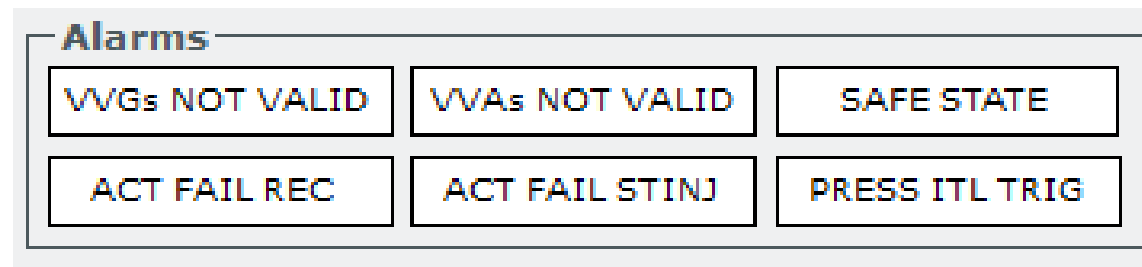
Testing and Installation

Testing Procedure and Installation Plans

Testing procedure

- As much effort in testing as in development

- Testing was carried out through simulations with a SCADA instance and a simulated PLC running on a desktop computer

- Only the BGC main controller was run, with signals and interlocks from pumping groups simulated in the software

- The code controlling each equipment (control types) was modified to simulate real-world behaviour and errors in equipment

- A checklist of tests was produced and followed so that every functionality and possible failure scenarios of the process were tested

- Testing checklist available:
  https://edms.cern.ch/document/3174228/1
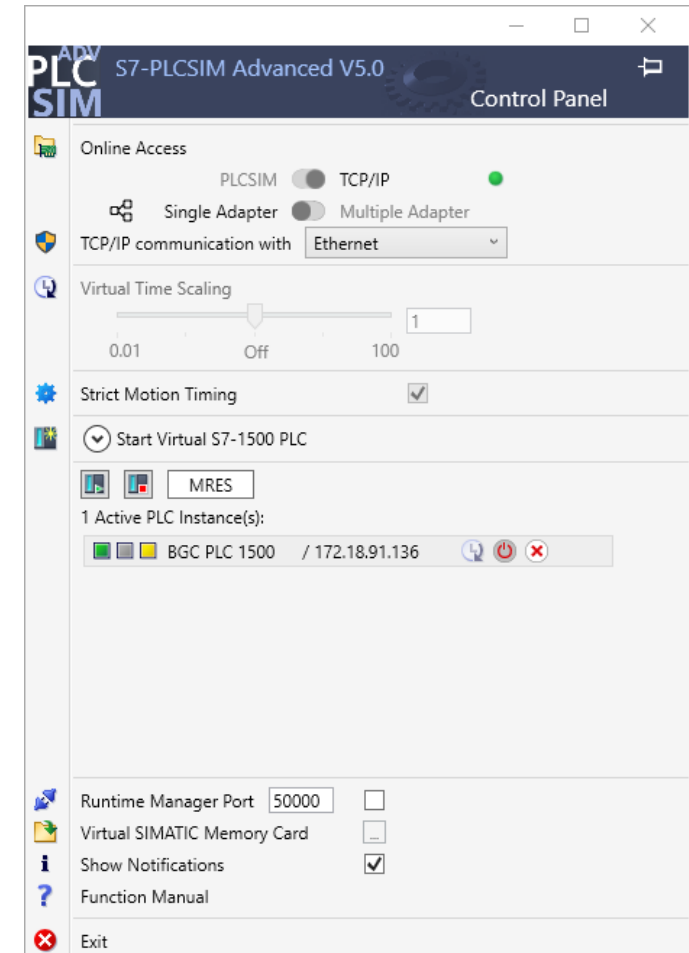
Installation plans

- W2 to W5 2025, coordinated with SY-BI skimmer exchange

- No major changes to cabling in the tunnel needed, only need to replace the old crate with the new one (W2)

- Coils on the VVGs to be changed to 24Vdc coils (W2)

- Three stages of commissioning (W4-5):

  1. Simulators connected to all the valves and test all functionality (by triggering process conditions as well with gauge simulators)

  2. Simulators connected only to the gate valves, test injection and functionality without injecting in the beam pipe

  3. Try a real injection with the sector valves closed

Thank You
For Your Attention

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Process Conditions

START CNDS (Stand-by State)

| Device	Process Interlock Conditions
VGR1A	< 1e-2 mbar, on and not in error
VGR1B, VGR2, VGR3, VGR5A	< 1e-1 mbar, on and not in error
VGP1	< 3e-8 mbar, on and not in error
VGP2	< 2e-9 mbar, on and not in error
VGP3	< 2e-9 mbar, on and not in error
VGP4A	< 2e-9 mbar, on and not in error
VGP4B	< 1e-9 mbar, on and not in error
VGP5	< 1e-8 mbar, on and not in error
PT101 (VGA1)	> 6000 mbar, on and not in error
VVGINJ, VVGDUMP, VVR4, VVA1, VVA2, VVA3	Closed, not in error and not in warning
PPINJ (VPRX), VPG1, VPG2, VPG3, VPG4, VPG5	In nominal state

PREPARE CNDS (Preparing and Prepared States)

Device	Process Interlock Conditions
VGR1A	< 2e-2 mbar, on and not in error
VGR1B, VGR2, VGR3, VGR5A	< 5e-1 mbar, on and not in error
VGP2	< 2e-9 mbar, on and not in error
VGP3	< 2e-9 mbar, on and not in error
VGP4A	< 5e-8 mbar, on and not in error
VGP5	< 1e-7 mbar, on and not in error
PT301 (VGA2)	> 2000 mbar, on and not in error
VVGINJ, VVGDUMP, VVR4, VVA1, VVA2, VVA3	Not in error and not in warning
PPINJ (VPRX), VPG1, VPG2, VPG3, VPG4, VPG5	In nominal state

INJECTION CNDS (Injection State)

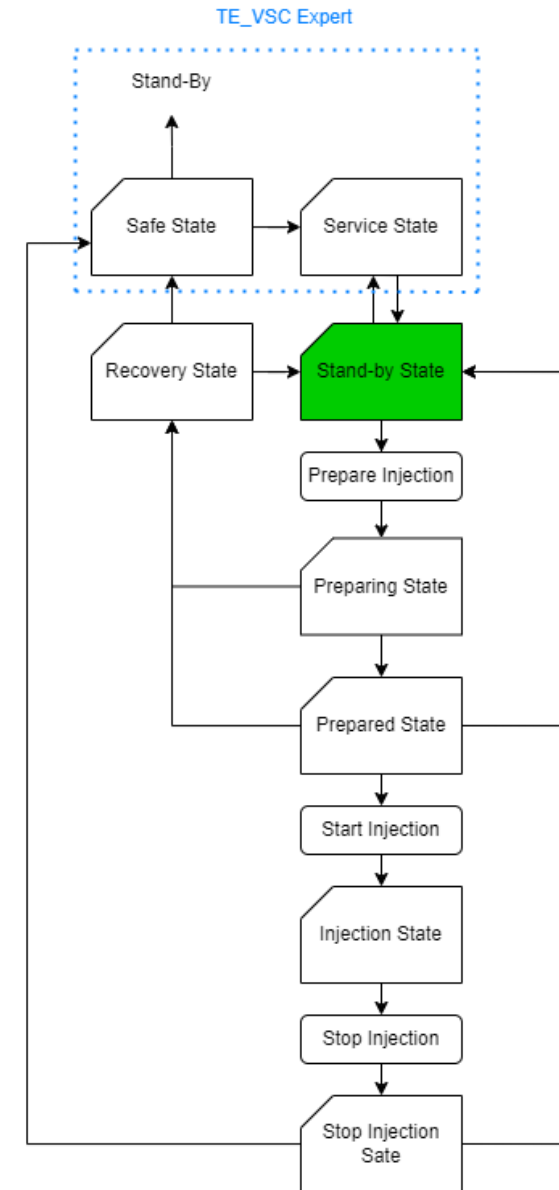| Device	Process Interlock Conditions
VGR1A	< 2e-2 mbar, on and not in error
VGR1B, VGR2, VGR3, VGR5A	< 5e-1 mbar, on and not in error
VGP2	< 3e-5 mbar, on and not in error
VGP3	< 3e-5 mbar, on and not in error
VGP4A	< 1e-7 mbar, on and not in error
VGP5	< 1e-6 mbar, on and not in error
PT101 (VGA1)	> 6000 mbar, on and not in error
PT301 (VGA2)	> 2000 mbar, on and not in error
VGM2 (VGMA2)	> 2000 mbar, on and not in error
VVGINJ, VVGDUMP, VVR4, VVA1, VVA2, VVA3	Not in error and not in warning
PPINJ (VPRX), VPG1, VPG2, VPG3, VPG4, VPG5	In nominal state

Safe State

- Entered when:
  - recovered from a process condition breach during the preparation phase or during the injection itself
  - failure of one of the steps/actuators during the recovery or injection stopping procedures
  - failure of one of the steps/actuators during the preparing or injecting states
  - after a power loss
  - after a restart of the PLC
- Can only be exited with command from a TE-VSC expert
- All valves forced closed (except VVR4 when the injection could not be stopped) and gauges forced on
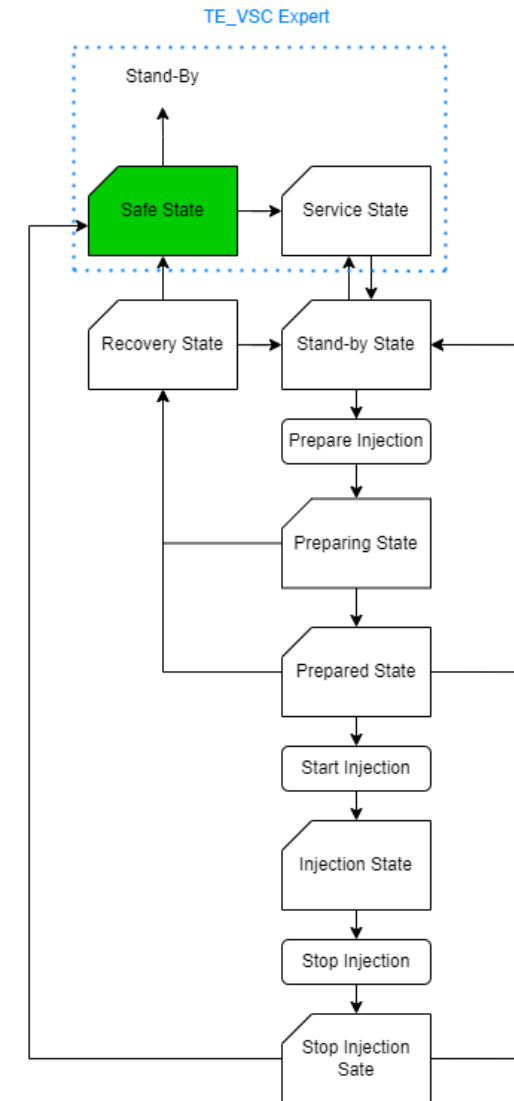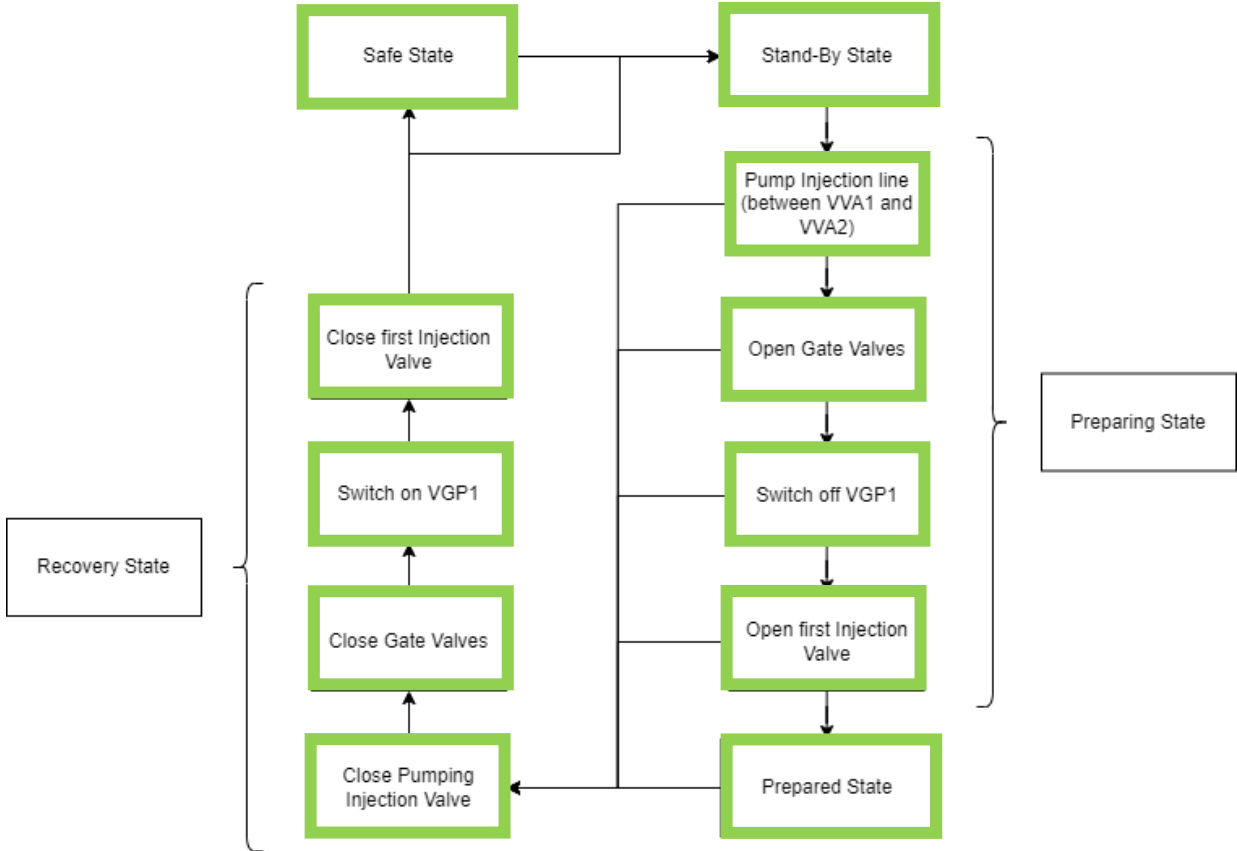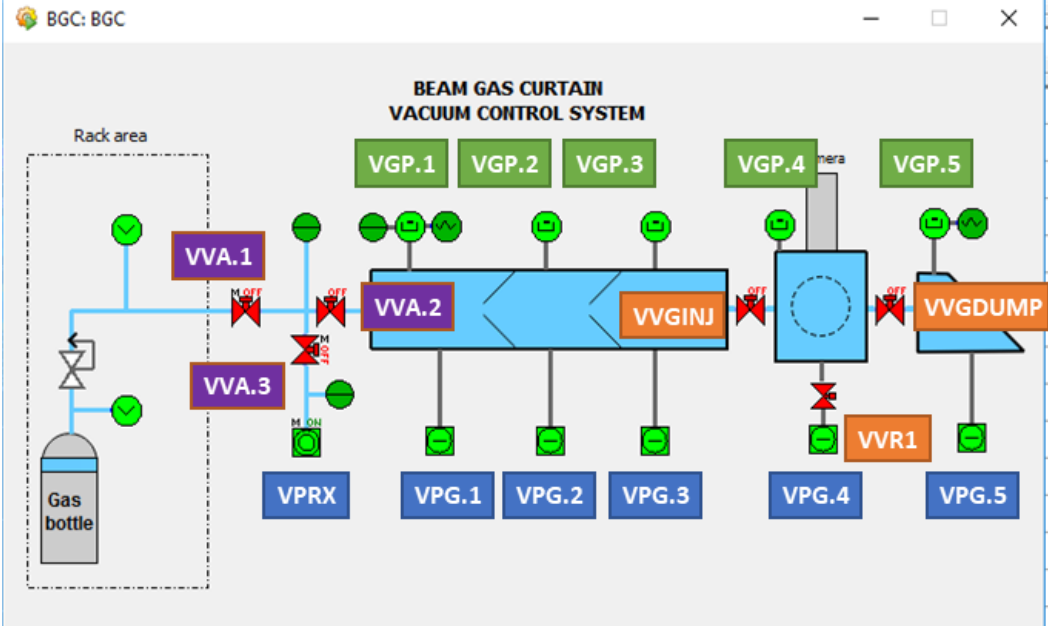
Stand-By State

- State in which the instrument remains when not currently in operation

- The instrument must be in this state and the START Process conditions must all be satisfied before the instrument can move to the Preparing state

- All valves are forced closed and gauges forced on

- Entered when:

  - The process completes with no issues

  - Timeout in prepared or injecting state

  - Force Recovery command sent

Service State

- Can only be entered/exited by TE-VSC experts

- The equipment is still forced to auto mode, but no auto commands are sent by the process

- To be used for manual operations undertaken by experts which are not part of the automatic process

Preparing and Recovery States

Prepared State

- There is a 10-minute timeout on the prepared state

- Injection can be started with Start Injection command

- Ready for Injection Status must be achieved to move to the Injecting State
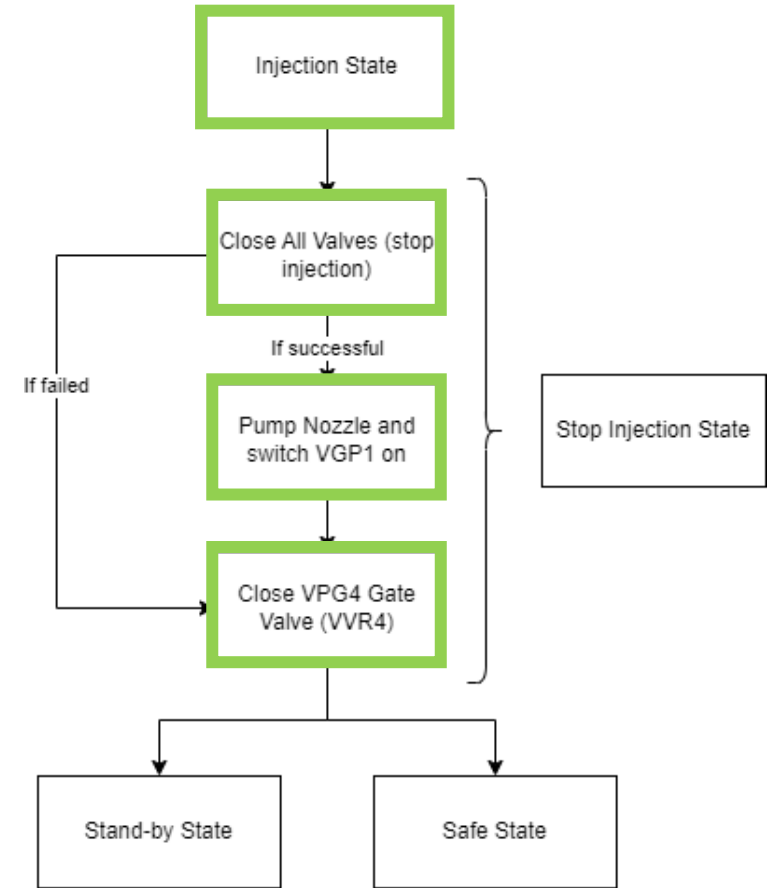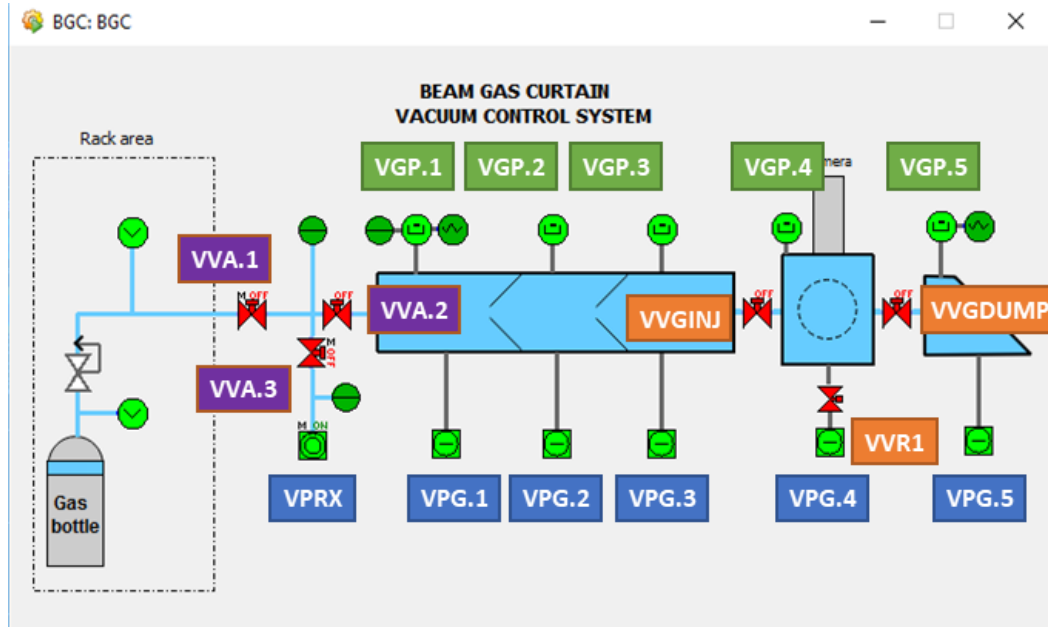
Device	Ready for Injection Conditions
VVGINJ, VVGDUMP, VVA1, VVR4	open
VVA2	closed
VGP1	off

Injecting State

- There is an 8-hour timeout on injection

- The injection is stopped with the "Stop Injection" command

- INJECTION process conditions are active
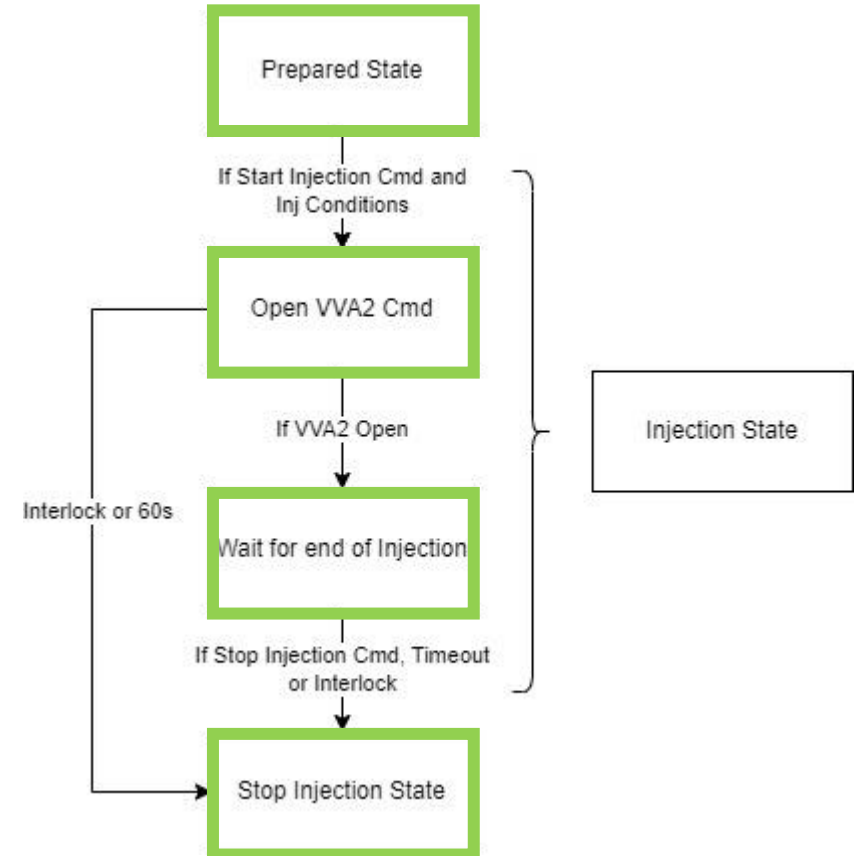
Stopping Injection State

Manual commands

- Components always kept in auto mode by default

- Manual Enable command only accessible to expert users:

    - Will allow components to be set to manual mode and not be controlled by the process

    - Must be used with care and only available to experts

    - Once disabled will set all equipment back to auto mode