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LAWRENCE LIVERMORE NATIONAL LABORATORY

B827 Chemical Synthhesis Project - Industrial Control System Integration - Statement of Work & Specification with Attachments 1-14

F. E. Wade

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Disclaimer

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B827 Chemical Synthesis Pilot Project

Control System Integration - Statement of Work & Specification

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Statement of Work and Specification

April 21, 2017

Revision A

Lawrence Livermore National Laboratory

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Prepared/reviewed by:

Fred Wade ______________

Project E/I/C Systems Engineer Signature Date

Approved by:

William Collins ______________

Project Manager Signature Date

Revision History			
Revision A	12 April 2017	Initial Draft	All

1 Introduction

The Chemical Synthesis Pilot Process at the Lawrence Livermore National Laboratory (LLNL) Site 300 827 Complex will be used to synthesize small quantities of material to support research and development.

The project will modernize and increase current capabilities for chemical synthesis at LLNL. The primary objective of this project is the conversion of a non-automated hands-on process to a remote-operation process, while providing enhanced batch process step control, stored recipe-specific parameter sets, process variable visibility, monitoring, alarm and warning handling, and comprehensive batch record data logging.

This *Statement of Work and Specification* provides the industrial-grade process control requirements for the chemical synthesis batching control system, hereafter referred to as the "Control System" to be delivered by the System Integrator.

2 Current State of Design

A significant portion of the control system design has already been performed by Lawrence Livermore National Security, LLC. (LLNS). These design elements will be provided to the Control System Integrator (CSI) Subcontractor whose scope of work is to complete the design and deliver the integrated hardware and software configurations, sequences, control and interlock logic, operator interfaces, utility and other support equipment controls, and any ancillary components and functions required for a fully-functional process control system based upon the ISA S88 framework.

LLNS will provide the CSI Subcontractor with the proposed control system hardware and network architecture (with specific make and model numbers), P&IDs, hardware data points list, batch recipe examples, raw material lists, schedule of required safety interlocks, and typical batch making sequences and checklists as source material. These are listed in Section 7.1 Design Documentation.

3 System Description

This following is a high-level overview of what LLNS had, and the background drivers and a description of what LLNS desires.

The Control System will be installed in two existing Buildings of the 827 Complex:

- Chemical Synthesis Cell in Process Building 827D
- B827 Complex Control Room, Building 827A

Future projects will add additional process cells within the 827 Complex, but will use a substantial portion of the infrastructure, and be monitored from, the 827 Complex Control Room.

3.1 Prior Process Control

The prior chemical synthesis process, de-commissioned and removed several years ago, was a fully hands-on system, requiring operators be present in Process Building 827D to execute *all* process tasks manually.

At that time, a paper-based system, known as the *Peer Review* document, was used as the process batch specification, or recipe, capturing the following details:

- Mass-fraction raw material quantities
- Task step sequences and duration times
- Recipe-specific, as well as the general-use, process parameter set-points and warning and alarm points …
    - Temperatures, flow rates, pressures, etc.
- Batch processing operating logic, all manually-executed
- Response to off-normal situations, all manually-executed

Logging of batch data: Manually-entered lab notebook notes captured the process log data for the batch record. Process variable information was limited to local process gauges and nearby bench-top analytical equipment, with all data collected in the lab notebook entries for the day's batch.

Once under contract, the operation's staff, and appropriate process-related records of this manual system, will be available for review for development of the successor Control System to be delivered by the CSI Subcontractor based upon this *Statement of Work and Specification*.

3.2 Successor Process Control System – This Project's Objective

The key functional driver for the new control systems is to provide ability to execute the majority of the batch process steps remotely.

The CSI Subcontractor shall deliver the batch processing Control System that meets this requirement, summarized as follows:

- **Contact Operations** – Performed in Synthesis Process Building 827D, Rooms 104 and 105:

  Set-Up:
  The process system will be mechanically configured via set-up of portable tanks, hoses, and recipe-specific analytical instrumentation.

  Raw Material Loading:
  Recipe-specific batch quantities of raw-materials are portioned into batch-size quantities and loaded into the raw material supply vessels, one per raw material, by the operator.

  Industrial class, environmentally-hardened operator workstations, similar in functionality to those in the Control Room 827A, will be located in Process Synthesis Building 827D to facilitate this process via equipment configurations checklists, raw material prompts and verifications, and log entry for all step completions.

- **Remote Operations –** Performed in 827 Complex Control Room, Building 827A, Room 107A:

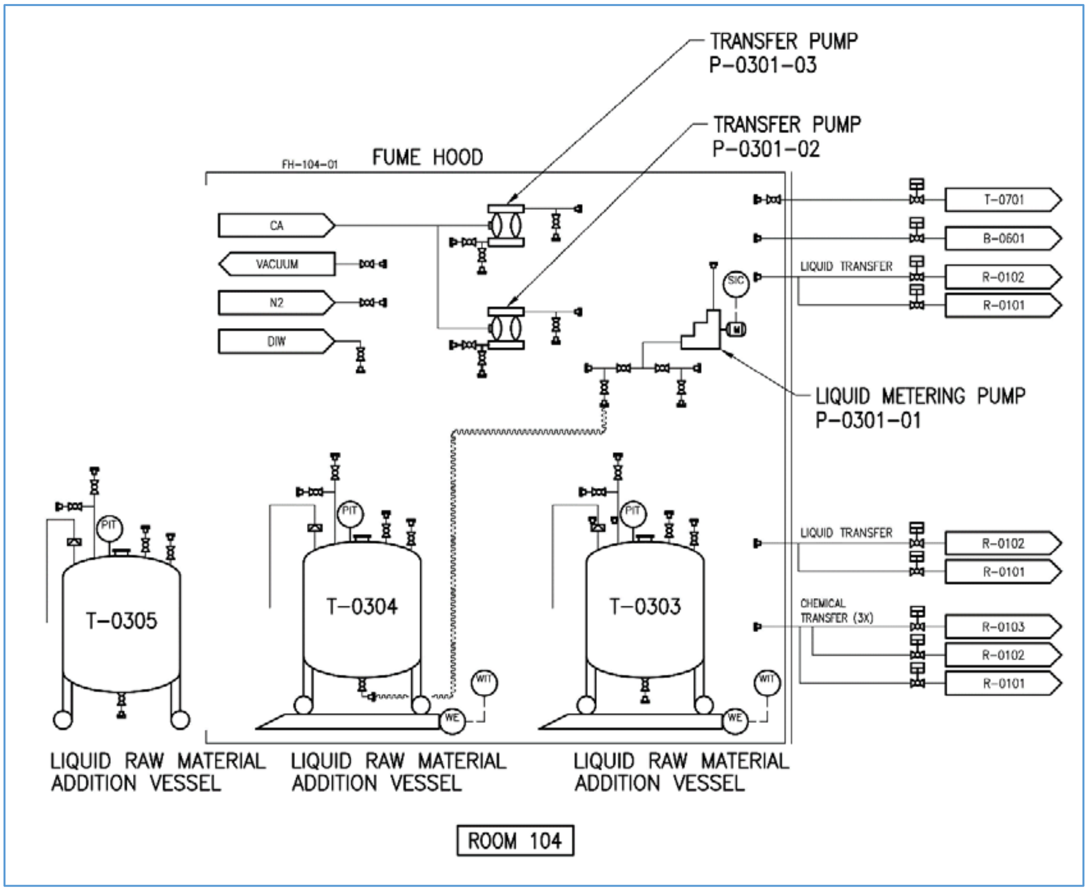
  Set-Up the Batch Record for the current run:
  Using the Control Room operations workstations, select from the stored sets of recipes in the Supervisory Control and Data Acquisition (SCADA) system, the specific recipe containing all the recipe-specific batch process parameters and logic for the current batch.

Enter the batch-specific production record data: Operator and Verifier log-ins (for 'Done By' / 'Checked By' logging), Operations Permit Number, Work Order Number, final finished product quantity requested and adjustments required due to raw material availability, etc.

Initiate and run the batch to completion by remote control and monitoring.

Simplified Process Flow Diagrams:

Figure 1 – Liquid Raw Material Feeding



Commentary on Figure 1 - Liquid Raw Material Feeding Unit:

Located in Synthesis Building 827D Room 104, the ~37 possible liquids are pre-measured by weight and loaded into three portable Liquid Raw Material Addition Vessels. Any liquid vessel may be used for any liquid raw material, but there will be a recipe-specific configuration for each batch.

There are two weigh scales that the raw material vessels are placed on for batch quantity weighing and as a loss-in-weight liquid feeder means to control flow to the synthesis reactors. An additional means of metering liquids is via the variable-stroke/variable-speed metering pump.

Transfer of liquids to the Synthesis reactor vessels use one of these means:

- Air-powered diaphragm pump
- Variable-stroke/variable-speed metering pump
- Nitrogen gas pressurization of the Liquid Raw Material Vessel

- Vacuum suction of liquid from the Liquid Raw Material Vessel to Synthesis Reactor

Batch recipe-specific configurations of hose connections from the Liquid Raw Material Addition Vessels, and the associated weigh scale, to the correct wall mounted piping port nozzle, and related Synthesis Reactor material feed inlet valve, shall be managed by the control system.

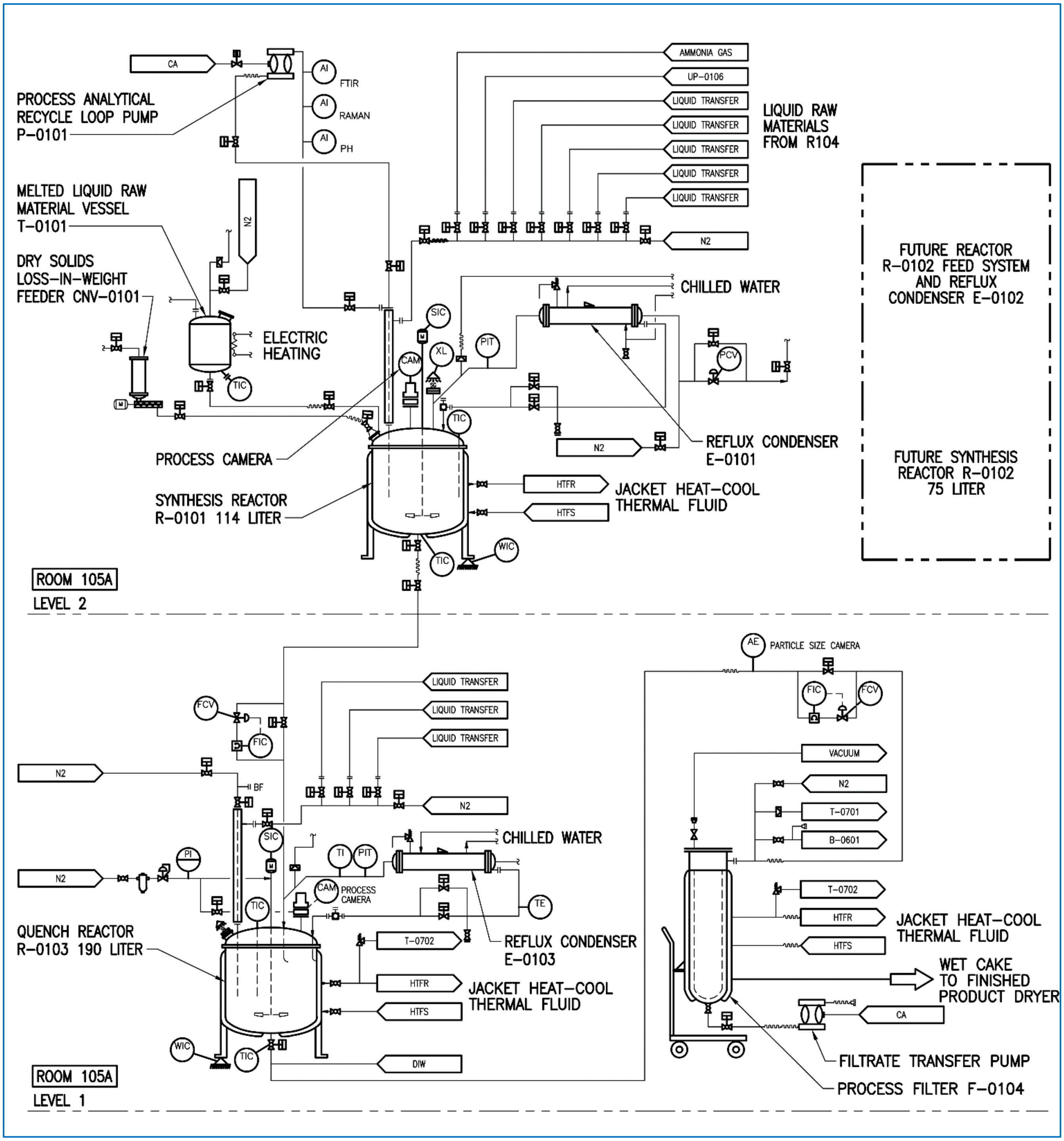


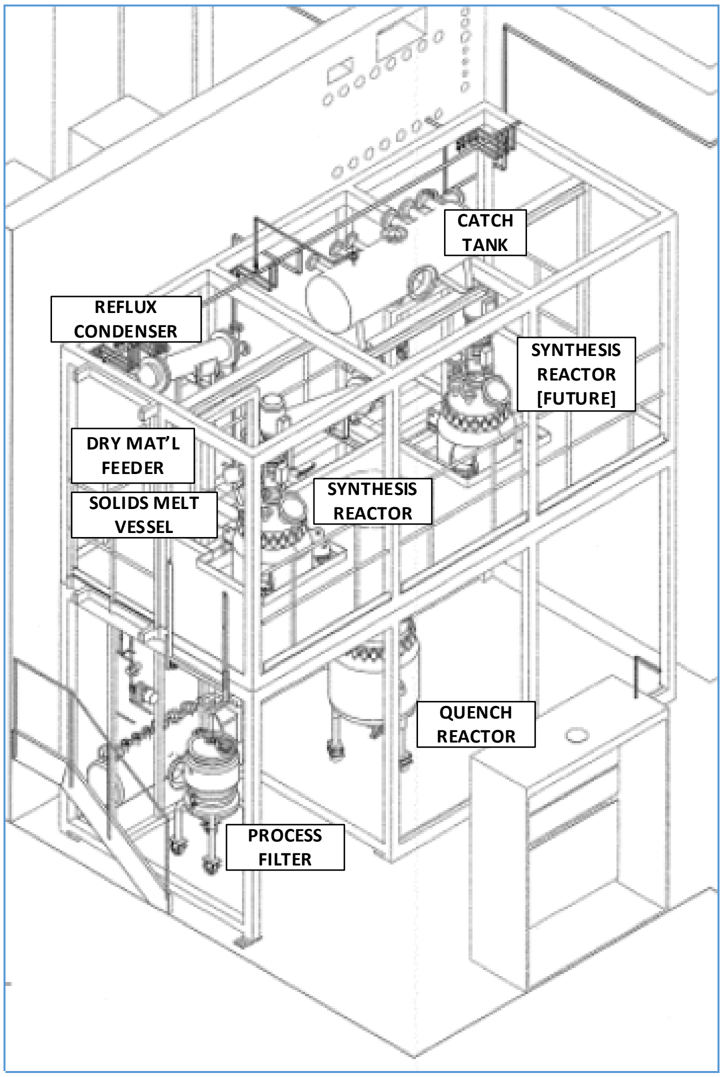
Figure 2 – Batch Making, Quenching, and Filtering Cell

Commentary on Figure 2 - Batch Making, Quenching, and Filtering Cell:

Located in Synthesis Building 827D Room 105A the synthesis process is comprised of a two-level process module. One Synthesis Reactor is on the upper level, with room for one future synthesis reactor.

Various liquid, solid, and gaseous raw materials enter the Synthesis Reactor where the chemical reactions occur. Batch-specific quantities of the ~12 possible solids are pre-weighed and loaded into the Dry Solids Feeder. Only one solid may be fed by this means per batch. One solid requires melting before being drained into the Synthesis Reactor; it is put into the Melted Liquid Raw Material Vessel and heated. The remaining liquids enter the Synthesis Reactor by transfer piping from the Liquid Raw Material Feeding system in Room 104. One gas raw material feed enters the Synthesis Reactor via a sparge line with total mass measured by a flow meter.

Figure 3 – General Arrangement of Batch Making, Quenching, and Filtering Cell, B827D Room 105A



One new, and one future, Synthesis Reactor are located on the upper level of the synthesis process unit.

Liquid raw materials are pumped, pushed by nitrogen gas, or vacuumed into the Synthesis Reactors from Room 104.

Solids enter via a small loss-in-weight dry material feeder located above the reactor.

One solid is heated to a liquid state, and then drains by gravity or nitrogen gas pressure to the synthesis reactor.

Volatiles are condensed in a Reflux Condenser above each synthesis reactor.

Once the synthesis reactions are complete, the batch drains by gravity or nitrogen pressure to the Quench Reactor on the lower center (main floor) level.

When the quench process is complete, the batch is vacuum and/or nitrogen gas pressure-transferred to and through the Process Filter to the left of the Quench Reactor.

Filtrate is pumped by an air-diagram pump to a storage carboy; the wet cake final product is removed from the process filter and sent to the drying cell.

The tank on the very top of the structure is the catch tank for any rupture disk flows.

Not shown – Utilities – See Attachment 1, Process Flow Diagrams (PFDs) & Attachment 2, Piping & Instrumentation Diagrams (P&IDs).

3.2.1 Process Flow Summary:

- Two chemical synthesis reactors with agitators:
  Note: Only one synthesis reactor will be used for any one batch.
  - 1 @ 114 Liters / 30 gallons
  - 1 @ 76 Liters / 20 gallons – FUTURE
- Raw materials feeding systems:
  Note: All liquid and solid raw materials will be pre-weighed to the batch-specific quantities required, then manually loaded into raw material supply vessels for by the operator.
  - Liquids – Quantity ~37 possible – total quantity and feed rate via loss-in-weight weigh scales
  - Liquid – Quantity 1 – melted solid, pre-weighed and loaded into melt supply vessel
  - Solids – Quantity 12 possible – total quantity and feed rate via loss-in-weight screw conveyor feeder
  - Raw material gas – Quantity 1 – this will be measured by flowmeter and integrated to a total during the batch processing
- Quench Reactor with agitator
  - 1 @ 190 Liters / 50 gallons
- Reflux Vapor Condensers
  - 3 total, 1 is future – for the future Synthesis Reactor
- Transfer pumps and dry material screw conveyors to move raw materials, intermediates, and finished product.
  For liquids transfers, other means may be used depending upon operational requirements:
  - Vacuum transfer between vessels,
    i.e., sucking liquid into a vessel from another source vessel
  - Dry nitrogen pressurization transfer,
    i.e., pressurization of the source vessel to push liquid to the receiving vessel
- Various process utilities and ancillary support system elements:
  - Thermal heat transfer fluid heating and cooling systems (Temperature Control Modules – TCMs) – 8 total, 3 are future
  - Central Process Chiller system
  - Central Process Vacuum system
  - Motor controllers – fixed speed starters and variable frequency drive controllers
  - Video cameras monitoring process reactor contents – 3 total, 1 is future
    Video synthesis process room cameras (remote operations monitoring) – 3 total

    - Synthesis reactor continuous liquid sample flow loop with process analytical transmitters (PATs) – 2 loops total, 1 future, each to be configured to support:
        - FTIR spectrometer
        - RAMAN spectrometer
        - pH monitoring

3.2.2 Process Batch Control 'By-the-Numbers' — Summary:

Note: these numbers are approximate, final counts shall be determined during *Control System Functional Specification* preparation by the Control System Integrator (CSI) Subcontractor. See Section 4.2.1 – Phase 1: Requirements Gathering and Detailing, Preparation, and Production of the *Control System Functional Specification* Document.

- ~30 unique recipes
    - Five of the thirty recipes will be initially used by LLNS, and shall be configured by the CSI Subcontractor
    - The initial production product will be the 'first-article' recipe used for system configuration, and LLNS review
    - The balance of the recipes will be done internally by LLNS
- The recipes draw from a raw material suite, supporting all current recipes, of:
    - 37 liquids, 12 solids, 1 gas
- Embedded in each recipe, per the ISA S88 framework, will be stored batch-specific operating parameter sets:
    - Mass-fraction formula
    - Step-wise procedure checklist (visibly-represented to the Operators as a *Process Sequence Dash Board*), with hold-points requiring Operator and Synthesis Chemist 'Done By – Checked By' confirmation of state

      Note: The 'Done By – Checked By' confirmation, for this project, does **not** require the rigor of the United States Food and Drug Administration (FDA) Title 21 CFR Part 11 life sciences industry requirements.
    - Process set points & batch control process variable limits
- Initial build (this project) will encompass ~400 I/O points;
  Full build-out system will have ~635 Inputs/Outputs
- ~25 closed-loop controls – primarily non-cascade simple temperature and flow control
- ~140 automatic valves
- ~12 Operator process mimic graphics, plus associated set-up, configuration, video control & monitoring, status, trending and logging, and alarm presentation and handling screens
- All batch parameters and process variables are recorded and logged in the historian, including process reactor contents video and analytical particle-size video, and process analytical transmitter value data

- All Operator actions recorded with time-stamped in batch record log
- Batch record log linked to Batch Number, Work Order Number, Peer Review Number, S300 Work Permit Number, …
- Designed for flexibility & extensibility; based upon ISA S88 Batch Standard framework

3.2.3 SCADA and Video Human-Machine Interface Workstations

Located in the 827 Complex Control Room in Building 827A, these will be the operator's batch set-up and view into the remote operation. Alternately, these tasks may also be performed in the Process Synthesis Building 827D using the industrially-hardened operator workstations.

Prior to starting the batch, the operator will perform the following set-up functions using a stored recipe-specific checklist:

- Recipe selection
- Finished product quantity-to-be-made set point
- Raw material pick-list viewing, and raw materials used Lot Number entry
- Stored recipe-specific process parameter review and adjustment (those not stored as recipe-specific quantities)
- Mechanical configuration of various portable process units to batch-making 'use stations' and piping connections – configuration stored in the recipe, executed and verified by the operator
- Verification of manual loading of measured raw materials, both liquid and solid, into the batch hoppers
- Operator acknowledgement of preceding required tasks and remote operations readiness, with 'Done By' and 'Checked-By' dual-verification

Located in the Process Synthesis Building 827D, the full-function industrial SCADA workstations will support raw material loading and configuration check list entries.

After the B827D batch preparations are completed and checklists are completed at any of the SCADA workstations, the remote operations phase may begin.

Once the remote control-phase of the batch process has begun, the 827 Complex Control Room SCADA system in Building B827A will allow the operator to:

- Initiate the start of Remote Operations
- Monitoring the batch progress, process variable and utility parameter trends
- See and respond to off-normal events, alarms, warnings, etc.
- Release process Operator verification manual entry check-point permissives needed to proceed to the next process step
  This will be done via the *Process Sequence Dash Board*, with 'Done By' and 'Checked-By' dual-verification process, applied to appropriate steps identified during the stakeholder interviews
- View video from the process room and from inside selected process vessels

- View and control room pan-tilt-zoom cameras - directly from the SCADA system
- Finalize the batch process and trigger data storage of the associated batch record data

3.3 Control System Solution Set — Design Documentation Provided by LLNS

The control system architecture and associated hardware and software solution sets have been pre-selected and specified by LLNS.

The architecture and all related control system design information that is being provided by LLNS is listed in Section 7.1 Drawings, Specifications and Procedures.

Salient elements found within Design Documentation:

- Hardware and software solution sets are portrayed in Attachment 6, *Control System Architecture* diagram, and the associated *Commentary - Control System Architecture.*
- The control room hardware and shrink-wrapped (i.e., commercial off-the-shelf, or COTS) software will be procured by LLNS and provided to the CSI Subcontractor as LLNS Government Furnished Equipment (GFE). See Attachment 7, *Schedule of LLNS Government Furnished Equipment*.
- The field I/O cabinets, PLC, HMIs, and field control devices will be procured and fabricated by LLNS and provided to the CSI Subcontractor as LLNS Government Furnished Equipment (GFE). See Attachment 7, *Schedule of LLNS Government Furnished Equipment*.

4 Statement of Work – Control System Integrator Subcontractor

This *Statement of Work (SOW) and Specification* defines the requirements to perform design, configuration, and complete integration of the Control System. This scope execution will deliver a fully-functional, Factories (Control System Integrator and Mechanical System Integrator) and Site Acceptance Tested, and operationally-qualified (commissioned) control system for the chemical synthesis batch process.

4.1 SCOPE OF WORK – GENERAL REQUIREMENTS:

A detailed schedule of separately-procured long lead equipment that will be provided by LLNS is provided in Attachment 7, *Schedule of LLNS Government Furnished Equipment*. The CSI Subcontractor shall determine the need, then furnish and provide all additional material procurements, both hardware and software, needed to provide a fully-functional batch process control system.

The CSI Subcontractor shall generate and deliver complete design documentation necessary to define the functional requirements in the form of a *Control System Functional Specification* that completely and unambiguously defines the hardware, software configurations, sequences, control and interlock logic, operator interfaces, utility and other support equipment controls, and any ancillary components and functions required to provide a fully-functional batch processing control system.

Following approval of the *Control System Functional Specification* by LLNS, the CSI Subcontractor shall then deliver the integrated, configured and programmed control system software and hardware for testing and acceptance based upon the approved *Control System Functional Specification*. The CSI

Subcontractor shall perform the design and configuration integration services required by the *Control System Functional Specification*, and resolve any design conflicts necessary to deliver the hardware, software configurations, sequences, control and interlock logic, operator interfaces, utility and other support equipment monitoring and control, and any ancillary components and functions required to provide a fully-functional batch processing control system.

The following scope-of-work elements shall apply to the entire project, except as noted:

4.1.1 Provide Control System Integration Project Management and LLNS Status Reporting

A. Plan all activities necessary to satisfy this SOW
B. Prepare a *Project Execution Plan* in accordance with Section 8
C. Prepare and maintain a fabrication and system integration project schedule in accordance with Section 8
D. Lead technical interchange meetings with LLNS required to develop the *Control System Functional Specification* in Accordance Section 4.2.1

4.1.2 Manage and Update Control System Source Data

A. Manage and contemporaneously update provided source material to make be consistent with, or becomes embedded within the project's *Control System Functional Specification*, and *Control System Tag Dataset*, and all related project documentation, as the details develop. The 'As-Built' versions shall become the *Control System Project Documentation Set*, a final deliverable from the CSI.

4.1.3 Provide Control System Development Hardware

A. For the duration of the system development at the CSI Subcontractors' site, and at the Mechanical System Integrators FAT, the CSI Subcontractor shall provide the virtual machine-based development environment hardware.

   Specifically:
   1) VMware®-based virtual machine servers
   2) Virtual Device Interface (VDI) graphics environment

   LLNS will not be supplying these elements for the CSI Subcontractor's development scope.

B. The CSI Subcontractor shall be responsible for providing a development system capable of developing, and fully-testing, all control system functions defined in the *Control System Functional Specification.*

C. LLNS will provide VMware® .OVA operating system template files for CSI Subcontractor's use, as follows:
   1) Windows™ 2012R2 for the virtual machine servers
   2) Windows™ 10 for the virtual desktop interfaces

D. The CSI Subcontractor shall coordinate the local system software and administrative configuration of their control system development environment with the WCI IT team via the LLNS Technical Representative.

   This would include the following details:

1) Accounts used for such examples as unattended service logins, database access, development testing, local security configuration, local administrative management, and the like.
2) If their control system development environment used MS Active Directory™ (MS AD) as part of a security construct, the LLNS WCI IT team would need this relevant configuration information as well.

The goal of this coordination is to develop a configuration that would require the minimum amount of effort and processes to migrate this control infrastructure into the LLNS environment, at the time this control system is put into production at the LLNL site location. This activity will occur during the LLNL Site 300 system commissioning.

4.1.4 Provide Wonderware® System Development Software

A. For the duration of the system development at the CSI Subcontractors' site, and at the Mechanical System Integrators FAT, the CSI Subcontractor shall provide the entire suite of Wonderware® software required for system development using a *Wonderware® Advanced Development Studio Consignment License* set, also known as a Wonderware® System Integrator License.

   The Industrial Video & Control (IVC) / Wonderware® *Longwatch*™ development software will be provided to the CSI Subcontractor by Wonderware® / IVC™ directly.

   LLNS will not be supplying these elements for the CSI Subcontractor's development scope.

B. LLNS' corresponding end-user software licenses will be pre-installed on the LLNS' virtual machine server hardware, by LLNS, before LLNL Site 300 fully-integrated system commissioning.

4.2 SCOPE OF WORK – WORK SEQUENCE & PRODUCTS:

This project will result in a functionally tested (Control System Integrator, Mechanical System Integrator, and Site Acceptance Tests), operationally-qualified, i.e., commissioned, control system for the chemical synthesis batch process plant. The deliverables of this system integration will be delivered in four nearly-sequential phases (Phases 3A and 3B may be interchanged, per direction by LLNS):

4.2.1 Phase 1: Requirements Gathering and Detailing, Preparation, and Production of the *Control System Functional Specification* Document

Background:
The success of the control system execution for this project will largely depend upon quality of the *Control System Functional Specification Document* that captures the chemical process and operational functional requirements for this project.

LLNS has determined that the most effective methodology for the project engineering resources and end-user stakeholders to collectively understand and capture the requirements for this document is to use the systems analysis and design conceptual framework contained in ANSI/ISA-S88.00.01-2010 *Batch Control Part 1: Models and Terminology*.

It is a front-loaded approach, with significant effort applied to getting the *Control System Functional Specification Document* detailed by the CSI Subcontractor, and vetted by the end-user stakeholders. If done properly, this will pay dividends later in the execution, testing, and, commissioning phases as there should be few surprises and changes.

Requirements:

A. Interview Workshops:
The CSI Subcontractor shall plan, schedule, lead, and perform on-LLNL site **CSI-led** detailed interviews, in an interactive workshop format, and reviews of progress of the *Control System Functional Specification*, with LLNS chemical synthesis subject-matter experts (SMEs), operation's team members, and project engineers.

These workshops will provide and capture the additional detail requirements, not previously provided by LLNS, for logic, sequences, checklists, operator interfaces, and reporting. Multiple iterations to validate sufficient detail and completeness are expected.

At a *minimum*, two two-day interview workshops on-site at LLNL.

B. Conceptual Framework:
This document shall be produced by the CSI Subcontractor using a system analysis and documentation methodology based upon the tenets and conceptual framework of ANSI/ISA-S88.01-1995: Batch Control Systems.

C. System Analysis & Modeling:
The CSI Subcontractor shall analyze the collected data and model the system functions and requirements per the ISA S88 framework, and develop the following to be incorporated into the *Control System Functional Specification*:

- Physical Model: Site, Area, and Unit, and Cell Levels
- Control and Equipment Module Models
- Recipe Types: General, Site, Master, and Control
- Procedures: Master and Control
- Equipment Control

The documentation of these analyses in the *Control System Functional Specification* shall be used as the centerpiece of the end-user stakeholder review, and approval, of system functionality; particularly process parameters related to raw materials, and control parameters and logic used in a specific recipe. For example, the control system's response to a specific raw material feed rate into an exothermic reaction.

D. Graphical User Interface Definition:
1) Based upon the system functions identified in the interviews /workshops, the CSI Subcontractor shall produce a proposed set of GUI screens in the *Control System Functional*

Specification for LLNS stakeholder review.

a) GUI screen development shall follow the guidelines presented in *LLNS Common Control System HMI Design Guide*. See Attachment 13.

b) These GUI screens should, as much as practicable, use the standard suite of batch system control screens in the Wonderware® System Platform and InBatch™ libraries, configured for this project's specific needs.

c) Wonderware® System Platform and InBatch™ 'intelligent' pre-built graphics content should be utilized as much as practicable. Custom, or script-based configurations should be avoided.

d) The InTouch® Wonderware® System Platform and InBatch™ configurations shall incorporate and leverage the built-in situational awareness (SA) concepts as provided in their *Situational Awareness Library with Symbol Wizards*, and related development tools.

   The goal is to lower the Operator's conceptual and data load while facilitating the Operator's awareness of what is happening in the process, and enhance the visibility of *context-specific relevant information*, events, and recommended actions, both immediately, and in the near future.

   For example: Process variable presentations should show the normal, expected range of values, along with the current value, in a simple and intuitive graphic presentation.

e) System Platform-based graphics should be optimized to incorporate built-in quality processing and diagnostic indicators to enable rapid determination of the root causes of communications problems.

2) It is anticipated that the following GUI functions and related screen types would be developed:
Note: See Attachments 11A & 11B – *Mock Batch Control Script and GUI Screen Graphic Slides* for more-specific descriptions and examples.

- Process mimic screens
- Raw materials type entry
- Recipe process parameters entry
- Linking of raw materials to recipe process parameters entry
  For example: maximum feed rates to manage exothermic reactions within acceptable temperature range
- Alarm and off-normal handling
- All-parameters data display and trending
- Batch execution history / data logging
- Video camera control, monitoring, and logging
  - Process Video
  - Room video

- Utility systems monitoring and/or control

3) Audio data and information presentation:
The CSI Subcontractor shall include use of audio output of process variables, warnings, alarms, and other pertinent process and control information. These shall be configurable, i.e., used or not, by the operators from the SCADA or audio output configuration screens, but shall be available for all process variables, alarms, and warnings, etc. An industry standard COTS software tool, WIN-911®, provided by LLNS, shall be used for this purpose. WIN-911® Professional links to Wonderware® System Platform using a built-in 'Direct Connect' feature and standard application configuration tools. Custom scripting to deliver this functionality shall not be used.

In the Control Room, this audio may be presented using the workstation zero-client's audio output capability, and the LCD monitor's built-in speakers.

4) Keyboard and Mouse Functions:
The CSI Subcontractor shall incorporate maximum usage of LCD touch screens for data entry, control manipulation (buttons and sliders), and related needs for operator interaction with the SCADA system.

The goal is to optimize the user interface to the process control system, while minimizing the number of keyboards and mouse pointers on the console desk.

E. Process Control Logic Definition

1) Design of Process Logic, Counting, Timing, and Loop Control:
The logic and loop control elements of this project shall be captured and analyzed during the interviews /workshops, and documented and presented in detail in the *Control System Functional Specification Document.*

2) Presentation Format:
The detail will be presented in the *Control System Functional Specification Document* shall be either the Sequential Function Charts or Structured Text format, whichever is most appropriate for the information presented.

The LLNS stakeholders will review the proposed control logic in these presentation formats.

3) PLC logic configuration development shall follow the guidelines presented in *LLNS Common Control System Coding Guide*. See Attachment 14.

F. The final product shall be a completely detailed specification, ready to program and configure the entire control system. The *Control System Functional Specification* will be the controlling document for system testing, performance validation, and LLNS acceptance.

G. During the process of *Control System Functional Specification* preparation, the CSI Subcontractor shall update the LLNS-provided source material.

This updating process shall make the documentation consistent with, or become a successor documentation element embedded within, the *Control System Functional Specification*. For example, the *Control System Tag Dataset,* Attachment 8, shall be revised and maintained current by the CSI Subcontractor during system development.

H. LLNS will provide the CSI Subcontractor with the proposed control system architecture (with specific make and model numbers), P&IDs, hardware data points list, batch recipe examples, raw material lists, schedule of required safety interlocks, and typical batch making sequences and checklists to be used by the CSI Subcontractor as source material for the *Control System Functional Specification*. These are listed in Section 7.1 Drawings, Specifications and Procedures.

   The CSI Subcontractor shall review this documentation and advise as soon as detected if there are any inconsistencies or gaps requiring clarification or modification.

I. **Hold Point**: Only after the *Control System Functional Specification* has been reviewed, and approved by LLNS, may configuration and programming in the next phase begins. Other CSI Subcontractor deliverable elements may be released by the Subcontract Technical Representative earlier.

4.2.2 Phase 2: Procurement, fabrication, configuration, and programming of the control system components

The hardware platform used on this project will be a Modicon® M580 ePAC PLC with X80 non-hazardous area, and Stahl hazardous-area distributed I/O. The SCADA operator interface software platform will be Wonderware® System Platform, Application Server, and InBatch®.

A. Procure, fabricate, and assemble and completely wire all control system I/O (Input/Output) component cabinets and enclosures and related I/O components **not provided by LLNS**. See *Attachment 7- Schedule of LLNS Government Furnished Equipment*, for sourcing detail.

B. Configuration of Graphical User Interface (GUI) Workstations and Human Machine Interfaces (HMIs), and all Supervisory Control and Data Acquisition (SCADA) functionality, per the requirements contained in the LLNS-approved *Control System Functional Specification.*

C. Configuration and programming of all Modicon® and Wonderware® COTS software per the requirements contained in the LLNS-approved *Control System Functional Specification.*

D. Configuration of all control system infrastructure-related items required to support the fully-functional control system shall be the responsibility of the CSI Subcontractor, **except** as indicated here:

   The software parameter configuration of the following listed items will be provided and loaded by LLNS:

   a. B827A Control Room virtual machine servers
   b. B827A Control Room and field located Zero-Clients supporting the CSI Subcontractor's SCADA configurations
   c. All network switches, both in the Control Room and field

d. All Uninterruptable Power Systems

NOTE: SCADA and data interface configurations for display and alarm handling and logging of these information technology items status, fault, and related diagnostic information contained in the LLNS-approved *Control System Functional Specification* shall be the responsibility of the CSI Subcontractor.

E. Develop and configure digital communication interfaces for pre-engineered system elements using data communications, also known as Distributed I/O, for control and monitoring per the LLNS' *Control System Architecture*, Attachment 6, and the requirements contained in the LLNS-approved *Control System Functional Specification*.

F. Provide engineering and project management oversight of the CSI Subcontractor's fabrication, configuration, programming, and testing tasks.

4.2.3 Phase 3A: Control System Integrator (CSI) Subcontractor-based control system Acceptance Test (CSI_FAT)

Factory assembly and testing shall be performed prior to proceeding to the next phase, as follows:

A. Infrastructure & Support Services CSI_FAT:
The System Integrator Subcontractor shall provide all necessary infrastructure and services, including engineering and technician support, for execution of the CSI Subcontractor's site-based Factory Acceptance Test (CSI_FAT).

B. Test Plan:
The CSI Subcontractor shall further develop the *Control System Functional Specification* into a specific *CSI Test Plan* which describes the all steps for loop-testing and device functional operation at the System Integrator's site.

C. Testing Scope:
Testing shall fully exercise all functions of all equipment and control elements (including end-to-end loop testing) consistent with the design documents. Full-function testing of performance relative to the requirements of the *Control System Functional Specification* shall be performed except where lack of final system elements requires simulated testing procedures.

D. Test Preparation & Set-Up:
The Subcontractor shall perform all preparations and set-up necessary to configure the system for testing. Physically assemble all the control system components, connect, install software and configurations, integrate, and functionally test, by real and/or simulated inputs and outputs (TBD), the entire process control system's features, functions, and performance.

E. Performance success, or re-work required, shall be based upon the requirements in the *Control System Functional Specification* document.
   - This will be a 'customer-witnessed' test process, with 3 or 4 LLNS personnel attending

F. Resolve all deficiencies compared to the *Control System Functional Specification* found during CSI_FAT testing.

G. Test Results Submittal:
Test results shall be submitted to LLNL for record.

H. Training to be Provided:
After the successful completion of testing, the Subcontractor shall provide support and facilities to host up to four LLNS personnel or representatives for three days of training.

I. Disassembly and Preparation for Shipment:
Upon completion of testing and training, the Control System Integrator shall disassemble the test assembly and prepare and pack the control system modules, components and loose equipment for shipment.

J. Shipping Plan:
The Subcontractor shall prepare and submit a detailed Shipping Plan for delivering the Control System components to Hart Design Group in Cumberland, RI for the Mechanical System Integrator Factory Acceptance Test (FAT).

Logistics planning shall be provided by CSI Subcontractor. The CSI Subcontractor shall coordinate all shipments and delivery schedules with LLNS' Traffic Department.

4.2.4 Phase 3B: Mechanical System Integrator-based loop check and critical safety interlock Factory Acceptance Testing (FAT)

The Chemical Synthesis Pilot Process system consists of modular equipment structures, processing equipment, piping, controls, instrumentation and related support equipment. The Mechanical System Integrator Factory Acceptance Test (FAT) will be performed at Hart Design Group's fabrication facility in Cumberland, Rhode Island.

The FAT will be based upon a *subset* of the equipment and controls to be used in the final B827D installation. This subset was selected to provide assurance that all synthesis-significant mechanical process hardware, as well as the safety-critical control points identified in a *Process Hazard Analysis* (PHA) are tested for correct wiring connection, scaling, interlock logic functionality, etc. Inert surrogate raw materials, e.g., water, sugar, corn meal, will be used to validate instrumentation signals and related safety logic.

Accordingly, a subset of the full control system, indicated on the Attachment 6A, LLNS *Control System Architecture – Mechanical System Integrator FAT Subset*, will be shipped to Hart Design Group in Cumberland, RI to support the Mechanical System Integrator Factory Acceptance Test FAT.

These control system hardware and software elements required for the FAT will be provided by a combination of the Hart Design Group-provided input-output enclosures, specifically, those that are mounted on the modular two-level process skids - the Stahl-brand hazardous-area Distributed I/O enclosures, plus the set of separate controls enclosures, with associated components, provided by the LLNS and the Control Systems Integrator (CSI) Subcontractor.

Some process equipment and sub-system items will not be tested at Hart's facility for logistical, project schedule, and test cost reasons. These include the temperature control modules, vacuum system, and liquid-solids filtration. Site acceptance testing (SAT), with a fully integrated mechanical and control system will be done later at LLNL Site 300 Process Synthesis Building 827D.

Following transport and verification of the subset of the full control system, temporary or permanent installation of the completed control system at the Hart Design Group's facility (permanent as possible; temporary as required), the CSI Subcontractor shall perform and provide the following:

A. **Infrastructure & Support Services for Mechanical System Integrator FAT**:
The Control System Integrator Subcontractor shall provide control system engineering and

technician services to support the control systems testing as part of the execution of the Mechanical System Integrator site-based Factory Acceptance Test at Hart Design Group.
Note:

- Hart Design Group will provide the test facilities and all related utilities and supporting systems required for this testing
- Hart Design Group will supply mechanical engineering and mechanical technician support for this testing
- The testing will consist of a thorough-as-possible loop check, followed by process system testing including transferring inert materials between vessels and simulating safety interlock logic verification

B. **Test Plan and Completion Criteria**:
Set up, and support running system component testing using connection to PLC and sufficient operator interfaces to allow loop testing and operational testing of each device using the LLNL/HDG-supplied FAT Test Plan as the test criteria.

The FAT Test Plan will be a subset of Control System Functional Specification, excerpted to be consistent with the process hardware configuration of the Mechanical System Integrator FAT.

Deficiencies in functional performance will be addressed as found and the testing resumed until the FAT is deemed complete by the LLNS Technical Representative.

C. **Loop Check:**

1) Validate that FAT-scope instrumentation sensors and final control elements are correctly wired to Programmable Logic Controller input/output points, are receiving correct voltage level, and ready for operational testing
2) Perform, and document, point-by-point signal verification of each point.
Record test results, success, or rework required, in a LLNL/HDG-supplied FAT Test Plan document.
    - Discrete I/O verification – physically operate sensor using real or simulated process fluids or states to produce signal at PLC I/O hardware. Verify signal is operating in correct state-mode (ON or OFF), and PLC I/O address is correct for the sensor being tested
    - Analog I/O verification – physically operate sensor using real or simulated process fluids to produce signal at PLC I/O hardware for analog inputs, and appropriate response at field-end for analog outputs. Verify signal is operating in correct up-scale or down-scale mode, that engineering unit scaling is correct, and PLC I/O address is correct for the sensor or control element being tested

D. **Critical Safety Interlock Testing:**

1) Validate critical safety interlocks operate as defined by the LLNL *Process Hazard Analysis.* These will include, but are not limited to, those connected to the Reactor High-Temperature Interlock Panel.
    - Discrete I/O verification – physically operate sensor using real or simulated process fluids or states to produce signal at PLC I/O hardware. Verify PLC logic response is correct.
    - Analog I/O verification – physically operate sensor using real or simulated process fluids to produce signal at PLC I/O hardware for analog inputs, and appropriate

response at field-end for analog outputs. Verify PLC logic response is correct.

E. **Test Results Submittal**:
Test results records shall be submitted to LLNS.

F. **Disassembly and Preparation for Shipment**:
Upon completion of testing, the Control System Integrator Subcontractor shall direct and assist in the demobilization of the control system test assembly and prepare and pack the control system enclosures, modules, components, operator interfaces, cords, cables, and related loose equipment, and make-ready and pack for transport with the skids to LLNL for permanent B827D installation at Site 300 in Tracy, CA.

G. **Shipping Plan:**
The Subcontractor shall prepare and submit a detailed Shipping Plan for delivering the Control System components to LLNL Site 300 in Tracy, CA for the Site Acceptance Testing and commissioning.

Logistics planning shall be provided by CSI Subcontractor with assistance of Hart Design Group and LLNS' Traffic Department. The CSI Subcontractor shall coordinate all shipments and delivery schedules with LLNS' Traffic Department.

4.2.5 Phase 4: Site Acceptance Testing (SAT), Support B827D synthesis plant OQ - Operational Qualification and Training (aka, commissioning)

A prerequisite task in this phase will be CSI Subcontractor's verification of full and correct control system infrastructure configuration and installation in B827D that is to be completed by the LLNS mechanical installation subcontractor.

Following this verification, the following shall be performed:
- Loading of all software, programming, and configurations into Wonderware® servers and Modicon® PLCs
- A complete Input/Output hardware loop check, to validate correct wiring of field devices to I/O cabinets
- Complete functional Site Acceptance Testing (SAT), using inert materials, to verify that all requirements in the *Control System Functional Specification Document* have been met. Resolve all deficiencies compared to the *Control System Functional Specification* found during testing.
- Test Results Submittal:
  Test result records shall be submitted to LLNS.

Based upon successful testing, using the *Control System Functional Specification* document as the test criteria, the Control system will be deemed IQ – Installation Qualification complete.

On-Site (LLNL Site 300) Support – the CSI Subcontractor shall provide:
- Two weeks of control system engineer-level support and training for system readiness verification and execution of the *Control System Functional Specification* SAT and LLNS-provided *Commissioning Test Plan*.

5 General Information

5.1 Definitions

Conformance	Verification that parts are manufactured according to the drawings, that assemblies are assembled according to the applicable assembly drawings and specifications.
LLNS Contract Analyst	The LLNS staff member authorized to negotiate, award, and process change orders to the subcontract. Refer to the Subcontract Article entitled “Coordination and Administration.”
Design Engineer	Engineer of Record for design of the System.
Subcontractor	Organization directly supplying product to LLNS. Corresponds to the term “supplier” in ISO 9001 “Sub”contractor follows from the relationship of LLNS as prime contractor to the US DoE for management and operations of LLNL.
Supplier	Any organization, supplying material or services to Subcontractor. Corresponds to “Subcontractor” in ISO 9001.
LLNL	Lawrence Livermore National Laboratory 7000 East Avenue, Livermore CA 94550 and affiliated facilities
LLNS	Lawrence Livermore National Security, LLC. Corresponds to “customer” in ISO 9001. LLNL is managed by Lawrence Livermore National Security, LLC (LLNS).
Contract Technical Representative(s)	Named individuals, or their designees, who have authority to discuss the technical interpretation of this SOW and Specification and referenced documents. The Subcontract Technical Representative for this Scope is Fred Wade, 925.422.0871, wade16@llnl.gov
Acceptance	Written response from LLNS that the submittal, documentation or other action is acceptable. Acceptance must be obtained before actions described by the submittal such as manufacturing, testing, cleaning, shipping or other operations may proceed.
Information	Submittals provided to LLNS for information only and do not require a written LLNS response indicating approval. However, the Subcontractor is responsible for meeting all contract requirements related to the submittal. If a submittal provided to LLNS for information indicates that contract requirements will not be met, LLNS may reject the submittal.

5.2 Acronyms & Definitions

Acceptance Tests:

- **FAT** **Mechanical System Integrators Factory Acceptance Test**
  (Performed at the Mechanical System Integrator’s site – Hart Design Group, Cumberland, RI)

- **CSI_FAT Control System Integrators Factory Acceptance Test**
  (Performed at the Control System Integrator's site)

- **SAT Site Acceptance Test**
  (Performed at LLNL Site 300 827 Complex Buildings 827A Control Room and 827D, Process Synthesis cell)

ARO After Receipt of Order
Commentary A systematic series of explanations or interpretations; and explanatory treatise
COTS Commercial Off-the-Shelf
DR Deviation Request
GFE LLNS Government Furnished Equipment
GUI Graphical User Interface, a generic term for the SCADA and HMI hardware and related software
HDG Hart Design Group, the process engineering consults for the project.
HMI Human-Machine Interface a generic term for the SCADA and HMI hardware and related software
I/O Input /Output, PLC hardware components and related field signals coming into the PLC
IQ Installation Qualification, also known as 'mechanical completion', meaning all elements are assembled, wired, and plumbed, ready to test.
IRD Interface Requirements Document
(Signal and data communications specifications for ancillary and supervisory systems)
ISA Acronym for *The Instrumentation, Systems, and Automation Society*, formerly known as the Instrument Society of America
ISA S88 ISA Standard No. ANSI/ISA-S88.01-1995: *Batch Control Systems, Part 1: Models and Terminology*. Often shortened to ISA S88 Batch Standard.
LLNL Lawrence Livermore National Laboratory
LLNS Lawrence Livermore National Security, LLC
Loop Test The testing of a correct end-to-end connectivity and PLC representation of field I/O and associated devices
NCR Non-Conformance Request
OQ Operationally Qualified, also called Commissioned. Successfully tested for meeting all specified functional requirements.
PLC Programmable Logic Controller
The PLC provides robust 'industrial-strength' solving of logic, counting, timing, and closed loop control functions.
Project Documentation Set
The suite of control system data and descriptions defining all elements of the design and configuration. This is the collection of all design element documentation produced, or modified from that provided by LLNS, which completely details the technical work of the Control System Integrator Subcontractor
RFI Request for Information
SCADA Supervisory Control & Data Acquisition
The human-machine interface to the PLC for all control, trending, alarms, recipe management, report generation, video monitoring & recording, etc.

CSI Control System Integrator

Site 300 Also written as S300, the name of the location of the project. Refers to LLNL Site 300 between Livermore and Tracy California

SA Situational Awareness

SME Subject Matter Expert

TCM Temperature Control Module

Virtual Desktop Interface (VDI)

An architecture that separates the desktop environment and associated application software from the physical client device that is used to access it. For this project, the control room and process area SCADA operator interfaces use the VDI architecture model. The local Zero-Clients provide the video, keyboard, mouse, and audio services. They connect to a Virtual Machine Server cluster located in the Control Room that provides the operating system support (Windows™ 10), applications, and data storage.

Virtual Machine

A virtual machine (VM) is an emulation of a computer system. Virtual machines are based on computer architectures and provide functionality of a physical computer. Virtual Machines support zero-clients.

Zero-Client A virtual machine server-based computing model in which the end user's computing device has no local storage, also known as ultrathin client. The 'end user's computing device' in context of this project are the control room and field SCADA workstations. The zero-client provides the keyboard and mouse (or equivalent functions using a touch screen), and video display connection points

6 Communication with LLNS

All communication from Subcontractor to LLNS shall be directed to either the Contract Analyst or the Technical Representative (others may be cc'd on electronic mail) in accordance with the Subcontract Article titled "Coordination and Administration" as appropriate. LLNS Contract Analyst and Technical Representative will redirect questions to the appropriate LLNS personnel as required. Any communication resulting in a change to work scope, delivery requirements, or pricing shall be provided exclusively by the LLNS Contract Analyst. In no case shall any communication with, or documents received from, any person other than the LLNS Contract Analyst be taken by Subcontractor as direction or modification of work scope, delivery requirements, or pricing.

6.1.1 **Deviation Request** (DR)

A deviation is any planned departure from Subcontractor requirements. The Subcontractor shall submit a DR for any planned deviation from any subcontract requirement. LLNS will provide a written disposition before any deviation may proceed.

6.1.2 **Non-Conformance Report** (NCR)

A non-conformance is any violation of the subcontract requirements that has already occurred. The Subcontractor shall submit a NCR for any non-conformance from any subcontract requirement. LLNS will review the NCR and provide a written disposition.

6.1.3 **Requests for Information** (RFI)

Clarification and interpretation of requirements that are not deviations or non-conformances may be necessary. The Subcontractor shall submit an RFI via the form attached stating the question or issue for LLNS review and written response.

6.1.4 Tracking Exchanges of Information

The Subcontractor shall sequentially number each deviation request, non-conformance report, and request for information submitted. The format for each form shall be:

- Deviation Request DR-n
- Non-conformance Report NCR-n
- Request for Information RFI-n

In all cases, "n" is the sequential iteration (e.g., RFI-010). The request/report number shall be unique and non-repeating. Requests/Reports that relate to earlier reports shall have their own unique identifier. The Subcontractor shall maintain logs of DRs, NCRs, and RFIs.

6.1.5 Forms

The Subcontractor will submit DR, NCR, and RFI forms in Microsoft Word format.

7 Referenced Documents

The following documents form a part of this SOW and Specification to the extent specified herein. For industry standards/specifications, unless otherwise indicated by a specific revision number or date suffix, the revision used shall be the one in effect on January 1, 2017. Additional drawings, standards, and specifications are called out by the documents listed in this SOW and Specification; hence, form part of this SOW and Specification to the extent specified with each such call-out. Any conflict between this document and a referenced document shall be brought to the attention of the LLNS Contractor Analyst in writing for resolution before Subcontractor takes any action.

7.1 Design Documentation & LLNS Government Furnished Equipment

The following documents comprise the requirements for the Control System Integration for the B827 Complex Chemical Synthesis Pilot Process. The Subcontractor is responsible for incorporating all aspects of the design requirements into the work product to be delivered under this subcontract.

Type/Drawing Number	Association to this SOW Document	Document / Drawing Description
PFD's	Attachment 1	Source: Hart Design Group
PFD-100	—	Process Flow Diagram; Pilot Plant Equipment
PFD-101	—	Process Flow Diagram; Kilo Scale Equipment and Utilities
P&ID's	Attachment 2	Source: Hart Design Group
PID-001	—	P&ID; Lead Sheet 1
PID-002	—	P&ID; Lead Sheet 2
PID-0101	—	P&ID; R-0101; 30 Gallon Reactor System
PID-0103	—	P&ID; R-0103; 50 Gallon Glass-Lined Quench Vessel
PID-0106	—	P&ID; Up-0106; Room 105A Utility Panel
PID-0301	—	P&ID; Chemical Distribution; Fume Hood FH-104-01
PID-0302		P&ID; Chemical Distribution; Fume Hood FH-104-02
PID-0303	—	P&ID; Portable Chemical Addition Vessel; T-0303
PID-0304	—	P&ID; Portable Chemical Addition Vessel; T-0304
PID-0305	—	P&ID; Portable Chemical Addition Vessel; T-0305
PID-0306	—	P&ID; Ammonia Charging
PID-0307	—	P&ID; Chemical Distribution Portable Pumps
PID-0401	—	P&ID; TCM-0401; R-0101 Temperature Control Module
PID-0403	—	P&ID; TCM-0403; R-0103 Temperature Control Module
PID-0404	—	P&ID; TCM-0404; Reflux Conden. Temp. Control Module
PID-0405	—	P&ID; TCM-0405; UP-0106 Temperature Control Module
PID-0501	—	P&ID; VP-0501; Dry Screw Vacuum Pump
PID-0601	—	P&ID; B-0601; Exhaust Blower
PID-0701	—	P&ID; T-0701; Emergency Relief Knock-Out Tank
PID-0702	—	P&ID; T-0702; HTF Catch Tank
PID-1002	—	P&ID; Compressed Air
PID-1101	—	P&ID; Bulk Nitrogen Storage & Distribution
PID-2000	—	P&ID; Deionized Water Generation
PID-3001	—	P&ID; Process Chiller
PID-3002	—	P&ID; Chilled Water Distribution
P&ID Control Interlock Sched.	Attachment 3	Source: Hart Design Group ***With Commentary***
PID-003	—	P&ID; Interlock Schedule
Instrument & Control Plan Drawings	Attachment 4	Source: Hart Design Group
G-005	—	First Floor Instrument Plan

G-006	—	First Floor Instrument Plan Callouts
G-007	—	First Floor Instrument Power Plan
G-008	—	Second Floor Instrument Plan
G-009	—	Second Floor Instrument Plan Callouts
Control Room Plan & Console Details	Attachment 5	Source: LLNS
I-701-2	—	Operations Control Console
Control System Architecture	Attachment 6	Source: LLNS ***With Commentary***
Control System Architecture – Mechanical System Integrator FAT Subset	Attachment 6A	Source: LLNS
Schedule of LLNS Government Furnished Equipment (GFE)	Attachment 7	Source: LLNS ***With Commentary***
Control System Tag Dataset	Attachment 8	Source: HDG Hardwired Inputs and Outputs, and control system tags derived therefrom
Sequence of Operations	Attachment 9	Source: Hart Design Group Outline of Functional Requirements; a narrative document describing the manner and means of system operation
Recipes, Equipment, & Raw Materials	Attachment 10	Source: LLNS ***With Commentary***
Mock Batch Control Script and GUI Screen Graphic Slides	Attachment 11	Source: LLNS
Mock Recipe with Detailed Sequence & Tasks (First-Article Recipe)	Attachment 12	Source: LLNS

7.2 Industry Standards and Specifications for Fabrication, Assembly and Construction

The following industry standard(s) are applicable to the extent referenced herein and in other referenced documents.

Designator	Title
NEC	Class I Division 1 and Class II Division 1 (dual-rated) wiring, fixtures, process equipment and instrumentation are required (B827D R105A, the chemical synthesis area), other areas unclassified
ANSI	American National Standards Institute
ANSI/ASQC	ANSI/American Society of Quality Control
ISA	International Society of Automation
NEMA	National Electrical Manufacturers' Association
NFPA	National Fire Protection Association
NIST	National Institute of Standards and Technology
OSHA	Occupational Safety and Health Administration

8 Project Management

8.1 Project Execution Plan

Subcontractor shall prepare and implement a Project Execution Plan for the Control Systems integration, fabrication, test, and training for the B827 Complex Chemical Synthesis Pilot Process. The Subcontractor shall submit its Project Execution Plan in accordance with Section 9 Deliverables.

Once accepted by LLNS, the plan shall be the basis for Subcontractor's actions pertaining to this SOW and Specification.

Any unplanned substantial deviations from the plan, which might affect Subcontractor's performance, shall be submitted, in writing, to LLNS, before implementation. Similarly, any unplanned actions or deviations from the plan, which might have a detrimental effect on schedule or quality of deliverables, shall be submitted, in writing, to LLNS, before implementation.

The plan shall include at a minimum the following sections:

8.1.1 Project Schedule

The Subcontractor shall provide a project schedule, preferably in Gantt chart format using MS Project in accordance with Section 9 Deliverables. This schedule shall clearly identify the steps in the fabrication, integration, and testing of the System. Subcontractor's Project Schedule shall reflect, at minimum, the following completion dates:

1. Procurement of Subcontractor-provided material
2. Receipt of GFE components and subassemblies
3. Assembly and verification of the system
4. Control System remote I/O hardware assembly and wiring
5. Performance testing
6. Packaging and shipping

The schedule shall address all activity through testing, training, and turnover. Schedule status shall be reported to LLNS on a regular basis, at least monthly.

8.1.2 Quality Assurance (QA)

The Subcontractor's QA program shall include all quality assurance efforts consistent with the control and assurance elements of ANSI/ASQC C1 or an equivalent. In accordance with Section 9, Deliverables, the Subcontractor shall submit a QA Plan for the Pilot Plant System subcontract as a section of the Project Management Plan. The QA Plan shall include, but is not limited to:

- The approach to maintain configuration control of the design configurations and documents and the means to implement changes;
- The method to implement quality control of the plant equipment and components:
- Identification of selected suppliers of sensitive and critical equipment,
- Oversight of the equipment suppliers,
- Verifying the performance of equipment,
- Documentation of verification and test results;
- Quality assurance during fabrication, assembly and construction of the system.

8.2 LLNS Government Furnished Equipment (GFE) & CSI Furnished Equipment

8.2.1 LLNS Government Furnished Equipment (GFE)

The Subcontractor will be provided LLNS Government Furnished Equipment (GFE) certain long lead equipment as indicated in Attachment 7 - *Schedule of LLNS Government Furnished Equipment*. The Subcontractor is responsible for receiving and integrating this equipment into the delivered system.

8.2.2 CSI Furnished Equipment

The Control System Integrator Subcontractor shall procure all other material, equipment and components required to construct the fully-functional Control System.

8.3 Monthly Project Status Reports

Subcontractor shall provide a brief written Project Status Report monthly. The Project Status Report shall include, but is not limited to:

- A narrative of work performed, tasks completed and, status of subcontract deliverables;

- Identification of problems encountered and proposed solutions, areas of concern, outstanding action items, and acceptances or approvals pending from LLNS;
- Key work activities planned next month;
- Other information deemed appropriate by Subcontractor or requested by LLNS.

The Monthly Project Status Report is expected to be brief, in bullet list or outline form, and may be sent via e-mail to the LLNS Contract Analyst.

8.4 As-Built Documentation & Project Close-out

8.4.1 Documentation:

The CSI Subcontractor shall provide complete 'as-built' documentation for the CSI-scope elements, including, but not limited to the following:

A. Control System Functional Specification
B. Control System Tag Dataset
C. Control Panel, I/O, Network
 and related hardware and enclosure designs
D. All Modicon® PLC-related licenses and configuration files
E. All Wonderware® SCADA-related licenses and configuration files
F. All ancillary support system licenses and configuration files

8.4.2 Project Close-Out:

The CSI shall provide return of all GFE components, including, but not limited to the following:

A. All Control System hardware and related components
B. All Commercial off-the-shelf (COTS) software licenses and media
C. Final 'As-Built' documentation, the *Control System Project Documentation Set*.

9 Deliverables

9.1 Documentation

LLNS review and acceptance or approval of plans, data, specifications, or procedures submitted by Subcontractor does not constitute acceptance of any means, methods, materials, process, or components which do not fulfill the requirements of the specification.

The schedule for submittal of documentation is given below.

1. The Subcontractor shall furnish the following documentation for LLNS approval or information as indicated herein. Documents referenced in this SOW and Specification may specify additional documentation-submittal requirements.

2. LLNS review and acceptance of documents submitted by the Subcontractor does not relieve the Subcontractor from strict compliance with this specification, the drawings and other Subcontract documents, except where explicitly approved by LLNS in writing.

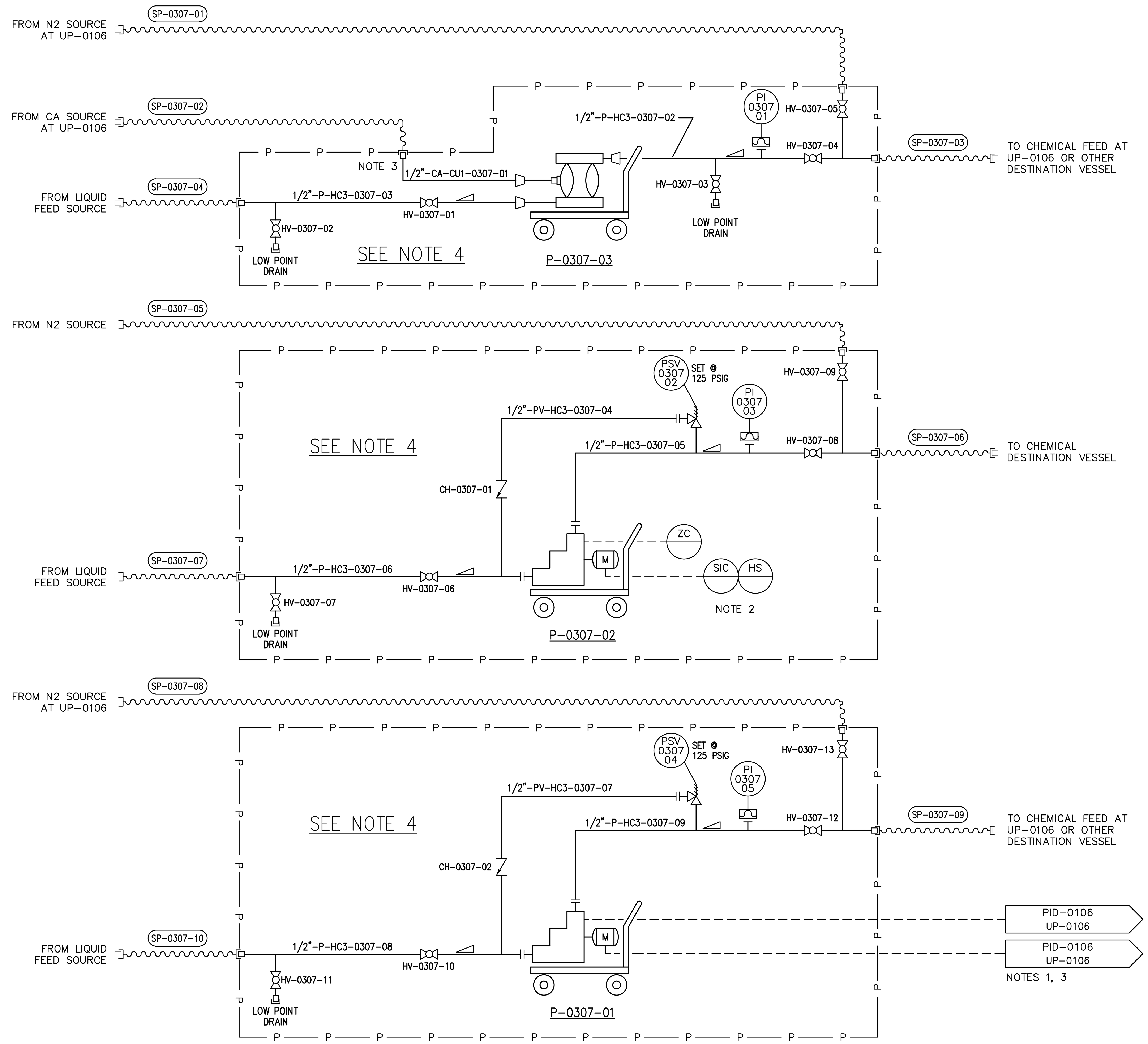
3. In addition to the required submittals, Subcontractor-generated documentation shall be available for reference and review by LLNS at the Subcontractor's site.

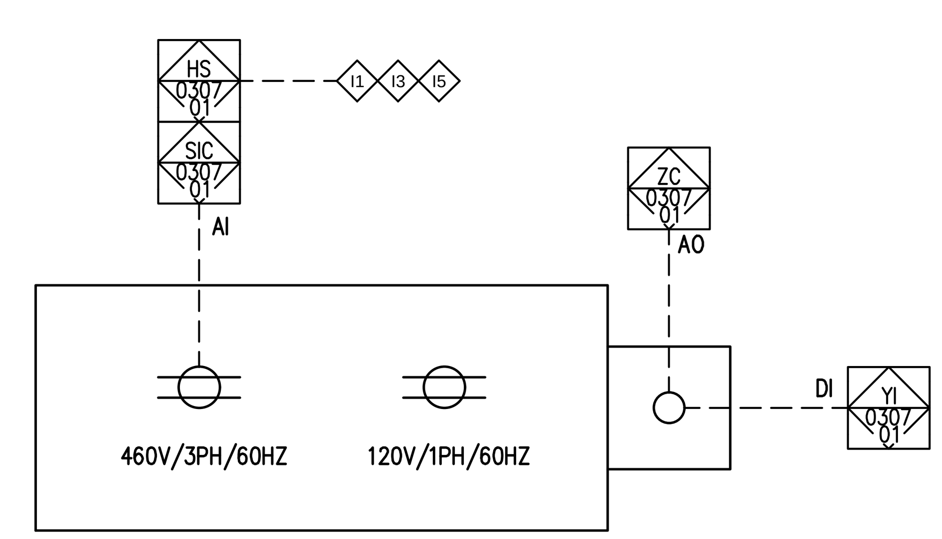
4. The Subcontractor shall submit all submittals, reports and documentation to the LLNS Contract Analyst.

5. The Subcontractor shall submit an electronic file for each document, except when stated otherwise in this document. Microsoft® application software is the preferred format.

6. LLNS will review and respond to submittal information in a timely manner except when stated otherwise in this document. Re-submittal shall be required for incomplete or deficient items.

Submittal	**Ref. Section**	**LLNS Acceptance Required**	**For Info.**	**Submittal Time & Frequency**
Project Execution Plan	8.1	X		Within 20 days ARO
Project Schedule	8.1.2		X	Within 20 days ARO
QA Program Plan	8.1.3	X		Within 20 days ARO
Project Status Reports	8.3		X	Monthly
Control System Functional Specification	4.2.1	X		TBD
Detailed CSI_FAT *Test Plan*	4.2.3	X		20 days prior to implementation
Test Records	4.2.3-G 4.2.4-E 4.2.5		X	Within 20 days of completion
Control System Project Documentation Set	4.1.3 & 8.4.2	X		Within 30 days of completion
Shipping Plan	4.2.3-J 4.2.4-G	X		30 days prior to shipment





P-0307-01 DOCKING STATION

SEE NOTE 5

TAG	P-0307-01	P-0307-02	P-0307-03
NAME	METERING PUMP WITH VARIABLE SPEED CONTROL AND ELECTRIC STROKE ACTUATOR	METERING PUMP WITH VARIABLE SPEED CONTROL AND ELECTRIC STROKE ACTUATOR	AIR OPERATED DIAPHRAGM PUMP
CAPACITY	0.4–40 LPH 5–100 FT TDH	0.4–40 LPH 5–100 FT TDH	0–2.6LPH, 20 PSI TDH
RATING	DESIGN TEMP: 752°F DESIGN PRESS: 275 PSIG	DESIGN TEMP: 752°F DESIGN PRESS: 275 PSIG	2 SCFM AIR @ 20 PSIG 120 PSIG @ 248°F
RATED CONNECTIONS	150# RFF	150# RFF	FNPT
MATERIAL	HASTELLOY C-22 / PTFE	HASTELLOY C-22 / PTFE	PTFE
ELECTRICAL	MOTOR: 1/2 HP, 460V/3PH/60HZ ACTUATOR: 120V/1PH/60HZ CLI, DIV1, GR C&D CLII, DIV1, GR F&G	MOTOR: 1/2 HP, 460V/3PH/60HZ ACTUATOR: 120V/1PH/60HZ	

INTERLOCKS:

I1 HIGH REACTOR TEMPERATURE SHUTS ALL FEEDS TO REACTOR, SHUTS DOWN HEATING TCM, DUMPS REACTOR TO QUENCH.

I3 HIGH REACTOR TEMPERATURE SHUTS ALL FEEDS TO REACTOR, SHUTS DOWN HEATING TCM, DUMPS REACTOR TO QUENCH

INSTRUMENTS
LAST NO. USED: 05
OPEN NOS.:

MAN. VALVES
LAST NO. USED: 13
OPEN NOS.:

CHECK VALVES
LAST NO. USED: 02
OPEN NOS.:

LINES
LAST NO. USED: 09
OPEN NOS.:

SPECIALS
LAST NO. USED: 10
OPEN NOS.:

Lawrence Livermore National Laboratory
P.O. Box 808 Livermore, California 94551

F&I Facilities & Infrastructure

Consultants

HART DESIGN GROUP
A MEMBER OF THE HART COMPANIES
HIGHLAND CORPORATE PARK
800 SCENIC VIEW DRIVE
CUMBERLAND, RI 02864
TEL: (401) 658-4600
FAX: (401) 658-4609
WWW.HARTCOMPANIES.COM

NOTES:

1. STROKE LIMITER TO BE CONNECTED TO 120V ELECTRICAL RECEPTACLE ON UP-0106. MOTOR TO BE CONNECTED TO 460V ELECTRICAL RECEPTACLE ON UP-0106.
2. VFD AND CONTROLS TO BE MOUNTED ON CART. PUMP MAY BE USED IN GENERAL PURPOSE AREAS VIA A STANDARD 460V RECEPTACLE. WARNING LABEL TO BE PROVIDED.
3. INTERLOCK I1, I3 AND I5 APPLY TO P-0307-01 AND P-0307-03 VIA UP-0106.
4. PUMP CARTS AND HOSE CONNECTIONS (SP-0307) ARE LFE.
5. DOCKING STATION IS LFE. INSTALLATION AND HOOK-UP BY SUBCONTRACTOR.

PE Stamps

0 1 2

Project Title

B 827 CHEMICAL SYNTHESIS PILOT PLANT

REV No	DATE	REVISIONS	DWN BY	CHK BY
A	6/17/16	ISSUED FOR PHA	JML	JH
B	09/07/16	ISSUED FOR DESIGN	RFB	JV
0	02/16/17	RELEASED FOR CONSTRUCTION	MTG	JH

Des: J. HORWATH
Dwn: J. LEVESQUE
Chk: J. HORWATH
File Name: 16022_PID-0307_RFC (CHEMICAL DISTRIBUTION PORTABLE PUMPS).dwg
DTN: | Scale: AS NOTED | Software: AutoCAD 2016

Sheet Title

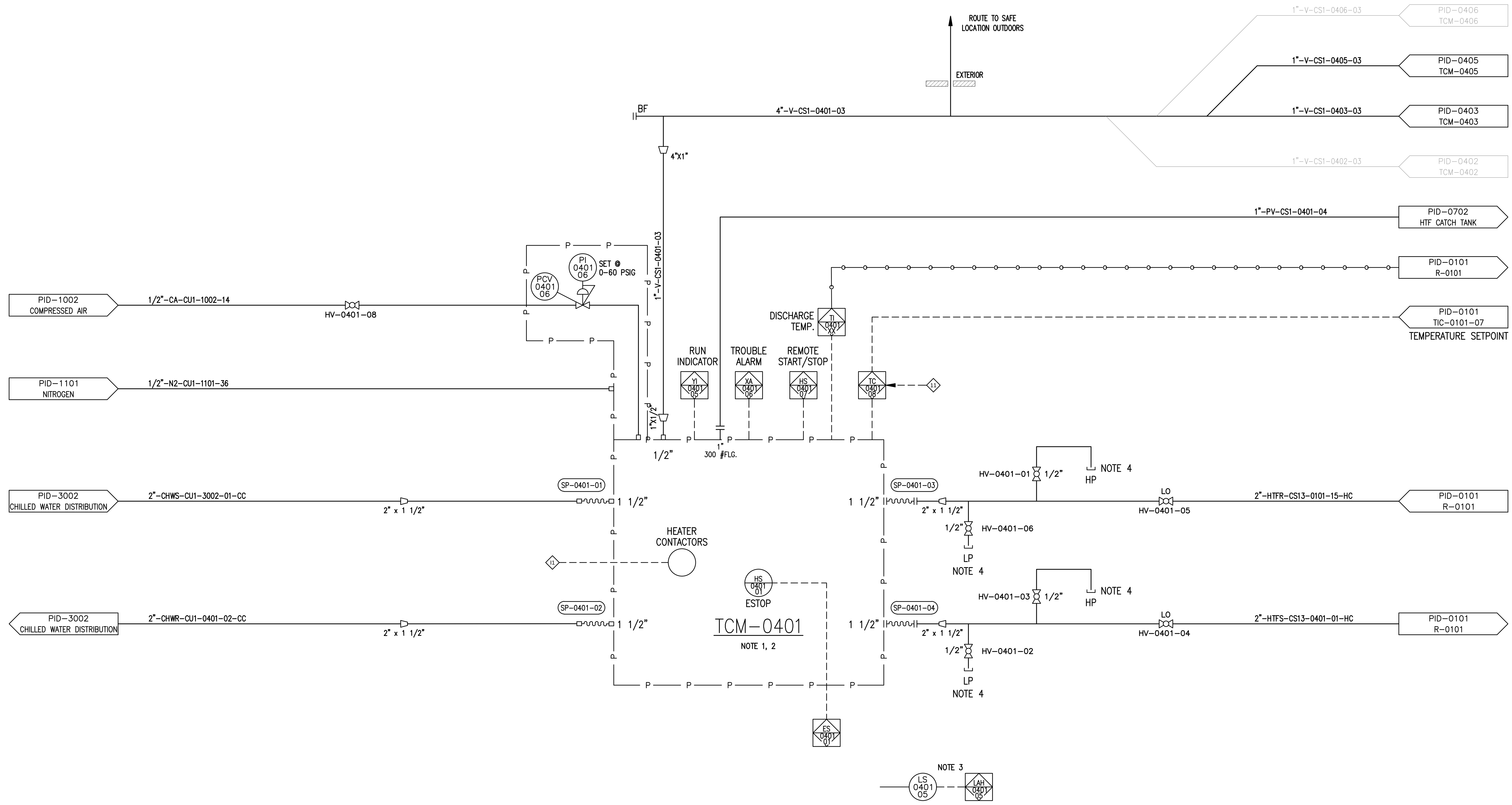
PROCESS P&ID CHEMICAL DISTRIBUTION PORTABLE PUMPS

Dwg. No. PSP2016-827D-0425D Rev.

Sht. No. PID-0307 1 of 1

Classification
UNCLASSIFIED/UNLIMITED RELEASE

REV. Dwg. No.



TAG	TCM-0401
NAME	R-0101 TEMPERATURE CONTROL MODULE
CAPACITY	COOLING: 73,531 BTU/HR @ -4°F HEATING: 81,891 BTU/HR
FLOW RATE	25 GPM @ 173 FT TDH
RATED CONNECTIONS	COOLING: NPT HEATING: 300# RFF
RATING	125 PSIG @ 450°F
ELECTRICAL	460V/3PH/60HZ; CL1 DIV2

INSTRUMENTS
LAST NO. USED: 08
OPEN NOS.:

MANUAL (HV) VALVES
LAST NO. USED: 08
OPEN NOS.: 07

CHECK (CH) VALVES
LAST NO. USED:
OPEN NOS.:

LINES
LAST NO. USED: 04
OPEN NOS.:

SPECIALS
LAST NO. USED: 04
OPEN NOS.:

INTERLOCKS:

I1 HIGH TEMPERATURE IN REACTOR R-0101 SHUTS DOWN TCM-0401.

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P.O. Box 808 Livermore, California 94551

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HART DESIGN GROUP
A MEMBER OF THE HART COMPANIES
HIGHLAND CORPORATE PARK
800 SCENIC VIEW DRIVE
CUMBERLAND, RI 02864
TEL: (401) 658-4600
FAX: (401) 658-4609
WWW.HARTCOMPANIES.COM

NOTES:

1. SEE VENDOR P&ID FOR PACKAGED UNIT DETAILS.
2. EXPANSION TANK, SEALESS MAG DRIVE PUMPS, SCR HEATER AND PLC CONTROL SYSTEM INCLUDED IN PACKAGED UNIT.
3. FLOOR OF ROOM 202A IS CONTAINMENT STRUCTURE. INSTALL LEAK DETECTOR IN CLOSE PROXIMITY TO TCMS.
4. HIGH POINT VENTS AND LOW POINT DRAINS SHALL BE LOCATED AS REQUIRED.

PE Stamps

Project Title

B 827 CHEMICAL SYNTHESIS PILOT PLANT

REV No	DATE	REVISIONS	DWN BY	CHK BY
A	05/24/16	ISSUED FOR CLIENT REVIEW	JML	JH
B	06/17/16	ISSUED FOR PHA	RJH	JH
C	08/01/16	ISSUED FOR DESIGN	JML	JV
D	09/07/16	ISSUED FOR DESIGN	CSCP	JV
0	02/16/17	RELEASED FOR CONSTRUCTION	JML	JH

Des: J. HORWATH
Dwn: J. LEVESQUE
Chk: J. HORWATH
File Name: 16022_PID-0401_RFC (TCM-0401_R0101).dwg
DTN:
Scale: AS NOTED
Software: AutoCAD 2016

Sheet Title

PROCESS P&ID
TCM-0401: R-0101 TEMPERATURE CONTROL MODULE

Dwg. No. PSP2016-827D-0427D
Rev.
Sht. No. PID-0401 1 of 1

Classification
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REV.
Dwg. No.

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CUMBERLAND, RI 02864
TEL: (401) 658-4600
FAX: (401) 658-4609
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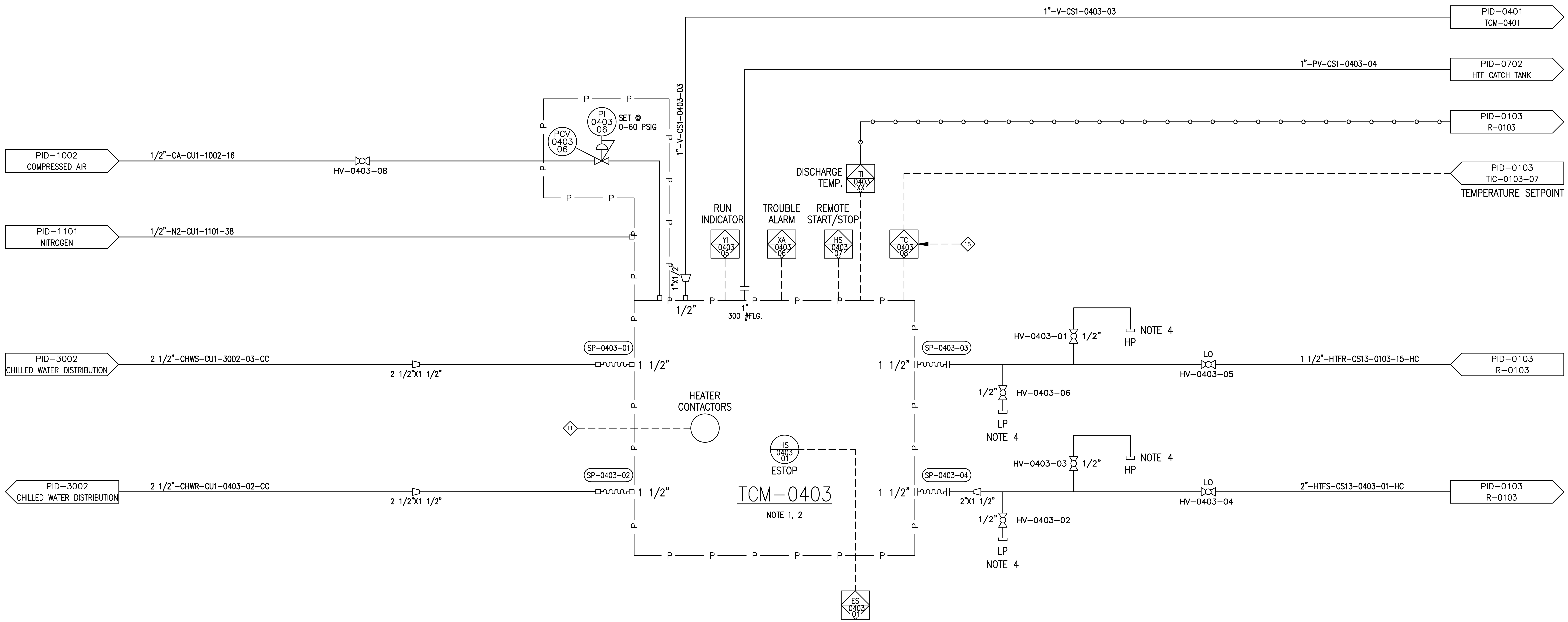


NOTES:

1. SEE VENDOR P&ID FOR PACKAGED UNIT DETAILS.
2. EXPANSION TANK, SEALESS MAG DRIVE PUMPS, SCR HEATER AND PLC CONTROL SYSTEM INCLUDED IN PACKAGED UNIT.
3. NOT USED.
4. HIGH POINT VENTS AND LOW POINT DRAINS SHALL BE LOCATED AS REQUIRED.

PE Stamps

Project Title

B 827 CHEMICAL SYNTHESIS PILOT PLANT

REV No	DATE	REVISIONS	DWN BY	CHK BY
A	05/27/16	ISSUED FOR CLIENT REVIEW	JML	JH
B	06/17/16	ISSUED FOR PHA	RJH	JH
C	08/01/16	ISSUED FOR DESIGN	JML	JV
D	09/07/16	ISSUED FOR DESIGN	CSCP	JV
0	02/16/17	RELEASED FOR CONSTRUCTION	JML	JH

Des: J. HORWATH
Dwn: J. LEVESQUE
Chk: J. HORWATH
File Name: 16022_PID-0403_RFC (TCM-0403_R-0103).dwg
DTN:
Scale: AS NOTED
Software: AutoCAD 2016

Sheet Title

PROCESS P&ID TCM-0403: R-0103 TEMPERATURE CONTROL MODULE

Dwg. No. PSP2016-827D-0429D
Rev.
Sht. No. PID-0403 1 of 1

Classification
UNCLASSIFIED/UNLIMITED RELEASE

TAG	TCM-0403
NAME	R-0103 TEMPERATURE CONTROL MODULE
CAPACITY	COOLING: 91,786 BTU/HR @ -4°F HEATING: 102,364 BTU/HR
FLOW RATE	25 GPM @ 173 FT TDH
RATED CONNECTIONS	COOLING: NPT HEATING: 300# RFF
RATING	125 PSIG @ 450°F
ELECTRICAL	460V/3PH/60HZ; CL1 DIV2

INSTRUMENTS
LAST NO. USED: 07
OPEN NOS.: 05

MANUAL (HV) VALVES
LAST NO. USED: 08
OPEN NOS.: 07

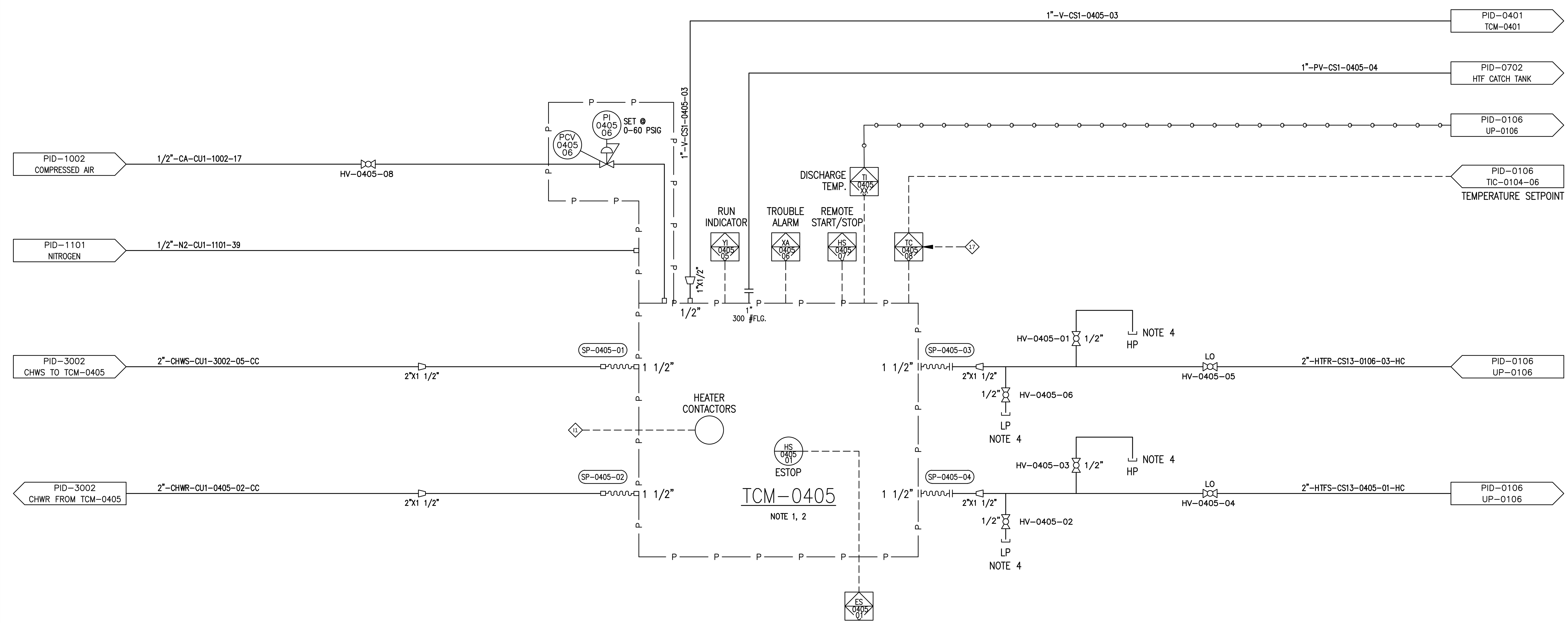
CHECK (CH) VALVES
LAST NO. USED:
OPEN NOS.:

LINES
LAST NO. USED: 04
OPEN NOS.:

SPECIALS
LAST NO. USED: 04
OPEN NOS.:

INTERLOCKS:

I1 HIGH TEMPERATURE IN REACTOR R-0103 SHUTS DOWN TCM-0403.



TAG	TCM-0405
NAME	R-0105 TEMPERATURE CONTROL MODULE
CAPACITY	COOLING: 49,646 BTU/HR @ -4°F HEATING: 40,946 BTU/HR
FLOW RATE	25 GPM @ 173 FT TDH
RATED CONNECTIONS	COOLING: NPT HEATING: 300# RFF
RATING	125 PSIG @ 450°F
ELECTRICAL	460V/3PH/60HZ; CL1 DIV2

INSTRUMENTS
LAST NO. USED: 07
OPEN NOS.: 05

MANUAL (HV) VALVES
LAST NO. USED: 08
OPEN NOS.: 07

CHECK (CH) VALVES
LAST NO. USED:
OPEN NOS.:

LINES
LAST NO. USED: 04
OPEN NOS.:

SPECIALS
LAST NO. USED: 04
OPEN NOS.:

INTERLOCKS:

(17) HIGH TEMPERATURE IN F-0104 (VIA UP-0106) SHUTS DOWN TCM-0405.

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HIGHLAND CORPORATE PARK
800 SCENIC VIEW DRIVE
CUMBERLAND, RI 02864
TEL: (401) 658-4600
FAX: (401) 658-4609
WWW.HARTCOMPANIES.COM

NOTES:

1. SEE VENDOR P&ID FOR PACKAGED UNIT DETAILS.
2. EXPANSION TANK, SEALESS MAG DRIVE PUMPS, SCR HEATER AND PLC CONTROL SYSTEM INCLUDED IN PACKAGED UNIT.
3. NOT USED.
4. HIGH POINT VENTS AND LOW POINT DRAINS SHALL BE LOCATED AS REQUIRED.

PE Stamps

Project Title

B 827 CHEMICAL SYNTHESIS PILOT PLANT

REV No	DATE	REVISIONS	DWN BY	CHK BY
A	05/27/16	ISSUED FOR CLIENT REVIEW	JML	JH
B	06/17/16	ISSUED FOR PHA	RJH	JH
C	08/01/16	ISSUED FOR DESIGN	JML	JV
D	09/07/16	ISSUED FOR DESIGN	CSCP	JV
0	02/16/17	RELEASED FOR CONSTRUCTION	JML	JH

Des: J. HORWATH
Dwn: J. LEVESQUE
Chk: J. HORWATH
File Name: 16022_PID-0405_RFC (TCM-0405_UP-0106).dwg
DTN: | Scale: AS NOTED | Software: AutoCAD 2016

Sheet Title

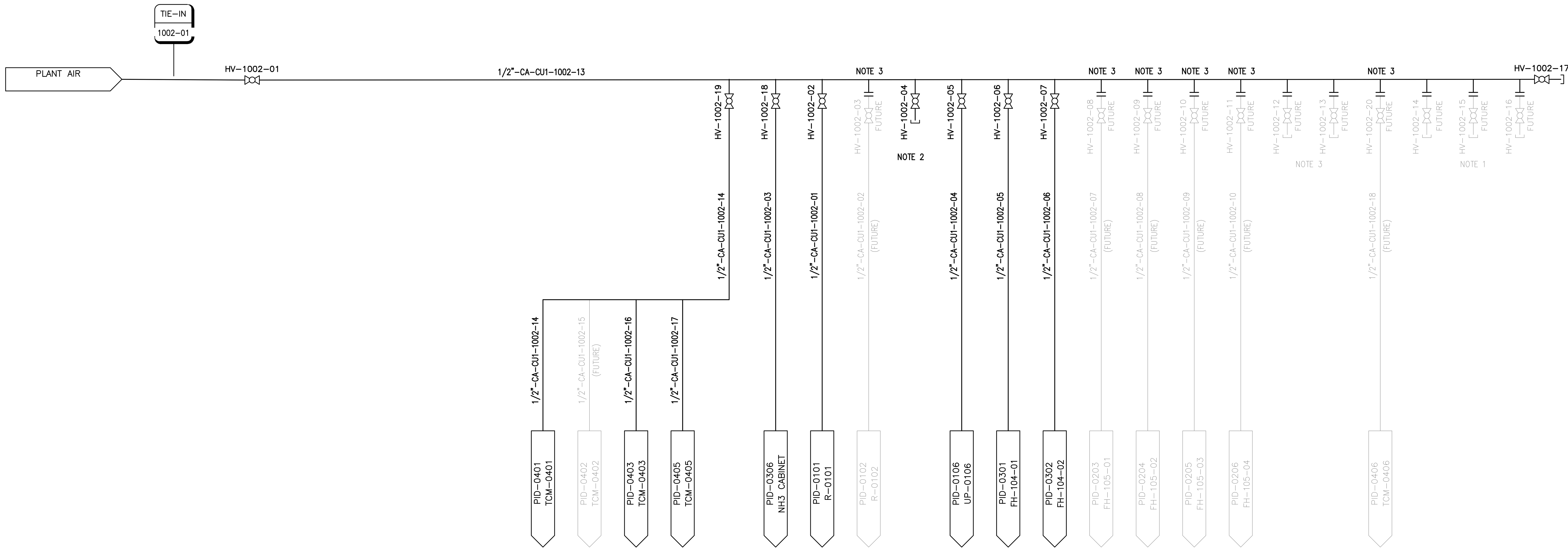
PROCESS P&ID TCM-0405: UP-0106 TEMPERATURE CONTROL MODULE

Dwg. No. PSP2016-827D-0431D | Rev.

Sht. No. PID-0405 | 1 of 1

Classification
UNCLASSIFIED/UNLIMITED RELEASE

REV. | Dwg. No.



<u>INSTRUMENTS</u>
LAST NO. USED:
OPEN NOS.:

<u>MAN. VALVES</u>
LAST NO. USED: 20

<u>LINES</u>
LAST NO. USED: 18
OPEN NOS.: 11,12

<u>SPECIALS</u>
LAST NO. USED:
OPEN NOS.:

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HIGHLAND CORPORATE PARK
800 SCENIC VIEW DRIVE
CUMBERLAND, RI 02864
TEL: (401) 658-4600
FAX: (401) 658-4609
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NOTES:

1. LOCATE DROPS THROUGHOUT FACILITY FOR FUTURE USE.
2. DROP FOR FUTURE SAMPLE LOOP AT R-0103.
3. PROVIDE TEE, FLANGE AND BLIND FLANGE AT FUTURE SERVICE LOCATIONS (TYP.)

PE Stamps

0 1 2

Project Title

B 827 CHEMICAL SYNTHESIS PILOT PLANT

REV No	DATE	REVISIONS	DWN BY	CHK BY
A	06/17/15	ISSUED FOR PHA	JML	JH
B	09/07/16	ISSUED FOR DESIGN	JML	JV
0	02/16/17	RELEASED FOR CONSTRUCTION	JML	JH

Des: J. HORWATH
Dwn: J. LEVESQUE
Chk: J. HORWATH
File Name: 16022_PID-1002_RFC (COMMRESSED AIR).dwg
DTN: | Scale: AS NOTED | Software: AutoCAD 2016

Sheet Title

PROCESS
P&ID
COMPRESSED AIR

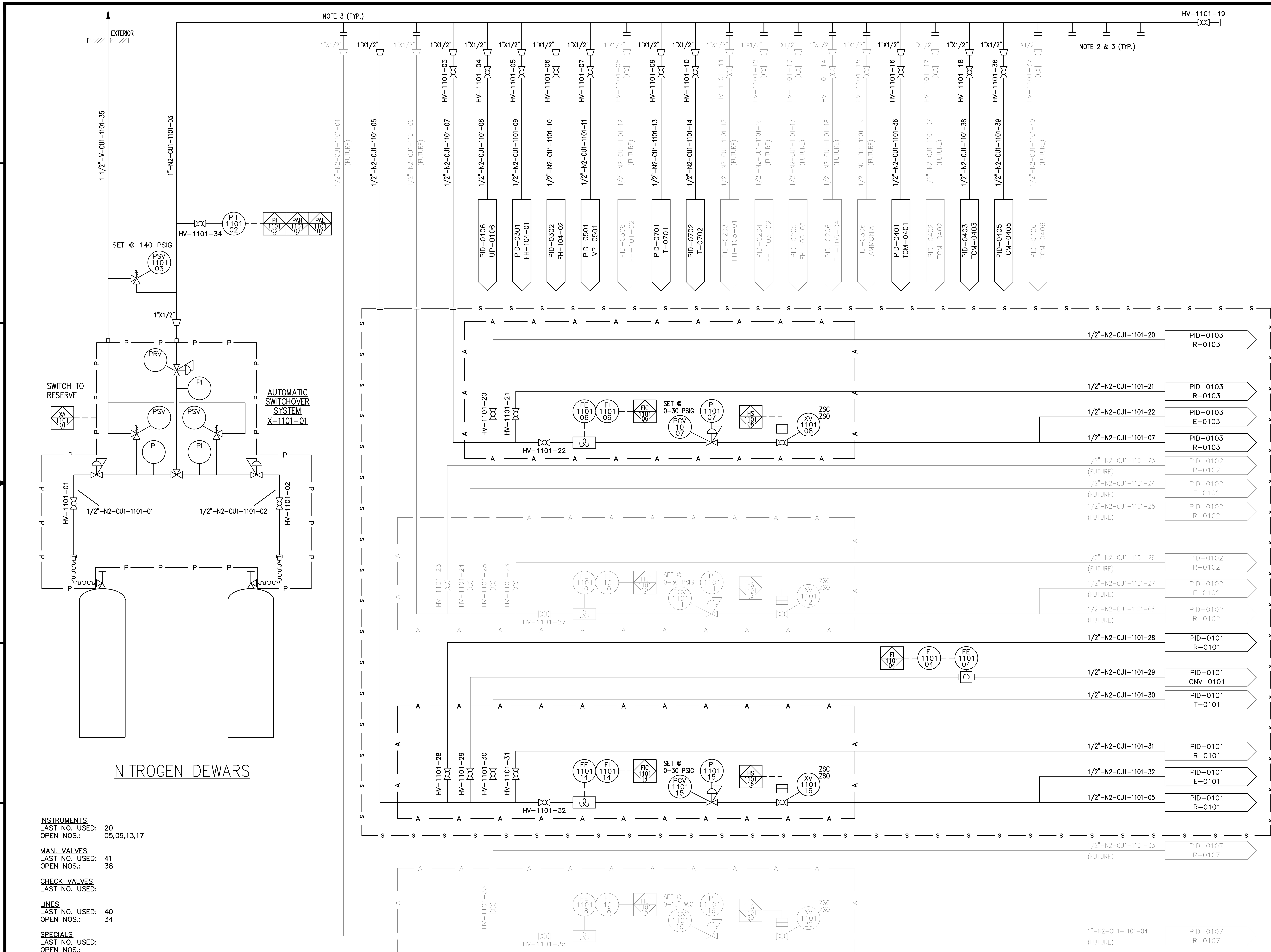
Dwg. No. PSP2016-827D-0437D Rev.

Sht. No. PID-1002 1 of 1

Classification
UNCLASSIFIED/UNLIMITED RELEASE

REV. Dwg. No.

A B C D E F
1 2 3 4 5 6 7 8



INSTRUMENTS
LAST NO. USED: 20
OPEN NOS.: 05,09,13,17

MAN. VALVES
LAST NO. USED: 41
OPEN NOS.: 38

CHECK VALVES
LAST NO. USED:

LINES
LAST NO. USED: 40
OPEN NOS.: 34

SPECIALS
LAST NO. USED:
OPEN NOS.:

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A MEMBER OF THE HART COMPANIES
HIGHLAND CORPORATE PARK
800 SCENIC VIEW DRIVE
CUMBERLAND, RI 02864
TEL: (401) 658-4600
FAX: (401) 658-4609
WWW.HARTCOMPANIES.COM

NOTES:
1. ALL AUTOMATED VALVES FAIL CLOSED UNLESS OTHERWISE NOTED.
2. DROPS FOR FUTURE EQUIPMENT TO BE LOCATED IN ROOM 101.
3. PROVIDE TEE, FLANGE AND BLIND FLANGE AT FUTURE SERVICE LOCATIONS (TYP.)

PE Stamps

Project Title
B 827 CHEMICAL SYNTHESIS PILOT PLANT

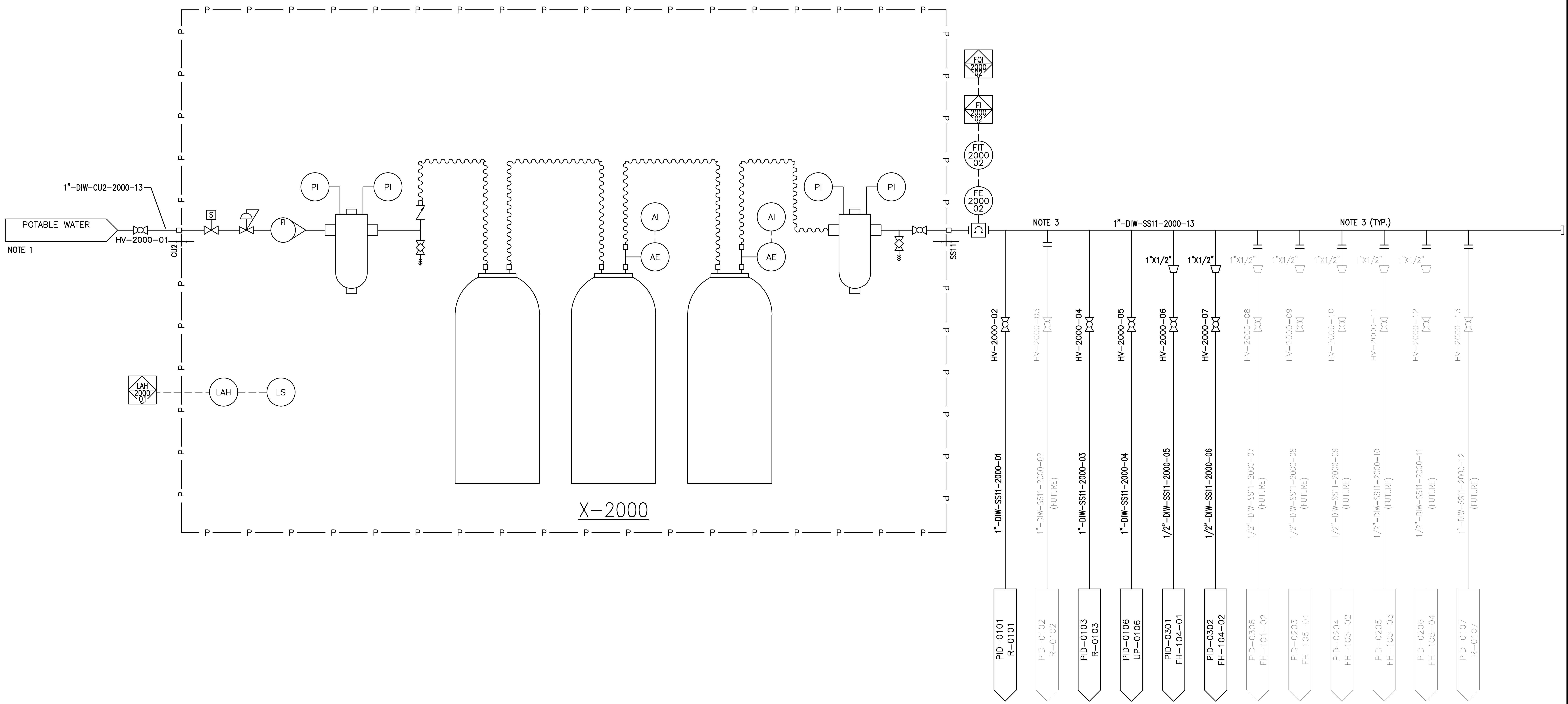
REV No	DATE	REVISIONS	DWN BY	CHK BY
A	05/27/16	ISSUED FOR CLIENT REVIEW	JML	JH
B	06/17/16	ISSUED FOR PHA	JML	JH
C	08/01/16	ISSUED FOR DESIGN	JML	JV
D	09/07/16	ISSUED FOR DESIGN	JLM	JV
0	02/16/17	RELEASED FOR CONSTRUCTION	JML	JH

Des: J. HORWATH
Dwn: J. LEVESQUE
Chk: J. HORWATH
File Name: 16022_PID-1101_RFC (NITROGEN STOREAGE AND DIST).dwg
DTN: Scale: AS NOTED Software: AutoCAD 2016

Sheet Title
PROCESS P&ID
BULK NITROGEN STORAGE AND DISTRIBUTION

Dwg. No. PSP2016-827D-0438D Rev.
Sht. No. PID-1101 1 of 1

Classification
UNCLASSIFIED/UNLIMITED RELEASE



TAG	X-2000
NAME	DI WATER SYSTEM
CAPACITY	10 GPM
RATING	
RATED CONNECTIONS	NPT
MATERIAL	PVC
ELECTRICAL	120V/1 PH/60 HZ

INSTRUMENTS
LAST NO. USED: 02
OPEN NOS.:

MANUAL (HV) VALVES
LAST NO. USED: 13
OPEN NOS.:

CHECK (CH) VALVES
LAST NO. USED:
OPEN NOS.:

LINES
LAST NO. USED: 13
OPEN NOS.:

SPECIALS
LAST NO. USED:
OPEN NOS.:

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HART DESIGN GROUP
A MEMBER OF THE HART COMPANIES
HIGHLAND CORPORATE PARK
800 SCENIC VIEW DRIVE
CUMBERLAND, RI 02864
TEL: (401) 658-4600
FAX: (401) 658-4609
WWW.HARTCOMPANIES.COM

NOTES:

1. BACKFLOW PREVENTERS TO BE PROVIDED UPSTREAM. (BY OTHERS)
2. FOR FUTURE TIE-INS TO ROOM 101
3. PROVIDE TEE, FLANGE AND BLIND FLANGE AT FUTURE SERVICE LOCATIONS (TYP.)

PE Stamps

0 1 2

Project Title

B 827 CHEMICAL SYNTHESIS PILOT PLANT

REV No	DATE	REVISIONS	DWN BY	CHK BY
A	06/17/16	ISSUED FOR PHA	RJH	JH
B	09/07/16	ISSUED FOR DESIGN	RFB	RFB
0	02/16/17	RELEASED FOR CONSTRUCTION	JML	JH

Des: J. HORWATH
Dwn: J. LEVESQUE
Chk: J. HORWATH
File Name: 16022_PID-2000_RFC (DEIONIZED WATER GENERATION).dwg
DTN:
Scale: AS NOTED
Software: AutoCAD 2016

Sheet Title

PROCESS P&ID DEIONIZED WATER GENERATION

Dwg. No. PSP2016-827D-0439D
Rev.
Sht. No. PID-2000 1 of 1

Classification
UNCLASSIFIED/UNLIMITED RELEASE

REV.
Dwg. No.

Control System Integration
B827 Complex
Chemical Synthesis Pilot Project

—

Commentary on
P&ID Interlock Schedule

March 1, 2017

Revision A

Lawrence Livermore National Laboratory

1.0 Overview

This is a commentary associated with Attachment 3, *P&ID Interlock Schedule*.

The *P&ID Interlock Schedule* is one sheet from the P&ID set, Drawing № PID-003.

It represents the collection of the critical process safety actions required based upon a detailed Process Hazards Analysis, aka PHA. The intent of this Schedule is to summarize the Process Hazards Analysis-required initiators and response elements in the process and control system.

The Schedule consists of nine Interlock Types, enumerated as I1 through I9. These interlocks are driven the specific hazards or events identified in the PHA.

Each interlock type may have one, or more, equipment responses required. For example, I1, a Reactor R-0101 Overtemperature, has 21 actions required should it occur. The instances of each interlock type appear on the P&ID drawings as diamonds by the respective initiator or equipment tag 'bubble'.

All Interlock Types, except I7 and I8, are hardwired, with control elements configured in a fail-safe manner. Most are managed and wired in the fail-safe mode via the High Temperature Interlock Panel in B827D Room 104.

Interlock Types I7 & I8, both high line pressures, rely on PLC logic as the initiating sensor states are only available from the PLCs inputs.

2.0 Requirements of Control System Integrator

Using the *P&ID Interlock Schedule,* and additional information gleaned from interviews and functional requirements detailing workshops with LLNL Subject Matter Experts, Operators, and project engineers, the Control System Integrator Subcontractor shall:

1. Incorporate requirements into the *Control System Functional Specification,* and deliver a fully-functional batch processing control system that meets all *P&ID Interlock Schedule* functions

2. Ensure all initiating events are visible on the SCADA status and process mimic screens and captured and logged as alarms and / or events in the SCADA system.

Interlock	Initiated By	Initiator Tag	Equipment	Fail Mode	Function	Hardwired	Software	Status	Comment
I1	R-0101 Overtemperature	TSH-0101-07	CNV-0101	Shutdown	De-energize Conveyor DC Drive	1			
I1	R-0101 Overtemperature	TSH-0101-07	P-0301-01	Shutdown	Open P-0301 E-stop Circuit	1			
I1	R-0101 Overtemperature	TSH-0101-07	P-0301-02	Shutdown	Shutoff CA to P-0301-02	1			Via SV-0301-03
I1	R-0101 Overtemperature	TSH-0101-07	P-0301-03	Shutdown	Shutoff CA to P-0301-03	1			Via SV-0301-03
I1	R-0101 Overtemperature	TSH-0101-07	P-0307-01	Shutdown	Open P-0307-01 E-stop Circuit	1			
I1	R-0101 Overtemperature	TSH-0101-07	SV-0106-03	Close	CA Distribution to Utility Panel	1			Via SV-0106-03A
I1	R-0101 Overtemperature	TSH-0101-07	SV-0106-26	Close	CA Distribution to Utility Panel	1			Via SV-0106-26A
I1	R-0101 Overtemperature	TSH-0101-07	TCM-0401	Shutdown	De-energize TCM Heater Contactors	1			
I1	R-0101 Overtemperature	TSH-0101-07	XV-0101-02	Close	Chemical Feed to R-0101	1			
I1	R-0101 Overtemperature	TSH-0101-07	XV-0101-03	Close	Chemical Feed to R-0101	1			
I1	R-0101 Overtemperature	TSH-0101-07	XV-0101-04	Close	Chemical Feed to R-0101	1			
I1	R-0101 Overtemperature	TSH-0101-07	XV-0101-05	Close	Chemical Feed to R-0101	1			
I1	R-0101 Overtemperature	TSH-0101-07	XV-0101-06	Close	Chemical Feed to R-0101	1			
I1	R-0101 Overtemperature	TSH-0101-07	XV-0101-07	Close	Chemical Feed to R-0101	1			
I1	R-0101 Overtemperature	TSH-0101-07	XV-0101-08	Close	Chemical Feed to R-0101	1			
I1	R-0101 Overtemperature	TSH-0101-07	XV-0101-24	Close	T-101 Transfer to T-0101	1			
I1	R-0101 Overtemperature	TSH-0101-07	XV-0101-25	Close	CNV-0101 Transfer to R-0101	1			
I1	R-0101 Overtemperature	TSH-0101-07	XV-0101-28	Open	R-0101 Bottom Valve	1			
I1	R-0101 Overtemperature	TSH-0101-07	XV-0101-30	Open	R-0101 to Quench Tank R-0103	1			
I1	R-0101 Overtemperature	TSH-0101-07	XV-0101-32	Open	R-0101 to Quench Tank R-0103	1			
I1	R-0101 Overtemperature	TSH-0101-07	XV-0103-05	Open	R-0101/R-0102 to Quench R-0103	1			Via SV-0103-05A
I2	FH-104-01 E-Stop	ES-0301-01	P-0301-01, P-0301-02, P-0301-03	Shutdown	Fume Hood FH-104-01 Chemical Distribution to Reactors	1			
I3	R-0102 Overtemperature	TSH-0102-07	CNV-0102	Shutdown	De-energize Conveyor DC Drive	1		FUTURE	
I3	R-0102 Overtemperature	TSH-0102-07	P-0301-01	Shutdown	Open P-0301 E-stop Circuit	1		FUTURE	
I3	R-0102 Overtemperature	TSH-0102-07	P-0301-02	Shutdown	Shutoff CA to P-0301-02	1		FUTURE	
I3	R-0102 Overtemperature	TSH-0102-07	P-0301-03	Shutdown	Shutoff CA to P-0301-03	1		FUTURE	
I3	R-0102 Overtemperature	TSH-0102-07	P-0307-01	Shutdown	Open P-0307-01 E-stop Circuit	1		FUTURE	
I3	R-0102 Overtemperature	TSH-0102-07	SV-0106-03	Close	CA Distribution to Utility Panel	1			Via SV-0106-03A
I3	R-0102 Overtemperature	TSH-0102-07	SV-0106-26	Close	CA Distribution to Utility Panel	1			Via SV-0106-26A
I3	R-0102 Overtemperature	TSH-0102-07	TCM-0402	Shutdown	De-energize TCM Heater Contactors	1		FUTURE	
I3	R-0102 Overtemperature	TSH-0102-07	XV-0101-27	Open	R-0102 to Quench Tank R-0103	1		FUTURE	
I3	R-0102 Overtemperature	TSH-0102-07	XV-0102-02	Close	Chemical Feed to R-0102	1		FUTURE	
I3	R-0102 Overtemperature	TSH-0102-07	XV-0102-03	Close	Chemical Feed to R-0102	1		FUTURE	
I3	R-0102 Overtemperature	TSH-0102-07	XV-0102-04	Close	Chemical Feed to R-0102	1		FUTURE	
I3	R-0102 Overtemperature	TSH-0102-07	XV-0102-05	Close	Chemical Feed to R-0102	1		FUTURE	
I3	R-0102 Overtemperature	TSH-0102-07	XV-0102-06	Close	Chemical Feed to R-0102	1		FUTURE	
I3	R-0102 Overtemperature	TSH-0102-07	XV-0102-07	Close	Chemical Feed to R-0102	1		FUTURE	
I3	R-0102 Overtemperature	TSH-0102-07	XV-0102-08	Close	Chemical Feed to R-0102	1		FUTURE	
I3	R-0102 Overtemperature	TSH-0102-07	XV-0102-24	Close	T-0102 Transfer to R-0102	1		FUTURE	
I3	R-0102 Overtemperature	TSH-0102-07	XV-0102-25	Close	CNV-0102 Transfer to R-0102	1		FUTURE	
I3	R-0102 Overtemperature	TSH-0102-07	XV-0102-28	Open	R-0102 BottomValve	1		FUTURE	
I3	R-0102 Overtemperature	TSH-0102-07	XV-0103-05	Open	R-0101/R-0102 to Quench R-0103	1		FUTURE	Via SV-0103-05A
I4	B827A Control Room Remote E-stop/Seismic Detection Shutdown	ESR-827A-01	All hardwired interlocks	Shutdown	Remote Safety Shutdown from E-Stop Pushbutton or Seismic Detection Switch in B827A Control Room	1			Cuts supply power to Hardwire Interlock Panel
I5	R-0103 Overtemperature	TSH-0103-07	P-0301-01	Shutdown	Open P-0301 E-stop Circuit	1			
I5	R-0103 Overtemperature	TSH-0103-07	P-0301-02	Shutdown	Shutoff CA to P-0301-02	1			
I5	R-0103 Overtemperature	TSH-0103-07	P-0301-03	Shutdown	Shutoff CA to P-0301-03	1			
I5	R-0103 Overtemperature	TSH-0103-07	P-0307-01	Shutdown	Open P-0307-01 E-stop Circuit	1			
I5	R-0103 Overtemperature	TSH-0103-07	SV-0106-03	Close	CA Distribution to Utility Panel	1			Via SV-0106-03A
I5	R-0103 Overtemperature	TSH-0103-07	SV-0106-26	Close	CA Distribution to Utility Panel	1			Via SV-0106-26A
I5	R-0103 Overtemperature	TSH-0103-07	TCM-0403	Shutdown	De-energize TCM Heater Contactors	1			
I5	R-0103 Overtemperature	TSH-0103-07	XV-0103-02	Close	Chemical Feed to R-0103	1			
I5	R-0103 Overtemperature	TSH-0103-07	XV-0103-03	Close	Chemical Feed to R-0103	1			
I5	R-0103 Overtemperature	TSH-0103-07	XV-0103-04	Close	Chemical Feed to R-0103	1			
I5	R-0103 Overtemperature	TSH-0103-07	XV-0103-23	Close	R-0103 Bottom Valve	1			
I6	RESERVED								
I7	Hi Line Pressure P-0301-02, P-0301-03	PIT-0301-02 OR PIT-0301-03	P-0301-02	Shutdown	Shutoff CA to P-0301-02		1		Via SV-0301-01
I7	Hi Line Pressure P-0301-02, P-0301-03	PIT-0301-02 OR PIT-0301-03	P-0301-03	Shutdown	Shutoff CA to P-0301-03		1		Via SV-0301-02
I8	Hi Line Pressure P-0301-01	PIT-0301-01	P-0301-01	Shutdown	Via Ethernet		1		
I9	R-0107 Overtemperature	TSH-0107-07	R-0107 Bottom Valve	Open	R-0107 to Quench	1		FUTURE	
I9	R-0107 Overtemperature	TSH-0107-07	TCM-0406	Shutdown	De-energize TCM Heater Contactors	1		FUTURE	

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TEL: (401) 658-4600
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Project Title
B 827 CHEMICAL SYNTHESIS PILOT PLANT

REV No	DATE	REVISIONS	DWN BY	CHK BY
0	01/31/17	RELEASED FOR CONSTRUCTION	CSCP	JH

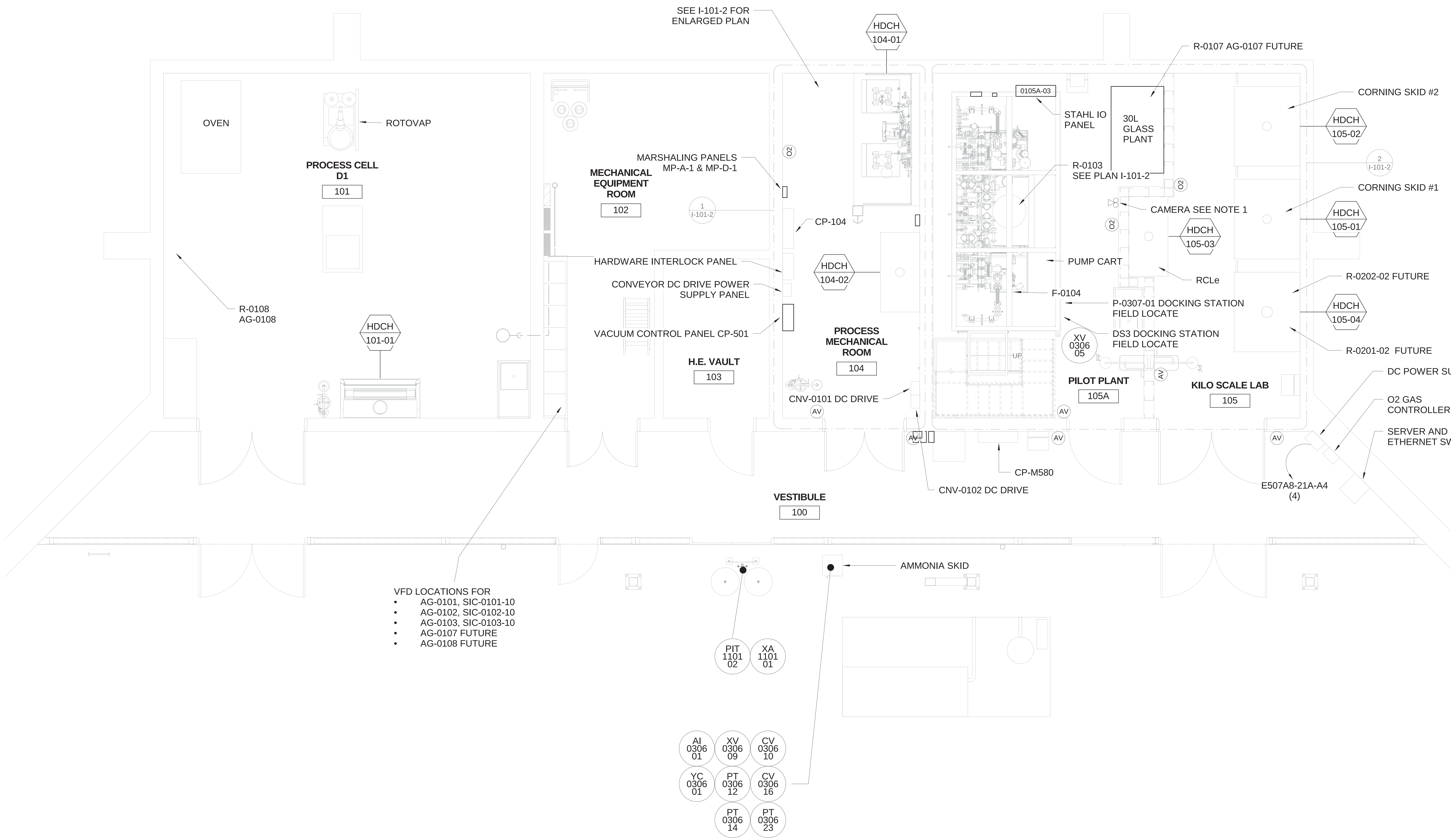
Des: J. HORWATH
Dwn: C.PEREIRA
Chk: J. HORWATH
File Name: 16022_PID-003_RFC (INTERLOCK SCHEDULE).dwg
DTN:
Scale: AS NOTED
Software: AutoCAD 2007

Sheet Title
PROCESS P&ID INTERLOCK SCHEDULE

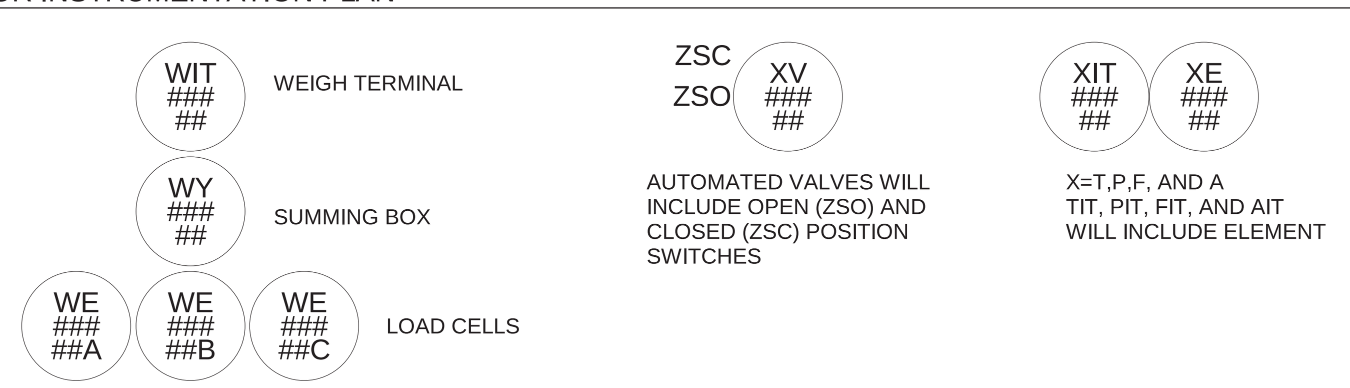
Dwg. No. PSP2016-827D-0402D
Rev.
Sht. No. PID-003 1 of 1

Classification
UNCLASSIFIED/UNLIMITED RELEASE

REV.
Dwg. No.



1 FIRST FLOOR INSTRUMENTATION PLAN
1/4" = 1'-0"



2 INSTRUMENTATION TYPICAL DETAILS
N.T.S.

PROJECT NOTES

1. SUBCONTRACTOR TO INSTALL SURVEILLANCE CAMERAS, CANTY PART NUMBER VSE5211EXP. PROVIDE 120 VAC POWER FROM NEAREST 208/120 VAC PANEL. PROVIDE CONDUIT SEAL AND SUPPORTS AS REQUIRED. SEE DETAIL SHEET E-508 DETAIL # 6 AND LEAD SHEET E-001 FROM PROJECT 16032. UPDATE PANEL SCHEDULE WITH CHANGES. PROVIDE ETHERNET CAT 6 CABLE FROM CAMERA TO ETHERNET SWITCH LOCATED IN VESTIBULE SHOWN ON THIS DRAWING.

GENERAL NOTE

- INSTRUMENTATION BUBBLES ONLY SHOW APPROXIMATE LOCATION OF INSTRUMENTS, SEE P&ID DRAWING AND PROCESS DRAWING FOR LOCATION.

DRAWING LEGEND

- O2 OXYGEN DETECTOR
- AV AUDIO AND VISUAL ALARM

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A MEMBER OF THE HART COMPANIES
HIGHLAND CORPORATE PARK
800 SCENIC VIEW DRIVE
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TEL: (401) 658-4600
FAX: (401) 658-4609
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Project Title

B827D
CHEMICAL SYNTHESIS
PILOT PLANT DESIGN

REV No	DATE	REVISIONS	DWN BY	CHK BY
A	10/24/16	ISSUED FOR BID	SPF	
0	01/31/17	RELEASED FOR CONSTRUCTION	SPF	JDK

Des: S.FITZGERALD 01/31/17
Dwn: S.FITZGERALD 01/31/17
Chk: J.KELLY 01/31/17
File Name:
DTN:
Scale: As indicated
Software: REVIT 2017

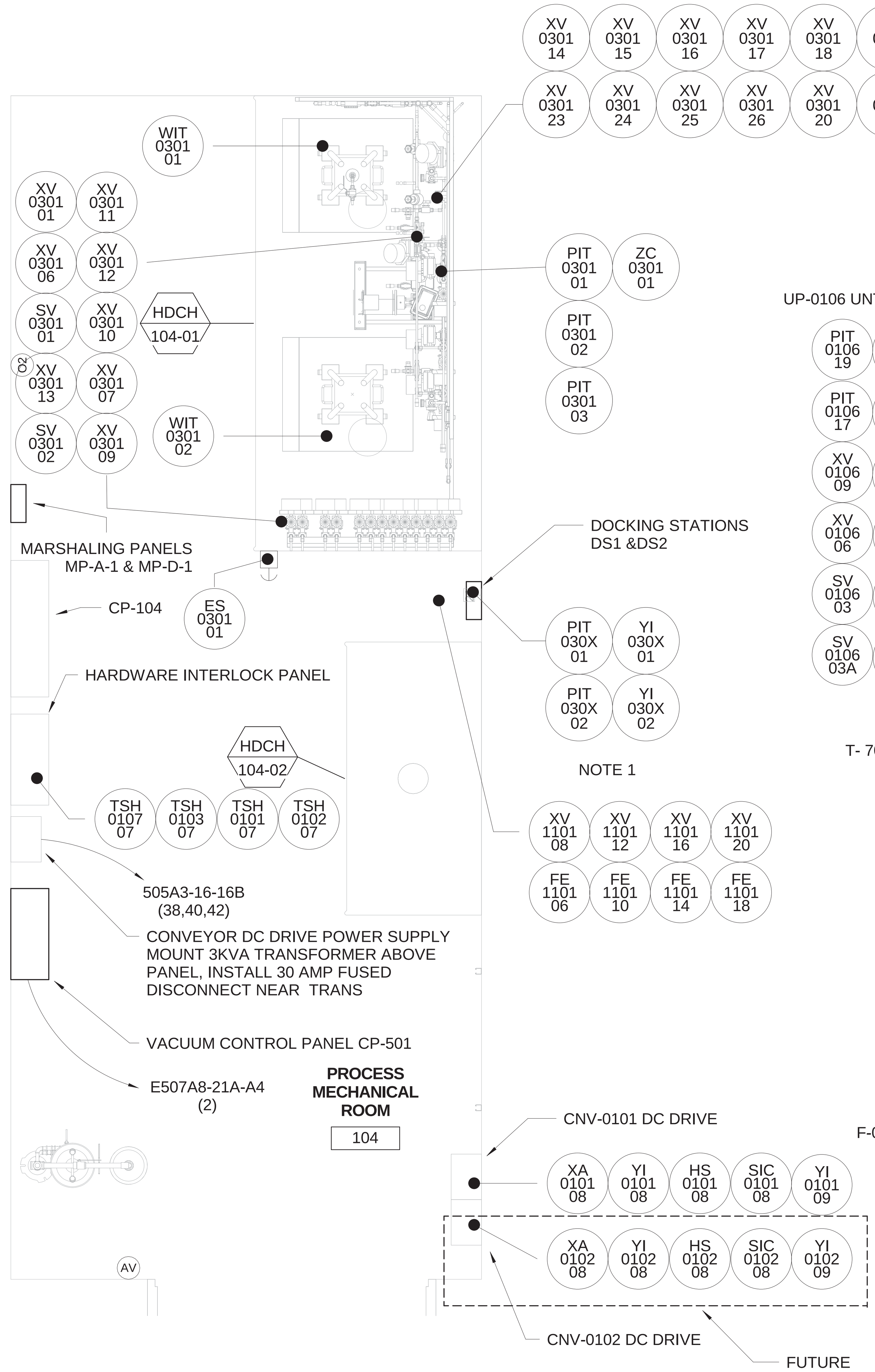
Sheet Title

FIRST FLOOR
INSTRUMENTATION PLAN

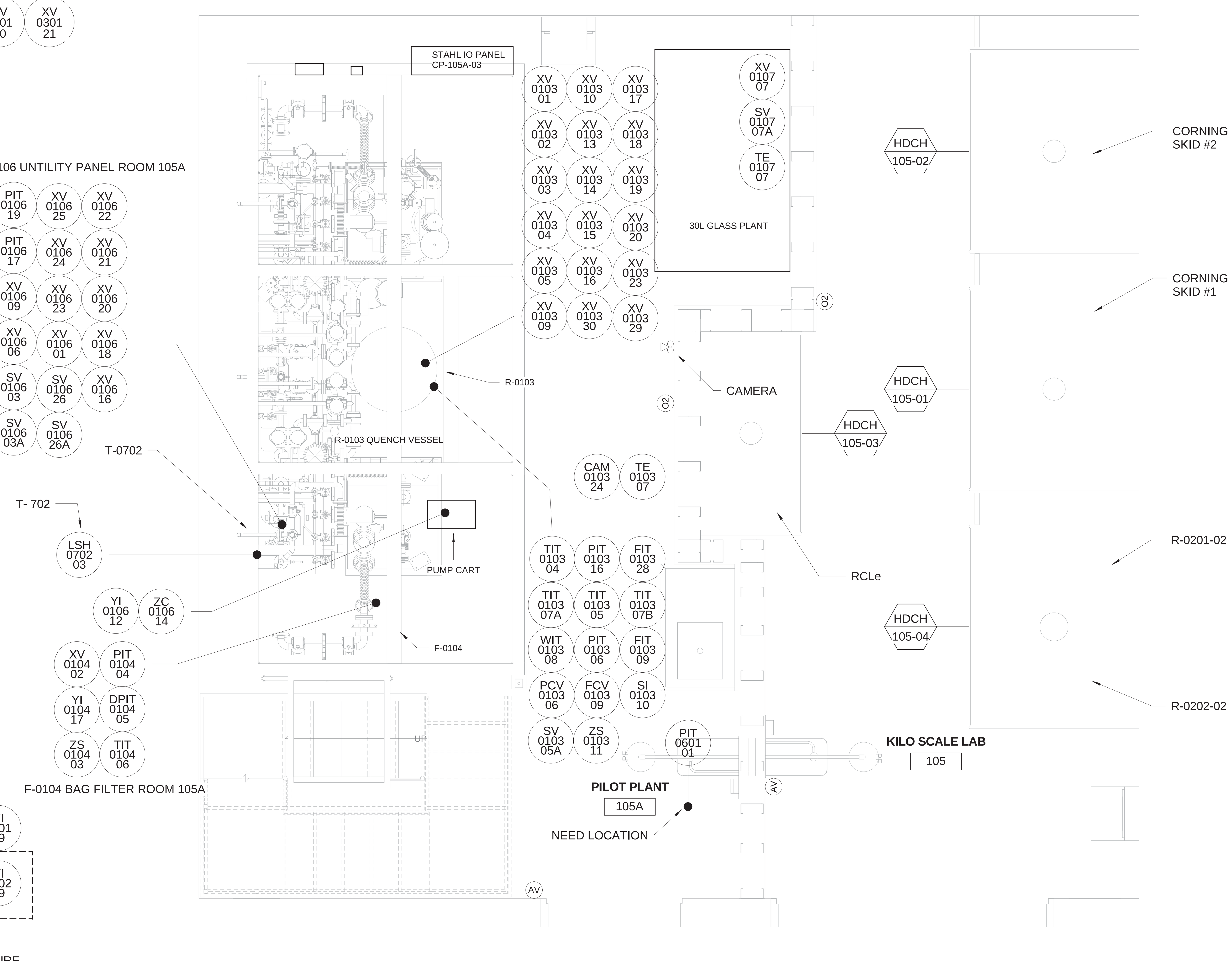
Dwg. No. PSI2016-827D-0401D
Rev.
Sht. No. I-101-1
Classification
UNCLASSIFIED/UNLIMITED RELEASE

FILE NAME:C:\Users\SFitzgerald\Documents\16022_LLNL_B827 Chemical Synthesis Pilot Plant Design_2017_seanfitzgerald6727.rvt
DATE PLOTTED: 2/6/2017 2:10:19 PM

REV.
Dwg. No. PSI2016-827D-0401D



1 FIRST FLOOR INSTRUMENTATION PLAN ROOM 104 - Callout 2
1/2" = 1'-0"



2 FIRST FLOOR INSTRUMENTATION PLAN ROOMS 105 AND 105A - Callout 1
1/2" = 1'-0"

WIT ### ##	WEIGH TERMINAL
WY ### ##	SUMMING BOX
WE ### ##A, WE ### ##B, WE ### ##C	LOAD CELLS
ZSC / ZSO XV ### ##	AUTOMATED VALVES WILL INCLUDE OPEN (ZSO) AND CLOSED (ZSC) POSITION SWITCHES
XIT ### ##, XE ### ##	X=T,P,F, AND A TIT, PIT, FIT, AND AIT WILL INCLUDE ELEMENT

3 INSTRUMENTATION TYPICAL DETAILS
N.T.S.

PROJECT NOTES

1. DOCKING STATIONS PIT-030X-01 AND PIT-030X-02 ARE USED TO CONNECT ANY TWO OF THREE PRESSURE TRANSMITTERS PIT-0303-01, PIT-0304-01, AND PIT-0305-01 ON PORTABLE CHEMICAL ADDITION TANKS T-0303, T-0304, AND T-0305.

GENERAL NOTE

- INSTRUMENTATION BUBBLES ONLY SHOW APPROXIMATE LOCATION OF INSTRUMENTS, SEE P&ID DRAWING AND PROCESS DRAWING FOR LOCATION.

DRAWING LEGEND

- O2 OXYGEN DETECTOR
- AV AUDIO AND VISUAL ALARM

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TEL: (401) 658-4600
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Project Title
B827D
CHEMICAL SYNTHESIS
PILOT PLANT DESIGN

REV No	DATE	REVISIONS	DWN BY	CHK BY
A	10/24/16	ISSUED FOR BID	SPF	
0	01/31/17	RELEASED FOR CONSTRUCTION	SPF	JDK

Des: S.FITZGERALD		01/31/17
Dwn: S.FITZGERALD		01/31/17
Chk: J.KELLY		01/31/17
File Name:		
DTN:	Scale: As indicated	Software: REVIT 2017

Sheet Title
FIRST FLOOR INSTRUMENTATION PLAN-CALLOUTS

Dwg. No. PSI2016-827D-0401D
Rev.
Sht. No. I-101-2

Classification
UNCLASSIFIED/UNLIMITED RELEASE

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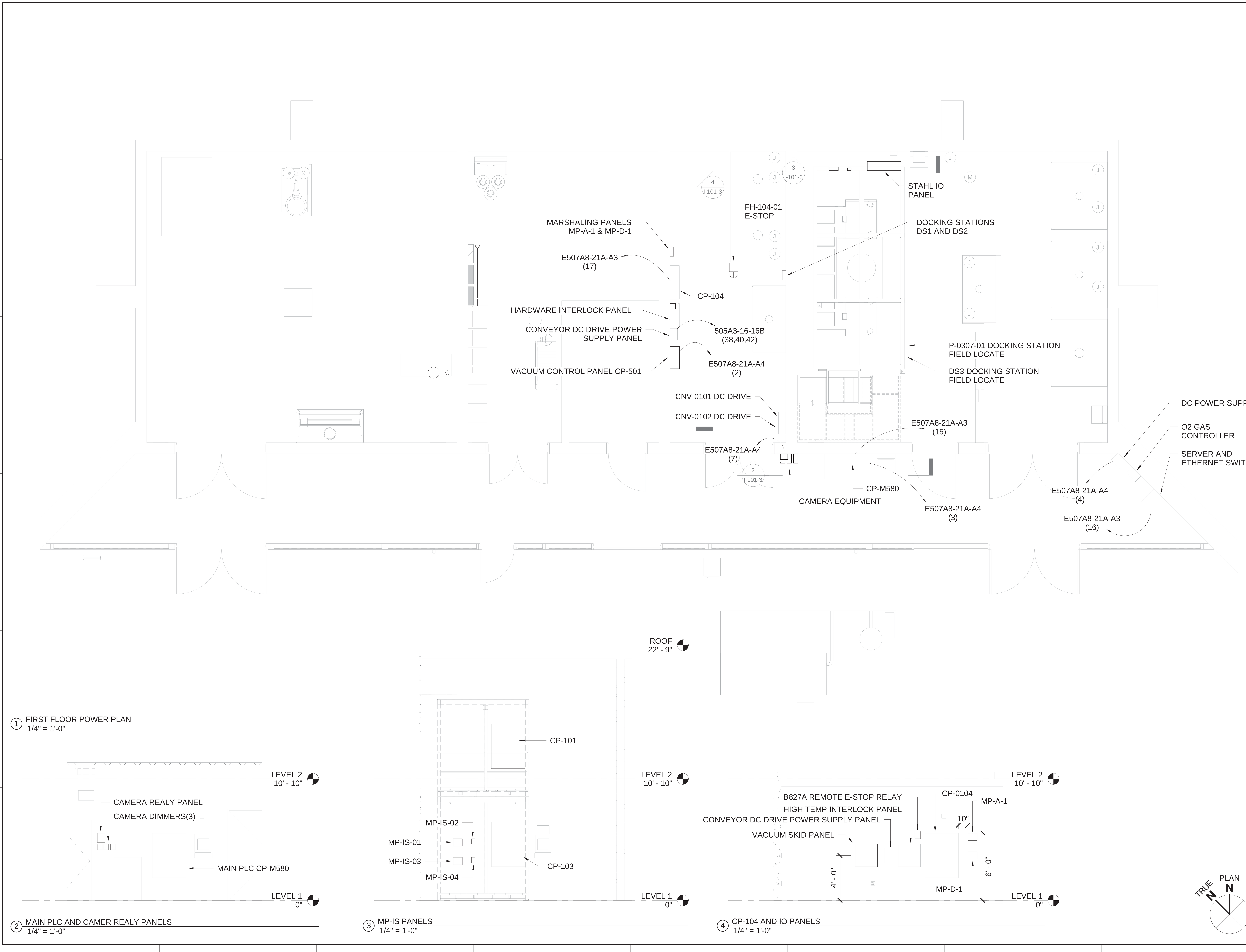
DATE PLOTTED: 2/6/2017 2:10:47 PM

REV.
Dwg. No. PSI2016-827D-0401D



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Project Title

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CHEMICAL SYNTHESIS
PILOT PLANT DESIGN

REV No	DATE	REVISIONS	DWN BY	CHK BY
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Des:	S.FITZGERALD	01/31/17
Dwn:	S.FITZGERALD	01/31/17
Chk:	M.POWERS	01/31/17

File Name:

DTN:	Scale: 1/4" = 1'-0"	Software: REVIT 2017

Sheet Title

FIRST FLOOR
INSTRUMENTATION POWER
PLAN

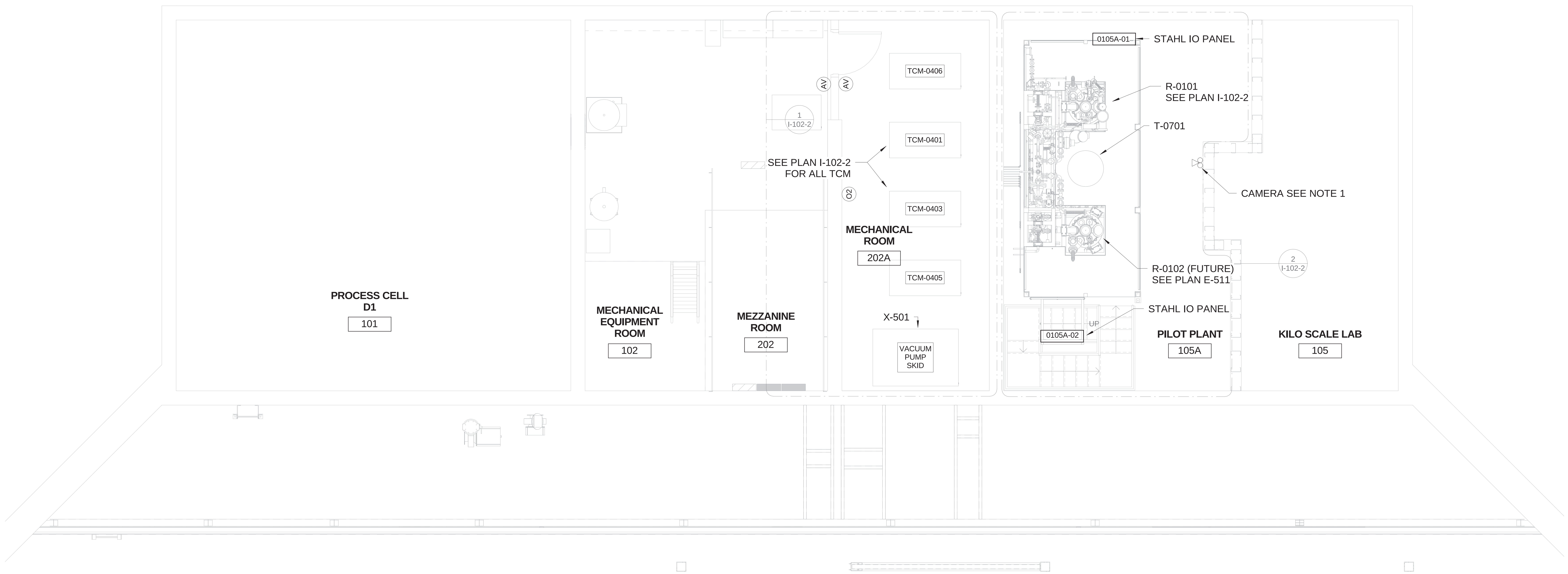
Dwg. No. PSI2016-827D-0401D Rev. 0

Sht. No. I-101-3

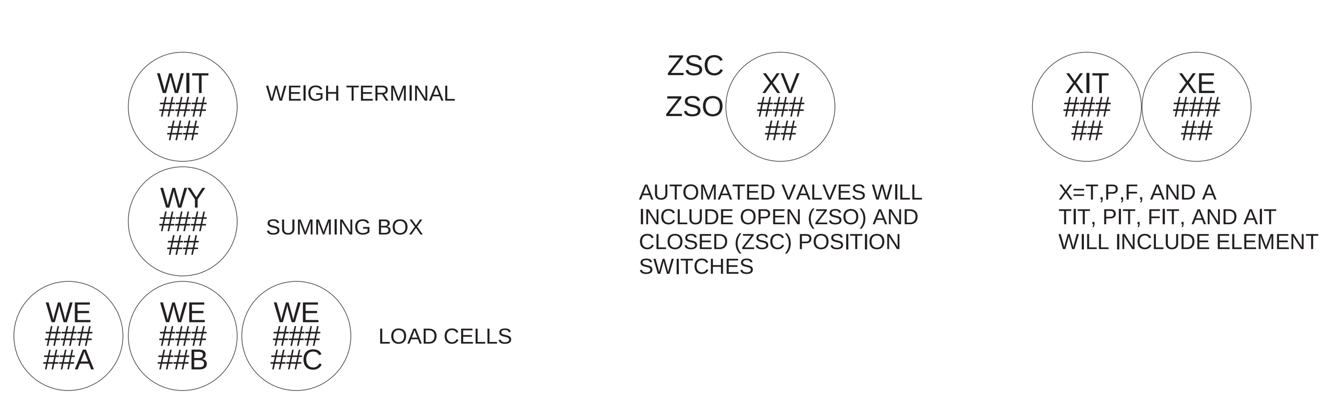
Classification
UNCLASSIFIED/UNLIMITED RELEASE

FILE NAME:C:\Users\SFitzgerald\Documents\16022_LLNL_B827 Chemical Synthesis Pilot Plant Design_2017_seanfitzgerald6727.rvt
DATE PLOTTED: 2/6/2017 2:33:55 PM

REV. 0
Dwg. No. PSI2016-827D-0401D



(1) SECOND FLOOR INSTRUMENTATION PLAN
1/4" = 1'-0"



(2) INSTRUMENTATION TYPICAL DETAILS
N.T.S.

PROJECT NOTES

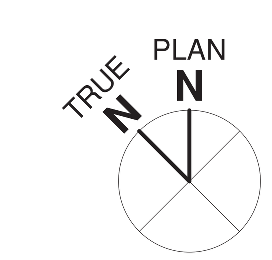
1. SUBCONTRACTOR TO INSTALL SURVEILLANCE CAMERAS, CANTY PART NUMBER VSE5211EXP. PROVIDE 120 VAC POWER FROM NEAREST 208/120 VAC PANEL. PROVIDE CONDUIT SEAL AND SUPPORTS AS REQUIRED. SEE DETAIL SHEET E-508 DETAIL # 6 AND LEAD SHEET E-001 FROM PROJECT 16032. UPDATE PANEL SCHEDULE WITH CHANGES. PROVIDE ETHERNET CAT 6 CABLE FROM CAMERA TO ETHERNET SWITCH LOCATED IN VESTIBULE SHOWN ON I-101.

GENERAL NOTE

- INSTRUMENTATION BUBBLES ONLY SHOW APPROXIMATE LOCATION OF INSTRUMENTS, SEE P&ID DRAWING AND PROCESS DRAWING FOR LOCATION.

DRAWING LEGEND

O2	OXYGEN DETECTOR
AV	AUDIO AND VISUAL ALARM



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Project Title

B827D
CHEMICAL SYNTHESIS
PILOT PLANT DESIGN

REV No	DATE	REVISIONS	DWN BY	CHK BY
A	10/24/16	ISSUED FOR BID	SPF	
0	01/31/17	RELEASED FOR CONSTRUCTION	SPF	JDK

Des:	S.FITZGERALD	01/31/17
Dwn:	S.FITZGERALD	01/31/17
Chk:	J.KELLY	01/31/17

File Name:

DTN:	Scale: As indicated	Software: REVIT 2017

Sheet Title

SECOND FLOOR
INSTRUMENTATION PLAN

Dwg. No. PSI2016-827D-0402D
Rev.

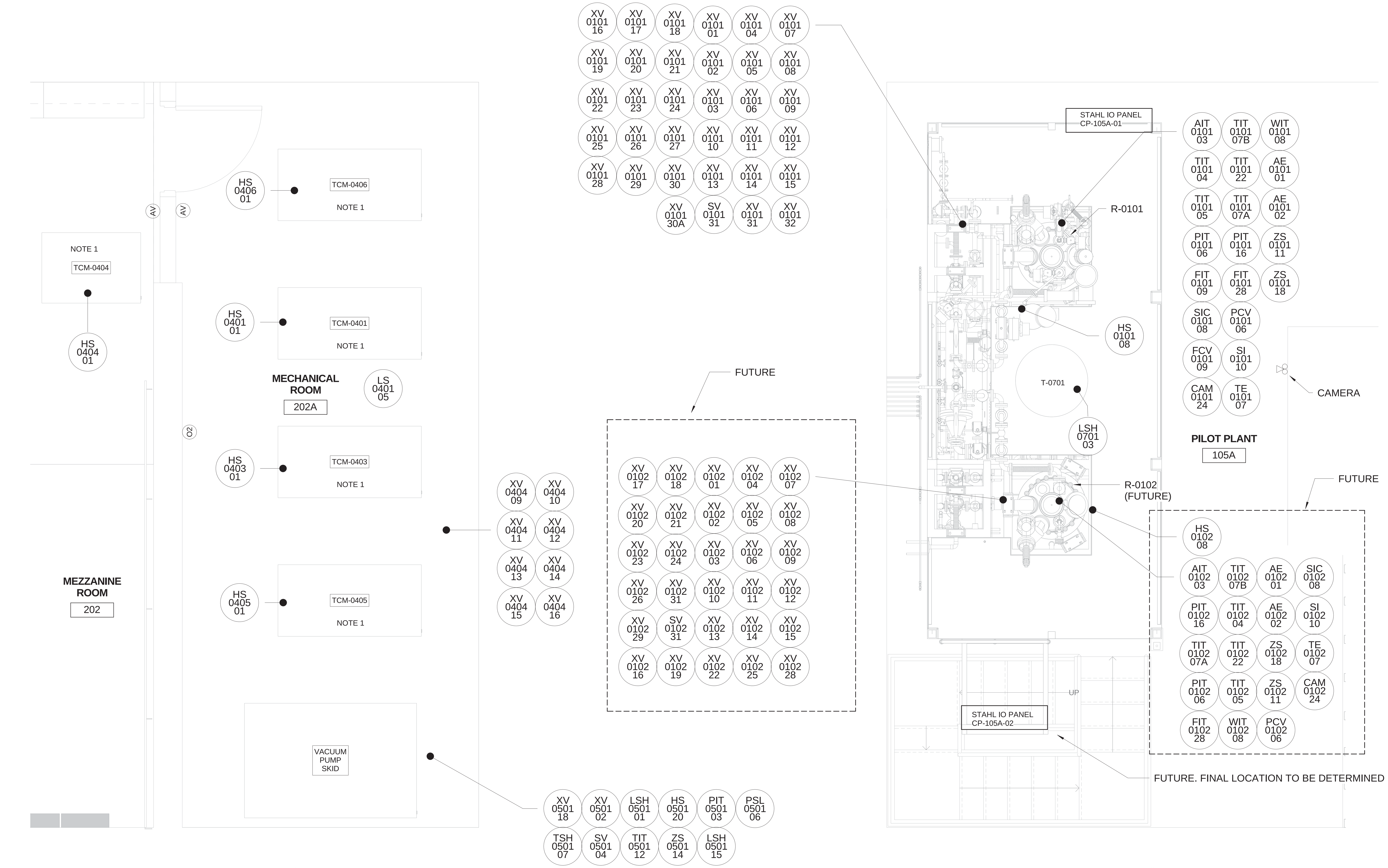
Sht. No. I-102-1

Classification
UNCLASSIFIED/UNLIMITED RELEASE

FILE NAME:C:\Users\SFitzgerald\Documents\16022_LLNL_B827 Chemical Synthesis Pilot Plant Design_2017_seanfitzgerald6727.rvt
DATE PLOTTED: 2/6/2017 2:11:10 PM

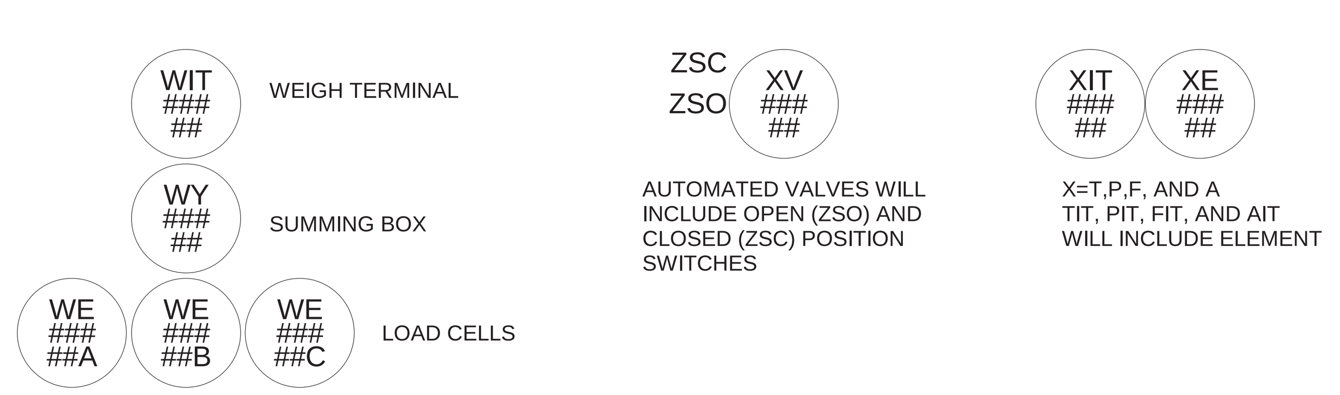
REV.

Dwg. No.
PSI2016-827D-0402D



1 SECOND FLOOR INSTRUMENTATION PLAN 16032 - Callout 2
1/2" = 1'-0"

2 SECOND FLOOR INSTRUMENTATION PLAN 16032 - Callout 1
1/2" = 1'-0"



4 INSTRUMENTATION TYPICAL DETAILS
N.T.S.

PROJECT NOTES

1. SUB CONTRACTOR TO INSTALL ETHERNET CAT 6 CABLE FROM CP-0104 TO EQUIPMENT SEE DWG I-102 PLC CONTROL SYSTEM DRAWING.

GENERAL NOTE

- INSTRUMENTATION BUBBLES ONLY SHOW APPROXIMATE LOCATION OF INSTRUMENTS, SEE P&ID DRAWING AND PROCESS DRAWING FOR LOCATION.

DRAWING LEGEND

- O2 OXYGEN DETECTOR
- AV AUDIO AND VISUAL ALARM

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Project Title

B827D CHEMICAL SYNTHESIS PILOT PLANT DESIGN

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Dwn: S.FITZGERALD	01/31/17
Chk: J.KELLY	01/31/17

File Name:

DTN: | Scale: As indicated | Software: REVIT 2017

Sheet Title

SECOND FLOOR INSTRUMENTATION PLAN - CALLOUTS

Dwg. No. PSI2016-827D-0402D Rev.

Sht. No. I-102-2

Classification
UNCLASSIFIED/UNLIMITED RELEASE

FILE NAME:C:\Users\SFitzgerald\Documents\16022_LLNL_B827 Chemical Synthesis Pilot Plant Design_2017_seanfitzgerald6727.rvt
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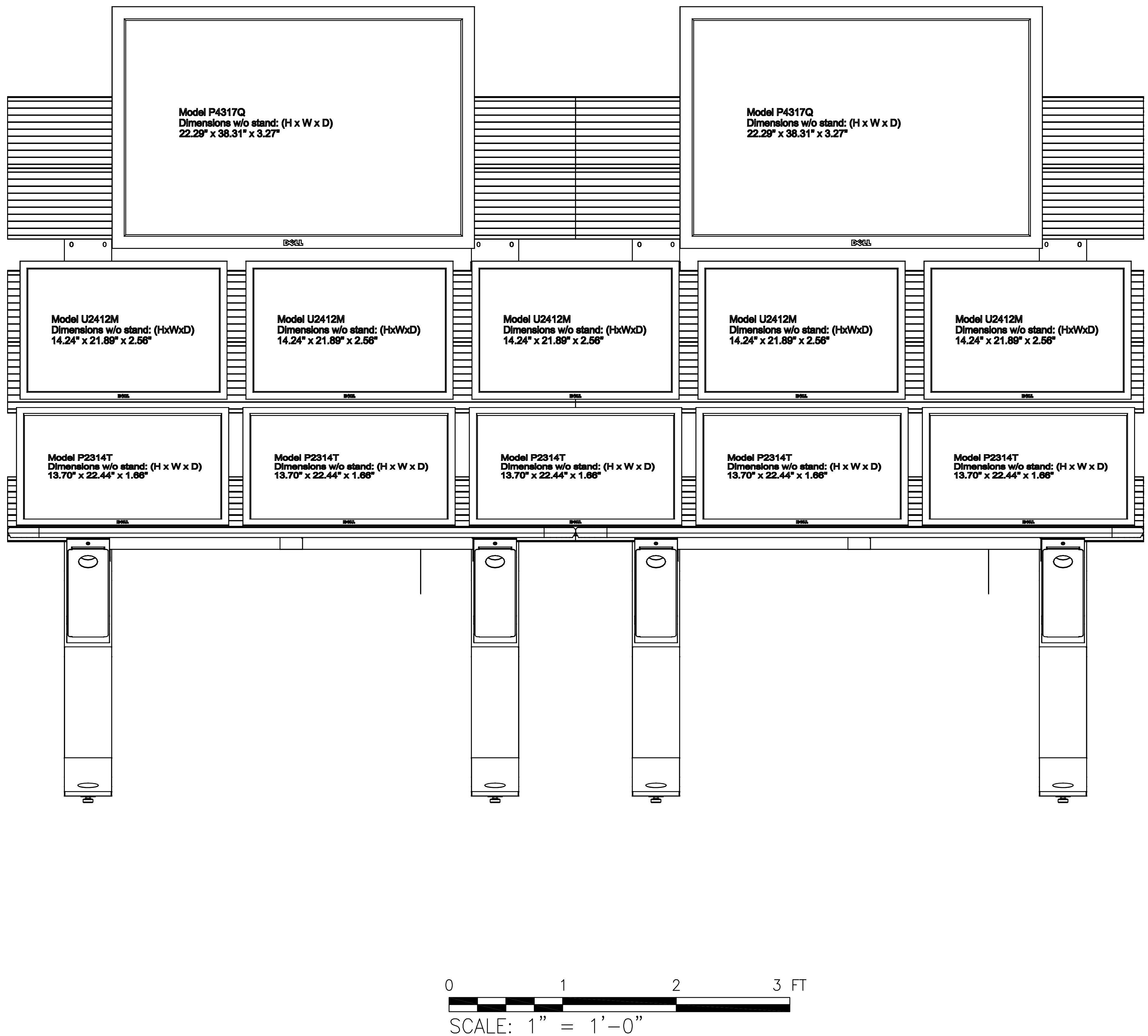

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Dimensions w/o stand: (H x W x D)
22.29" x 38.31" x 3.27"
Model P4317Q
Dimensions w/o stand: (H x W x D)
22.29" x 38.31" x 3.27"
Model U2412M
Dimensions w/o stand: (HxWxD)
14.24" x 21.89" x 2.56"
Model U2412M
Dimensions w/o stand: (HxWxD)
14.24" x 21.89" x 2.56"
Model U2412M
Dimensions w/o stand: (HxWxD)
14.24" x 21.89" x 2.56"
Model U2412M
Dimensions w/o stand: (HxWxD)
14.24" x 21.89" x 2.56"
Model U2412M
Dimensions w/o stand: (HxWxD)
14.24" x 21.89" x 2.56"
Model P2314T
Dimensions w/o stand: (H x W x D)
13.70" x 22.44" x 1.66"
Model P2314T
Dimensions w/o stand: (H x W x D)
13.70" x 22.44" x 1.66"
Model P2314T
Dimensions w/o stand: (H x W x D)
13.70" x 22.44" x 1.66"
Model P2314T
Dimensions w/o stand: (H x W x D)
13.70" x 22.44" x 1.66"
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Dimensions w/o stand: (H x W x D)
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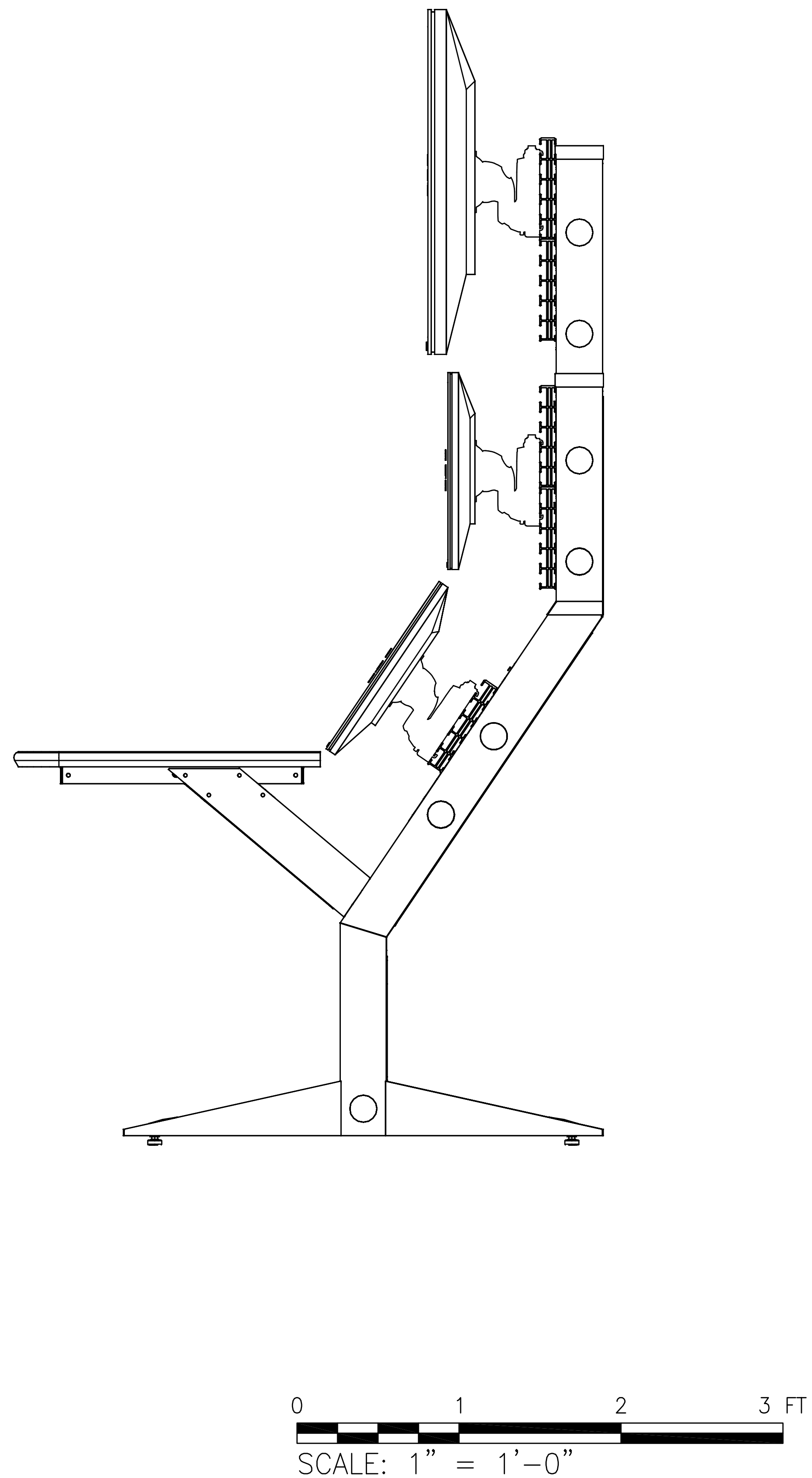


0 1 2 3 FT
SCALE: 1" = 1'-0"

Control System Integration
B827 Complex
Chemical Synthesis Pilot Project

—

Commentary on
Control System Architecture

March 30, 2017

Revision A

Lawrence Livermore National Laboratory

Overview

The control system architecture and associated hardware and software solution set has been pre-selected and specified by LLNS. Much of the control room hardware and shrink-wrapped software will be procured by LLNS and provided to the System Integrator as Government Furnished Equipment (GFE). The field I/O cabinets, HMIs, and field control devices will be provided by LLNS as LLNS Government Furnished Equipment (GFE). Specific lists appear in Attachments to the Statement of Work.

The underlying design principles for this control system architecture are:

- Provide a robust, fault-tolerant control system consistent with the application
- Be consistent with the existing solutions sets used at LLNL Site 300, and the associated skills and knowledge of the existing Site 300 operations and support resources
- Rationalize and modularize component selections so that the same elements of design are re-used as much as practical; minimize the number of different solution elements required to deliver a functioning system
- Deliver an intuitive and easily understood and supportable infrastructure architecture
- Provide a flexible set of human-machine interfaces, both in the control room workstations and in the process area; modularize designs to maximize re-use of hardware components and software objects
- Allow for future control system growth and application changes with relatively simple additions and modifications to underlying infrastructure elements – both hardware and software
- Deliver an intuitive and consistent look-and-feel to all the human-machine interfaces in all areas as much as practical, and have a consistent user human-machine interface and experience at all locations
- Design the infrastructure to support operations and control in two separate buildings; ensure that connectivity between buildings is robust and fault tolerant consistent with the application
- Provide infrastructure to support and robustly address requirements identified in the Process Hazards Analysis (PHA) reviews

These principles led to the specific solution sets described hereinafter.

1.0 Salient Details - Hardware

To be consistent with the current installed base at LLNL Site 300, a Modicon® M580 ePAC system with Wonderware SCADA solution was chosen.

Virtual machines as a solution for the need for multiple PC operating systems (and even single user workstations) is an emerging solution being installed throughout the LLNL complex. It clearly provided significant benefits in system fault-tolerance / robustness, system support (particularly maintenance, troubleshooting, and upgrades), as well as being cost effective given this project's SCADA multiple operating system requirements.

The Virtual Device Interface (VDI) approach is being used for all SCADA control room operator workstations and field SCADA Remote Terminal Human-Machine Interfaces (HMIs). All are connected to the control network via zero-client access points communicating over Ethernet to the virtual machine servers.

Additional fault-tolerance features of a hot standby PLC processor configuration, a self-healing Ethernet Remote I/O (RIO) dual-ring, and fiber-optic control Ethernet network were provided.

The hardware solution set consists of:

1. Two Modicon® M580 ePAC Programmable Logic Controllers (PLCs) in a hot-standby configuration as one logical PLC processor

2. Modicon® X80 Ethernet Remote Input/Outputs (ERIO) in a dual-ring redundant cabling configuration

3. Two Stahl-brand intrinsically-safe remote I/O cabinets (RIO), with provision for a third future I/O cabinet

4. A cluster of three VMware® virtual machine servers, along with control room-located Server (10 Gb) and Core (1 Gb) network switches, as wells as field Distributed I/O, 'Remote Terminal' Human Machine Interfaces (HMIs), and video 1Gb network switches

5. Supervisory Control and Data Acquisition (SCADA) Virtual Desktop Interface (VDI) workstations, both in the control room (approximately eight screens fed by five zero-clients), and two field Remote Terminal HMIs each with a zero-client.
   [All running virtual machine-served Wonderware System Platform InTouch, and related applications.]

6. Process reactor vessel analytical video and process area room video monitoring cameras and displays

7. Various process area Input-Output and control component enclosures and related supporting elements

8. Two Remote Terminal Human-Machine Interfaces:

   These are industrial class, environmentally-hardened operator workstations running virtual machine-served Wonderware InTouch, and related applications. They will be equivalent in functionality to those in the Control Room.

   Located in the Process Synthesis Building, they will be used to facilitate process equipment configurations checklists, raw material prompts and verifications, and log entry for all step completions. They will be connected to the virtual servers as virtual desktop interfaces using local zero-clients for keyboard, mouse, and video services.

9. Local process area machine and device-level control stations, and process utility system controls

2.0 Salient Details – Commercial Off-the-Shelf (Shrink-Wrapped0 Software

The shrink-wrapped software solution set, running on the virtual machine (VM) VMware® servers, consists of:

1. Wonderware®, and related applications
   - 1.1 System Platform
   - 1.2 Galaxy Repository
   - 1.3 InTouch
   - 1.4 InBatch®
   - 1.5 IVC Longwatch™
   - 1.6 Historian
   - 1.7 Win-911® Alarm Audio Notification
   - 1.8 . . . and related Wonderware supporting products

2. Modicon® Unity™ Pro PLC development environment

3. SCADA interface drivers for a suite of Distributed I/O

4. Other system support applications for the aforementioned shrink-wrapped COTS software packages

3.0 Salient Details – Distributed I/O:
Pre-engineered Process and Utilities System Elements Communicating via Ethernet IP

There are also multiple instances of pre-engineered equipment that the Control System Integrator Subcontractor will configure and integrate an interface into the control system as digital Distributed I/O items. This Distributed I/O is as follows:

1. Variable frequency drives (VFDs) in the Motor Control Center
   Tag Numbers:
   SIC-0101-10 for Synthesis Reactor Agitator AG-0101
   SIC-0102-10 for Synthesis Reactor Agitator AG-0102 [Future agitator; VFD being installed now]
   SIC-0107-10 for Synthesis Reactor Agitator AG-0107 [Future agitator; VFD being installed now]
   SIC-0108-10 for Synthesis Reactor Agitator AG-0108 [Future agitator; VFD being installed now]
   SIC-0107-10 for Synthesis Reactor Agitator AG-0202 [Future agitator; VFD being installed now]
   SIC-0103-10 for Quench Reactor Agitator AG-0103
   SIC-0301-01 for Raw Material Metering Pump P-0301-01
   SIC-0307-01 for Raw Material Metering Pump P-0307-01
   SIC-0101-01 for AG-0101

   General Electric AF-6 Series drives mounted in a General Electric Motor Control Center

   Control & Monitoring Interface:
   ODVA EtherNet Industrial Protocol (EtherNet/IP™)
   via General Electric Product № OPCEIP Ethernet IP Communications Module

2. Temperature Control Modules
   Tag Numbers:
   TCM-0401 serving Synthesis Reactor R-0103
   TCM-0403 serving Quench Reactor R-0103
   TCM-0404 serving Reactor Condensers E-0101 and E-0103
   TCM-0405 serving Utility Station UP-0106

   Budzar Industries, Inc. Willoughby, OH

   Control & Monitoring Interface:
   ODVA EtherNet Industrial Protocol (EtherNet/IP™)
   via Allen-Bradley CompactLogix™ EtherNet/IP™ Communication Module,
   Catalog № 1768-ENBT

3. Dry Bulk Solids Loss-in-Weight Volumetric Feeders
   Tag Numbers:
   CNV-0101 serving Synthesis Reactor R-0101
   CNV-0102 serving Synthesis Reactor R-0102 FUTURE

   Coperion K-tron Pitman, Inc. Sewell, NJ

   Control & Monitoring Interface:
   ODVA EtherNet Industrial Protocol (EtherNet/IP™)

   Field Wired I/O:

RUN Permissive output from Modicon® dry contact output card
Feed Rate analog set-point from Modicon® 4-20mADC analog output card

4. Fixed process batching vessel weigh scales – Toledo Scale

5. Portable weigh scales for liquid raw material loading and feeding – Toledo Scale

6. Central Process Vacuum Pump – Tag VP-0501

   Busch Cobra Model NC0100.BM06.41VG

   Control & Monitoring Interface:
   ODVA EtherNet Industrial Protocol (EtherNet/IP™)
   via Modicon® M340 EtherNet/IP™ Communication Module, Catalog № BMX NOC 0401

   Field Wired I/O: RUN Permissive output from Modicon® dry contact output card

7. Process Chiller – Tag X-3001

   Multistack, Sparta, WI

   Control & Monitoring Interface:
   BACnet over MS/TP (Master-slave/token-passing)
   passing through a LLNL-furnished Automated Logic Control (Kennesaw, GA) Model LGR25 router, with a TCP/IP uplink to the Control System.

   Field Wired I/O: RUN Permissive output from Modicon® dry contact output card

8. Solenoid Valve Control Panel Manifold

   Festo
   Hauppauge, NY

   Control & Monitoring Interface:
   ODVA EtherNet Industrial Protocol (EtherNet/IP™)
   via EtherNet/IP™ Bus Node Module, Type CPX-FB36, Catalog № 1912451

9. Process reactors (Quantity 2) and particle-size analytical (Quantity 1) video

   Canty Process Technology
   JM Canty, Inc. Lockport, NY

   Monitoring Interface:
   CantyVisionClient™ Software

Ethernet TCP/IP

10. Process Room 105A Video

    Bosch Pan-Tilt-Zoom (PTZ) cameras into control system
    via Ethernet via Wonderware Longwatch™ IVC converter

    Monitoring & Camera Control Interface:
    Ethernet TCP/IP from Wonderware Longwatch™ IVC interface

11. Building HVAC monitoring

    Monitoring Interface (Control of Building HVAC is not in scope):
    LLNS-furnished Automated Logic Control (Kennesaw, GA) Model LGR25 router, with a TCP/IP uplink to the Control System.

4.0 Control System Architecture - Requirements of Control System Integrator

The Control System Integration Subcontractor shall do all the following:

1. Assess the entire control system architecture, identify, and provide any additional components, both hardware and software, required for a complete functioning process control system not listed as provided by LLNS as LLNS Government Furnished Equipment (GFE), or as part of the field installation infrastructure provided by the LLNS field installation contractor (cabling, power, etc.) to meet all requirements contained in the *Control System Functional Specification.*

2. Provide programming and configurations required to meet all requirements contained in the *Control System Functional Specification.*

3. Where available from original equipment manufacturer, use that manufacturer's EtherNet Industrial Protocol (EtherNet/IP™) Device Type Manager, aka 'DTM' interface configuration. Using the OEM's DTM will ensure the most efficient, accurate, and robust communications interface.

4. For the Supervisory Control and Data Acquisition (SCADA) Virtual Desktop Interface (VDI) workstations, both in the control room (approximately eight screens fed by five zero-clients), and two field Remote Terminal HMIs each with a zero client, use to the maximum extent practicable a touch-screen interface approach. One set of Control Room LCD screens, the center tier on the control console, has been specified as the control screen set.

    The CSI Subcontractor shall incorporate maximum usage of LCD touch screens for data entry, control manipulation (buttons and sliders), and related needs for operator interaction with the SCADA system.

The goal is to optimize the user interface to the process control system, while minimizing the number of keyboards and mouse pointers on the console desk and in the field.

5. For all control system infrastructure elements, read any available element status, warning, and fault data and display as warnings and alarms, as appropriate, in the SCADA system. All these warnings and alarms shall be logged in the SCADA alarm management system and included in the batch record for the batch being made.

The control system infrastructure status, warning, and fault data shall be acquired from, but not limited to, the following:

5.1 Modicon® PLC system elements:
- a) M580 ePAC Processors
- b) X80 Power Supplies
- c) All X80 input, output, and communication cards

5.2 All field devices communicating via Distributed I/O, including, but not limited to the following:
- a) Stahl Intrinsically-Safe I/O
- b) General Electric MCC Variable Speed Drives
- c) General Electric MCC Fixed Speed Motor ControllersX80
- d) Budzar Temperature Control Modules
- e) Busch Vacuum Pump
- f) Toledo weigh scale system
- g) K-tron bulk solids loss-in-weight feeder

5.3 Control Room information technology infrastructure elements:
[Note: IP address, word, bit, and tag data to be provided by LLNS WCI IT]
- a) Virtual Machine Servers
- b) All network switches – Control Room and Process Synthesis areas
- c) Zero Clients
- d) Uninterruptable Power Supplies


FUTURE
To B801 & B191
via WISEnet
For:
WCI IT Tech Support
S300 Control Sys Support
WW Enterprise Historian
FUTURE WISEnet
Zero Client
Room 105A Video_1
Room 105A Video_2
Room 105A Video_3
Virtual Desktop Interfaces
Operating System V04
WW/IVC Longwatch
Video Control
Video Engine
Video Storage
Synthesis Reactor R-0101 Contents Video
[Future] Synthesis Reactor R-0102 Contents Video
Quench Reactor R-0103 Contents Video
Reactor Particle Size Video
Crash Button [Hardwired]
Fail-Safe FWIO Input to High-Temp Interlock Panel
Process Trend_2
Process Trend_1
Process Warnings & Alarm Handling
Batch Set-up + Utilities
Process Sequence Dashboard
Process Mimic_2
Process Mimic_1
System Support
Color Printer
Operating Systems V01A, V01B, V02, V03, & V06
WW InTouch
Visualization Ap
Boots Ap
WW Trend Tool
To B827D VIDEO Network Switches in Vestibule Network Rack
Operating System V05
Modicon Unity Pro
Cisco Switch Mgmt.
VMWare Mgmt.
Operating System_V06
Mettler-Toledo IC-IR Weigh Scales
CantyVision Particle Size Ap
BACnet Comms Process Chiller Temp. Control Modules
Instrumentation & Utilities
Operating System_V05
Modicon Unity Pro
Cisco Switch Management Console
VMWare Management Console
Unitrends Enterprise Backup
System Support Aps
PLC Network 1 Gb F.O.
827 Complex Control Room 1 Gb 'CORE' SWITCHES
Fiber
Copper
Cisco Switch Links
PLC Network Copper Express Links to VM Server Cluster
827 Complex Control Room 10 Gb SERVER SWITCH
PLC Network 1 Gb copper 'Express Links' from Core Switch to each Virtual Server (3 Total) using VLAN Tagging + Port Security (MAC Address Filtering) for WW AOS aps on V01A & V01B
VM Server Cluster O.S., Storage, & Back-Up Links 4 F.O. per Server (2 Network + 2 Storage) 12 Total
Virtual Machine Cluster of 3 Rack Servers
Dell R730 Servers with 2 x 2.4GHz 10-core Xeon, HT
Operating System_V01A
WW InBatch
WW Ap Engine
WW DA / OI
WIN-911 Pro
Automation Object Server - A
Operating System_V01B
WW InBatch
WW Ap Engine
WW DA / OI
WIN-911 Hot Backup
Automation Object Server - B
Operating System_V02
WW System Platform Galaxy Repository
WW Development System
MS SQL Server
Operating System_V03
WW Historian
MS SQL Server
WW InBatch Database
Operating System_V04
IVC Video Control
IVC Video Engine
Video Storage
Est. @ <200GB per Month
B827A Control Room
B827D Chemical Synthesis Pilot Process Area
DIO Ethernet Self-Healing RSTP Ring - Copper
B827D Vestibule Distributed Control Network Switch w/RSTP
2 x PLC Network Modbus TCP/IP Fiber to Control Room Core Switch
Primary
Standby
Modbus TCP/IP TO DIO RSTP Switch
Modicon X80 Remote I/O Self-Healing Ring
ALC LGR-25 Router
BACnet to TCP/IP Router
BACnet MS/TP (RS-422)
X3001 Process Chiller
FWIO
Media Converters
ERIO
Vestibule X80 I/O
NH₃ Gas Supply System
Facility Status Safety-Interlock System [Process Operating Permissive]
Needs Definition
Vestibule Control Panel CP-M580
B827D Control Network Rack in Vestibule
PLC Network Ethernet TCP/IP Fiber to Control Room Core Switch
B827D CONTROLS DISTRIBUTION 1 Gb SWITCH
TCP/IP
RS-170 & RS-485 to Ethernet Converters
RS-170 & RS-485
To B827D Control Network Rack in Vestibule
VESTIBULE Remote Terminal HMI
To B827D Control Network Rack HMI Switch in Vestibule
Lower Skid Remote Terminal HMI PURGED
Room 105A R-0101 Cam
Room 105A R-0102 FUTURE Cam
Room 105A R-0103 Cam
Room 105A R-0101&2 Particle Size Cam
Reactor Analytic Sensor
Room 105A Cam № 1
Room 105A Cam № 2
Room 105A Cam № 3
To B827D Vestibule Distributed Control Network Switch
TCP /IP
Raman Spectrom
FTIR (Future)
Process Analytic Sensors
Modbus TCP/IP F.O.
I.S. FWIO [Stahl] CP-105A-01 [Synthesis Reactor R-0101]
I.S. FWIO [Stahl] CP-105A-02 [Future Synthesis Reactor R-0102]
I.S. FWIO [Stahl] CP-105A-03 [Quench Reactor R-0103]
Intrinsically Safe FWIO
Process Filter F-0104 Docking Station
Metering Pump P-0307-01/03 Docking Station
30L. Reactor R-0107 [Future]
FUTURE
To B827D Control Network Rack in Vestibule
R101 FUTURE Remote Terminal HMI
R105 FUTURE Remote Terminal HMI
TCM Valve Limit Sws.
CP-M580-based I/O (Unless otherwise noted)
CP-104-based I/O
FWIO (Analog)
DIO TCP/IP
WIT-0101-08 R-0101
WIT-0102-08 R-0102 FUTURE
WIT-0103-08 R-0103
Weight Transducers in R104
Reactors R-101, -102, &-103 Camera Light Control Panel R104
PVM-0501 Vacuum System
R202A
N2 Gas Supply System FUTURE
CP-104 Room 104 X80 I/O
Reactor High-Temp Interlock Panel R104
Metering Pump PIT-030x-01 Docking Station
Metering Pump PIT-030x-02 Docking Station
R104
DIO Modbus TCP/IP
TCM-0401
TCM-0402
TCM-0403
TCM-0404
TCM-0405
TCM-0406
R202
Future
R202A
VFD 1
VFD 2
VFD 3
VFD 4
VFD 5
VFD 6
MCC in R102
Valve Control Panel R104
CNV-0101
CNV-0102
Controllers in R104
CP-104 R104 Distributed Control Network Switch w/RSTP
DIO Ethernet Self-Healing RSTP Ring - Copper
LEGEND
FWIO Field Wiring I/O; Discrete or Analog individual points wired to PLC I/O cards
ERIO Ethernet Remote I/O; the media and protocol (EtherNet/IP™ standard from ODVA®) used by Modicon M580 PLCs to communicate with its remote I/O infrastructure.
DIO Distributed I/O; TCP/IP control & monitoring data connected to PLC and/or SCADA
SCADA System Supervisory Control & Data Acquisition; human-machine interface to PLC for all control, trending, alarms, recipe management, report generation, video monitoring & recording, etc.
PLC Programmable Logic Controller; provides robust 'industrial-strength' solving of logic, counting, timing, and closed loop control functions. Time resolution of control is deterministic; typically ≤ 20 mSec. total from change in input state -to- solve logic -to- change in output state.
Rev. 16 – 13 April 2017
LLNL WCI
B827 Chem. Syn. Pilot Project
Control System Architecture
W:\B827D Pilot Plant\Control System Integration\Control System Architecture & Block Diagram\B827D CSPP - Control System Architecture - Rev 16 - 2017 04 13A.vsdx

COMMENTARY

Control System Architecture For Mechanical System Integration Factory Acceptance Test

Control System Integrator Subcontractor to provide PLC communicating PCs with and sufficient application software to run logic to mechanically and hydraulically test systems shown on right.

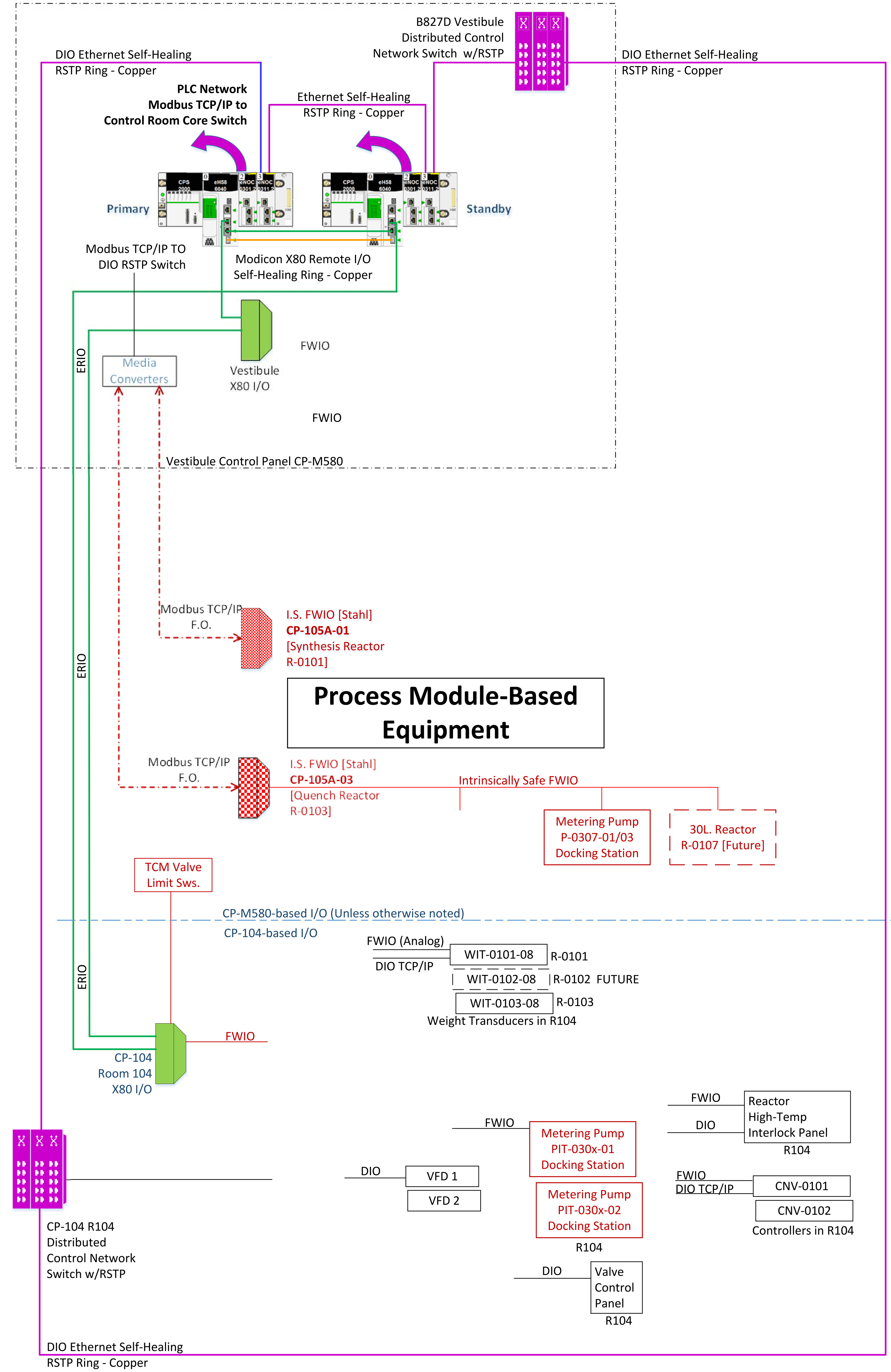
The goals of this FAT are:

1. PLC or High Temperature Interlock Panel -to- sensor or final control element loop testing of all batch process module-based equipment, ***except the following***:
 - o All Temperature Control Modules (TCMs) and related heat and cooling clients
 - o Vacuum system
 - o N_2 system
 - o Liquid raw material loss-in-weight feed system (Pumping system will be tested)
 - o NH_3 Gas Supply System
 - o RAMAN spectrometer
 - o All video cameras and related control
 - o Process Filter

2. Validate full functionality of the Reactor High Temperature Interlock panel

PLC for this testing may be operated in a completely manual mode using actual Control System Dataset adderssing and forced inputs and outputs for loop testing. Logic, timing, counting, and loop controls are NOT REQUIRED,

The SCADA System (Wonderware InTouch and InBatch) monitoring and control functionality is NOT REQUIRED.



LEGEND

FWIO	Field Wiring I/O; Discrete or Analog individual points wired to PLC I/O cards
ERIO	Ethernet Remote I/O; the media and protocol (EtherNet/IP™ standard from ODVA®) used by Modicon M580 PLCs to communicate with its remote I/O infrastructure.
DIO	Distributed I/O; TCP/IP control & monitoring data connected to PLC and/or SCADA
SCADA System	Supervisory Control & Data Acquisition; human-machine interface to PLC for all control, trending, alarms, recipe management, report generation, video monitoring & recording, etc.
PLC	Programmable Logic Controller; provides robust 'industrial-strength' solving of logic, counting, timing, and closed loop control functions. Time resolution of control is deterministic; typically ≤ 20 mSec. total from change in input state -to- solve logic -to- change in output state.

Rev. 15 – 28 Mar 2017

LLNL WCI
B827 Chem. Syn. Pilot Project
Control System Architecture
For Mechanical Integrator FAT

Control System Integration
B827 Complex
Chemical Synthesis Pilot Project

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Commentary on

Schedule of LLNS Government Furnished Equipment

April 12, 2017

Revision A

Lawrence Livermore National Laboratory

1.0 Overview

This is a commentary associated with Attachment 7, *Schedule of LLNS Government Furnished Equipment*.

This schedule represents a compilation of the major elements of the control system, grouped as follows:

- Information Technology (IT) Hardware
- IT Software Licenses
- Operations Control Room and Support Technical Workstation Hardware
- SCADA Software Licenses
- Video Software Licenses & Hardware
- B827D Vestibule Network Rack Enclosure + 24VDC UPS
- Chemical Synthesis PLC Control Panel (Hart Design Group Tag CP-M580)
- Raw Material Supply Control Panel (Hart Design Group Tag CP-104)
- Reactors High Temperature Interlock Panel
- Field Human-Machine Interface (HMI) Control Panels
- Miscellaneous Control Equipment

Some, but not all, of the hardware and software licenses for Control System Integrator Subcontractor system development will be provided to the CSI Subcontractor for their development use.

What is, and is not, being provided to the CSI Subcontractor for their development use is shown in Schedule Column titled "Provided by LLNS to CSI for System Development", with a YES or NO in each applicable field below.

All the control panels, enclosures, and related internal components will be provided by LLNS, and shipped to the CSI Subcontractor for development and CSI_FAT testing.

2.0 Requirements of Control System Integrator

Using the *Schedule of LLNS Government Furnished Equipment* the Control System Integrator Subcontractor shall:

1. Provide hardware required for system development consistent with all the functionality indicated in this *Statement of Work and Specification*.

   Note: This includes, but is not limited to, the virtual machine servers, and related virtual machine operating software.

2. Provide hardware capable of running, concurrently, the entire suite of applications shown on the *Control System Architecture* – see Attachment 6 - Control System Architecture.

3. Provide Wonderware® System Development Software.

For the duration of the system development at the CSI Subcontractors' site, and at the Mechanical System Integrators FAT, the CSI Subcontractor shall provide the entire suite of Wonderware® software required for system development using a Wonderware® Advanced Development Studio Consignment License set, also known as a Wonderware® System Integrator License.

The Industrial Video & Control (IVC) / Wonderware® Longwatch™ development software will be provided to the CSI Subcontractor by Wonderware® / IVC™ directly.

The WIN-911® Professional software licenses will be provided to the Control System Integrator Subcontractor by LLNS.

4. Receive, set-up, and provide interconnecting cabling and wiring for all control panels and enclosures provided by LLNS, for system development and testing.

B827D Chemical Synthesis Pilot Project:

Bill of Materials - LLNS Supplied to Control System Integrator

Provided by LLNS to CSI for System Development				Qty.	Manufacturer	Model
	IT Equipment & Shrink-Wrapped Software					
		IT Hardware Equipment				
NO			Virtual Machine Servers	3	Dell	PowerEdge R730 Server: 2 x 2.4GHz 10-core Xeon, HT
NO			10Gb SERVER Network Switch - 24 Port	1	Cisco	C3850-24XS-S w/ dual 715WAC power
NO			1 Gb CORE Fiber Network Switch - 24 Port	1	Cisco	C3850-24S-S w/ dual C350WAC power and (1) 4x1GE NM
NO			1 Gb CORE Copper Network Switch - 24 Port	1	Cisco	C3850-24T-S w/ dual 350WAC power and (1) 4x1GE NM
NO			Fiber Optic Interface 'SFP' Modules for above	1	Curvature	14@1GbLC + 12@10GbLC850nm + 7@1Gb 850nmLC
		IT Software Licenses				
NO				6	Vmware	Virtual SAN 6 Advanced
NO				1	Vmware	vSphere 6.5 Enterprise Plus
NO				1	Vmware	vSphere Enterprise Plus Acceleration Kit
NO				1	Vmware	Horizon 7 Standard - 10 Pack (CCU)
NO				1	Vmware	Horizon 7 Standard - 10 Pack 1 Year Subscription
NO				6	Vmware	Virtual SAN 6 Advanced
NO			IT Racks, 19-inch Std. Chassis, 42-inch Deep	4	APC	
		Operator's Control + Support Tech Workstations				
YES			Virtual Desktop Interface - HD Video Out	6	Dell-Wyse	5030 Zero Client for Vmware
YES			Virtual Desktop Interface - Super HD Vid.	1	Dell-Wyse	7030 Zero Client for Vmware
YES			Video Display - 24-inch, HD	3	Dell	24-inch UltraSharp Monitor (1920 x 1080) IPS
YES			Video Display - 23-inch, HD, Touch Control	3	Dell	23-inch Multi-Touch Monitor (1920 x 1080) VA
YES			Video Display - 43-inch, 4K Ultra HD	1	Dell	43-inch Ultra HD 4K Monitor (3840 x 2160) IPS
NO			Operator Console	1	Winsted	Envision-series, 10-foot wide, 3 levels of monitor supports
NO			Virtual Desktop Interface - VESA Mounts	8	Dell-Wyse	Mounting Bracket
		SCADA Software Licenses				
NO			OS V01A: System Platform	1	Wonderware	2104R2 1k I/O
NO			OS V01A: InBatch Server	1	Wonderware	2014R3 (1-15 units)
YES			OS V01A: Win-911	1	Win-911	Win-911 Pro
NO			OS V01B: Application Server	1	Wonderware	2014R2, Platform
NO			OS V01B: Device Integration Server	1	Wonderware	2014R2
NO			OS V01B: InBatch Redundant Server	1	Wonderware	2014R3
YES			OS V01B: Win-911 Hot Backup	1	Win-911	Win-911HB
NO			OS V02: Advanced Dev Studio	1	Wonderware	2014R2 Medium
NO			OS V03: Dream Report	1	Wonderware	250 Tags, Ver. 4.7
NO			OS V03: Dream Report Web Client	1	Wonderware	2 Concurrent, Ver. 4.7
NO			OS V01A/V01B: InTouch for System Platform	5	Wonderware	2014R2 with Historian Client
NO			OS V04: InTouch for Sys. Platf. w/Hist.	4	Wonderware	2014R2 with Historian Client

Bill of Materials - LLNS Supplied to Control System Integrator

Provided by LLNS to CSI for System Development				Qty.	Manufacturer	Model
		VIDEO Software Licenses & Hardware				
NO			Video Historian Platform	1	Wonderware	Longwatch
NO			Camera Use License	1	Wonderware	Longwatch
NO			Camera Analog-to-IP Server Unit	1	Wonderware	Longwatch For 4 cameras
	Field-Located Control System Hardware					
YES		**Chem Synthesis PLC Control Panel (HDG: CP-M580)**				
YES			Enclosure	1		
YES			Modicon PLC Hardware	1		
YES			Miscellaneous Hardware	1		HDG design indicates: 20-in High x 16-in Wide x 8-in Deep
YES			Wiring	1		HDG design indicates: 60-in High x 36-in Wide x 10-in Deep
YES			Testing	1		
YES		**B827D Vestibule Network Rack Enclosure + 24VDC UPS**				
YES			Enclosure	1		
YES			Network Switches	1		
YES			24VDC UPS Hardware	1		HDG design indicates: 20-in High x 16-in Wide x 8-in Deep
YES			Wiring	1		HDG design indicates: 60-in High x 36-in Wide x 10-in Deep
YES			Testing	1		
YES		**Raw Material Supply Control Panel (HDG: CP-104)**				
YES			Enclosure	1		
YES			Modicon PLC Hardware	1		
YES			Miscellaneous Hardware	1		HDG design indicates: 20-in High x 16-in Wide x 8-in Deep
YES			Wiring	1		HDG design indicates: 60-in High x 36-in Wide x 10-in Deep
YES			Testing	1		
YES		**Reactors High-Temperature Interlock Panel**				
YES			Enclosure	1		
YES			Hardware	1		
YES			Miscellaneous	1		HDG design indicates: 20-in High x 16-in Wide x 8-in Deep
YES			Wiring	1		HDG design indicates: 60-in High x 36-in Wide x 10-in Deep
YES			Testing	1		
YES		**Field Human-Machine Interfaces (HMI) Control Panels**				
YES			HMI, Hazardous Area, SS, Wall Mount	1	StrongArm	Hazardous Area MiniStation, SS, 22-inch Display, Wall
YES			HMI, NEMA 4X, Stainless Steel, Wall Mount	1	StrongArm	MiniStation, SS, 22-inch Display, Wall Mount
YES			Industrial PC, DIN Rail Mount, 24VDC Power	2	Nematron	Intel QuadCore Atom E3845, Win7 64-bit, 8 Gb DRAM, SSD
				0		
			Sub-Total - HMIs			
		Miscellaneous Control Equipment				
NO			O_2 Difficiency Monitor Controller	1		HDG design indicates: 20-in High x 16-in Wide x 8-in Deep
NO			Bulk Solids Feeders - Power Transformer	1		
NO			Reactor Camera Lighting Controller	1		
YES			Hardwired E-Stops & related	1		

Lawrence Livermore National Laboratory
P.O. Box 808
Livermore, California, 94551
B827 Synthesis Pilot Plant
I/O List
Approved for Construction
1/31/2017

Revision History		
Rev.	**Date**	**Revision Code**
0	1/31/2017	Approved for Construction

Inst.	System	Number	Instrument Description	Setpoint/Range	Area Classification	Panel	IO Type	Rack	Slot	Channel	Ethernet	SV	IS	XP	Safety Interlock (Hard Wired)	Software Interlock	Status	Comments
XA	CP104	01	PS1 Fault			CP-104	DI	X80-02	01	0								X80-02 Power Supply Fault Relay
XA	CP104	02	PS2 Fault			CP-104	DI	X80-02	01	1								X80-03 Power Supply Fault Relay
TAH	0101	07	R-0101 Hi Hi Temperature Alarm	°C		CP-104	DI	X80-02	01	2					I1			Relay contacts from Hardwired Interlock Panel
TAH	0102	07	R-0102 Hi Hi Temperature Alarm	°C		CP-104	DI	X80-02	01	3					I3		FUTURE	Relay contacts from Hardwired Interlock Panel
TAH	0103	07	R-0103 Hi Hi Temperature Alarm	°C		CP-104	DI	X80-02	01	4					I5			Relay contacts from Hardwired Interlock Panel
TAH	0107	07	R-0107 Hi Hi Temperature Alarm	°C		CP-104	DI	X80-02	01	5					I9		FUTURE	Relay contacts from Hardwired Interlock Panel
ESA	0301	01	FH-104-01 Pumps Emergency Stop Status			CP-104	DI	X80-02	01	6					I1, I3, I5, I7			Safety Relay Contacts in Hardwired Interlock Panel
			Spare			CP-104	DI	X80-02	01	7					I4			Relay contacts from B827A Remote E-Stop Safety Relay
XA	0101	08	Conveyor CNV-0101 Fault Alarm			CP-104	DI	X80-02	01	8								Relay contacts from motor DC drive board
YI	0101	08	CNV-0101 RUN Status			CP-104	DI	X80-02	01	9								Relay contacts from motor DC drive board
XA	0102	08	Conveyor CNV-0102 Fault Alarm			CP-104	DI	X80-02	01	10							FUTURE	Relay contacts from motor DC drive board
YI	0102	09	CNV-0102 RUN Status			CP-104	DI	X80-02	01	11							FUTURE	Relay contacts from motor DC drive board
YI	0101	09	CNV-0101 Speed Pickup Purge Ready			CP-104	DI	X80-02	01	12								Purge Contactor Auxillary contacts
YI	0102	09	CNV-0102 Speed Pickup Purge Ready			CP-104	DI	X80-02	01	13							FUTURE	Purge Contactor Auxillary contacts
ESA	0404	01	TCM-0404 Emergency Stop Status			CP-104	DI	X80-02	01	14								Secondary N.C. contacts on local TCM-0404 E-Stop pushbutton
YI	0404	05	TCM-0404 RUN Status			CP-104	DI	X80-02	01	15								Aux. contacts on local TCM-0404 pump contactor.
ZSC	0301	01	XV-0301-01 Closed			CP-104	DI	X80-02	01	16								
ZSO	0301	01	XV-0301-01 Open			CP-104	DI	X80-02	01	17								
ZSC	0301	06	XV-0301-06 Closed			CP-104	DI	X80-02	01	18								
ZSO	0301	06	XV-0301-06 Open			CP-104	DI	X80-02	01	19								
ZSC	0301	07	XV-0301-07 Closed			CP-104	DI	X80-02	01	20								
ZSO	0301	07	XV-0301-07 Open			CP-104	DI	X80-02	01	21								
ZSC	0301	09	XV-0301-09 Closed			CP-104	DI	X80-02	01	22								
ZSO	0301	09	XV-0301-09 Open			CP-104	DI	X80-02	01	23								
ZSC	0301	10	XV-0301-10 Closed			CP-104	DI	X80-02	01	24								
ZSO	0301	10	XV-0301-10 Open			CP-104	DI	X80-02	01	25								
ZSC	0301	11	XV-0301-11 Closed			CP-104	DI	X80-02	01	26								
ZSO	0301	11	XV-0301-11 Open			CP-104	DI	X80-02	01	27								
ZSC	0301	12	XV-0301-12 Closed			CP-104	DI	X80-02	01	28								
ZSO	0301	12	XV-0301-12 Open			CP-104	DI	X80-02	01	29								
ZSC	0301	13	XV-0301-13 Closed			CP-104	DI	X80-02	01	30								
ZSO	0301	13	XV-0301-13 Open			CP-104	DI	X80-02	01	31								
ZSC	0301	14	XV-0301-14 Closed			CP-104	DI	X80-02	02	0								
ZSO	0301	14	XV-0301-14 Open			CP-104	DI	X80-02	02	1								
ZSC	0301	15	XV-0301-15 Closed			CP-104	DI	X80-02	02	2								
ZSO	0301	15	XV-0301-15 Open			CP-104	DI	X80-02	02	3								
ZSC	0301	16	XV-0301-16 Closed			CP-104	DI	X80-02	02	4								
ZSO	0301	16	XV-0301-16 Open			CP-104	DI	X80-02	02	5								
ZSC	0301	17	XV-0301-17 Closed			CP-104	DI	X80-02	02	6								
ZSO	0301	17	XV-0301-17 Open			CP-104	DI	X80-02	02	7								
ZSC	0301	18	XV-0301-18 Closed			CP-104	DI	X80-02	02	8								
ZSO	0301	18	XV-0301-18 Open			CP-104	DI	X80-02	02	9								
ZSC	0301	19	XV-0301-19 Closed			CP-104	DI	X80-02	02	10								
ZSO	0301	19	XV-0301-19 Open			CP-104	DI	X80-02	02	11								
ZSC	0301	20	XV-0301-20 Closed			CP-104	DI	X80-02	02	12								
ZSO	0301	20	XV-0301-20 Open			CP-104	DI	X80-02	02	13								
ZSC	0301	21	XV-0301-21 Closed			CP-104	DI	X80-02	02	14								
ZSO	0301	21	XV-0301-21 Open			CP-104	DI	X80-02	02	15								
ZSC	0301	22	XV-0301-22 Closed			CP-104	DI	X80-02	02	16								
ZSO	0301	22	XV-0301-22 Open			CP-104	DI	X80-02	02	17								
ZSC	0301	23	XV-0301-23 Closed			CP-104	DI	X80-02	02	18								
ZSO	0301	23	XV-0301-23 Open			CP-104	DI	X80-02	02	19								
ZSC	0301	24	XV-0301-24 Closed			CP-104	DI	X80-02	02	20								
ZSO	0301	24	XV-0301-24 Open			CP-104	DI	X80-02	02	21								
ZSC	0301	25	XV-0301-25 Closed			CP-104	DI	X80-02	02	22								
ZSO	0301	25	XV-0301-25 Open			CP-104	DI	X80-02	02	23								
ZSC	0301	26	XV-0301-26 Closed			CP-104	DI	X80-02	02	24								
ZSO	0301	26	XV-0301-26 Open			CP-104	DI	X80-02	02	25								
			Spare			CP-104	DI	X80-02	02	26								
			Spare			CP-104	DI	X80-02	02	27								
			Spare			CP-104	DI	X80-02	02	28								
			Spare			CP-104	DI	X80-02	02	29								
			Spare			CP-104	DI	X80-02	02	30								
			Spare			CP-104	DI	X80-02	02	31								
ZSC	0404	09	XV-0404-09 Closed		CL I/II, Div 1	CP-104	DI	X80-02	03	0			ISB01-1					
ZSO	0404	09	XV-0404-09 Open		CL I/II, Div 1	CP-104	DI	X80-02	03	1			ISB01-2					

Inst.	System	Number	Instrument Description	Setpoint/Range	Area Classification	Panel	IO Type	Rack	Slot	Channel	Ethernet	SV	IS	XP	Safety Interlock (Hard Wired)	Software Interlock	Status	Comments
ZSC	0404	10	XV-0404-10 Closed		CL I/II, Div 1	CP-104	DI	X80-02	03	2			ISB02-1					
ZSO	0404	10	XV-0404-10 Open		CL I/II, Div 1	CP-104	DI	X80-02	03	3			ISB02-2					
ZSC	0404	11	XV-0404-11 Closed		CL I/II, Div 1	CP-104	DI	X80-02	03	4			ISB03-1					
ZSO	0404	11	XV-0404-11 Open		CL I/II, Div 1	CP-104	DI	X80-02	03	5			ISB03-2					
ZSC	0404	12	XV-0404-12 Closed		CL I/II, Div 1	CP-104	DI	X80-02	03	6			ISB04-1					
ZSO	0404	12	XV-0404-12 Open		CL I/II, Div 1	CP-104	DI	X80-02	03	7			ISB04-2					
ZSC	0404	13	XV-0404-13 Closed		CL I/II, Div 1	CP-104	DI	X80-02	03	8			ISB05-1					
ZSO	0404	13	XV-0404-13 Open		CL I/II, Div 1	CP-104	DI	X80-02	03	9			ISB05-2					
ZSC	0404	14	XV-0404-14 Closed		CL I/II, Div 1	CP-104	DI	X80-02	03	10			ISB06-1					
ZSO	0404	14	XV-0404-14 Open		CL I/II, Div 1	CP-104	DI	X80-02	03	11			ISB06-2					
ZSC	0404	15	XV-0404-15 Closed		CL I/II, Div 1	CP-104	DI	X80-02	03	12			ISB07-1					
ZSO	0404	15	XV-0404-15 Open		CL I/II, Div 1	CP-104	DI	X80-02	03	13			ISB07-2					
ZSC	0404	16	XV-0404-16 Closed		CL I/II, Div 1	CP-104	DI	X80-02	03	14			ISB08-1					
ZSO	0404	16	XV-0404-16 Open		CL I/II, Div 1	CP-104	DI	X80-02	03	15			ISB08-2					
LS	0401	05	TCM Containment Spill Alarm		CL I, Div 2	CP-104	DI	X80-02	03	16			ISB09-1					
ZS	0501	14	V-0501 Overpressure Alarm		CL I, Div 2	CP-104	DI	X80-02	03	17			ISB09-2					
PAL	3002	04	Low Pressure Chilled Water Alarm		CL I, Div 2	CP-104	DI	X80-02	03	18			ISB10-1					
			Spare I.S. DI			CP-104	DI	X80-02	03	19			ISB10-2					
ESA	0501	20	VP-0501 Emergency Stop Alarm		CL I, Div 2	CP-104	DI	X80-02	03	20								Monitored by PLC. Contacts in purged enclosure.
PAL	0404	04	TCM-0404 Low Pressure Alarm			CP-104	DI	X80-02	03	21								
ESA	827A	01	B827A Control Room Emergency Shutdown Alarm			CP-104	DI	X80-02	03	22								
SDA	827A	01	B827A Seismic Detection Alarm			CP-104	DI	X80-02	03	23								
			Spare			CP-104	DI	X80-02	03	24								
			Spare			CP-104	DI	X80-02	03	25								
			Spare			CP-104	DI	X80-02	03	26								
			Spare			CP-104	DI	X80-02	03	27								
			Spare			CP-104	DI	X80-02	03	28								
			Spare			CP-104	DI	X80-02	03	29								
			Spare			CP-104	DI	X80-02	03	30								
			Spare			CP-104	DI	X80-02	03	31								
YI	0303	01	PIT-0303-01 Connection Status			CP-104	DI	X80-02	04	0								Jumper on T-0303 multi-pin connector
YI	0304	01	PIT-0304-01 Connection Status			CP-104	DI	X80-02	04	1								Jumper on T-0304 multi-pin connector
YI	0305	01	PIT-0305-01 Connection Status			CP-104	DI	X80-02	04	2								Jumper on T-0305 multi-pin connector
YI	0303	02	PIT-0303-02 Connection Status			CP-104	DI	X80-02	04	3								Jumper on T-0303 multi-pin connector
YI	0304	02	PIT-0304-02 Connection Status			CP-104	DI	X80-02	04	4								Jumper on T-0304 multi-pin connector
YI	0305	02	PIT-0305-02 Connection Status			CP-104	DI	X80-02	04	5								Jumper on T-0305 multi-pin connector
ZSC	1101	08	XV-1101-08 Closed			CP-104	DI	X80-02	04	6								
ZSO	1101	08	XV-1101-08 Open			CP-104	DI	X80-02	04	7								
ZSC	1101	12	XV-1101-12 Closed			CP-104	DI	X80-02	04	8								
ZSO	1101	12	XV-1101-12 Open			CP-104	DI	X80-02	04	9								
ZSC	1101	16	XV-1101-16 Closed			CP-104	DI	X80-02	04	10								
ZSO	1101	16	XV-1101-16 Open			CP-104	DI	X80-02	04	11								
ZSC	1101	20	XV-1101-20 Closed			CP-104	DI	X80-02	04	12								
ZSO	1101	20	XV-1101-20 Open			CP-104	DI	X80-02	04	13								
XA	1101	01	N2 Switch to Reserve Alarm			CP-104	DI	X80-02	04	14								
YI	0601	02	Blower FE-03 RUN Status			CP-104	DI	X80-02	04	15								Aux. contacts from blower motor starter contactor
HS	0101	08	CNV-0101 START/STOP			CP-104	DO	X80-02	05	0								
HS	0102	08	CNV-0102 START/STOP			CP-104	DO	X80-02	05	1							FUTURE	
			Spare			CP-104	DO	X80-02	05	2								
			Spare			CP-104	DO	X80-02	05	3								
			Spare			CP-104	DO	X80-02	05	4								
SV	0301	01	Compressed Air to P-0301-03			CP-104	DO	X80-02	05	5					I1,I3,I5,I2	I7		Hardwired Interlock via SV-0301-03 CA divert solenoid valve.
SV	0301	02	Compressed Air to P-0301-02			CP-104	DO	X80-02	05	6					I1,I3,I5,I2	I7		Hardwired Interlock via SV-0301-03 CA divert solenoid valve.
HS	0404	07	TCM-0404 Remote START/STOP			CP-104	DO	X80-02	05	7								Connect to 24V relay coil in TCM-0404 local control panel.
HS	1101	04	FIC-1101-04 Valve Override			CP-104	DO	X80-02	06	0								
HS	1101	05	FIC-1101-05 Valve Override			CP-104	DO	X80-02	06	1								
HS	1101	06	FIC-1101-06 Valve Override			CP-104	DO	X80-02	06	2								
HS	1101	10	FIC-1101-10 Valve Override			CP-104	DO	X80-02	06	3								
HS	1101	14	FIC-1101-14 Valve Override			CP-104	DO	X80-02	06	4								
HS	1101	18	FIC-1101-18 Valve Override			CP-104	DO	X80-02	06	5								
			Spare			CP-104	DO	X80-02	06	6								
			Spare			CP-104	DO	X80-02	06	7								
PIT	0301	01	P-0301-01 Discharge Pressure			CP-104	AI	X80-03	01	0								
PIT	0301	02	P-0301-02 Discharge Pressure			CP-104	AI	X80-03	01	1								
PIT	0301	03	P-0301-03 Discharge Pressure			CP-104	AI	X80-03	01	2								
PIT	1101	02	N2 Distribution Pressure			CP-104	AI	X80-03	01	3								

Inst.	System	Number	Instrument Description	Setpoint/Range	Area Classification	Panel	IO Type	Rack	Slot	Channel	Ethernet	SV	IS	XP	Safety Interlock (Hard Wired)	Software Interlock	Status	Comments
WE/WIT	0301	01	T-030X Weight			CP-104	AI	X80-03	02	0	1							
WE/WIT	0301	02	T-030X Weight			CP-104	AI	X80-03	02	1	1							
FI	1101	04	N2 Flow to CNV-0101			CP-104	AI	X80-03	02	2								
FI	1101	05	N2 Flow to CNV-0102			CP-104	AI	X80-03	02	3							FUTURE	
FI	1101	06	N2 Flow to R-0103	0-6 slpm		CP-104	AI	X80-03	03	0								
FI	1101	10	N2 Flow to R-0102	0-6 slpm		CP-104	AI	X80-03	03	1							FUTURE	
FI	1101	14	N2 Flow to R-0101	0-6 slpm		CP-104	AI	X80-03	03	2								
FI	1101	18	N2 Flow to R-0107	0-6 slpm		CP-104	AI	X80-03	03	3							FUTURE	
PIT	030X	01	T-030X Pressure			CP-104	AI	X80-03	04	0								From V-030X Docking Station
PIT	030X	02	T-030X Pressure			CP-104	AI	X80-03	04	1								From V-030X Docking Station
WIT	0101	08	R-0101 Weight			CP-104	AI	X80-03	04	2	1							
WIT	0102	08	R-0102 Weight			CP-104	AI	X80-03	04	3	1						FUTURE	
WIT	0103	08	R-0103 Weight	rpm		CP-104	AI	X80-03	05	0	1							
SI	0101	10	Agitator AG-0101 Speed Indication	rpm		CP-104	AI	X80-03	05	1								Local readout is in XP housing. AI is 4-wire.
SI	0102	10	Agitator AG-0102 Speed Indication	rpm		CP-104	AI	X80-03	05	2							FUTURE	Local readout is in XP housing. AI is 4-wire.
SI	0103	10	Agitator AG-0103 Speed Indication	rpm		CP-104	AI	X80-03	05	3								Local readout is in XP housing. AI is 4-wire.
SI	0101	08	CNV-0101-08 Speed Indication	rpm		CP-104	AI	X80-03	06	0	1							Ethernet requires additional Ethernet/IP board to KCM Controller
SI	0102	08	CNV-0102-08 Speed Indication	rpm		CP-104	AI	X80-03	06	1	1						FUTURE	Ethernet requires additional Ethernet/IP board to KCM Controller
FIT	0101	09	R-0101 Flow to R-0103			CP-104	AI	X80-03	06	2				1				Moved from CP-105A-01
FIT	0103	09	R-0103 Flow to F-0104			CP-104	AI	X80-03	06	3				1				Moved from CP-105A-03
FC	1101	04	N2 Flow to CNV-0101 Setpoint			CP-104	AO	X80-03	07	0								
FC	1101	05	N2 Flow to CNV-0102 Setpoint			CP-104	AO	X80-03	07	1							FUTURE	
FC	1101	06	N2 Flow to R-0103 Setpoint			CP-104	AO	X80-03	07	2								
FC	1101	10	N2 Flow to R-0102 Setpoint			CP-104	AO	X80-03	07	3							FUTURE	
FC	1101	14	N2 Flow to R-0101 Setpoint			CP-104	AO	X80-03	07	4								
FC	1101	18	N2 Flow to R-0107 Setpoint			CP-104	AO	X80-03	07	5								
SIC	0101	08	CNV-0101 Speed Control	0-100%		CP-104	AO	X80-03	07	6								
SIC	0102	08	CNV-0102 Speed Control	0-100%		CP-104	AO	X80-03	07	7							FUTURE	
ZC	0301	01	P-0301-01 Stroke Length Control	0-100%		CP-104	AO	X80-03	08	0								
			Spare			CP-104	AO	X80-03	08	1							FUTURE	
			Spare			CP-104	AO	X80-03	08	2							FUTURE	
			Spare			CP-104	AO	X80-03	08	3							FUTURE	
			Spare			CP-104	AO	X80-03	08	4							FUTURE	
			Spare			CP-104	AO	X80-03	08	5							FUTURE	
			Spare			CP-104	AO	X80-03	08	6							FUTURE	
			Spare			CP-104	AO	X80-03	08	7							FUTURE	
HS	0501	05	VP-0501 START/STOP Control		CL I, Div 2	CP-104					1							Ethernet connection to vacuum pump PLC
HS	0101	10	Agitator AG-0101 START/STOP			CP-104					1							Ethernet connection to VFD
SC	0101	10	Agitator AG-0101 Speed Control	0-100%		CP-104					1							Ethernet connection to VFD
YI	0101	10	Agitator AG-0101 RUN Status			CP-104					1							Ethernet connection to VFD
HS	0102	10	Agitator AG-0102 START/STOP			CP-104					1						FUTURE	Ethernet connection to VFD
SC	0102	10	Agitator AG-0102 Speed Control	0-100%		CP-104					1						FUTURE	Ethernet connection to VFD
YI	0102	10	Agitator AG-0102 RUN Status			CP-104					1						FUTURE	Ethernet connection to VFD
HS	0103	10	Agitator AG-0103 START/STOP			CP-104					1							Ethernet connection to VFD
SC	0103	10	Agitator AG-0103 Speed Control	0-100%		CP-104					1							Ethernet connection to VFD
YI	0103	10	Agitator AG-0103 RUN Status			CP-104					1							Ethernet connection to VFD
HS	0307	01	P-0307-01 START/STOP		CL I/II, Div 1	CP-104					1				I1, I3, I5			Ethernet connection to VFD
SC	0307	01	P-0307-01 Speed Control	0-100%	CL I/II, Div 1	CP-104					1							Ethernet connection to VFD
HS	0301	01	P-0301-01 START/STOP			CP-104					1				I1, I3, I5	I8		Ethernet connection to VFD
SC	0301	01	P-0301-01 Speed Control	0-100%		CP-104					1							Ethernet connection to VFD
YI	0401	05	TCM-0401 RUN Status Indication		CL I, Div 2	CP-104					1							Ethernet connection to TCM control panel
XA	0401	06	TCM-0401 Alarm		CL I, Div 2	CP-104					1							Ethernet connection to TCM control panel
HS	0401	07	TCM-0401 Remote START/STOP		CL I, Div 2	CP-104					1							Ethernet connection to TCM control panel
TC	0401	08	TCM-0401 Temperature Setpoint	°C	CL I, Div 2	CP-104					1				I1			Ethernet connection to TCM control panel
YI	0402	05	TCM-0402 RUN Status Indication		CL I, Div 2	CP-104					1						FUTURE	Ethernet connection to TCM control panel
XA	0402	06	TCM-0402 Alarm		CL I, Div 2	CP-104					1						FUTURE	Ethernet connection to TCM control panel
HS	0402	07	TCM-0402 Remote START/STOP		CL I, Div 2	CP-104					1						FUTURE	Ethernet connection to TCM control panel
TC	0402	08	TCM-0402 Temperature Setpoint	°C	CL I, Div 2	CP-104					1				I3		FUTURE	Ethernet connection to TCM control panel
YI	0403	05	TCM-0403 RUN Status Indication		CL I, Div 2	CP-104					1							Ethernet connection to TCM control panel
XA	0403	06	TCM-0403 Remote Alarm Status		CL I, Div 2	CP-104					1							Ethernet connection to TCM control panel
HS	0403	07	TCM-0403 Remote START/STOP		CL I, Div 2	CP-104					1							Ethernet connection to TCM control panel
TC	0403	08	TCM-0403 Temperature Setpoint	°C	CL I, Div 2	CP-104					1				I5			Ethernet connection to TCM control panel
XA	0404	06	TCM-0404 Remote Alarm Status			CP-104					1							Ethernet connection to TCM Temperature Controller
TC	0404	08	TCM-0404 Temperature Setpoint	°C		CP-104					1							Ethernet connection to TCM Temperature Controller
YI	0405	05	TCM-0405 RUN Status Indication		CL I, Div 2	CP-104					1							Ethernet connection to TCM control panel
XA	0405	06	TCM-0405 Alarm		CL I, Div 2	CP-104					1							Ethernet connection to TCM control panel

Inst.	System	Number	Instrument Description	Setpoint/Range	Area Classification	Panel	IO Type	Rack	Slot	Channel	Ethernet	SV	IS	XP	Safety Interlock (Hard Wired)	Software Interlock	Status	Comments
HS	0405	07	TCM-0405 Remote START/STOP		CL I, Div 2	CP-104					1							Ethernet connection to TCM control panel
TC	0405	08	TCM-0405 Temperature Setpoint	°C	CL I, Div 2	CP-104					1					I7		Ethernet connection to TCM control panel
YI	0406	05	TCM-0406 RUN Status Indication		CL I, Div 2	CP-104					1						FUTURE	Ethernet connection to TCM control panel
XA	0406	06	TCM-0406 Alarm		CL I, Div 2	CP-104					1				I9		FUTURE	Ethernet connection to TCM control panel
HS	0406	07	TCM-0406 Remote START/STOP		CL I, Div 2	CP-104					1						FUTURE	Ethernet connection to TCM control panel
TC	0406	08	TCM-0406 Temperature Setpoint	°C	CL I, Div 2	CP-104					1						FUTURE	Ethernet connection to TCM control panel
XA	0501	05	VP-0501 Fault Alarm		CL I, Div 2	CP-104					1							Ethernet connection to vacuum pump PLC
YI	0501	05	VP-0501 Run Status Indication		CL I, Div 2	CP-104					1							Ethernet connection to vacuum pump PLC
XV	0501	03	VP-0501 to Knockout Tank T-0501		CL I, Div 2	CP-104					1							Ethernet connection to vacuum pump PLC
TS	0501	62	Cooling Water Temperature Switch	30-250°F	CL I, Div 2	CP-104					1							Ethernet connection to vacuum pump PLC
LAH	0501	61	Knockout Pot T-0501 High Level Alarm		CL I, Div 2	CP-104					1							Ethernet connection to vacuum pump PLC
PSL	0501	63	Seal Gas Low Pressure Switch		CL I, Div 2	CP-104					1							Ethernet connection to vacuum pump PLC
TS	0501	55	Exhuast Temperature Switch	°C	CL I, Div 2	CP-104					1							Ethernet connection to vacuum pump PLC
LAH	0501	56	Receiver Tank V-0501 High Level Alarm		CL I, Div 2	CP-104					1							Ethernet connection to vacuum pump PLC
SV	0501	51	Seal Purge Valve Solenoid		CL I, Div 2	CP-104					1							Ethernet connection to vacuum pump PLC
XV	0501	02	Inlet Purge Valve Solenoid		CL I, Div 2	CP-104					1							Ethernet connection to vacuum pump PLC
PIT	0501	52	Inlet Pressure	0-30" Hg	CL I, Div 2	CP-104					1							Ethernet connection to vacuum pump PLC
FS	0501	65	Seal Gas Low Flow Switch		CL I, Div 2	CP-104					1							Ethernet connection to vacuum pump PLC
PSL	0501	54	Exhaust Low Pressure Switch		CL I, Div 2	CP-104					1							Ethernet connection to vacuum pump PLC
TI	0501	60	Heat Exchanger Discharge Temperature	°C	CL I, Div 2	CP-104					1							Ethernet connection to vacuum pump PLC
ESA	0401	01	TCM-0401 Emergency Stop Status		CL I, Div 2	CP-104					1							Ethernet connection to TCM control panel
XA	0401	01	TCM-0401 Loss of Cabinet Purge		CL I, Div 2	CP-104					1							Ethernet connection to TCM control panel
ESA	0403	01	TCM-0403 Emergency Stop Status		CL I, Div 2	CP-104					1							Ethernet connection to TCM control panel
XA	0403	01	TCM-0403 Loss of Cabinet Purge		CL I, Div 2	CP-104					1							Ethernet connection to TCM control panel
ESA	0405	01	TCM-0405 Emergency Stop Status		CL I, Div 2	CP-104					1							Ethernet connection to TCM control panel
XA	0405	01	TCM-0405 Loss of Cabinet Purge		CL I, Div 2	CP-104					1							Ethernet connection to TCM control panel
ESA	0406	01	TCM-0406 Emergency Stop Status		CL I, Div 2	CP-104					1						FUTURE	Ethernet connection to TCM control panel
XA	0406	01	TCM-0406 Loss of Cabinet Purge		CL I, Div 2	CP-104					1						FUTURE	Ethernet connection to TCM control panel
XV	0301	01	DIW Distribution Valve			CP-104	SV					1						
XV	0301	06	Chemical Distribution from P-0301-02			CP-104	SV					2						
XV	0301	07	N2 Purge Valve			CP-104	SV					3						
XV	0301	09	Chemical Distribution from P-0301-03			CP-104	SV					4						
XV	0301	10	N2 Purge Valve			CP-104	SV					5						
XV	0301	11	Chemical Distribution from P-0301-01			CP-104	SV					6						
XV	0301	12	N2 Purge Valve			CP-104	SV					7						
XV	0301	13	N2 Distribution Valve			CP-104	SV					8						
XV	0301	14	Nitric Acid Transfer to R-0102			CP-104	SV					9					FUTURE	
XV	0301	15	Nitric Acid Transfer to R-0101			CP-104	SV					10						
XV	0301	16	Oleum/Sulfuric Acid Transfer to R-0102			CP-104	SV					11					FUTURE	
XV	0301	17	Oleum/Sulfuric Acid Transfer to R-0101			CP-104	SV					12						
XV	0301	18	Process Transfer to R-0103			CP-104	SV					13						
XV	0301	19	Process Transfer to R-0102			CP-104	SV					14					FUTURE	
XV	0301	20	Process Transfer to R-0101			CP-104	SV					15						
XV	0301	21	Process Transfer to R-0103			CP-104	SV					16						
XV	0301	22	Process Transfer to R-0102			CP-104	SV					17					FUTURE	
XV	0301	23	Process Transfer to R-0101			CP-104	SV					18						
XV	0301	24	Process Transfer to R-0103			CP-104	SV					19						
XV	0301	25	Process Transfer to R-0102			CP-104	SV					20					FUTURE	
XV	0301	26	Process Transfer to R-0101			CP-104	SV					21						
XV	0404	09	Glycol Supply to E-0101		CL I, Div 2	CP-104	SV					22						
XV	0404	10	Glycol Supply to E-0102		CL I, Div 2	CP-104	SV					23					FUTURE	
XV	0404	11	Glycol Supply to E-0103		CL I, Div 2	CP-104	SV					24						
XV	0404	12	Glycol Supply to E-0107		CL I, Div 2	CP-104	SV					25					FUTURE	
XV	0404	13	Glycol Return from E-0101		CL I, Div 2	CP-104	SV					26						
XV	0404	14	Glycol Return from E-0102		CL I, Div 2	CP-104	SV					27					FUTURE	
XV	0404	15	Glycol Return from E-0103		CL I, Div 2	CP-104	SV					28						
XV	0404	16	Glycol Return from E-0107		CL I, Div 2	CP-104	SV					29					FUTURE	
XV	1101	08	N2 Distribution to R-0103			CP-104	SV					30						
XV	1101	12	N2 Distribution to R-0102			CP-104	SV					31					FUTURE	
XV	1101	16	N2 Distribution to R-0101			CP-104	SV					32						
XV	1101	20	N2 Distribution to R-0107			CP-104	SV					33					FUTURE	
			Spare SV			CP-104	SV					34						
			Spare SV			CP-104	SV					35						
			Spare SV			CP-104	SV					36						
			Spare SV			CP-104	SV					37						
			Spare SV			CP-104	SV					38						

I/O LIST - CP-104

Inst.	System	Number	Instrument Description	Setpoint/Range	Area Classification	Panel	IO Type	Rack	Slot	Channel	Ethernet	SV	IS	XP	Safety Interlock (Hard Wired)	Software Interlock	Status	Comments
			Spare SV			CP-104	SV					39						
			Spare SV			CP-104	SV					40						

Inst.	System	Number	Instrument Description	Setpoint/Range	Area Classification	Panel	IO Type	Rack	Slot	Channel	Ethernet	SV	IS	XP	Safety Interlock (Hard Wired)	Software Interlock	Status	Comments
AIT	0101	03	R-0101 Sample pH		CL I/II, Div 1	CP-105A-01	AI		01	0			1					
TIT	0101	04	E-0101 Inlet Temperature	°C	CL I/II, Div 1	CP-105A-01	AI		01	1			1					
TIT	0101	05	E-0101 Outlet Temperature	°C	CL I/II, Div 1	CP-105A-01	AI		01	2			1					
PIT	0101	06	E-0101 Inlet Pressure		CL I/II, Div 1	CP-105A-01	AI		01	3			1					
~~FIT~~	~~0101~~	~~09~~	~~R-0101 Flow to R-0103~~		CL I/II, Div 1	CP-105A-01	AI		01	4			1					Moved FIT-0101-09 to CP-104. Make point Spare.
PIT	0101	16	N2 to Agitator Seal Pressure		CL I/II, Div 1	CP-105A-01	AI		01	5			1					
			Spare Analog Input or Output		CL I/II, Div 1	CP-105A-01	AIO		01	6			1					
			Spare Analog Input or Output		CL I/II, Div 1	CP-105A-01	AIO		01	7			1					
TIT	0101	22	T-0101 Temperature	°C	CL I/II, Div 1	CP-105A-01	AI		02	0			1					
FIT	0101	28	Syltherm return flow from R-0101 to TCM-0401		CL I/II, Div 1	CP-105A-01	AI		02	1			1					
TIT	0101	07	R-0101 Temperature	°C	CL I/II, Div 1	CP-105A-01	AI		02	2			1					Tag Change from 07A to 07
TIT	0101	08	R-0101 Temperature	°C	CL I/II, Div 1	CP-105A-01	AI		02	3			1					Tag Change from 07B to 08
PCV	0101	06	Vent Pressure Control		CL I/II, Div 1	CP-105A-01	AO		02	4			1					
FCV	0101	09	R-0101 Flow to R-0103	5-20 lpm	CL I/II, Div 1	CP-105A-01	AO		02	5			1					
			Spare Analog Input or Output		CL I/II, Div 1	CP-105A-01	AIO		02	6			1					
			Spare Analog Input or Output		CL I/II, Div 1	CP-105A-01	AIO		02	7			1					
ZSC	0101	01	XV-0101-01 Closed		CL I/II, Div 1	CP-105A-01	DI		03	0			1					
ZSO	0101	01	XV-0101-01 Open		CL I/II, Div 1	CP-105A-01	DI		03	1			1					
ZSC	0101	02	XV-0101-02 Closed		CL I/II, Div 1	CP-105A-01	DI		03	2			1					
ZSO	0101	02	XV-0101-02 Open		CL I/II, Div 1	CP-105A-01	DI		03	3			1					
ZSC	0101	03	XV-0101-03 Closed		CL I/II, Div 1	CP-105A-01	DI		03	4			1					
ZSO	0101	03	XV-0101-03 Open		CL I/II, Div 1	CP-105A-01	DI		03	5			1					
ZSC	0101	04	XV-0101-04 Closed		CL I/II, Div 1	CP-105A-01	DI		03	6			1					
ZSO	0101	04	XV-0101-04 Open		CL I/II, Div 1	CP-105A-01	DI		03	7			1					
ZSC	0101	05	XV-0101-05 Closed		CL I/II, Div 1	CP-105A-01	DI		03	8			1					
ZSO	0101	05	XV-0101-05 Open		CL I/II, Div 1	CP-105A-01	DI		03	9			1					
ZSC	0101	06	XV-0101-06 Closed		CL I/II, Div 1	CP-105A-01	DI		03	10			1					
ZSO	0101	06	XV-0101-06 Open		CL I/II, Div 1	CP-105A-01	DI		03	11			1					
ZSC	0101	07	XV-0101-07 Closed		CL I/II, Div 1	CP-105A-01	DI		03	12			1					
ZSO	0101	07	XV-0101-07 Open		CL I/II, Div 1	CP-105A-01	DI		03	13			1					
ZSC	0101	08	XV-0101-08 Closed		CL I/II, Div 1	CP-105A-01	DI		03	14			1					
ZSO	0101	08	XV-0101-08 Open		CL I/II, Div 1	CP-105A-01	DI		03	15			1					
ZSC	0101	09	XV-0101-09 Closed		CL I/II, Div 1	CP-105A-01	DI		04	0			1					
ZSO	0101	09	XV-0101-09 Open		CL I/II, Div 1	CP-105A-01	DI		04	1			1					
ZSC	0101	10	XV-0101-10 Closed		CL I/II, Div 1	CP-105A-01	DI		04	2			1					
ZSO	0101	10	XV-0101-10 Open		CL I/II, Div 1	CP-105A-01	DI		04	3			1					
ZSC	0101	11	XV-0101-11 Closed		CL I/II, Div 1	CP-105A-01	DI		04	4			1					
ZSO	0101	11	XV-0101-11 Open		CL I/II, Div 1	CP-105A-01	DI		04	5			1					
ZSC	0101	12	XV-0101-12 Closed		CL I/II, Div 1	CP-105A-01	DI		04	6			1					
ZSO	0101	12	XV-0101-12 Open		CL I/II, Div 1	CP-105A-01	DI		04	7			1					
ZSC	0101	13	XV-0101-13 Closed		CL I/II, Div 1	CP-105A-01	DI		04	8			1					
ZSO	0101	13	XV-0101-13 Open		CL I/II, Div 1	CP-105A-01	DI		04	9			1					
ZSC	0101	14	XV-0101-14 Closed		CL I/II, Div 1	CP-105A-01	DI		04	10			1					
ZSO	0101	14	XV-0101-14 Open		CL I/II, Div 1	CP-105A-01	DI		04	11			1					
ZSC	0101	15	XV-0101-15 Closed		CL I/II, Div 1	CP-105A-01	DI		04	12			1					
ZSO	0101	15	XV-0101-15 Open		CL I/II, Div 1	CP-105A-01	DI		04	13			1					
ZSC	0101	16	XV-0101-16 Closed		CL I/II, Div 1	CP-105A-01	DI		04	14			1					
ZSO	0101	16	XV-0101-16 Open		CL I/II, Div 1	CP-105A-01	DI		04	15			1					
ZSC	0101	17	XV-0101-17 Closed		CL I/II, Div 1	CP-105A-01	DI		05	0			1					
ZSO	0101	17	XV-0101-17 Open		CL I/II, Div 1	CP-105A-01	DI		05	1			1					
ZSC	0101	18	XV-0101-18 Closed		CL I/II, Div 1	CP-105A-01	DI		05	2			1					
ZSO	0101	18	XV-0101-18 Open		CL I/II, Div 1	CP-105A-01	DI		05	3			1					
ZSC	0101	19	XV-0101-19 Closed		CL I/II, Div 1	CP-105A-01	DI		05	4			1					
ZSO	0101	19	XV-0101-19 Open		CL I/II, Div 1	CP-105A-01	DI		05	5			1					
ZSC	0101	20	XV-0101-20 Closed		CL I/II, Div 1	CP-105A-01	DI		05	6			1					
ZSO	0101	20	XV-0101-20 Open		CL I/II, Div 1	CP-105A-01	DI		05	7			1					
ZSC	0101	21	XV-0101-21 Closed		CL I/II, Div 1	CP-105A-01	DI		05	8			1					
ZSO	0101	21	XV-0101-21 Open		CL I/II, Div 1	CP-105A-01	DI		05	9			1					
ZSC	0101	22	XV-0101-22 Closed		CL I/II, Div 1	CP-105A-01	DI		05	10			1					
ZSO	0101	22	XV-0101-22 Open		CL I/II, Div 1	CP-105A-01	DI		05	11			1					
ZSC	0101	23	XV-0101-23 Closed		CL I/II, Div 1	CP-105A-01	DI		05	12			1					
ZSO	0101	23	XV-0101-23 Open		CL I/II, Div 1	CP-105A-01	DI		05	13			1					
ZSC	0101	24	XV-0101-24 Closed		CL I/II, Div 1	CP-105A-01	DI		05	14			1				HOLD	
ZSO	0101	24	XV-0101-24 Open		CL I/II, Div 1	CP-105A-01	DI		05	15			1				HOLD	
ZSC	0101	25	XV-0101-25 Closed		CL I/II, Div 1	CP-105A-01	DI		06	0			1				HOLD	

Inst.	System	Number	Instrument Description	Setpoint/Range	Area Classification	Panel	IO Type	Rack	Slot	Channel	Ethernet	SV	IS	XP	Safety Interlock (Hard Wired)	Software Interlock	Status	Comments
ZSO	0101	25	XV-0101-25 Open		CL I/II, Div 1	CP-105A-01	DI		06	1			1				HOLD	
ZSC	0101	26	XV-0101-26 Closed		CL I/II, Div 1	CP-105A-01	DI		06	2			1					
ZSO	0101	26	XV-0101-26 Open		CL I/II, Div 1	CP-105A-01	DI		06	3			1					
ZSC	0101	27	XV-0101-27 Closed		CL I/II, Div 1	CP-105A-01	DI		06	4			1					
ZSO	0101	27	XV-0101-27 Open		CL I/II, Div 1	CP-105A-01	DI		06	5			1					
ZSC	0101	28	XV-0101-28 Closed		CL I/II, Div 1	CP-105A-01	DI		06	6			1					
ZSO	0101	28	XV-0101-28 Open		CL I/II, Div 1	CP-105A-01	DI		06	7			1					
ZSC	0101	29	XV-0101-29 Closed		CL I/II, Div 1	CP-105A-01	DI		06	8			1					
ZSO	0101	29	XV-0101-29 Open		CL I/II, Div 1	CP-105A-01	DI		06	9			1					
ZSC	0101	30	XV-0101-30 Closed		CL I/II, Div 1	CP-105A-01	DI		06	10			1					
ZSO	0101	30	XV-0101-30 Open		CL I/II, Div 1	CP-105A-01	DI		06	11			1					
ZSC	0101	31	XV-0101-31 Closed		CL I/II, Div 1	CP-105A-01	DI		06	12			1					
ZSO	0101	31	XV-0101-31 Open		CL I/II, Div 1	CP-105A-01	DI		06	13			1					
ZSC	0101	32	XV-0101-32 Closed		CL I/II, Div 1	CP-105A-01	DI		06	14			1					
ZSO	0101	32	XV-0101-32 Open		CL I/II, Div 1	CP-105A-01	DI		06	15			1					
ZS	0101	11	PSE-0101-11 Burst Status		CL I/II, Div 1	CP-105A-01	DI		07	0			1					
ZS	0101	18	PSE-0101-18 Burst Status		CL I/II, Div 1	CP-105A-01	DI		07	1			1					
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-01	DIO		07	2			1					
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-01	DIO		07	3			1					
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-01	DIO		07	4			1					
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-01	DIO		07	5			1					
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-01	DIO		07	6			1					
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-01	DIO		07	7			1					
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-01	DIO		07	8			1					
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-01	DIO		07	9			1					
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-01	DIO		07	10			1					
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-01	DIO		07	11			1					
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-01	DIO		07	12			1					
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-01	DIO		07	13			1					
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-01	DIO		07	14			1					
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-01	DIO		07	15			1					
XV	0101	02	Ammonia to R-0101		CL I/II, Div 1	CP-105A-01	SV		08	0		1			I1			Fails Closed on R-0101 Overtemperature
XV	0101	03	Chemical Distribution to R-0101		CL I/II, Div 1	CP-105A-01	SV		08	1		1			I1			Fails Closed on R-0101 Overtemperature
XV	0101	04	Chemical Distribution to R-0101		CL I/II, Div 1	CP-105A-01	SV		08	2		1			I1			Fails Closed on R-0101 Overtemperature
XV	0101	05	Chemical Distribution to R-0101		CL I/II, Div 1	CP-105A-01	SV		08	3		1			I1			Fails Closed on R-0101 Overtemperature
XV	0101	06	Chemical Distribution to R-0101		CL I/II, Div 1	CP-105A-01	SV		08	4		1			I1			Fails Closed on R-0101 Overtemperature
XV	0101	07	Chemical Distribution to R-0101		CL I/II, Div 1	CP-105A-01	SV		08	5		1			I1			Fails Closed on R-0101 Overtemperature
XV	0101	08	Chemical Distribution to R-0101		CL I/II, Div 1	CP-105A-01	SV		08	6		1			I1			Fails Closed on R-0101 Overtemperature
XV	0101	24	T-0101 to R-0101		CL I/II, Div 1	CP-105A-01	SV		08	7		1			I1		HOLD	Fails Closed on R-0101 Overtemperature
XV	0101	25	CNV-0101 to R-0101		CL I/II, Div 1	CP-105A-01	SV		09	0		1			I1		HOLD	Fails Closed on R-0101 Overtemperature
XV	0101	28	R-0101 Bottom Valve		CL I/II, Div 1	CP-105A-01	SV		09	1		1			I1			Fails open on R-0101 Overtemperature
XV	0101	30	FCV-0101-09 Bypass		CL I/II, Div 1	CP-105A-01	SV		09	2		1			I1, I3			Fails Open on R-0101 or R-0102 Overtemperature
XV	0101	32	R-0101 to R-0103		CL I/II, Div 1	CP-105A-01	SV		09	3		1			I1			Fails open on R-0101 Overtemperature
			Spare I1 Interlocked SV		CL I/II, Div 1	CP-105A-01	SV		09	4		1			I1			Do not use unless I5 Interlock is required.
			Spare I1 Interlocked SV		CL I/II, Div 1	CP-105A-01	SV		09	5		1			I1			Do not use unless I5 Interlock is required.
			Spare I1 Interlocked SV		CL I/II, Div 1	CP-105A-01	SV		09	6		1			I1			Do not use unless I5 Interlock is required.
			Spare I1 Interlocked SV		CL I/II, Div 1	CP-105A-01	SV		09	7		1			I1			Do not use unless I5 Interlock is required.
XV	0101	01	N2 Purge		CL I/II, Div 1	CP-105A-01	SV		10	0		1						
XV	0101	09	Chemical Distribution to R-0101		CL I/II, Div 1	CP-105A-01	SV		10	1		1						
XV	0101	10	N2 Distribution to Dip Tube		CL I/II, Div 1	CP-105A-01	SV		10	2		1						
XV	0101	11	Sample to P-0101 Inlet		CL I/II, Div 1	CP-105A-01	SV		10	3		1						
XV	0101	12	Sample Loop Return to R-0101		CL I/II, Div 1	CP-105A-01	SV		10	4		1						
XV	0101	13	Chemical Distribution to R-0101		CL I/II, Div 1	CP-105A-01	SV		10	5		1						
XV	0101	14	N2 Purge to R-0101 Camera and Port Light		CL I/II, Div 1	CP-105A-01	SV		10	6		1						
XV	0101	15	R-0101 to E-0101 Inlet Bypass Valve		CL I/II, Div 1	CP-105A-01	SV		10	7		1						
XV	0101	16	R-0101 to E-0101 Inlet		CL I/II, Div 1	CP-105A-01	SV		11	0		1						
XV	0101	17	Process Vent to Caustic Scrubber		CL I/II, Div 1	CP-105A-01	SV		11	1		1						
XV	0101	18	Process Vent to Vacuum Pump VP-0501		CL I/II, Div 1	CP-105A-01	SV		11	2		1						
XV	0101	19	PCV-0101-06 Bypass		CL I/II, Div 1	CP-105A-01	SV		11	3		1						
XV	0101	20	N2 Distribution		CL I/II, Div 1	CP-105A-01	SV		11	4		1						
XV	0101	21	T-0101 to B-0601		CL I/II, Div 1	CP-105A-01	SV		11	5		1						
XV	0101	22	N2 to T-0101		CL I/II, Div 1	CP-105A-01	SV		11	6		1						
XV	0101	23	N2 to CNV-0101		CL I/II, Div 1	CP-105A-01	SV		11	7		1						
XV	0101	26	CNV-0101 to R-0101		CL I/II, Div 1	CP-105A-01	SV		12	0		1						
XV	0101	29	DIW to R-0101		CL I/II, Div 1	CP-105A-01	SV		12	1		1						

I/O LIST - CP-105A-01
INTRINSICALLY SAFE REMOTE I/O

Inst.	System	Number	Instrument Description	Setpoint/Range	Area Classification	Panel	IO Type	Rack	Slot	Channel	Ethernet	SV	IS	XP	Safety Interlock (Hard Wired)	Software Interlock	Status	Comments
XV	0101	31	T-0101 to R-0101		CL I/II, Div 1	CP-105A-01	SV		12	2		1						
SV	0101	31	Compressed Air to P-0101		CL I/II, Div 1	CP-105A-01	SV		12	3		1						Piloted from control cabinet pneumatic output module.
			Spare SV (no Interlock)		CL I/II, Div 1	CP-105A-01	SV		12	4		1						
			Spare SV (no Interlock)		CL I/II, Div 1	CP-105A-01	SV		12	5		1						
			Spare SV (no Interlock)		CL I/II, Div 1	CP-105A-01	SV		12	6		1						
			Spare SV (no Interlock)		CL I/II, Div 1	CP-105A-01	SV		12	7		1						

I/O LIST - CP-105A-02 (FUTURE)
INTRINSICALLY SAFE REMOTE I/O

Inst.	System	Number	Instrument Description	Setpoint/Range	Area Classification	Panel	IO Type	Rack	Slot	Channel	Ethernet	SV	IS	XP	Safety Interlock (Hard Wired)	Software Interlock	Status	Comments
AIT	0102	03	R-0102 Sample pH		CL I/II, Div 1	CP-105A-02	AI		01	0			1				FUTURE	
FIT	0102	28	Syltherm return flow from R-0102 to TCM-0402		CL I/II, Div 1	CP-105A-02	AI		01	1			1				FUTURE	
TIT	0102	04	E-0102 Inlet Temperature	°C	CL I/II, Div 1	CP-105A-02	AI		01	2			1				FUTURE	
TIT	0102	05	E-0102 Outlet Temperature	°C	CL I/II, Div 1	CP-105A-02	AI		01	3			1				FUTURE	
PIT	0102	06	E-0102 Inlet Pressure		CL I/II, Div 1	CP-105A-02	AI		01	4			1				FUTURE	
			Spare Analog Input or Output		CL I/II, Div 1	CP-105A-02	AIO		01	5			1				FUTURE	
SI	0102	10	Agitator AG-0102 Speed Indication	rpm	CL I/II, Div 1	CP-105A-02	AI		01	6			1	1			FUTURE	Local readout is in XP housing (FUTURE)
PIT	0102	16	N2 to Agitator Seal Pressure		CL I/II, Div 1	CP-105A-02	AI		01	7			1				FUTURE	
TIT	0102	22	T-0102 Temperature	°C	CL I/II, Div 1	CP-105A-02	AI		01	0			1				FUTURE	
TIT	0102	07A	R-0102 Temperature	°C	CL I/II, Div 1	CP-105A-02	AI		02	1			1				FUTURE	
TIT	0102	07B	R-0102 Temperature	°C	CL I/II, Div 1	CP-105A-02	AI		02	2			1				FUTURE	
PCV	0102	06	Vent Pressure Control		CL I/II, Div 1	CP-105A-02	AO		02	3			1				FUTURE	
			Spare Analog Input or Output		CL I/II, Div 1	CP-105A-02	AIO		02	4			1				FUTURE	
			Spare Analog Input or Output		CL I/II, Div 1	CP-105A-02	AIO		02	5			1				FUTURE	
			Spare Analog Input or Output		CL I/II, Div 1	CP-105A-02	AIO		02	6			1				FUTURE	
			Spare Analog Input or Output		CL I/II, Div 1	CP-105A-02	AIO		02	7			1				FUTURE	
ZSC	0102	01	XV-0102-01 Closed		CL I/II, Div 1	CP-105A-02	DI		03	0			1				FUTURE	
ZSO	0102	01	XV-0102-01 Open		CL I/II, Div 1	CP-105A-02	DI		03	1			1				FUTURE	
ZSC	0102	02	XV-0102-02 Closed		CL I/II, Div 1	CP-105A-02	DI		03	2			1				FUTURE	
ZSO	0102	02	XV-0102-02 Open		CL I/II, Div 1	CP-105A-02	DI		03	3			1				FUTURE	
ZSC	0102	03	XV-0102-03 Closed		CL I/II, Div 1	CP-105A-02	DI		03	4			1				FUTURE	
ZSO	0102	03	XV-0102-03 Open		CL I/II, Div 1	CP-105A-02	DI		03	5			1				FUTURE	
ZSC	0102	04	XV-0102-04 Closed		CL I/II, Div 1	CP-105A-02	DI		03	6			1				FUTURE	
ZSO	0102	04	XV-0102-04 Open		CL I/II, Div 1	CP-105A-02	DI		03	7			1				FUTURE	
ZSC	0102	05	XV-0102-05 Closed		CL I/II, Div 1	CP-105A-02	DI		03	8			1				FUTURE	
ZSO	0102	05	XV-0102-05 Open		CL I/II, Div 1	CP-105A-02	DI		03	9			1				FUTURE	
ZSC	0102	06	XV-0102-06 Closed		CL I/II, Div 1	CP-105A-02	DI		03	10			1				FUTURE	
ZSO	0102	06	XV-0102-06 Open		CL I/II, Div 1	CP-105A-02	DI		03	11			1				FUTURE	
ZSC	0102	07	XV-0102-07 Closed		CL I/II, Div 1	CP-105A-02	DI		03	12			1				FUTURE	
ZSO	0102	07	XV-0102-07 Open		CL I/II, Div 1	CP-105A-02	DI		03	13			1				FUTURE	
ZSC	0102	08	XV-0102-08 Closed		CL I/II, Div 1	CP-105A-02	DI		03	14			1				FUTURE	
ZSO	0102	08	XV-0102-08 Open		CL I/II, Div 1	CP-105A-02	DI		03	15			1				FUTURE	
ZSC	0102	09	XV-0102-09 Closed		CL I/II, Div 1	CP-105A-02	DI		04	0			1				FUTURE	
ZSO	0102	09	XV-0102-09 Open		CL I/II, Div 1	CP-105A-02	DI		04	1			1				FUTURE	
ZSC	0102	10	XV-0102-10 Closed		CL I/II, Div 1	CP-105A-02	DI		04	2			1				FUTURE	
ZSO	0102	10	XV-0102-10 Open		CL I/II, Div 1	CP-105A-02	DI		04	3			1				FUTURE	
ZS	0102	11	PSE-0102-11 Burst Status		CL I/II, Div 1	CP-105A-02	DI		04	4			1				FUTURE	
ZSC	0102	11	XV-0102-11 Closed		CL I/II, Div 1	CP-105A-02	DI		04	5			1				FUTURE	
ZSO	0102	11	XV-0102-11 Open		CL I/II, Div 1	CP-105A-02	DI		04	6			1				FUTURE	
ZSC	0102	12	XV-0102-12 Closed		CL I/II, Div 1	CP-105A-02	DI		04	7			1				FUTURE	
ZSO	0102	12	XV-0102-12 Open		CL I/II, Div 1	CP-105A-02	DI		04	8			1				FUTURE	
ZSC	0102	13	XV-0102-13 Closed		CL I/II, Div 1	CP-105A-02	DI		04	9			1				FUTURE	
ZSO	0102	13	XV-0102-13 Open		CL I/II, Div 1	CP-105A-02	DI		04	10			1				FUTURE	
ZSC	0102	14	XV-0102-14 Closed		CL I/II, Div 1	CP-105A-02	DI		04	11			1				FUTURE	
ZSO	0102	14	XV-0102-14 Open		CL I/II, Div 1	CP-105A-02	DI		04	12			1				FUTURE	
ZSC	0102	15	XV-0102-15 Closed		CL I/II, Div 1	CP-105A-02	DI		04	13			1				FUTURE	
ZSO	0102	15	XV-0102-15 Open		CL I/II, Div 1	CP-105A-02	DI		04	14			1				FUTURE	
ZSC	0102	16	XV-0102-16 Closed		CL I/II, Div 1	CP-105A-02	DI		04	15			1				FUTURE	
ZSO	0102	16	XV-0102-16 Open		CL I/II, Div 1	CP-105A-02	DI		05	0			1				FUTURE	
ZSC	0102	17	XV-0102-17 Closed		CL I/II, Div 1	CP-105A-02	DI		05	1			1				FUTURE	
ZSO	0102	17	XV-0102-17 Open		CL I/II, Div 1	CP-105A-02	DI		05	2			1				FUTURE	
ZS	0102	18	PSE-0102-18 Burst Status		CL I/II, Div 1	CP-105A-02	DI		05	3			1				FUTURE	
ZSC	0102	18	XV-0102-18 Closed		CL I/II, Div 1	CP-105A-02	DI		05	4			1				FUTURE	
ZSO	0102	18	XV-0102-18 Open		CL I/II, Div 1	CP-105A-02	DI		05	5			1				FUTURE	
ZSC	0102	19	XV-0102-19 Closed		CL I/II, Div 1	CP-105A-02	DI		05	6			1				FUTURE	
ZSO	0102	19	XV-0102-19 Open		CL I/II, Div 1	CP-105A-02	DI		05	7			1				FUTURE	
ZSC	0102	20	XV-0102-20 Closed		CL I/II, Div 1	CP-105A-02	DI		05	8			1				FUTURE	
ZSO	0102	20	XV-0102-20 Open		CL I/II, Div 1	CP-105A-02	DI		05	9			1				FUTURE	
ZSC	0102	21	XV-0102-21 Closed		CL I/II, Div 1	CP-105A-02	DI		05	10			1				FUTURE	
ZSO	0102	21	XV-0102-21 Open		CL I/II, Div 1	CP-105A-02	DI		05	11			1				FUTURE	
ZSC	0102	22	XV-0102-22 Closed		CL I/II, Div 1	CP-105A-02	DI		05	12			1				FUTURE	
ZSO	0102	22	XV-0102-22 Open		CL I/II, Div 1	CP-105A-02	DI		05	13			1				FUTURE	
ZSC	0102	23	XV-0102-23 Closed		CL I/II, Div 1	CP-105A-02	DI		05	14			1				FUTURE	
ZSO	0102	23	XV-0102-23 Open		CL I/II, Div 1	CP-105A-02	DI		05	15			1				FUTURE	
ZSC	0102	24	XV-0102-24 Closed		CL I/II, Div 1	CP-105A-02	DI		06	0			1				FUTURE	

I/O LIST - CP-105A-02 (FUTURE)
INTRINSICALLY SAFE REMOTE I/O

Inst.	System	Number	Instrument Description	Setpoint/Range	Area Classification	Panel	IO Type	Rack	Slot	Channel	Ethernet	SV	IS	XP	Safety Interlock (Hard Wired)	Software Interlock	Status	Comments
ZSO	0102	24	XV-0102-24 Open		CL I/II, Div 1	CP-105A-02	DI		06	1			1				FUTURE	
ZSC	0102	25	XV-0102-25 Closed		CL I/II, Div 1	CP-105A-02	DI		06	2			1				FUTURE	
ZSO	0102	25	XV-0102-25 Open		CL I/II, Div 1	CP-105A-02	DI		06	3			1				FUTURE	
ZSC	0102	26	XV-0102-26 Closed		CL I/II, Div 1	CP-105A-02	DI		06	4			1				FUTURE	
ZSO	0102	26	XV-0102-26 Open		CL I/II, Div 1	CP-105A-02	DI		06	5			1				FUTURE	
ZSC	0102	28	XV-0102-28 Closed		CL I/II, Div 1	CP-105A-02	DI		06	6			1				FUTURE	
ZSO	0102	28	XV-0102-28 Open		CL I/II, Div 1	CP-105A-02	DI		06	7			1				FUTURE	
ZSC	0102	29	XV-0102-29 Closed		CL I/II, Div 1	CP-105A-02	DI		06	8			1				FUTURE	
ZSO	0102	29	XV-0102-29 Open		CL I/II, Div 1	CP-105A-02	DI		06	9			1				FUTURE	
ZSC	0102	31	XV-0102-31 Closed		CL I/II, Div 1	CP-105A-02	DI		06	10			1				FUTURE	
ZSO	0102	31	XV-0102-31 Open		CL I/II, Div 1	CP-105A-02	DI		06	11			1				FUTURE	
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-02	DIO		06	12			1				FUTURE	
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-02	DIO		06	13			1				FUTURE	
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-02	DIO		06	14			1				FUTURE	
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-02	DIO		06	15			1				FUTURE	
XV	0102	02	Ammonia to R-0102		CL I/II, Div 1	CP-105A-02	SV		07	0		1			I3		FUTURE	Fails Closed on R-0102 Overtemperature (FUTURE)
XV	0102	03	Chemical Distribution to R-0102		CL I/II, Div 1	CP-105A-02	SV		07	1		1			I3		FUTURE	Fails Closed on R-0102 Overtemperature (FUTURE)
XV	0102	04	Chemical Distribution to R-0102		CL I/II, Div 1	CP-105A-02	SV		07	2		1			I3		FUTURE	Fails Closed on R-0102 Overtemperature (FUTURE)
XV	0102	05	Chemical Distribution to R-0102		CL I/II, Div 1	CP-105A-02	SV		07	3		1			I3		FUTURE	Fails Closed on R-0102 Overtemperature (FUTURE)
XV	0102	06	Chemical Distribution to R-0102		CL I/II, Div 1	CP-105A-02	SV		07	4		1			I3		FUTURE	Fails Closed on R-0102 Overtemperature (FUTURE)
XV	0102	07	Chemical Distribution to R-0102		CL I/II, Div 1	CP-105A-02	SV		07	5		1			I3		FUTURE	Fails Closed on R-0102 Overtemperature (FUTURE)
XV	0102	08	Chemical Distribution to R-0102		CL I/II, Div 1	CP-105A-02	SV		07	6		1			I3		FUTURE	Fails Closed on R-0102 Overtemperature (FUTURE)
XV	0102	24	T-0102 to R-0102		CL I/II, Div 1	CP-105A-02	SV		07	7		1			I3		FUTURE	Fails Closed on R-0102 Overtemperature (FUTURE)
XV	0102	25	CNV-0102 to R-0102		CL I/II, Div 1	CP-105A-02	SV		08	0		1			I3		FUTURE	Fails Closed on R-0102 Overtemperature (FUTURE)
XV	0102	28	R-0102 Bottom Valve		CL I/II, Div 1	CP-105A-02	SV		08	1		1			I3		FUTURE	Fails Open on R-0102 Overtemperature (FUTURE)
XV	0101	27	R-0102 to R-0103		CL I/II, Div 1	CP-105A-02	SV		08	2		1			I3		FUTURE	Fails Open on R-0102 Overtemperature (FUTURE)
			Spare I3 Interlocked SV		CL I/II, Div 1	CP-105A-02	SV		08	3		1			I3		FUTURE	Do not use unless I3 Interlock is required.
			Spare I3 Interlocked SV		CL I/II, Div 1	CP-105A-02	SV		08	4		1			I3		FUTURE	Do not use unless I3 Interlock is required.
			Spare I3 Interlocked SV		CL I/II, Div 1	CP-105A-02	SV		08	5		1			I3		FUTURE	Do not use unless I3 Interlock is required.
			Spare I3 Interlocked SV		CL I/II, Div 1	CP-105A-02	SV		08	6		1			I3		FUTURE	Do not use unless I3 Interlock is required.
			Spare I3 Interlocked SV		CL I/II, Div 1	CP-105A-02	SV		08	7		1			I3		FUTURE	Do not use unless I3 Interlock is required.
XV	0102	01	N2 Purge		CL I/II, Div 1	CP-105A-02	SV		09	0		1					FUTURE	
XV	0102	09	Chemical Distribution to R-0102		CL I/II, Div 1	CP-105A-02	SV		09	1		1					FUTURE	
XV	0102	10	N2 Distribution to Dip Tube		CL I/II, Div 1	CP-105A-02	SV		09	2		1					FUTURE	
XV	0102	11	Sample to P-0102 Inlet		CL I/II, Div 1	CP-105A-02	SV		09	3		1					FUTURE	
XV	0102	12	Sample Loop Return to R-0102		CL I/II, Div 1	CP-105A-02	SV		09	4		1					FUTURE	
XV	0102	13	Chemical Distribution to R-0102		CL I/II, Div 1	CP-105A-02	SV		09	5		1					FUTURE	
XV	0102	14	N2 Purge to R-0102 Camera and Port Light		CL I/II, Div 1	CP-105A-02	SV		09	6		1					FUTURE	
XV	0102	15	R-0102 to E-0102 Inlet Bypass Valve		CL I/II, Div 1	CP-105A-02	SV		09	7		1					FUTURE	
XV	0102	16	R-0102 to E-0102 Inlet		CL I/II, Div 1	CP-105A-02	SV		10	0		1					FUTURE	
XV	0102	17	Process Vent to Caustic Scrubber		CL I/II, Div 1	CP-105A-02	SV		10	1		1					FUTURE	
XV	0102	18	Process Vent to Vacuum Pump VP-0501		CL I/II, Div 1	CP-105A-02	SV		10	2		1					FUTURE	
XV	0102	19	PCV-0102-06 Bypass		CL I/II, Div 1	CP-105A-02	SV		10	3		1					FUTURE	
XV	0102	20	N2 Distribution		CL I/II, Div 1	CP-105A-02	SV		10	4		1					FUTURE	
XV	0102	21	T-0102 to B-0601		CL I/II, Div 1	CP-105A-02	SV		10	5		1					FUTURE	
XV	0102	22	N2 to T-0102		CL I/II, Div 1	CP-105A-02	SV		10	6		1					FUTURE	
XV	0102	23	N2 to CNV-0102		CL I/II, Div 1	CP-105A-02	SV		10	7		1					FUTURE	
XV	0102	26	CNV-0102 to R-0102		CL I/II, Div 1	CP-105A-02	SV		11	0		1					FUTURE	
XV	0102	29	DIW to R-0102		CL I/II, Div 1	CP-105A-02	SV		11	1		1					FUTURE	
XV	0102	31	T-0102 to R-0102		CL I/II, Div 1	CP-105A-02	SV		11	2		1					FUTURE	
SV	0102	31	Compressed Air to P-0102		CL I/II, Div 1	CP-105A-02	SV		11	3		1					FUTURE	Piloted from control cabinet pneumatic output module (FUTURE).
			Spare SV (no Interlock)		CL I/II, Div 1	CP-105A-02	SV		11	4		1					FUTURE	
			Spare SV (no Interlock)		CL I/II, Div 1	CP-105A-02	SV		11	5		1					FUTURE	
			Spare SV (no Interlock)		CL I/II, Div 1	CP-105A-02	SV		11	6		1					FUTURE	
			Spare SV (no Interlock)		CL I/II, Div 1	CP-105A-02	SV		11	7		1					FUTURE	

Inst.	System	Number	Instrument Description	Setpoint/Range	Area Classification	Panel	IO Type	Rack	Slot	Channel	Ethernet	SV	IS	XP	Safety Interlock (Hard Wired)	Software Interlock	Status	Comments
TIT	0103	04	E-0103 Inlet Temperature	°C	CL I/II, Div 1	CP-105A-03	AI		01	0			1					
TIT	0103	05	E-0103 Outlet Temperature	°C	CL I/II, Div 1	CP-105A-03	AI		01	1			1					
PIT	0103	06	E-0103 Inlet Pressure		CL I/II, Div 1	CP-105A-03	AI		01	2			1					
TIT	0106	29	HTFR to TCM-0405 Temperature	°C	CL I/II, Div 1	CP-105A-03	AI		01	3			1					Moved FIT-0103-09 to CP-104. Replaced with TIT-0106-29.
PIT	0103	16	N2 to Agitator Seal Pressure		CL I/II, Div 1	CP-105A-03	AI		01	4			1					
FIT	0103	28	Syltherm return flow from R-0103 to TCM-04013		CL I/II, Div 1	CP-105A-03	AI		01	5			1					
TIT	0103	07	R-0103 Temperature	°C	CL I/II, Div 1	CP-105A-03	AI		01	6			1					Tag Change
TIT	0103	08	R-0103 Temperature	°C	CL I/II, Div 1	CP-105A-03	AI		01	7			1					Tag Change
PIT	0104	04	F-0104 Feed Pressure		CL I/II, Div 1	CP-105A-03	AI		02	0			1					
DPIT	0104	05	F-0104 Filter Differential Pressure	0-30 psi	CL I/II, Div 1	CP-105A-03	AI		02	1			1					
TIT	0104	06	F-0104 Jacket Temperature	°C	CL I/II, Div 1	CP-105A-03	AI		02	2			1					
PIT	0106	17	Line Pressure to R-0102		CL I/II, Div 1	CP-105A-03	AI		02	3			1					
PIT	0106	19	Line Pressure to R-0101		CL I/II, Div 1	CP-105A-03	AI		02	4			1					
PIT	0601	01	Blower B-0601 Inlet Pressure		CL I/II, Div 1	CP-105A-03	AI		02	5			1					
AIT	0106	30	F-0104 Bag Filtrate pH		CL I/II, Div 1	CP-105A-03	AI		02	6			1					
			Spare Analog Input or Output		CL I/II, Div 1	CP-105A-03	AIO		02	7			1					
PIT	030X	03	V-030X Pressure		CL I/II, Div 1	CP-105A-03	AIO		03	0			1					From F-0104/V-030X-01 Docking Station
PCV	0103	06	Vent Pressure Control		CL I/II, Div 1	CP-105A-03	AO		03	1			1					
FCV	0103	09	R-0103 Flow to F-0104	5-20 lpm	CL I/II, Div 1	CP-105A-03	AO		03	2			1					
ZC	0307	01	P-0307-01 Stroke Length Control	0-100%	CL I/II, Div 1	CP-105A-03	AO		03	3			1					
			Spare Analog Input or Output		CL I/II, Div 1	CP-105A-03	AIO		03	4			1					
			Spare Analog Input or Output		CL I/II, Div 1	CP-105A-03	AIO		03	5			1					
			Spare Analog Input or Output		CL I/II, Div 1	CP-105A-03	AIO		03	6			1					
			Spare Analog Input or Output		CL I/II, Div 1	CP-105A-03	AIO		03	7			1					
ZSC	0103	01	XV-0103-01 Closed		CL I/II, Div 1	CP-105A-03	DI		04	0			1					
ZSO	0103	01	XV-0103-01 Open		CL I/II, Div 1	CP-105A-03	DI		04	1			1					
ZSC	0103	02	XV-0103-02 Closed		CL I/II, Div 1	CP-105A-03	DI		04	2			1					
ZSO	0103	02	XV-0103-02 Open		CL I/II, Div 1	CP-105A-03	DI		04	3			1					
ZSC	0103	03	XV-0103-03 Closed		CL I/II, Div 1	CP-105A-03	DI		04	4			1					
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-03	DIO		04	4			1					
ZSO	0103	03	XV-0103-03 Open		CL I/II, Div 1	CP-105A-03	DI		04	5			1					
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-03	DIO		04	5			1					
ZSC	0103	04	XV-0103-04 Closed		CL I/II, Div 1	CP-105A-03	DI		04	6			1					
ZSO	0103	04	XV-0103-04 Open		CL I/II, Div 1	CP-105A-03	DI		04	7			1					
ZSC	0103	05	XV-0103-05 Closed		CL I/II, Div 1	CP-105A-03	DI		04	8			1				HOLD	
ZSO	0103	05	XV-0103-05 Open		CL I/II, Div 1	CP-105A-03	DI		04	9			1				HOLD	
ZSC	0103	09	XV-0103-09 Closed		CL I/II, Div 1	CP-105A-03	DI		04	10			1					
ZSO	0103	09	XV-0103-09 Open		CL I/II, Div 1	CP-105A-03	DI		04	11			1					
ZSC	0103	10	XV-0103-10 Closed		CL I/II, Div 1	CP-105A-03	DI		04	12			1					
ZSO	0103	10	XV-0103-10 Open		CL I/II, Div 1	CP-105A-03	DI		04	13			1					
ZSC	0103	13	XV-0103-13 Closed		CL I/II, Div 1	CP-105A-03	DI		04	14			1					
ZSO	0103	13	XV-0103-13 Open		CL I/II, Div 1	CP-105A-03	DI		04	15			1					
ZSC	0103	14	XV-0103-14 Closed		CL I/II, Div 1	CP-105A-03	DI		05	0			1					
ZSO	0103	14	XV-0103-14 Open		CL I/II, Div 1	CP-105A-03	DI		05	1			1					
ZSC	0103	15	XV-0103-15 Closed		CL I/II, Div 1	CP-105A-03	DI		05	2			1					
ZSO	0103	15	XV-0103-15 Open		CL I/II, Div 1	CP-105A-03	DI		05	3			1					
ZSC	0103	16	XV-0103-16 Closed		CL I/II, Div 1	CP-105A-03	DI		05	4			1					
ZSO	0103	16	XV-0103-16 Open		CL I/II, Div 1	CP-105A-03	DI		05	5			1					
ZSC	0103	17	XV-0103-17 Closed		CL I/II, Div 1	CP-105A-03	DI		05	6			1					
ZSO	0103	17	XV-0103-17 Open		CL I/II, Div 1	CP-105A-03	DI		05	7			1					
ZSC	0103	18	XV-0103-18 Closed		CL I/II, Div 1	CP-105A-03	DI		05	8			1					
ZSO	0103	18	XV-0103-18 Open		CL I/II, Div 1	CP-105A-03	DI		05	9			1					
ZSC	0103	19	XV-0103-19 Closed		CL I/II, Div 1	CP-105A-03	DI		05	10			1					
ZSO	0103	19	XV-0103-19 Open		CL I/II, Div 1	CP-105A-03	DI		05	11			1					
ZSC	0103	20	XV-0103-20 Closed		CL I/II, Div 1	CP-105A-03	DI		05	12			1					
ZSO	0103	20	XV-0103-20 Open		CL I/II, Div 1	CP-105A-03	DI		05	13			1					
ZSC	0103	23	XV-0103-23 Closed		CL I/II, Div 1	CP-105A-03	DI		05	14			1					
ZSO	0103	23	XV-0103-23 Open		CL I/II, Div 1	CP-105A-03	DI		05	15			1					
ZSC	0103	29	XV-0103-29 Closed		CL I/II, Div 1	CP-105A-03	DI		06	0			1					
ZSO	0103	29	XV-0103-29 Open		CL I/II, Div 1	CP-105A-03	DI		06	1			1					
ZSC	0103	30	XV-0103-30 Closed		CL I/II, Div 1	CP-105A-03	DI		06	2			1					
ZSO	0103	30	XV-0103-30 Open		CL I/II, Div 1	CP-105A-03	DI		06	3			1					
ZSC	0106	01	XV-0106-01 Closed		CL I/II, Div 1	CP-105A-03	DI		06	4			1					
ZSO	0106	01	XV-0106-01 Open		CL I/II, Div 1	CP-105A-03	DI		06	5			1					
ZSC	0106	06	XV-0106-06 Closed		CL I/II, Div 1	CP-105A-03	DI		06	6			1					

Inst.	System	Number	Instrument Description	Setpoint/Range	Area Classification	Panel	IO Type	Rack	Slot	Channel	Ethernet	SV	IS	XP	Safety Interlock (Hard Wired)	Software Interlock	Status	Comments
ZSO	0106	06	XV-0106-06 Open		CL I/II, Div 1	CP-105A-03	DI		06	7			1					
ZSC	0106	09	XV-0106-09 Closed		CL I/II, Div 1	CP-105A-03	DI		06	8			1					
ZSO	0106	09	XV-0106-09 Open		CL I/II, Div 1	CP-105A-03	DI		06	9			1					
ZSC	0106	16	XV-0106-16 Closed		CL I/II, Div 1	CP-105A-03	DI		06	10			1					
ZSO	0106	16	XV-0106-16 Open		CL I/II, Div 1	CP-105A-03	DI		06	11			1					
ZSC	0106	18	XV-0106-18 Closed		CL I/II, Div 1	CP-105A-03	DI		06	12			1					
ZSO	0106	18	XV-0106-18 Open		CL I/II, Div 1	CP-105A-03	DI		06	13			1					
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-03	DIO		06	14			1					
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-03	DIO		06	15			1					
ZSC	0106	20	XV-0106-20 Closed		CL I/II, Div 1	CP-105A-03	DI		07	0			1					
ZSO	0106	20	XV-0106-20 Open		CL I/II, Div 1	CP-105A-03	DI		07	1			1					
ZSC	0106	21	XV-0106-21 Closed		CL I/II, Div 1	CP-105A-03	DI		07	2			1					
ZSO	0106	21	XV-0106-21 Open		CL I/II, Div 1	CP-105A-03	DI		07	3			1					
ZSC	0106	22	XV-0106-22 Closed		CL I/II, Div 1	CP-105A-03	DI		07	4			1					
ZSO	0106	22	XV-0106-22 Open		CL I/II, Div 1	CP-105A-03	DI		07	5			1					
ZSC	0106	23	XV-0106-23 Closed		CL I/II, Div 1	CP-105A-03	DI		07	6			1					
ZSO	0106	23	XV-0106-23 Open		CL I/II, Div 1	CP-105A-03	DI		07	7			1					
ZSC	0106	24	XV-0106-24 Closed		CL I/II, Div 1	CP-105A-03	DI		07	8			1					
ZSO	0106	24	XV-0106-24 Open		CL I/II, Div 1	CP-105A-03	DI		07	9			1					
ZSC	0106	25	XV-0106-25 Closed		CL I/II, Div 1	CP-105A-03	DI		07	10			1					
ZSO	0106	25	XV-0106-25 Open		CL I/II, Div 1	CP-105A-03	DI		07	11			1					
ZSC	0306	05	XV-0306-05 Closed		CL I/II, Div 1	CP-105A-03	DI		07	12			1					
ZSO	0306	05	XV-0306-05 Open		CL I/II, Div 1	CP-105A-03	DI		07	13			1					
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-03	DIO		07	14			1					
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-03	DIO		07	15			1					
YI	0303	03	V-0303 Cable Connection Confirm		CL I/II, Div 1	CP-105A-03	DI		08	0			1					From F-0104/V-030X-01 Docking Station
YI	0304	03	V-0304 Cable Connection Confirm		CL I/II, Div 1	CP-105A-03	DI		08	1			1					From F-0104/V-030X-01 Docking Station
YI	0305	03	V-0305 Cable Connection Confirm		CL I/II, Div 1	CP-105A-03	DI		08	2			1					From F-0104/V-030X-01 Docking Station
YI	0104	17	F-0104 Cable Connection Confrim		CL I/II, Div 1	CP-105A-03	DI		08	3			1					From F-0104/V-030X-01 Docking Station
ZSC	0104	02	XV-0104-02 Closed		CL I/II, Div 1	CP-105A-03	DI		08	4			1					From F-0104/V-030X-01 Docking Station
ZSO	0104	02	XV-0104-02 Open		CL I/II, Div 1	CP-105A-03	DI		08	5			1					From F-0104/V-030X-01 Docking Station
PAH	0104	03	Rupture Disk PSE-0104-03 Burst		CL I/II, Div 1	CP-105A-03	DI		08	6			1					From F-0104/V-030X-01 Docking Station
XA	HMI	01	HMI Purge Loss Alarm		CL I/II, Div 1	CP-105A-03	DIO		08	7			1					
YI	0307	01	ZC-0307-01 Cable Connection Confirm		CL I/II, Div 1	CP-105A-03	DI		08	8			1					From P-0307-01 Docking Station
ZS	0103	11	PSE-0103-11 Burst Status		CL I/II, Div 1	CP-105A-03	DI		08	9			1					
LSH	0701	03	T-0701 High Level (Liquid present in vessel)		CL I/II, Div 1	CP-105A-03	DI		08	10			1					
LSH	0702	03	T-0702 High Level (Liquid present in vessel)		CL I/II, Div 1	CP-105A-03	DI		08	11			1					
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-03	DO		08	12			1					
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-03	DO		08	13			1					
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-03	DIO		08	14			1					
			Spare Digital Input or Output		CL I/II, Div 1	CP-105A-03	DIO		08	15			1					
XV	0103	02	Chemical Addition to R-0103		CL I/II, Div 1	CP-105A-03	SV		09	0		1			I5			Fails Closed on R-0103 Overtemperature
XV	0103	03	Chemical Addition to R-0103		CL I/II, Div 1	CP-105A-03	SV		09	1		1			I5			Fails Closed on R-0103 Overtemperature
XV	0103	04	Chemical Addition to R-0103		CL I/II, Div 1	CP-105A-03	SV		09	2		1			I5			Fails Closed on R-0103 Overtemperature
XV	0103	23	R-0102 Bottom Valve		CL I/II, Div 1	CP-105A-03	SV		09	3		1			I5			Fails Closed on R-0103 Overtemperature
SV	0106	03	CA Distribution to Utility Panel UP-0106		CL I/II, Div 1	CP-105A-03	SV		09	4		1			I1, I3, I5			Air-piloted
SV	0106	26	CA Distribution to Utility Panel UP-0106		CL I/II, Div 1	CP-105A-03	SV		09	5		1			I1, I3, I5			Air-piloted
			Spare I5 Interlocked SV		CL I/II, Div 1	CP-105A-03	SV		09	6		1			I5			Do not use unless I5 Interlock is required.
			Spare I5 Interlocked SV		CL I/II, Div 1	CP-105A-03	SV		09	7		1			I5			Do not use unless I5 Interlock is required.
XV	0103	05	R-0101/R-0102 to R-0103		CL I/II, Div 1	CP-105A-03	SV		10	0		1			I1, I3		HOLD	Fail OPEN on R-01011 or R-0102 overtemperature alarm.
XV	0103	01	N2 Distribution		CL I/II, Div 1	CP-105A-03	SV		10	1		1						
XV	0103	09	Chemical Distribution to R-0103		CL I/II, Div 1	CP-105A-03	SV		10	2		1						
XV	0103	10	N2 Distribution to Dip Tube		CL I/II, Div 1	CP-105A-03	SV		10	3		1						
XV	0103	13	N2 to R-0103		CL I/II, Div 1	CP-105A-03	SV		10	4		1						
XV	0103	14	N2 Purge to R-0103 Camera and Port Light		CL I/II, Div 1	CP-105A-03	SV		10	5		1						
XV	0103	15	R-0103 to E-0103 Inlet Bypass Valve		CL I/II, Div 1	CP-105A-03	SV		10	6		1						
XV	0103	16	R-0103 to E-0103 Inlet		CL I/II, Div 1	CP-105A-03	SV		10	7		1						
XV	0103	17	Process Vent to Caustic Scrubber		CL I/II, Div 1	CP-105A-03	SV		11	0		1						
XV	0103	18	Process Vent to Vacuum Pump VP-0501		CL I/II, Div 1	CP-105A-03	SV		11	1		1						
XV	0103	19	PCV-0103-06 Bypass		CL I/II, Div 1	CP-105A-03	SV		11	2		1						
XV	0103	20	N2 Distribution		CL I/II, Div 1	CP-105A-03	SV		11	3		1						
XV	0103	29	DIW to R-0103		CL I/II, Div 1	CP-105A-03	SV		11	4		1						
XV	0103	30	FCV-0103-09 Bypass		CL I/II, Div 1	CP-105A-03	SV		11	5		1						
XV	0104	02	F-0104 Bottom Outlet Valve		CL I/II, Div 1	CP-105A-03	SV		11	6		1						
XV	0106	01	DIW Distribution Valve		CL I/II, Div 1	CP-105A-03	SV		11	7		1						

I/O LIST - CP-105A-03
INTRINSICALLY SAFE REMOTE I/O

Inst.	System	Number	Instrument Description	Setpoint/Range	Area Classification	Panel	IO Type	Rack	Slot	Channel	Ethernet	SV	IS	XP	Safety Interlock (Hard Wired)	Software Interlock	Status	Comments
XV	0106	06	N2 Distribution		CL I/II, Div 1	CP-105A-03	SV		12	0		1						
XV	0106	09	N2 Distribution		CL I/II, Div 1	CP-105A-03	SV		12	1		1						
XV	0106	16	To R-0102		CL I/II, Div 1	CP-105A-03	SV		12	2		1						
XV	0106	18	To R-0101		CL I/II, Div 1	CP-105A-03	SV		12	3		1						
XV	0106	20	Utility Station to VP-0501		CL I/II, Div 1	CP-105A-03	SV		12	4		1						
XV	0106	21	F-0104 Process Vent to B-0601		CL I/II, Div 1	CP-105A-03	SV		12	5		1						
XV	0106	22	Utility Station to T-0701		CL I/II, Div 1	CP-105A-03	SV		12	6		1						
XV	0106	23	Utility Station to T-0702		CL I/II, Div 1	CP-105A-03	SV		12	7		1						
XV	0106	24	HTFR to TCM-0405		CL I/II, Div 1	CP-105A-03	SV		13	0		1						
XV	0106	25	HTFS from TCM-0405		CL I/II, Div 1	CP-105A-03	SV		13	1		1						
XV	0107	07	R-0107 Bottom Valve (FUTURE)		CL I/II, Div 1	CP-105A-03	SV		13	2		1			IX			For interlock only. Control is stand alone by Vendor.
XV	0306	05	NH3 to Exhaust Blower		CL I/II, Div 1	CP-105A-03	SV		13	3		1						
			Spare SV (no Interlock)		CL I/II, Div 1	CP-105A-03	SV		13	4		1						
			Spare SV (no Interlock)		CL I/II, Div 1	CP-105A-03	SV		13	5		1						
			Spare SV (no Interlock)		CL I/II, Div 1	CP-105A-03	SV		13	6		1						
			Spare SV (no Interlock)		CL I/II, Div 1	CP-105A-03	SV		13	7		1						

Inst.	System	Number	Instrument Description	Setpoint/Range	Area Classification	Panel	IO Type	Rack	Slot	Channel	Ethernet	SV	IS	XP	Safety Interlock (Hard Wired)	Software Interlock	Status	Comments
			PS1 Fault			CP-M580	DI	X80-01	01	0								M580-01 Power Supply Fault Relay
			PS2 Fault			CP-M580	DI	X80-01	01	1								M580-02 Power Supply Fault Relay
			PS3 Fault			CP-M580	DI	X80-01	01	2								X80-03 Power Supply Fault Relay
			PULS-01 Fault			CP-M580	DI	X80-01	01	3								PULS-01 Power Supply Fault Relay
			PULS-02 Fault			CP-M580	DI	X80-01	01	4								PULS-02 Power Supply Fault Relay
YI	0306	01	NH3 Cylinder On-line / ESO Valve Open			CP-M580	DI	X80-01	01	5								
XA	0306	02	Low Cylinder			CP-M580	DI	X80-01	01	6								
XA	0306	03	Ammonia System Controller Alarm			CP-M580	DI	X80-01	01	7							FUTURE	General Alarm for Gas Detector Alarm and/or Excess Flow
XA	0306	04	Gas Monitor Ammonia Detection Alarm			CP-M580	DI	X80-01	01	8							FUTURE	Gas Detector High Ammonia Alarm
XA	0306	05	Gas Monitor Fail Alarm			CP-M580	DI	X80-01	01	9							FUTURE	Gas Detector Fail (normally energized during powered operation)
XA	0306	06	Mass Flow Controller Cabinet Purge Fail Alarm			CP-M580	DI	X80-01	01	10							FUTURE	MFC Cabinet Z-Purge Loss of Pressure Alarm
LS	2000	01	Leak Detection in Mechanical Room 102 (DI Water System)			CP-M580	DI	X80-01	01	11								
			Spare			CP-M580	DI	X80-01	01	12								
			Spare			CP-M580	DI	X80-01	01	13								
			Spare			CP-M580	DI	X80-01	01	14								
			Spare			CP-M580	DI	X80-01	01	15								
HS	0306	01	Ammonia System Controller Remote Start			CP-M580	DO	X80-01	02	0							FUTURE	
HS	0306	02	Ammonia System Controller Remote Shutdown			CP-M580	DO	X80-01	02	1							FUTURE	
HS	0101	24	Camera CAM-0101-24 ON/OFF			CP-M580	DO	X80-01	02	2								
HS	0102	24	Camera CAM-0102-24 ON/OFF			CP-M580	DO	X80-01	02	3							FUTURE	
HS	0103	24	Camera CAM-0103-24 ON/OFF			CP-M580	DO	X80-01	02	4								
			Spare			CP-M580	DO	X80-01	02	5								
			Spare			CP-M580	DO	X80-01	02	6								
			Spare			CP-M580	DO	X80-01	02	7								
			Spare			CP-M580	DO	X80-01	02	8								
			Spare			CP-M580	DO	X80-01	02	9								
			Spare			CP-M580	DO	X80-01	02	10								
			Spare			CP-M580	DO	X80-01	02	11								
			Spare			CP-M580	DO	X80-01	02	12								
			Spare			CP-M580	DO	X80-01	02	13								
			Spare			CP-M580	DO	X80-01	02	14								
			Spare			CP-M580	DO	X80-01	02	15								
AI	0306	09	Ammonia %LEL	0-100%		CP-M580	AI	X80-01	03	0							FUTURE	
WI	0306	11	Ammonia Tank Weight			CP-M580	AI	X80-01	03	1							FUTURE	
FIT	2000	02	DI Water Flow to Header	GPM		CP-M580	AI	X80-01	03	2								
			Spare			CP-M580	AI	X80-01	03	3								
			Spare			CP-M580	AI	X80-01	04	0								
			Spare			CP-M580	AI	X80-01	04	1								
			Spare			CP-M580	AI	X80-01	04	2								
			Spare			CP-M580	AI	X80-01	04	3								
FC	0306	08	Ammonia Flow Remote Setpoint	0-5V		CP-M580	AO	X80-01	05	0							FUTURE	Use 0-20mA output w/ 250 ohm precision resistor for 0-5V
			Spare			CP-M580	AO	X80-01	05	1								
			Spare			CP-M580	AO	X80-01	05	2								
			Spare			CP-M580	AO	X80-01	05	3								

LAWRENCE LIVERMORE NATIONAL LABORATORIES

Livermore, CA

Renovation of Chemical Synthesis Pilot Plant at B827 Complex

Release Date: October 14, 2016

Revision: A

Sequence of Operations

Prepared by:

Hart Design Group
800 Scenic View Drive
Cumberland, RI 02864

The Hart Companies

Hart Design Group

Prepared	Reviewed	Approved
James Horwath	Mark Lindgren	Mark Lindgren

Client Approval

Reviewed	Approved	Date

Client Acceptance of the contents of this document will be assumed within 10 business days unless otherwise communicated

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PART 1 Process Flow Description

The following is a brief description of the process flow scheme. It is meant to provide an overview to better explain the reaction sequences described below. For a complete description of the process, consult the Process Design Basis, PFD's and P&ID's.

1.1 Reference Drawings

A. The listing of relevant P&ID's is contained in Attachment 1.

1.2 Related Documents

A. Functional Requirement Specification

1.3 Design Intent

A. This intent of the automation of this process is to provide the capability of remote operation.

B. It is the design intent that all operations are manually initiated. There is no batch sequencing.

C. All operation thru filtration will be controlled remote to the room. Entry into the room for configuration of hoses, equipment set-up, etc. will only be at stages in the process when a reaction is not occurring.

D. It is the intent that only one reaction will be operated at a time in Room 105A. Either R-0101 or R-0107 will be in operation.

1.4 Control Functionality

A. Automated valves – On-off
   1. Operated remotely from an HMI.
   2. Include both open and closed limit switches

B. Control Loops
   1. Control loops are depicted on the P&ID's.
   2. All control loops are either single loop or cascade control. There is no multivariate control.
   3. All control devices shall be functional in either an automatic or manual mode.

C. Alarms
   1. All configured analog control blocks will be configured with the following:
      a. High Alarm
      b. High-High Alarm
      c. Low Alarm
      d. Low-Low Alarm
      e. Deviation
      f. Rate of change

1.5 Modules

The pilot plant system consists of the following modules:

A. Raw Material Charge from fume hood in Room 104 to reactors in Room 105A

B. Reactors, including vessel and overhead condenser.
   1. R-0101/E-0101
   2. R-0103/E-0103

C. Filtration (via bag filter), F-0104

D. Process Utility Station

E. Temperature Control Modules (TCM's)
   1. One for each of the reactors,
   2. One for all condensers
   3. One for F-0104.

F. Process Utilities
   1. Vacuum Pump
   2. Process Chiller (supplies all TCM's)
   3. Exhaust stack blower
   4. Emergency Relief Knock-out Tank for process streams
   5. Emergency Relief Catch Tank for Syltherm (from vessel jackets)
   6. Nitrogen (from liquid nitrogen dewars) Distribution
   7. Instrument Air Distribution (from existing compressor)

1.6 Functionality/process flow

A. Raw Material Charge,
   1. Reference P&ID
      a. PID-0301
   2. Raw materials are staged in Room 104. Storage is outside of the building
   3. Room 104 is equipped two hoods.
      a. Hood FH-104-01 contains metering and transfer pumps to move material from Room 104 to the Reactors in Room 105A.
      b. Dispensing of raw material is done in hood FH-104-02
   4. Raw material transfers are accomplished using one of three pumps located in Room 104.
      a. One pump is a metering pump for low flow rates.
      b. Two pumps are Air Operated Double Diaphragm pumps intended for "rapid" transfers or higher, less precise metered rates.
   5. Three Liquid dispensing vessels (T-0303, T-0304 and T-0305) are provided to stage raw materials for transfer from Room 104 into R-0101.
   6. Three Liquid dispensing vessels may be connected to any one of the three raw material transfer pumps noted above. There is room inside FH-104-01 for two Liquid Addition Vessels
   7. Each of the three pumps can be connected to any of the three transfer lines in the hood to feed to transfer manifold near R-0101.
   8. There are dedicated transfer lines dedicated for nitric acid from FH-0104-01 to R-0101 and reserved for R-0102.

9. There are dedicated transfer lines dedicated for sulfuric acid/oleum from FH-0104-01 to R-0101 and reserved for R-0102.
10. There are three additional transfer lines each from FH-0104-01 to R-0101, R-0102 (future) and R-0103.

B. R-0101

1. Reference P&ID
    a. PID-0101
2. R-0101 is equipped with an overhead condenser and an independent TCM for heating and cooling.
    a. The reactor is equipped with an external recirculation loop for use of analytical instruments (pH, spectroscopy).
    b. The reactor is equipped with a dip-tube that can be used for either the suction side of the sample recirculation loop or gas sparging.
3. The overhead condenser is used for reflux operation and limiting vapor control.
4. Liquid feeds into R-0101 are via the transfer lines noted above.
5. Solid feed is accomplished using a solids conveyor for both metered feed and bulk charge. The conveyor is equipped with a variable speed drive.
6. Ammonia feed.
    a. Anhydrous ammonia is fed from a cylinder stored in a gas cabinet external to the building. Ammonia is feed to maintain a constant pressure in R-0101. A flowmeter is provided to measure uptake.

C. R-0103

1. Reference P&ID
    a. PID-0103
2. R-0103 is equipped with an overhead condenser and an independent TCM for heating and cooling.
    a. The reactor discharge piping is equipped with a spool piece to allow installation of a particle size analyzer.
3. The overhead condenser is used for reflux operation and limiting vapor control.
4. The primary purpose of R-0103 is to serve as a reaction quench vessel for material from R-0101. It is in this vessel that crystallization of the final product takes place.
5. The solids are separated from the Mother Liquor using F-0104 as described below.
6. Transfer of the mother liquor from R-0103 is accomplished via N_2 overpressure on R-0103 and a flow control valve in the transfer line.

D. F-0104

1. Reference P&ID
    a. PID-0104
    b. PID-0106
2. F-0104 is a bag filter used to separate the crystals created in R-0103 from the mother liquor.
3. The filter is jacketed to maintain mother liquid temperature during filtration.
4. All utilities for F-0104 are supplied thru/from transfer station UP-0106.
5. Mother liquor is transferred from R-0103 as described above.
6. The mother liquor passes thru the bag and is collected in a tote.
7. Following complete transfer of the mother liquor, the liquid transfer piping from R-0103 is blown clear with N_2.
8. As required, the filter cake can be washed with DI water.

9. Drying of the product is done in a separate vacuum tray dryer that is not part of this installation.

E. UP-0106

1. Reference P&ID
   a. PID-0106
2. UP-0106 contains connections for:
   a. instrument air,
   b. nitrogen
   c. DI Water
   d. Vacuum
   e. Connections to the Catch Tanks
   f. Connection to the Exhaust Blower
   g. Transfer piping to R-0101
3. The intent for UP-0106 is primarily to provide services to F-0104. However, the station can also provide services to portable vessels and/or transfer pumps to feed R-0101 or R-0103.

F. Portable Pumps

1. Reference P&ID
   a. PID-0307
2. Three portable pumps are included. All are mounted on a cart.
   a. One air operated diaphragm pump, P-0307-03.
      1) Compressed air and automated valve are provided at UP-0106 for motive air.
   b. One Positive displacement Lewa pump with a maximum feed of 0.38-3.18 LPH, P-0307-02.
      1) P-0307-02 is mounted on a cart with the VFD and controls.
      2) P-0307-02 may be used in any electrically unclassified area, such as the Kilo Lab, Room 105 or the raw material charging hood in Room 104.
   c. One Positive displacement Lewa pump with a maximum feed of 0.4-40 LPH, P-0307-01.
      1) The VFD and controls for the pump are located outside of the electrically classified area.
      2) A connection for the VFD and controls is provided at UP-0106.
      3) P-0307-01 may be used in any electrically unclassified area, such as the Kilo Lab, Room 105 or the raw material charging hood in Room 104.

G. Ammonia Charge System

1. Ref P&ID
   a. PID-0306
2. System is designed to feed ammonia from a single cylinder to R-0101.
3. Cylinder contains anhydrous liquid ammonia.
4. Cylinder is stored in a single cylinder cabinet, located exterior to the building.
5. A cylinder blanket heater is provided to produce the required ammonia feed rate.
6. Cylinder Scale to measure inventory in the cylinder.
7. Ammonia is fed into reactor under pressure control of the reactor head space.

H. 30 Liter Buchi Glass Reactor System, R-0107
1. Ref P&ID
   a. PID-0107
2. R-0107 is a packaged Buchi Glass Plant. Equipped with:
   a. 30 Liter Glass lined carbon Steel Reactor Vessel,
   b. Glass vessel head,
   c. Overhead condenser,
   d. Glass Feed vessel
   e. Glass Receiver vessel
3. Heating/Cooling of the reactor vessel is provided from TCM-0406.
4. Coolant to the overhead condenser is provided from TCM-0404.
5. **NOTE: The functionality of this system is still being defined.**

PART 2 Sequence From Cold Start

This sequence is intended to describe the operation when system is initially in a completely idle state.

2.1 Verify/Turn-on Utility Systems

A. Verify Operation of Air Compressor/Instrument Air

B. Verify Operation of HVAC

C. Verify Process Control System is on.

D. Turn on Process Chiller Plant.

E. Turn on Nitrogen System

F. Verity Operation of Water System

G. Turn on Exhaust Blower

H. Turn on the Vacuum Pump System

PART 3 Process Start-up (examples using R-0101 as example)

This process set-up is a hypothetical reaction sequence. It was intended to demonstrate the system capabilities and is not intended to define a particular batch sequence. This is an upper level view of the system functionality.

3.1 Set-up Reactor R-0101

A. Ref. P&ID's: PID-0101, PID-0401, PID-0404, PID-0501, PID-1101.

B. Operator verifies via HMI that all automated valves around reactor are closed.

C. Align Condenser Water Supply and Return valves to E-0101.
1. Visually verify that drain and vent valves on system are closed.

2. Open manual valves from and return to between TCM-0404 and E-0101.
3. Open automated valves on the Chilled Glycol Supply to E-0101
   a. XV-0404-09
   b. XV-0404-13
4. Turn on TCM-0404 from via the HMI
   a. Turn on HS-0404-07.
   b. Select Set-point TIC-0101-05

D. Open N_2 supply to R-0101 by opening valve XV-1101-16

E. Initiate Nitrogen Purge Sequence
1. All pressure is measured using PIT-0101-06
2. If necessary, initiate vacuum pump VP-0501 purge sequence.
3. When vacuum pump VP-0501 purge sequence is complete, evacuate R-0101:
   a. Open valve XV-0101-28 to VP-0501.
   b. Open PCV-0101-06 to slowly bring pressure down.
   c. Evacuate R-0101 to 50 Hg abs
   d. Close valve XV-0101-28
4. Pressurize R-0101 to 15 psig
   a. Open N_2 supply valve XV-0101-30, pressurize R-0101 to 15 psig with N_2.
5. Relieve Pressure thru vent blower
   a. Open XV-0101-27.
   b. Control discharge flow using PCV-0101-06.
   c. When pressure reaches 0 psig, close XV-0101-27.
6. Repeat sequence Steps 3 thru 5 three (3) times.

3.2 Raw Material Charges, Set-Up And Feed

A. Fill Liquid Addition Vessel(s), T-0303, T-0304, T-0305 as required.
1. Ref P&ID's: PID-0301, PID-0303, PID-0304, PID-0305, PID-0501.
2. This can be done in Room 104 or Room 105A
3. In Room 104, material from drums or other containers can be transferred into any of the Liquid Addition vessels using the air operated diaphragm pumps and weigh scales in FH-104-01. The scale can be used to weigh either the amount transferred into T-030X or loss of weight from the source container.
4. An alternative to using the air operated diaphragm pump is to use VP-0501 to draw a vacuum on a Liquid Addition Vessel to induce flow from a carboy or other container.

B. For transfer from carboy into Liquid Addition Vessel, using T-0303 and P-0301-03 as an example.
1. Ref P&ID's: PID-0301, PID-0303, PID-0304, PID-0305.
2. Locate T-0303 (or the originating container) on scale WIT-0301-02.
3. Connect Relief Line of T-0303 to Relief Line header.
4. Connect N_2. Connect hose to T-0303 inlet nozzle N1.
5. Connect hose with dip tube (shown as SP-0301-06 on P&ID) to the inlet of P-0301-02 upstream of valve HV-0301-21.
6. Place dip tube in carboy. [Ed Note: the dip tube could be designed to thread into the 2" bung on the carboy.]

7. Connect hose (not shown on P&ID) between the discharge of P-0301-03 downstream of valve HS-0301-09 and the dip-tube connection on T-0303, nozzle N_2 (quick connect on valve HV-0303-04).
8. Open suction side valves.
    a. Valve on dip-tube (not currently numbered.
    b. HV-0301-21.
9. Open discharge side valves
    a. Valve on tank, HV-0303-04
    b. Discharge of pump XV-0301-09 via HMI.
10. Turn on P-0301-03 by opening the motive air supply valve, SV-0303-02 via HMI.
11. Transfer is monitored using WIT-0301-02 which is observable on the HMI.
12. When transfer is complete, turn off P-0301-02 by closing the motive air supply valve, SV-0303-01 via HMI.
13. Blow-out the discharge section of tubing into T-0303.
    a. Close pump discharge piping valve, XV-0301-09.
    b. Open Nitrogen purge valve XV-0301-10.
    c. When weight indicated on scale does not change, close XV-0301-10.
14. Drain Suction piping using HV-0301-22.
15. Drain Discharge Piping using HV-0301-19.
16. Disconnect Hose

C. For transfer from carboy into T-0303, using vacuum as an example.
1. Ref P&ID's: PID-0301, PID-0303, PID-0304, PID-0305, PID-0501.
2. Locate T-0303 (or the originating container) on scale WIT-0301-02.
3. Connect Relief Line of T-0303 to Relief Line header.
4. Connect N_2. Connect hose to T-0303 inlet nozzle N1.
5. Connect T-0303 to Vacuum line in hood.
6. Connect hose with dip tube (shown as SP-0301-10 on P&ID) to the inlet of T-0303 (Nozzle N2).
7. Place dip tube in carboy. [Ed Note: the dip tube could be designed to thread into the 2" bung on the carboy.]
8. Open vent bung on carboy.
9. Open suction side valves.
    a. Valve on dip-tube (not currently numbered.
10. Draw vacuum on T-0303.
    a. Close Needle valve HV-0301-24.
    b. Open vacuum isolation valve HV-0301-23.
    c. Slowly open HV-0301-24 to draw a vacuum on T-0303.
    d. Vacuum level can be observed on PI-0301-04.
11. Transfer is monitored using WIT-0301-02 which is observable on the scale.
12. When transfer is complete, close the inlet valve on the vessel, HV-0303-04.
13. Close HV-0301-23 to isolate the vacuum source.
14. Remove the dip-tube above the liquid level.
15. Open the inlet valve on the vessel, HV-0303-04. Residual vacuum in the vessel will clear the transfer tubing.

D. Liquid Charge Prep, metered feed from Liquid addition vessels (using T-0303 as example)
1. Ref P&ID's: PID-0101, PID-0301, PID-0303, PID-0304, PID-0305.
2. Place pre-filled Liquid Addition vessel on scale WE-0301-01 in fume hood

3. Connect Blower Vent
   a. Connect hose between valve HV-0303-03 and HV-0301-10
   b. Open HV-0303-03 and HV-0301-10
4. Connect Rupture Disk
   a. Connect hose between valve PSE-0303-02 and HV-0301-11
   b. Open HV-0301-11.
5. Close Blower Vent Line valve HV-0303-03.
6. Connect nitrogen supply.
   a. Connect hose between valve HV-0303-05 and HV-0301-07
   b. Open HV-0303-05 and HV-0301-07
7. Connect hose from T-0303 to P-0301-01
   a. Connect hose between valve HV-0303-01 and HV-0301-14
8. Connect hose from P-0301-01 to transfer piping to reactor.
   a. Connect hose between valve HV-0301-11 and HV-0301-26
9. Set-up suction piping
   a. Close drain valves HV-0301-15 and HV-0301-16
   b. Close unused suction valve HV-0301-17
   c. Open HV-0301-14
10. Set-up discharge piping
    a. Close suction side drain valve.
    b. Verify Discharge Side N_2 blow-out valve XV-0301-12 is closed
    c. Open XV-0301-11
11. Turn on pump using HX-0301-01.
12. Pump operation is monitored by PIT-0301-03
13. Set Speed control.
14. Material transfer/flowrate is monitored by WIC-0101-08 and WIC-0301-10 (via HMI).
15. See description of loop operation in Section 6.

E. Bulk charge from Room 104 into R-0101 (initial charge to reactor via line ½”-P-HC3-0301-12).
   1. Ref P&ID’s: PID-0101, PID-0301, PID-0303, PID-0304, PID-0305.
   2. This example is based on charging from original container into R-0101 using P-0301-03.
   3. Locate original container on scale WIT-0301-02.
      a. Connect hose with dip tube (shown as SP-0301-06 on P&ID) to the inlet of P-0301-03 upstream of valve HV-0301-21.
      b. Place dip tube in carboy.
      c. Connect hose (not shown on P&ID) between the discharge of P-0301-03 downstream of valve HS-0301-09 and desired charge line. In this case, charge line ½”-P-HC3-0301-12 (quick connect on valve XV-0301-20).
      d. Open suction side valves.
         1) Valve on dip-tube (not currently numbered).
         2) HV-0301-21.
      e. Open discharge side valves
         1) Discharge of pump XV-0301-09 via HMI.
         2) Valve to manifold in FH-104-01, XV-0301-20
         3) Valve at reactor manifold, XV-0101-05,
         4) Valve at reactor, XV-0101-09.

f. Turn on P-0301-03 by opening the motive air supply valve, SV-0303-02 via HMI.
g. Transfer is monitored using WIT-0301-02 which is observable on the HMI.
h. When transfer is complete, turn off P-0301-03 by closing the motive air supply valve, SV-0303-02 via HMI.
i. Blow-out the discharge section of tubing into R-0101.
   1) Close pump discharge piping valve, XV-0301-09.
   2) Open Nitrogen purge valve XV-0301-10.
   3) When weight indicated on scale does not change, close XV-0301-10.
j. Drain Suction piping using HV-0301-22.
k. Drain Discharge Piping using HV-0301-19.
l. Disconnect hose.

F. Solids Charge from Conveyor (metered).
1. Ref P&ID's: PID-0101.
2. Add Pre-weighed material to hopper on CNV-0101 in Room 105A.
3. Close lid.
4. Initiate nitrogen purge/sweep by opening N_2 inlet to hopper, HV-0101-15.
5. When solids need to be added to R-0101,
   a. open valve XV-0101-19
6. Begin transfer from conveyor by opening valve XV-0101-16
   a. The conveyor can be started and the speed controlled using SIC-0101-08.
   b. Flow control can be manual or the flow control loop can be activated.
   c. Weight and Flow control are conducted by the PLC.
7. When the transfer is complete, turn off conveyor and close XV-0101-16.
8. Nitrogen sweep on the conveyor hopper may remain on for duration of reaction.
9. Clear the solids transfer line using nitrogen.
   a. Open XV-0101-20.
   b. Nitrogen flow rate is controlled by FIC-0101-XX (this control loop needs to be added, or FIC-1101-06, N_2 flow control needs to be modified to contain a pressure control loop.
   c. Maintain flow as required.
   d. Stop N_2 flow by turning off XV-0101-20.
   e. Close valve at vessel, XV-0101-19.

G. Solids Charge from Molten Vessel T-0101.
1. Ref P&ID's: PID-0101.
2. T-0101 is loaded with a pre-weighed amount of material thru the 3" nozzle on the vessel.
3. Following closure of the nozzle, open vent line to B-0601 by opening XV-0101-21
4. Turn on heat tracing on the connected piping.
5. Set TIC-0101-22 to desired set-point.
6. When temperature set point is reached, feed to R-0101 can be started.
7. Begin feed:
   a. Flow rate from T-0101 to R-0101 is limited by the setting of manual needle valve HV-0101-14.
   b. Close vent line to B-0601, XV-0101-21
   c. Open nitrogen supply valve to T-0101, XV-0101-22
   d. Open XV-0101-24,

e. Open XV-0101-31.
f. If R-0101 temperature exceeds XX°C. Valve XV-0101-31 is closed.
g. The amount transferred is monitored by the reactor weight from WIC-0101-08. Transfer is complete when no change in weight is detected.

8. To complete feed
   a. Close XV-0101-31.
   b. Close XV-0101-24.
   c. Close nitrogen supply valve to T-0101, XV-0101-22
   d. Open vent line to B-0601, XV-0101-21

H. Ammonia (gas) feed to R-0101.

1. Ref P&ID's: PID-0101, PID-0306.
2. Anhydrous ammonia is stored in a gas cabinet outside the building.
3. Feed to R-0101 is controlled by pressure in the head space of R-0101.
   a. Pressure is measured by PIT-0101-06.
   b. Pressure from the cylinder is controlled by manual regulator PCV-0306-18
4. To connect cylinder
   a. Close XV-0306-02.
   b. Connect flex hose SP-0306-01 to cylinder.
5. To set-up the ammonia feed
   a. The ammonia line is hard piped to R-0101.
   b. Confirm the nitrogen line to the ammonia transfer piping is closed, XV-0306-09.
   c. Open the following manual valves.
      1) HV-0306-04 (inlet to flow control instrumentation.
      2) HV-0306-02 (supply to R-0101).
6. Verify valve XV-0101-28 from R-0101 to the vacuum pump (VP-0501) is closed.
7. The reactor pressure control (PIT-0101-06) is set to the desired head pressure in the reactor.
8. Automated valve (HV-0306-02) at the cylinder is opened first to establish pressure in the transfer piping.
9. Align control valves on ammonia skid.
   a. Open CV-0306-16
   b. Open Cv-0306-21
10. After pressure is detected on PIT-0306-06, the next valve in line to the reactor is opened (XV-0101-02), followed by the valve at the reactor (XV-0101-09). **Note**: PIT-0306-06 is indicated as a PI on the current P&ID's.
11. Uptake is measured by FQI-0306-08
12. When feed is completed, turn off the auto valve at the reactor (XV-0101-09).
13. Turn off the automated valve at the cylinder (XV-0306-02).
14. Vent line to the exhaust stack by opening XV-0306-05.
15. When no pressure is detected via PIT-0306-06, close XV-0306-05.
16. When the ammonia line requires to be opened, or cleared out at the end of a campaign or cylinder change out, the line can be cleared of ammonia by purging with N_2.
    a. Vent line to the exhaust stack by opening XV-0306-05.
    b. Open all vent lines to blower exhaust
       1) CV-0306-15
       2) CV-0306-22
       3) CV-0306-05

4) CV-0306-21
5) CV-0306-16
6) FV-0306-08

c. Evacuate line thru N_2 eductor.
1) Open XV-0306-09
2) Open XV-0306-10

d. Evacuate until ultimate vacuum detected on:
1) PT-0306-15
2) PT-0306-16
3) PT-0306-23

e. Close process vacuum evacuation valves
1) CV-0306-05
2) CV-0306-15
3) CV-0306-22

f. Shut-off Process vacuum evacuation nitrogen
1) Close XV-0306-10

g. Backfill System with Nitrogen
1) Open CV-0306-11
2) When pressure as measured by PIT-0306-06 reaches 80 psig
   a) Close CV-0306-11
   b) Open XV-0306-05 to depressurize system
   c) Close XV-0306-05 when PIT-0306-06 reaches "0".

3.3 Reactor (R-0101) Set-up

A. Ref P&ID's: PID-0101.

B. The following steps assume that the "Cold Start" steps described above have been completed.

C. Agitator N_2 Seal Gas Control
1. Verify that Agitator N_2 Seal Gas Control Panel is turned on.
2. Confirm pressure setting is 1 bar above operating pressure.

D. Set-up/verify hoses are aligned for proper transfer

E. Align manual Valves on Liquid Return from E-0101 to R-0101.

F. Verify via the HMI that all feed valves are closed.
1. XV-0101-01
2. XV-0101-02
3. XV-0101-03
4. XV-0101-04
5. XV-0101-05
6. XV-0101-06
7. XV-0101-10
8. XV-0101-24
9. XV-0101-25
10. XV-0101-26

G. Verify that Sample Loop is closed.

1. XV-0101-11
2. XV-0101-12

H. Verify that Bottom valve is Closed
1. XV-0101-28

I. Open Vent Valves
1. XV-0101-17
2. XV-0101-18

J. Set-up solids charge as described above.

K. Add Initial Bulk Raw Materials (Acids) from Room 104 as described above.

L. Turn on TCM and Set temperature control to desired temperature.

M. Transfer subsequent material from Room 104 to R-0101 as described above as required by batch recipe.

3.4 R-0103 Set-up

A. Ref P&ID's: PID-0103.

B. The following steps assume that the "Cold Start" steps described above have been completed.

C. Agitator N_2 Seal Gas Control
1. Verify that Agitator N_2 Seal Gas Control Panel is turned on.
2. Confirm pressure setting is 1 bar above operating pressure.

D. Align manual Valves on Liquid Return from E-0103

E. Verify via the HMI that all feed valves are closed.
1. XV-0103-01
2. XV-0103-02
3. XV-0103-03
4. XV-0103-04
5. XV-0103-09
6. XV-0103-13
7. XV-0103-05

F. Verify that Bottom valve is Closed
1. XV-0103-23

G. Open Vent Valves
1. XV-0103-17
2. XV-0103-18

H. Pre-Charge water to R-0103
1. Add DI Water to R-0103 thru the Dispensing hood in Room 104.

a. Connect Hose from hose connection downstream of valve XV-0301-01 to transfer line to R-0103 (for example, ½”-P-HC3-0301-13.
b. Open XV-0301-01.
c. Open XV-0103-03.
d. Monitor amount transferred based on weight in R-0103 using WI-0103-08.

2. Turn on TCM-0403
3. Set reactor temperature control set-point to 2°C by setting TIC-0103-.
4. Cool reactor to 2°C.
5. Add Ice (if required) to R-0103 thru manway.
6. Maintain temperature at 2°C to minimize ice melting in Quench vessel prior to transfer from R-0101.

3.5 Routine Transfer from R-0101 into R-0103.

A. Ref P&ID’s: PID-0101, PID-0103.

B. Maintain R-0103 at 2°C.

C. Transfer R-0101 to R-0103 using N_2 overpressure on R-0101 to maintain temperature below 5°C in R-0103.

1. Verify as closed feed and sample valves
   a. XV-0101-13
   b. XV-0101-12
   c. XV-0101-09
2. Close Vent Valves to vacuum pump and blower
   a. Close XV-0101-17
   b. Close and XV-0101-18
3. Disable nitrogen mass flow control loop FIC-1101-14
4. Open Nitrogen supply to R-0101
   a. Open Nitrogen valve at nitrogen manifold
      1) XV-1101-16
      2) Pressure is controlled by PCV-1101-15
   b. Open valve XV-0101-20 to pressurize R-0101.
5. Open Isolation valves between R-0101 and R-0103
   a. XV-0101-32
   b. XV-0103-05
6. Set/modulate Flowrate using FCV-0101-09.
   a. Flowrate is measured using a mass flow meter (FIT-0101-09)
7. Open R-0101 Bottom valve
   a. XV-0101-28
8. Control temperature in R-0103 by monitoring TIC-0103-07
9. When transfer is complete, allow nitrogen flow from R-0101 to R-0103 to clear transfer piping. The absence of liquid in the transfer piping will be detected by a marked change in the flow as measured by the mass flow meter (FIT-0101-09)
   a. Transfer can also be monitored by the loss in weight in R-0101.

3.6 Emergency Quench Transfer from R-0101 into R-0103.

A. Ref P&ID’s: PID-0101, PID-0103.

B. This is a hardwired interlock circuit.
   1. Closed feed and sample valves
      a. XV-0101-13
      b. XV-0101-12
      c. XV-0101-09
   2. Close Vent Valves to vacuum pump and blower
      a. Close XV-0101-17
      b. Close XV-0101-18
   3. Disable nitrogen mass flow control loop FIC-1101-14
   4. Open Nitrogen supply to R-0101
      a. Open Nitrogen valve at nitrogen manifold
         1) XV-1101-16
         2) Open valve XV-0101-20 to pressurize R-0101.
   5. Open Isolation valves between R-0101 and R-0103
      a. XV-0101-32
      b. XV-0103-05
      c. XV-0101-30
      d. XV-0101-28

3.7 F-104 Set-up

A. Ref P&ID's: PID-0103, PID-0104, PID-0106.

B. The design is based on F-104 being fed from R-0103.

C. Utilities available to F-0104 from Utility Station 0106 include:
   1. Nitrogen
   2. DIW
   3. Vacuum
   4. Heat Transfer Fluid
   5. Normal vent connection
   6. Pressure Relief Venting.

D. Station equipment
   1. Station Filter at operating location
   2. Station Portable air diaphragm pump at operating location.
   3. Station Filtrate Receiving Tote at operating location

E. Connect F-0104
   1. Ref P&ID's: PID-0104, PID-0106.
   2. Connect F-0104 to blower.
      a. Make hose connection on filter riser (between CH-0104-02 and XV-0106-21.
      b. Open HV-0104-03
      c. Open XV-0106-21
   3. Connect Relief Vent
      a. Remove "Storage" discharge connection.
      b. Connect hose from discharge of PSV-0104-03 to Utility Panel connection at valve XV-0106-22.
      c. Open XV-0106-22.

4. Close line from F-0104 to Blower.
   a. Close HV-0104-03
5. Connect HTF to jacket
   a. Connect hose from discharge of PSV-0104-04 to Utility Panel connection at valve XV-0106-23.
   b. Open VX-0106-23.
   c. Connect hose from the filter jacket inlet, HV-0104-0104-07 to the HTF supply connection at the utility panel, valve XV-0106-25.
   d. Connect hose from filter jacket discharge to the HTF supply connection at the utility panel, valve XV-0106-24.
6. Connect Filtrate Discharge from F-0104 to tote.
   a. Connect hose from F-0104, at Sight Glass SP-0104-12 to Tote inlet
   b. Connect tote vent to vent system at valve HV-0104-02. Open Valve HV-0104-02.
7. Connect R-0103 Bottom Discharge to F-0104.
   a. Connect Hose between R-0103 and F-0104 at HV-0104-04.
8. Connect Instrumentation
   a. Plug multiple conductor into local jack.

3.8 Filtration

A. Ref P&ID's: PID-0103, PID-0104, PID-0106.

B. Pressurize R-0103
1. Close vents
   a. XV-0103-17
   b. XV-0103-18
2. Set Nitrogen pad on R-0103
   a. Open XV-1101-08
   b. Open XV-0103-20

C. Transfer batch thru F-0104.
1. Verify Flow meter by-pass, XV-0103-30 is closed
2. Verify Water flush valve, XV-0103-29 is closed
3. Open F-0104 Filtrate Line, XV-0104-24
4. Open bottom discharge nozzle, XV-0103-23
5. Monitor pressure drop thru bag filter using DPIT-0104-05.
6. Flow is monitored by FE-0103-09 and controlled by FCV-0103-09.
7. Transfer is complete when flow rate indicated on FIC-0103-09 decreases.
   a. Transfer can be confirmed visually using vessel camera CAM-0103-24.
8. At the end of transfer, nitrogen will blow thru the filter, forcing residual liquid out.
9. Close R-0103 bottom valve, XV-0103-23.

D. Nitrogen blow filter body clear

The intent of this operation is to evacuate the bulk of liquid from the bag filter housing. The flowrate is controlled by FIC-1101-06.

1. Vent R-0103 to relieve residual pressure.
2. Close vent
3. Set FIC-1101-06 to X LPM.
4. Continue until no liquid is observed flowing into tote.

5. Close R-0103 Bottom valve, XV-0103-23

E. Wash with DI water

This sequence is written for an individual wash the sequence can be repeated as necessary.

1. Close vessel bottom valve.
2. Open DI Water Valve at bottom of vessel.
3. Flush at 5 gpm for XX minutes

Note: The 5 GPM is arbitrary assigned based on “rule of thumb” of 5 to 7 feet per second velocity thru the piping to suspend any solids. An alternative would be to flush at the 5 gpm for a specific volume. The effect of filter solids washing will also need to be considered during initial operation of the plant.

4. Follow-up with nitrogen blow-out.

F. Remove lid/Open Bag Housing/Remove Bag

G. Disconnect Filter.

1. Disconnect Instrumentation
    a. Unplug multiple conductor from local jack.
2. Disconnect R-0103 Bottom Discharge to F-0104.
    a. Disconnect Hose between R-0103 and F-0104 at HV-0104-04.
3. Disconnect Filtrate Discharge from F-0104 to tote.
    a. Disconnect hose from F-0104, between Sight Glass SP-0104-12 and Tote inlet
    b. Close Valve HV-0104-02. Disconnect tote vent to vent system at valve HV-0104-02.
4. Disconnect HTF to jacket
    a. Disconnect hose from filter jacket discharge to the HTF supply connection at the utility panel, valve XV-0106-24.
    b. Disconnect hose from the filter jacket inlet, HV-0104-0104-07 and the HTF supply connection at the utility panel, valve XV-0106-25.
    c. Close XV-0106-23.
    d. Disconnect hose from discharge of PSV-0104-04 to Utility Panel connection at valve XV-0106-23.
    e. Reinstall PSV-0104-04 Extension.
5. Close line from F-0104 to Blower.
    a. Close HV-0104-03
6. Disconnect F-0104 from blower.
    a. Close XV-0106-21
    b. Close HV-0104-03
    c. Disconnect hose on filter riser (between CH-0104-02 and XV-0106-21).
7. Disconnect Relief vent
    a. Close XV-0106-22.
    b. Disconnect hose from discharge of PSV-0104-03 to Utility Panel connection at valve XV-0106-22.
    c. Replace “Storage” discharge connection.

PART 4 Miscellaneous/General

4.1 Back-up Agitation

A. Ref P&ID's: PID- 0101, PID-0103.

B. Nitrogen back-up agitation is provided and is noted in the interlock schedule on the P&ID's.

C. Note: Pressure supply for the agitation back-up will need to be adjusted based on reaction pressure. Pressure of 30 psig may be sufficient for atmospheric reactions, however, 100 psig (or more) may be required for the reaction using ammonia.

4.2 Process Exhaust Blower (B-0601) start-up

A. Ref P&ID's: PID-0601.

B. Verify Isolation Spectacle Blind (SP-0601-01) is in the open position.

C. Turn on blower via HS-0601-02.

D. Open Manual Valve HV-0601-04 on process header vent discharge.

E. Confirm Manual valve to PIT-0601-01 (HV-0601-03).

4.3 Vacuum System

A. Ref P&ID's: PID-0501.

B. Vacuum Pump Purge Cycle
1. When vacuum pump is turned on, a five (5) minute nitrogen purge cycle is initiated to remove air from the system.
2. The sequence of the purge cycle will be provided by the vacuum pump supplier.

4.4 Portable Pump Operation

A. Ref P&ID's: PID-0106, PID-0307.

B. One of two portable pumps can be connected to UP-0106 for transferring material into the reactor.

C. The pumps may be used in conjunction with the Liquid Addition Vessels or original containers.

D. P-0307-01, Lewa Metering Pump
1. Connect Suction Tubing
2. Connect Discharge Side to transfer Line to R-0101. Line No. 1"-P-0106-24 at XV-0106-18
3. Connect Multi-pin connector to control panel at UP-0106.
4. Connect 120V (control) power for pump
5. Connect 480V (motive) power for pump.

E. P-0307-03, Air Operated Diaphragm Pump
1. Connect Suction Tubing
2. Connect Discharge Side to transfer Line to R-0101. Line No. 1”-P-0106-24 at XV-0106-18.
3. Connect motive air supply line to Line No. 1”-CA-CU1-1002-04.

4.5 TCM Operation - Reactors

A. Ref P&ID’s: PID-0101, PID-0103, PID-0401, PID-0403.

B. Set-point of reactor TCM’s is normally in cascade control from the reactor temperature.

C. Communication with the PLC is via Ethernet.

D. Cascade control can be disabled to allow direct setting of the TCM set-point.

E. High Temperature alarm (software)
1. Provided as first level protection
2. Turns off TCM Heater and initiates full cooling.
3. Programmatically turns off feeds.

F. A hard-wired high-high temperature interlock is provided to protect R-0101 from over temperature.
1. Electrically connected to turn off TCM heater.
2. Closes all feed valves to the reactor.
3. Closes all reactor vent valves.
4. Opens all valves to Quench vessel.
5. Opens nitrogen overpressurization to reactor.

4.6 TCM Operation – Overhead Condenser

A. Ref P&ID’s: PID-0101, PID-0404.

B. The Overhead condenser being to which flow will be routed shall be user selectable from the HMI.

C. Set-point of overhead condenser TCM is normally in cascade control from the overhead condenser.

4.7 Material transfer from scale to Reactor via loss in weight from platform scale.

A. Ref P&ID’s: PID-0101, PID-0301.

B. Material transfer from platform scales WE/WIT-0301-01 and 0301-02 can be automated or manual.

C. WIC is configured to display a loss in weight on the HMI.

D. Manual operation
1. Operator sets stroke on the pump using ZC-0301-01 accessible from the HMI.

a. Stroke can be predetermined from the “estimated” feed rate and allowing for operating the pump speed between 30 and 70% of full range.

2. Operator varies speed to maintain flow at required range or to control reactor temperature.

E. Automatic control.
1. Operator sets designed flowrate via HMI.
2. Control loop sets stroke length from predefined, programmed table.
3. Controller varies pump speed to maintain flowrate.

F. In either automatic or manual operation, the pump is interlocked with high temperature in the reactor.

PART 5 Interlocks

Interlock descriptions are contained on the P&ID. The interlock type (software of hardwired) is described below.

Interlock No.	**Type**
I-1	Hardwire
I-2	Software
I-3	Future - Hardwire
I-4	Future - Software
I-5	Hardwire
I-6	Software
I-7	Software
I-8	Software

Attachment 1 – Reference Drawings

Sheet No.	Title	Revision	Rev. Date
PFD-100	Process Flow Diagram; Pilot Plant Equipment	B	6/17/2016
PFD-101	Process Flow Diagram; Kilo Scale Equipment And Utilities	B	6/17/2016
PID-001	P&ID; Lead Sheet 1	B	6/17/2016
PID-002	P&ID; Lead Sheet 2	B	6/17/2016
PID-0101	P&ID; R-0101; 30 Gallon Reactor System	D	9/6/2016
PID-0102	P&ID; R-0102; 20 Gallon Reactor System (Future)	C	9/7/2016
PID-0103	P&ID; R-0103; 50 Gallon Glass-Lined Quench Vessel	C	9/7/2016
PID-0104	P&ID; F-0104; Bag Filter	C	9/7/2016
PID-0106	P&ID; UP-0106; Room 105A Utility Panel	D	9/7/2016
PID-0107	P&ID; 30 Liter Glass Plant	A	9/7/2016
PID-0301	P&ID; Chemical Distribution; Fume Hood FH-104-01	C	9/7/2016
PID-0302	P&ID; Fume Hood FH-104-02	C	9/7/2016
PID-0303	P&ID; Portable Chemical Addition Vessel; T-0303	D	9/7/2016
PID-0304	P&ID; Portable Chemical Addition Vessel; T-0304	C	9/7/2016
PID-0305	P&ID; Portable Chemical Addition Vessel; T-0305	C	9/7/2016
PID-0306	P&ID; Ammonia Charging	B	9/7/2016
PID-0307	P&ID; Chemical Distribution Portable Pumps	B	9/7/2016
PID-0401	P&ID; TCM-0401; R-0101 Temperature Control Module	D	9/7/2016
PID-0402	P&ID; TCM-0402; R-0102 Temperature Control Module (Future)	D	9/7/2016
PID-0403	P&ID; TCM-0403; R-0103 Temperature Control Module	D	9/7/2016
PID-0404	P&ID; TCM-0404; Reactor Condenser Temperature Control Module	D	9/7/2016
PID-0405	P&ID; TCM-0405; UP-0106 Temperature Control Module	D	9/7/2016
PID-0406	P&ID; TCM-0406; R-0107 Temperature Control Module	B	9/7/2016
PID-0501	P&ID; VP-0501; Dry Screw Vacuum Pump	E	9/7/2016
PID-0601	P&ID; B-0601; Exhaust Blower	D	9/7/2016
PID-0701	P&ID; T-0701; Emergency Relief Knock-Out Tank	D	9/7/2016
PID-0702	P&ID; T-0702; HTF Catch Tank	C	9/7/2016
PID-1002	P&ID; Compressed Air	B	9/7/2016
PID-1101	P&ID; Bulk Nitrogen Storage & Distribution System	C	9/7/2016
PID-2000	P&ID; Deionized Water Generation	B	9/7/2016
PID-3001	P&ID; Chiller System	B	9/7/2016
PID-3002	P&ID; Chilled Glycol Distribution	D	9/7/2016

Control System Integration
B827 Complex
Chemical Synthesis Pilot Project

—

Commentary on
Recipes, Equipment & Raw Materials

March 2, 2017

Revision A

Lawrence Livermore National Laboratory

1.0 Overview

This is a commentary associated with Attachment 10, *Recipes, Equipment & Raw Materials*.

The *Recipes, Equipment & Raw Materials* is a flat-file matrix of all the project's recipes, their associated raw materials, and the entire project suite of batch processing equipment.

The intent of this presentation is to facilitate understanding of the big picture of all recipes, materials and equipment while also indicating which raw materials and equipment set are specifically used for each recipe.

The consolidation of project data and this format should enable efficient entry of the data into the ISA S88 Physical Model framework.

2.0 'By-the-Numbers' — Summary:

Note: the numbers below numbers are approximate; final counts shall be determined during Control System Functional Specification preparation by the Control System Integrator (CSI) Subcontractor. See the *Statement of Work and Specification*, Section 4.2.1 – Phase 1: *Requirements Gathering and Detailing, Preparation, and Production of the Control System Functional Specification Document*.

- Recipe Suite:
    - Unique Recipes: ~20
    - Process types:
        - Nitration
        - Oxidation
        - Purification
- Raw material suite:
    - ~21 liquids
    - ~11 solids
    - 1 gas
- Process Equipment suite:
    - Raw Material Feed System – Liquids & Dry: 12 elements, 4 of these are future
    - Synthesis Reactors Units: 2 total, 1 is future
    - Reflux Condensers: 3 total, 1 is future
    - Quench Reactor Unit: 1
    - Process Filter: 1

- Finished Product Dryer: 1
- Utilities:
  - Process Vacuum Unit
  - Process Chiller Unit
  - Exhaust Blower Unit
  - Temperature Control Module (heating & cooling thermal transfer fluids):

3.0 Requirements of Control System Integrator

Using the *Recipes, Equipment & Raw Materials* matrix, and additional information gleaned from interviews and functional requirements detailing workshops with LLNL Subject Matter Experts, Operators, and project engineers, the Control System Integrator Subcontractor shall:

1. Develop the batch process control system model using the ISA S88 framework

2. Using the ISA S88 model developed, and the *Control System Functional Specification* provide the control system configurations, sequences, control and interlock logic, operator interfaces, utility and other support equipment controls, and any ancillary components and functions required to provide a fully-functional batch processing control system.

3. Incorporate capabilities to add, change, and modify recipe configurations easily using the Wonderware InBatch application.

   In this context, the recipe contains all batch-specific process parameters: equipment configurations, raw material mass fractions, maximum feed rates to manage exothermic reactions within acceptable temperature range, process variable set point ranges, limits, and applicable interlocks – e.g., raw material feed rates, temperatures, pressures, agitation speeds & durations, etc.

4. Select, as the first articles for Recipe development, recipes in the matrix tagged “CSI Item № 1 and № 2.” In the first column. These are the high-priority initial products resulting from this Project.

Recipe, Equipment, & Raw Materials Matrix

B827D Chemical Synthesis Pilot Process

										E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11
									P&ID Equipment Tag №:	T-030x [x= 1,2, or 3]	T-030X [X= 1,2, or 3]	P-0301-1	P-0301-2	P-0301-3	CNV-0101	CNV-0102 [FUTURE]	T-0101	T-0102 [FUTURE]	T-0102 [FUTURE]	TBD [FUTURE]
		Matrix Tag № for CSI Proposals: →→→→→→→→→→→→→→→→→								E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11
										RAW MATERIALS FEED SYSTEM										
CSI Item №	Ops. Priority	Recipe Index №	Peer Review №	Peer Review Date	Peer Review Expriation Date	Process Type	Peer Review Title	Product Weight in Grams	Location	Liquid Raw Material Hopper ON Weigh Scale № 1	Liquid Raw Material Hopper ON Weigh Scale № 2	Pump, Liquid Metering, Portable	Pump, Liquid Transfer, Air Operated	Pump, Liquid Metering, Portable	Solids Feeder, Reactor № 1	Solids Feeder, Reactor № 2	Molten Liquid Raw Material Hopper, Reactor № 1	Molten Liquid Raw Material Hopper, Reactor № 2	Molten Liquid Raw Material Hopper, Reactor № 2	Amonia Gas Charging System
1	1	101D	2945	11-Nov-2016	11-Nov-2017	Nitration	Preparation of L5	3,000	B827D	●	●					Future		Future	Future	Future
2	1	101E	2945	11-Nov-2016	11-Nov-2017	Purification	Recrystallize L5	3,000	B827D	●	●					Future		Future	Future	Future
3	1	101A	2945	11-Nov-2016	11-Nov-2017	Nitration	Synthesis of D	3,000	B827D	●	●					Future		Future	Future	Future
4	1	101B	2945	11-Nov-2016	11-Nov-2017	Nitration	Synthesis of A	3,000	B827D	●	●					Future		Future	Future	Future
5	1	101C	2945	11-Nov-2016	11-Nov-2017	Oxidation	Synthesis of L	3,000	B827D	●	●					Future		Future	Future	Future
6	2	103A	2737	18-Nov-2013	5-May-2014	Nitration	Synthesis of C	3,000	B827D	●	●					Future		Future	Future	Future
7	2	103B1	2737	18-Nov-2013	5-May-2014	Nitration	Synthesis of L6	3,000	B827D	●	●					Future		Future	Future	Future
8	2	103B2	2737	18-Nov-2013	5-May-2014	Purification	Purification of L6	3,000	B827D	●	●					Future		Future	Future	Future
9	3	104A	2711	1-Aug-2013	1-Feb-2014	Oxidation	Preparation of L2	3,000	B827D	●	●					Future		Future	Future	Future
10	3	104B	2711	1-Aug-2013	1-Feb-2014	Purification	Recrystallize L2	3,000	B827D	●	●					Future		Future	Future	Future

LEGEND:

(green)	Green highlighting indicates 'First Article' Recipe for Control System Integrator
	Remaining eight recipes to be configured as Recipes after approval of First Article
●	Indicates recipe-specific use of equipment or raw material

Recipe, Equipment, & Raw Materials Matrix

B827D Chemical Synthesis Pilot Process

CSI Item №	Ops. Priority	Recipe Index №	Peer Review №	Peer Review Date	Peer Review Expiration Date	Process Type	Peer Review Title	№ 1 Reactor, Jacketed	Agitator, № 1 Reactor	Pump, Liquid Sample Loop, Reactor № 1, Air Operated	№ 2 Reactor, Jacketed	Agitator, № 2 Reactor	Pump, Liquid Sample Loop, Reactor № 2, Air Operated	Reactor Jacket Cooling	Reactor Jacket Heating	Reactor № 1 Condenser, Reflux + TCM Cooling	Reactor № 2 Condenser, Reflux + TCM Cooling	Quench Vessel with Cold Water + TCM Cooling	Agitator, Quench Reactor	Filter, Bag, Vacuum	Bag, Cellulose for Vacuum Filter	Bag, Whatman Cellulose - backed with sharkskin or glass-fiber for Vacuum Filter	Filtered Solids Water Wash Supply System	Filtered Solids Brine Wash Supply System	Filtered Solids Liquid Acetonitrile Wash Supply System	Filtered Solids Liquid Methyl Alcohol (MeOH) Wash Supply System	Filtered Solids Liquid Ethyl Acohol (EtOH) Wash Supply System	Wash Liquid Litmus Paper	Wash Liquids Collection Vessel	Heating, Solids	Vacuum Pump	Chiller, Process	Exhaust Blower, Process
								R-0101	AG-0101	P-0101	R-0102 [FUTURE]	AG-0102 [FUTURE]	P-0102 [FUTURE]	TCM-01 thru TCM-08	TCM-01 thru TCM-08	E-0101	E-0102 [FUTURE]	R-0103	AG-0103	F-0104	NA	NA	TBD	TBD	TBD	TBD	TBD	NA	TBD	HEATER	VP-0501	X-3001	B-0601
		Matrix Tag № for CSI Proposals: →→→→→→→→→→→→						E12	E13	E14	E15	E16	E17	E18	E19	E20	E21	E22	E23	E24			E25	E26	E27	E28	E29	E30	E31	E32	E33	E34	E35
								EQUIPMENT																									
								SYNTHESIS REACTORS								CONDENSERS		QUENCH REACTOR		FILTERING & WASHING										HEATING	UTILITIES		
1	1	101D	2945	11-Nov-2016	11-Nov-2017	Nitration	Preparation of L5	•	•	•	Future	Future	Future	•			Future	•	•	•	•		•					•	•	•	•		•
2	1	101E	2945	11-Nov-2016	11-Nov-2017	Purification	Recrystallize L5	•	•	•	Future	Future	Future		•		Future		•	•	•		•						•	•	•		•
3	1	101A	2945	11-Nov-2016	11-Nov-2017	Nitration	Synthesis of D	•	•	•	Future	Future	Future	•			Future	•	•				•										
4	1	101B	2945	11-Nov-2016	11-Nov-2017	Nitration	Synthesis of A	•	•	•	Future	Future	Future		•	•	Future	•	•	•	•		•		•	•			•	•	•	•	•
5	1	101C	2945	11-Nov-2016	11-Nov-2017	Oxidation	Synthesis of L	•	•	•	Future	Future	Future	•	•	•	Future	•	•	•		•	•			•		•	•	•	•	•	•
6	2	103A	2737	18-Nov-2013	5-May-2014	Nitration	Synthesis of C	•	•	•	Future	Future	Future	•	•	•	Future	•	•	•	•		•	•					•	•	•	•	•
7	2	103B1	2737	18-Nov-2013	5-May-2014	Nitration	Synthesis of L6	•	•	•	Future	Future	Future	•	•		Future		•	•	•		•								•		•
8	2	103B2	2737	18-Nov-2013	5-May-2014	Purification	Purification of L6	•	•	•	Future	Future	Future				Future		•	•	•		•	•							•		•
9	3	104A	2711	1-Aug-2013	1-Feb-2014	Oxidation	Preparation of L2	•	•	•	Future	Future	Future		•		Future		•	•	•		•								•		•
10	3	104B	2711	1-Aug-2013	1-Feb-2014	Purification	Recrystallize L2	•	•	•	Future	Future	Future		•		Future		•	•	•		•				•				•		•

LEGEND:

(green)	Green highlighting indicates 'First Article' Recipe for Control System Int
	Remaining eight recipes to be configured as Recipes after approval of Fi
•	Indicates recipe-specific use of equipment or raw material

Recipe, Equipment, & Raw Materials Matrix

B827D Chemical Synthesis Pilot Process

								RL1	RL2	RL3	RL4	RL5	RL6	RL7	RL8	RL9	RL10	RL11	RL12	RL13	RL14	RL15	RL16	RL17	RL18	RL19	RL20	RL21
		Matrix Tag № for CSI Proposals: →→→→→→→→→→→→→→																										
								RAW MATERIALS																				
								Liquids Type A Addition															Liquids Type O Addition					
CSI Item №	**Ops. Priority**	**Recipe Index №**	**Peer Review №**	**Peer Review Date**	**Peer Review Expiration Date**	**Process Type**	**Peer Review Title**																					
1	1	101D	2945	11-Nov-2016	11-Nov-2017	Nitration	Preparation of L5				•	•															•	
2	1	101E	2945	11-Nov-2016	11-Nov-2017	Purification	Recrystallize L5							• or	or •	• or	or •	or •										
3	1	101A	2945	11-Nov-2016	11-Nov-2017	Nitration	Synthesis of D		•				•															
4	1	101B	2945	11-Nov-2016	11-Nov-2017	Nitration	Synthesis of A																•	•			•	
5	1	101C	2945	11-Nov-2016	11-Nov-2017	Oxidation	Synthesis of L									•	•	?	•		•						•	
6	2	103A	2737	18-Nov-2013	5-May-2014	Nitration	Synthesis of C				•	•													•			
7	2	103B1	2737	18-Nov-2013	5-May-2014	Nitration	Synthesis of L6																	•				
8	2	103B2	2737	18-Nov-2013	5-May-2014	Purification	Purification of L6		•																•			
9	3	104A	2711	1-Aug-2013	1-Feb-2014	Oxidation	Preparation of L2												•			•				•		•
10	3	104B	2711	1-Aug-2013	1-Feb-2014	Purification	Recrystallize L2																		•	•		

LEGEND:

(green)	Green highlighting indicates 'First Article' Recipe for Control System Inte
	Remaining eight recipes to be configured as Recipes after approval of Fi
•	Indicates recipe-specific use of equipment or raw material

Recipe, Equipment, & Raw Materials Matrix

B827D Chemical Synthesis Pilot Process

Matrix Tag № for CSI Proposals: →→→→→→→→→→→→→

CSI Item №	Ops. Priority	Recipe Index №	Peer Review №	Peer Review Date	Peer Review Expriation Date	Process Type	Peer Review Title	RS1	RS2	RS3	RS4	RS5	RS6	RS7	RS8	RS9	RS10	RS11
								Dry SOLIDS Addition										
1	1	101D	2945	11-Nov-2016	11-Nov-2017	Nitration	Preparation of L5	•	•									
2	1	101E	2945	11-Nov-2016	11-Nov-2017	Purification	Recrystallize L5						•					
3	1	101A	2945	11-Nov-2016	11-Nov-2017	Nitration	Synthesis of D			•								
4	1	101B	2945	11-Nov-2016	11-Nov-2017	Nitration	Synthesis of A				•							
5	1	101C	2945	11-Nov-2016	11-Nov-2017	Oxidation	Synthesis of L					• or	or •					
6	2	103A	2737	18-Nov-2013	5-May-2014	Nitration	Synthesis of C							•	•			
7	2	103B1	2737	18-Nov-2013	5-May-2014	Nitration	Synthesis of L6									•		
8	2	103B2	2737	18-Nov-2013	5-May-2014	Purification	Purification of L6									•		
9	3	104A	2711	1-Aug-2013	1-Feb-2014	Oxidation	Preparation of L2										•	
10	3	104B	2711	1-Aug-2013	1-Feb-2014	Purification	Recrystallize L2											

LEGEND:

(green)	Green highlighting indicates 'First Article' Recipe for Control System Int
	Remaining eight recipes to be configured as Recipes after approval of F
•	Indicates recipe-specific use of equipment or raw material

Site 300 B827D Chemical Synthesis Pilot Project:
Mock Batch Control Script

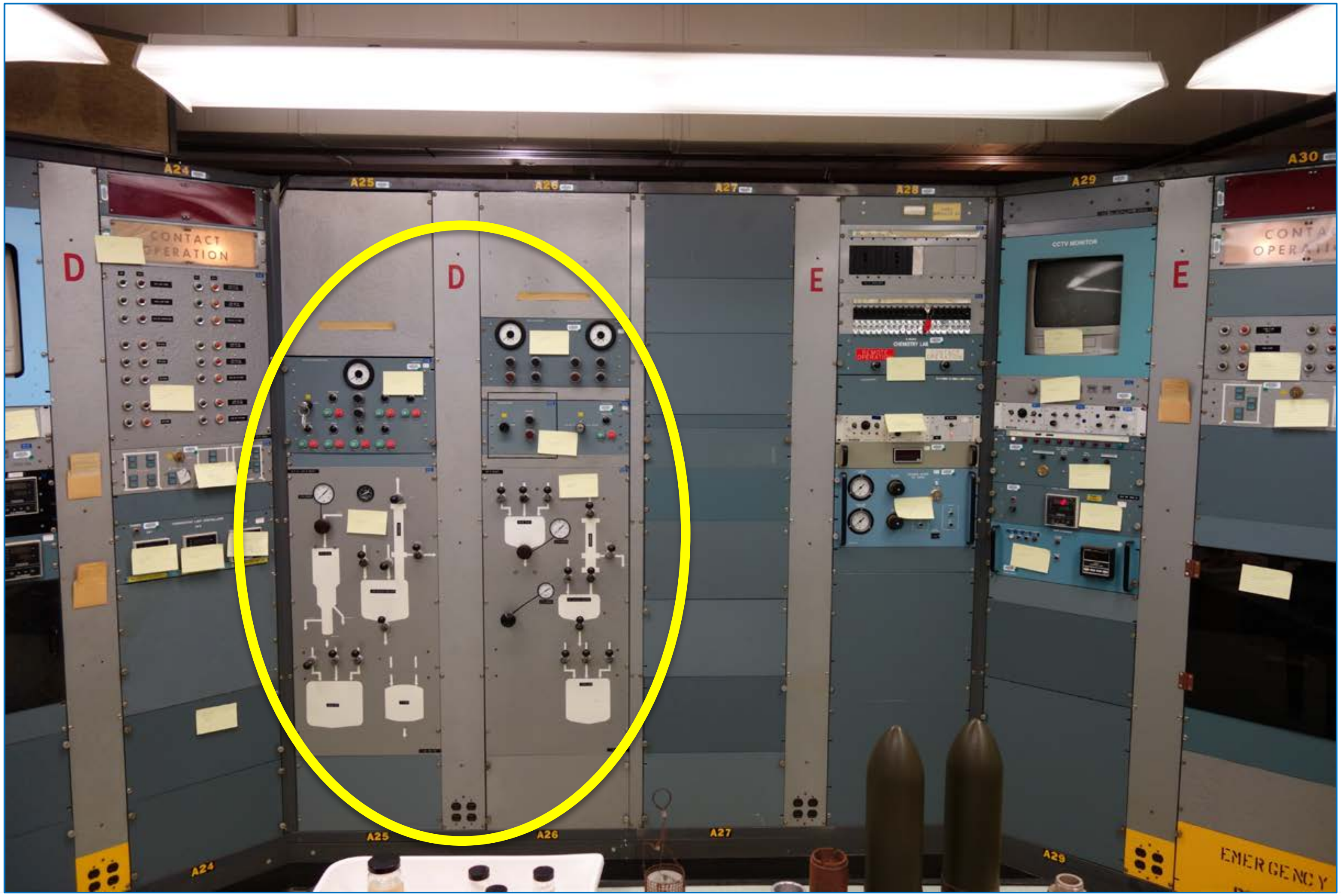
Fred Wade

Rev. December 30, 2016

LLNL-PRES-XXXXXX
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

Lawrence Livermore National Laboratory

B827A – Existing Control Room Chemical Synthesis Process Mimic



B827A Control Room . . .
Vision for B827D & B827E Control Consoles

Operations Screen Suite

1. Operator batch set-up:
   a) Log-in
   b) Recipe selection
   c) Initiate new batch
   d) Enter finished quantity required
   e) Validate equipment configuration
   f) Raw materials required
      - Print Pick List
2. Process mimics (2)
3. Process sequence dashboard
4. Process variable trends (2)
5. Warnings & Alarms
6. Process videos (2)
7. Process room videos (3)

Support Workstations

1. PLC developer
2. SCADA developer
3. Network / VM support

Preface 1 of 3 …

What follows is a commentary on the script of how a *production* batch would be made. Its purpose is to provide the 'look-and-feel' of how a batch would be made from the perspective of the process operator.
Notes regarding this information:

- This scenario is based upon the standard, built-in capabilities of the Wonderware® InBatch® SCADA system, using standard recipe entry/management development screens; no custom programming is required
  - Once the raw materials suite and equipment unit configurations are entered into InBatch® (initially by the Control System Integrator; on-going by the Chem Engineer or Control System Support resources), the end-user (read chemist) only needs to graphically '**connect-the-dots**' to configure alternate process equipment configurations and recipe formulas. (Similar to the Mettler-Toledo *iControl* system used in B191).

A SCADA or PLC programming specialist is not required to create new recipes or variations as the configurations are not hard-coded into PLC / SCADA logic.

This is THE key benefit of the ISA S88 framework used in system development.

Preface 2 of 3 …

- A sequential step-wise checklist format is utilized:
  - Sub-steps grouped into logical sequential sets, consistent with the Peer Review, and would embed the Site 300 (S300) Work Permit operational requirements
  - Raw materials, parameter set-points and limit ranges are selected by choosing a pre-loaded and stored recipe for mass fractions, procedural steps, control set-points, warning and alarm levels, and safety interlocking
  - Release to the next step requires validation of readiness by the human Operator, and satisfaction of the pre-configured logic interlocks, before a permissive would allow moving forward

Preface 3 of 3 …

- This same script would also apply to R&D trial runs; the only requirement would be that the equipment configuration, raw materials to be used, and expected parameters would need to be entered, most likely based upon an already-existing recipe *copy/edit/save* as a new recipe. All these would be drawn from, and be consistent with, the applicable Peer Review and Work Permit.

- Completely 'manual' operation will also be possible, where every component may be operated independently of any stored configuration, but with only minimal hardwired safety interlocks being available

- 'Mock Screen' placeholders that follow, e.g., "{Mock Screen № 1}", indicate a specific mock-up graphic of the proposed screen as viewed and interacted with by the Operator. These will all be developed by the Control System Integrator. Many of these 'screens' will share a physical LCD screen on the Control Console; exact mapping & configuration TBD.

Typical Batch Making Scenario

Typical Batch Making Scenario . . . Page 1 of 7

- Preparation
  - Clean equipment
  - Identify Raw Materials required from Peer Review, S300 Work Permit, and Operations Work
- Set-Up in Control System (CS) B827A Control Room or B827D Process Area
  - Verify batch recipe Peer Review, S300 Work Permit, and Operations Work Order
  - Operator Logs-In to CS {Mock Screen № 1}
  - Select pre-loaded recipe parameter configuration set from list on control screen (Based upon applicable Peer Review) {Mock Screen № 2}
    - *This contains all batch-specific process parameters: equipment configurations, raw material mass fractions, maximum feed rates to manage exothermic reactions within acceptable temperature range, process variable set point ranges, limits, and applicable interlocks – e.g., raw material feed rates, temperatures, pressures, agitation speeds & durations, etc.*
  - Initiate in CS new batch record, creating unique batch-tracking number, using this Recipe, Peer Review, S300 Work Permit, and Work Order {Mock Screen № 3}
  - Enter finished product mass quantity required {Mock Screen № 4}
  - Review raw material amounts needed based upon finished quantity required
    - Print-out 'Pick-List' loading quantities {Mock Screen № 4}
  - Review & validate equipment and instrumentation configuration {Mock Screen № 5}

Typical Batch Making Scenario . . . Page 2 of 7

- Set-Up in B827D Process Area
  - Physically inventory and stage required materials per Pick List
    - *Adjust finished quantity to be made on batch set-up screen, as required, based upon actual on-hand raw material availability (short batches)*
  - Set-up equipment and instruments per recipe equipment configuration

- Raw Material Loading
  - Liquids pre-measured and loaded into CS-directed feed vessels; Operator verifies by entering amount loaded into local CS terminal along with raw material source's Lot Number {Mock Screen № 6}
  - Dry solids pre-weighed and loaded into CS-directed hoppers; verify by entering amount loaded into local CS terminal and enter raw material source's Lot Number

- Operator walk-through of Process Area to verify all is ready
  - Secure Process Area Room 105 doors
  - Confirm on CS screen in vestibule that all batch permissives are satisfied (Green indicators) to allow batch process to begin {Mock Screen № 7}

Typical Batch Making Scenario . . . Page 3 of 7

- Go to B827A Control Room – In CS, initiate Remote (Non-Contact) Operations Mode
    - *Batch-specific video log recording is automatically initiated*

- Operator brings up the following screens on control console layout:
    - — Process mimics showing: {Mock Screen № 8}
      Reactors, valves, pumps, all in correct configuration, instrument data
    - — Process Sequence Dashboard {Mock Screen № 9}
        - Header: Batch №, Work Order №, Peer Review №, S300 Work Permit №, Total Finished Mass Quantity
        - Sequence steps grouped by ‘hold points’
        - Status Indicators (Red/Yellow/Green) for each step & sub-step, if applicable
        - Footer: Total Batch Time Clock, Current Clock Time
    - — Process variable trending screen(s) {Mock Screen № 10}
    - — Process Warnings & Alarms handling screen {Mock Screen № 11}
    - — Reactors agitation process video {Mock Screen № 12}, Particle-size video
    - — Room camera videos (≤ 3 cameras)

- Process Chemist logs-in to CS as operational support resource
    - — This is captured in batch log

Typical Batch Making Scenario . . . Page 4 of 7

- Operator reviews Process Sequence Dashboard: {Mock Screen № 9}
  - Batch Number, Peer Review, S300 Work Permit, and Work-Order have been entered and are as expected
  - Finished product quantity and mass fractions are as expected
  - Batch raw material loading confirmations are Green
  - Batch Permissives and Warnings/Alarms are Green

- Operator initiates 1st Sequence Step:
  - Liquid addition to Synthesis Reactor R-010n (n=1 or 2)
  - Flow rate and total raw material quantity transferred are observed on Process Mimic (also viewed on R-010n contents video)
  - Agitator starts based upon preset liquid quantity transferred, RPM visible on Process Mimic
  - Liquid addition continues until set point of total quantity has been achieved and confirmed by Reactor total weight on Process Mimic; failure to transfer expected quantity triggers alarm and stops process sequence

- Operator confirms 1st Sequence Step has been successfully completed by observing Green on Process Sequence Dashboard {Mock Screen № 9}

Typical Batch Making Scenario . . . Page 5 of 7

- Operator initiates 2nd Sequence Step:
  [Only possible if 1st Step has been successfully completed and Permissives and Warnings & Alarms states are nominal]
  - Dry solid addition to Synthesis Reactor R-010n
  - Mass flow rate and total raw material weight transferred are observed on Process Mimic (also viewed on R-010n contents video)
    Temperatures of batch reaction, cooling flows and temperatures, pressures, etc., are continuously monitored versus batch recipe parameter set limits. Alarms and process interlocks intervene as required by CS Programmable Logic Controller (PLC).
  - Dry solid addition continues until set point of total quantity has been achieved and confirmed by Reactor R-010n total weight on Process Mimic; failure to transfer expected quantity triggers alarm and stops process sequence

- Operator confirms 2nd Sequence Step has been successfully completed by observing Green on Process Sequence Dashboard
  {Mock Screen № 9}

Typical Batch Making Scenario . . . Page 6 of 7

Liquids and solids additions continue, in sequence per batch recipe parameter set, until all batch constituent additions have been completed…

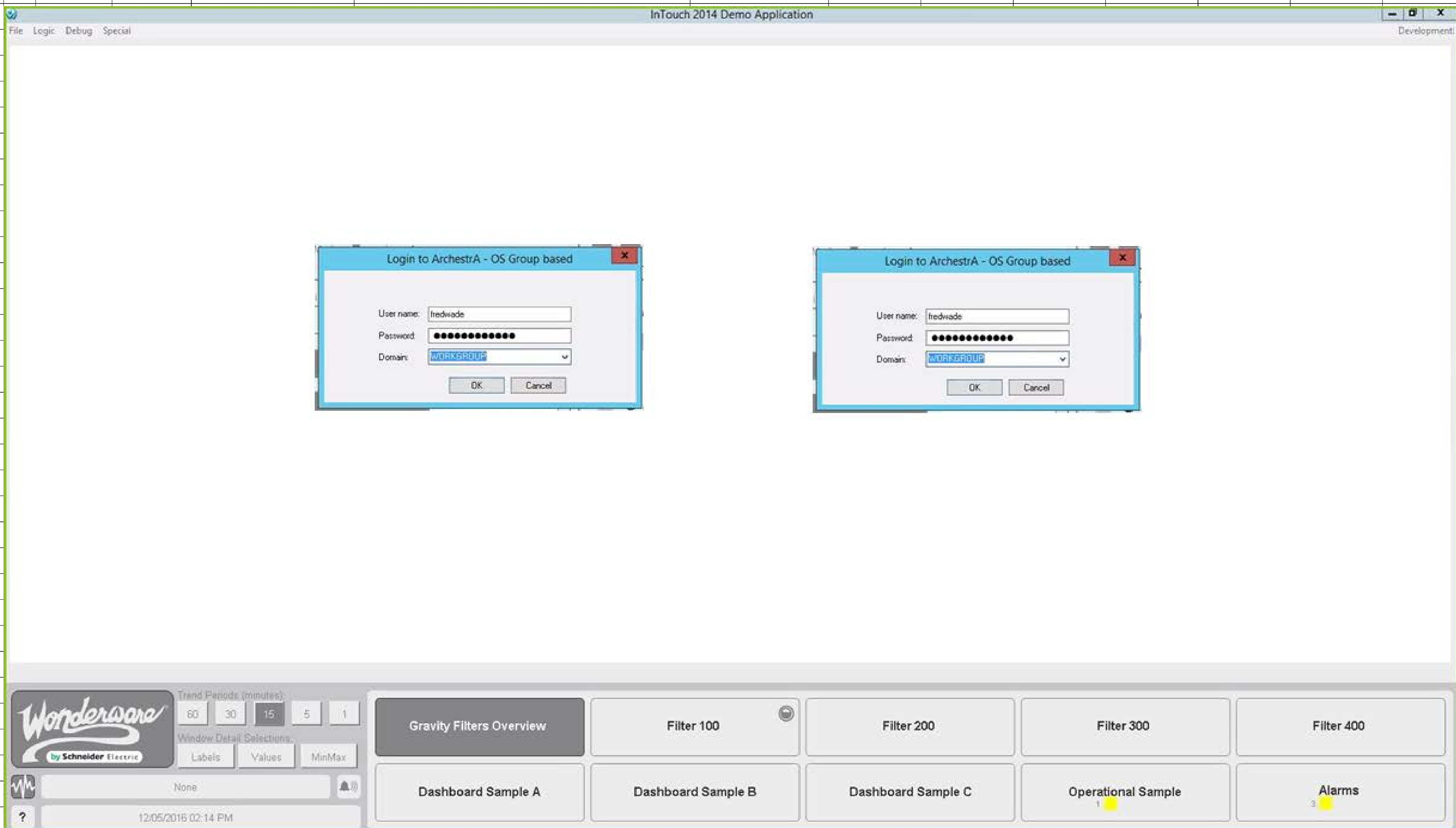
- Operator initiates Sequence Step starting completed batch agitation time clock
  - Time remaining shown on Process Mimic
- When completed batch agitation time set point has been achieved, Operator confirms Quench Reactor R-0103 has been pre-loaded with proper amount of quench liquid (total reactor R-0103 weight confirms) and liquid charge is at correct temperature, and agitator is running at correct RPM (also viewed on R-0103 contents video)
- Operator initiates transfer from Synthesis Reactor R-010n to Quench Reactor R-0103
- Quench Reactor processing is continued for set point time and / or desired crystal particle size has been achieved

Typical Batch Making Scenario . . . Page 7 of 7

- Operator initiates Bag Filter F-0104 vacuum; vacuum pressure monitored on Process Mimic
- Operator opens Quench Reactor R-0103 drain valve and starts pump to send finished batch to Bag Filter
- When Synthesis Reactor R-010n has delivered complete batch as indicated by Synthesis Reactor weight, Operator stops pumping operation
- Vacuum on Bag Filter F-0104 continues for pre-set time
- When vacuum filtering complete, ‘Batch Complete’ status is set in CS, all data is stored in CS historian

Lawrence Livermore National Laboratory

Operator Log-In



		Recipe №	Peer Review №	Process Type	Description	Peer Review Expiration Date
Recipe Parameter Set Selection						
	☑	100	42359	Nitration	Preparation of LXZ-105 from DADY	10/Mar/2017
		101	20216	Amination	Put more amines in peanut butter	7/May/1955
	☐	102	10145	Re-crystallization	Purify not-so-good stuff	1/Jun/2017
	☐	103	20202	Distillation	Extract gold from rock	5/Sep/2017
	☐	104				
	☐	105				
	☐	106				
	☐	107				
	☐	108				
	☐	109				
	☐	110				

Initiate New Batch Record

Recipe №	Peer Review №	Process Type	Description	Peer Review Expiration Date
100	42359	Nitration	Preparation of LXZ-105 from DADY	17/Mar/2017

S300 Permit №	Work Order №	TARGET Finished Product Quantity This Batch [Grams]		
94526	123547	2,000		

CREATE BATCH RECORD (Button)

BATCH Number: 1255892

Operator's Batch Log	Batch 2 of 5 for W.O 123547 TCM-5 down for maintenance.

Raw Materials Required / Adjustment

BATCH Number: 1255892

Recipe №	Peer Review №	Process Type	Description	Peer Review Expiration Date
100	42359	Nitration	Preparation of LXZ-105 from DADY	17/Mar/2017

S300 Permit №	Work Order №	TARGET Finished Product Quantity This Batch [Grams]		
94526	123547	2,000		

Adjust: **MORE ↑ | LESS ↓** (Buttons)

Calculated Quantities - Batch №: 1255892

Raw	Type	Name	Quantity Required for Batch	Unit
1	Liquid	RL4	25.0	Liters
2	Solid	RS1	2.5	Kilograms
3	Gas	Gas 1	15.0	Liters or Kilos
4	Liquid	Acid 2	5.0	Liters

(Button) **PRINT RAW MATERIALS PICK-LIST**

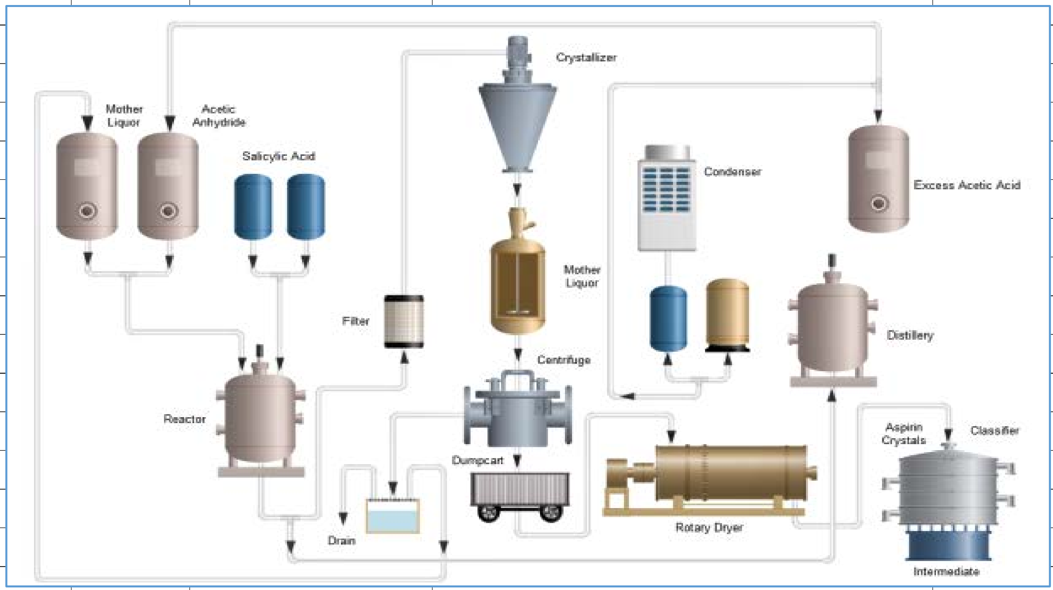
(Button) **CONFIRM RAW MATERIALS**

Operator's Batch Log:
Batch 2 of 5 for W.O 123547
TCM-5 down for maintenance.
Running low on Gas 1, need to reorder.

Equipment & Instrumentation Configuration

Recipe №	Peer Review №	Process Type	Description	Peer Review Expiration Date
100	42359	Nitration	Preparation of LXZ-105 from DADY	17/Mar/2017

S300 Permit №	Work Order №	Finished Product Quantity This Batch [Grams]	Operator Notes	
94526	123547	2,000	Batch 2 of 5 for W.O 123547	



(Button) **VALIDATE CONFIGURATION**

BATCH Number: 1255892

Operator's Batch Log	TCM-5 down for maintenance. Running low on Gas 1, need to reorder. TCM-5 down for maintenance.

Raw Material Loading Confirmation

BATCH Number: 1255892

Recipe №	Peer Review №	Process Type	Description
100	42359	Nitration	Preparation of LXZ-105 from DADY

S300 Permit №	94526
Work Order №	123547
Finished Product Quantity This Batch [Grams]	2000

Batch №: 1255892

Raw	Type	Name	Quantity	Unit	RM Manfacturer	RM Mfg. Lot №	Loading Confirmation	
1	Liquid	Acid 1	25	Liters	Fisher Scientific	123456	CONFIRMED	(Button)
2	Solid	Dry 1	50	Kilograms	LLNL	5XY1213	CONFIRMED	(Button)
3	Gas	Gas 1	15	Liters	Dow Chemical	X2.105.43	CONFIRMED	(Button)
4	Liquid	Acid 2	5	Liters	Hooker Chemical	123.45.A	WAITING	(Button)

ALL RMs LOADED Ready for Batch (Button)

Operator's Batch Log	
	TCM-5 down for maintenance. Running low on Gas 1, need to reorder. TCM-5 down for maintenance.

Process Area Permissives Status

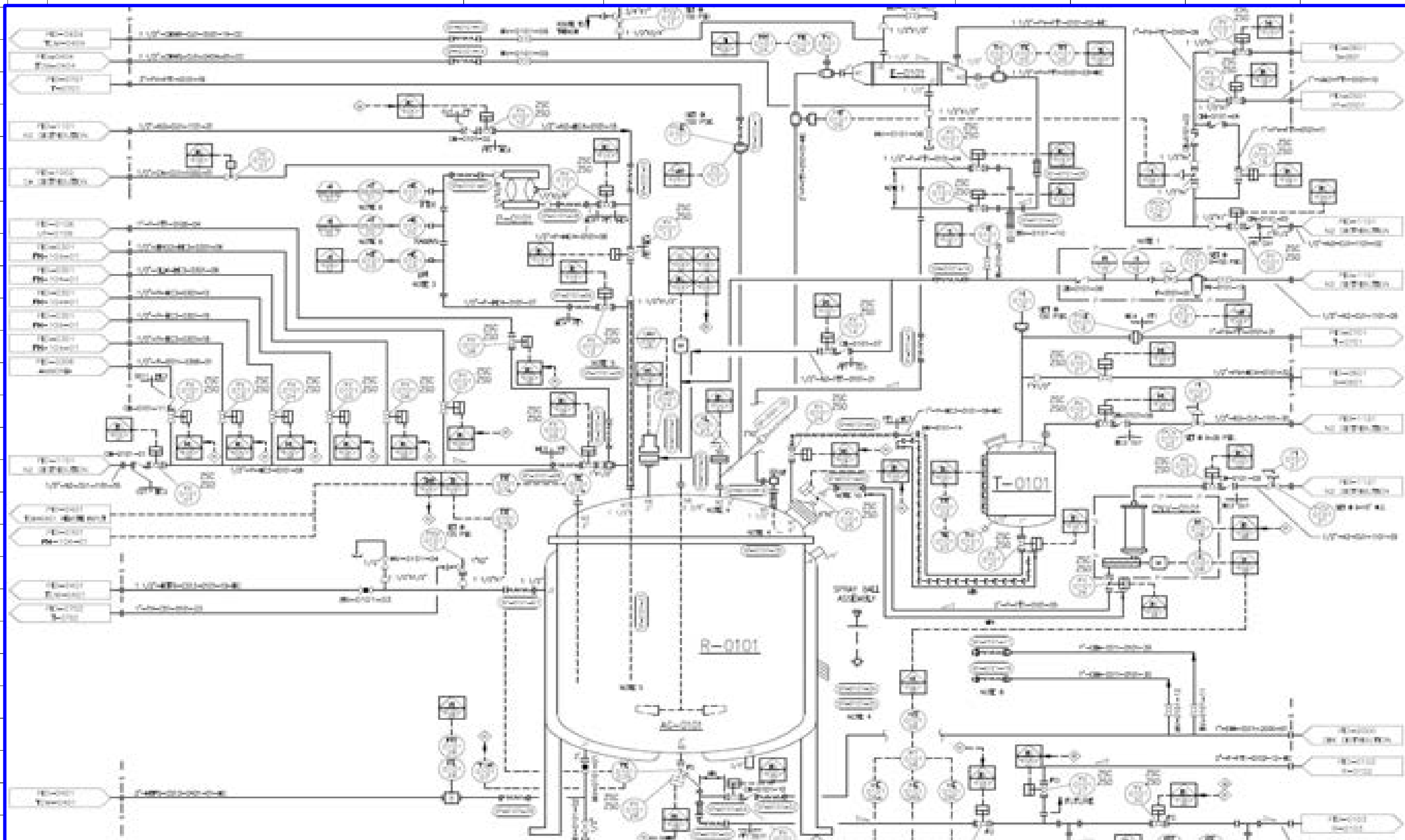
	Required Permissive	Permissive Status	Issues
1	Pre-load fills	NOMINAL	
2	Equipment Configuration Validated	**FAULT**	Manual connection not verified
3	Manual valves & Hoses Configrued	Waiting	
4	Process Area Doors	**FAULT**	Door 6 not confirmed secure
5	Remote Operation Mode Set	Waiting	
6	Remote Operation Mode Announced	Waiting	
7			
8			
9			
10			

Operator's Batch Log

TCM-5 down for maintenance.
Running low on Gas 1, need to reorder.
TCM-5 down for maintenance.

PROCESS AREA PERMISSIVES
Ready for Batch (Button)

Process Mimic



Operator's Batch Log

TCM-5 down for maintenance.

Running low on Gas 1, need to reorder.

TCM-5 down for maintenance.

Raw Material Loading Confirmation

BATCH Number:	1255892

Recipe №	Peer Review №	Process Type	Description
100	42359	Nitration	Preparation of LXZ-105 from DADY

S300 Permit №	94526
Work Order №	123547
Finished Product Quantity This Batch [Grams]	2000

Sequence Group	Batch Step №	Description	Operator Confirmation	Step Status	Issues
A		PREPARATION & RAW MATERIAL LOADING		COMPLETE	
	1	All equipment cleaned & ready	☑	Complete	
	2	Equipment Configuration Confirmed	☑	Complete	
	3	Liquid raw materials pre-loaded & ready	☑	Complete	
	4	Solids raw materials pre-loaded & ready	☑	Complete	
	5	Process Secured & Remote Ops. Set	☑	Complete	
B		TRANSFER FIRST RAW			
	1	Initiate Transfer	☑	Complete	
	2	Agitation Confirmed	☐	Waiting	
	3	Totalized Transfer Confirmed	☐	Waiting	
C		TRANSFER SECOND RAW			
	1	Initiate Transfer	☐	Waiting	
	2	Agitation Confirmed	☐	Waiting	
	3	Totalized Transfer Confirmed	☐	Waiting	
D		TRANSFER THIRD RAW			
	1	Initiate Transfer	☐	Waiting	
	2	Agitation Confirmed	☐	Waiting	
	3	Totalized Transfer Confirmed	☐	Waiting	
E		AGITATE FINAL BATCH MIX			
	1	Initiate Agitation Timer	☐	Waiting	
	2	Agitation Confirmed	☐	Waiting	
	3	Agitation Time Completed	☐	Waiting	
F		TRANSFER BATCH TO QUENCH & QUENCH			
	1	Quench Reactor Charged & Ready	☐	Waiting	
	2	Initiate Transfer	☐	Waiting	
	3	Totalized Transfer Confirmed	☐	Waiting	
	4	Initiate Agitation Timer	☐	Waiting	
	5	Agitation Confirmed	☐	Waiting	
	6	Agitation Time Completed	☐	Waiting	
G		TRANSFER TO BAG FILTER & SEPARATION			
	1	Batch Tests Nominal Confirmed	☐	Waiting	
	2	Initiate Vacuum	☐	Waiting	
	3	Initiate Transfer from Synthesis Reactor	☐	Waiting	
	4	Totalized Transfer Confirmed	☐	Waiting	
	5	Initiate Vacuum Residence Timer	☐	Waiting	
	6	Vacuum Residence Time Completed	☐	Waiting	
H		BATCH COMPLETE			
	1	Remote Operations Cleared	☐	Waiting	
	2	Vacuum Shut-Down	☐	Waiting	
	3	Batch Completed	☐	Waiting	

Total Batch Time:	1:05:34
Current Time:	13:30:55

Operator's Batch Log	
	TCM-5 down for maintenance. Running low on Gas 1, need to reorder. TCM-5 down for maintenance.

Raw Material Loading Confirmation

BATCH Number:	1255892

Recipe №	Peer Review №	Process Type	Description
101D	42359	Nitration	Preparation of LXZ-105 from DADY

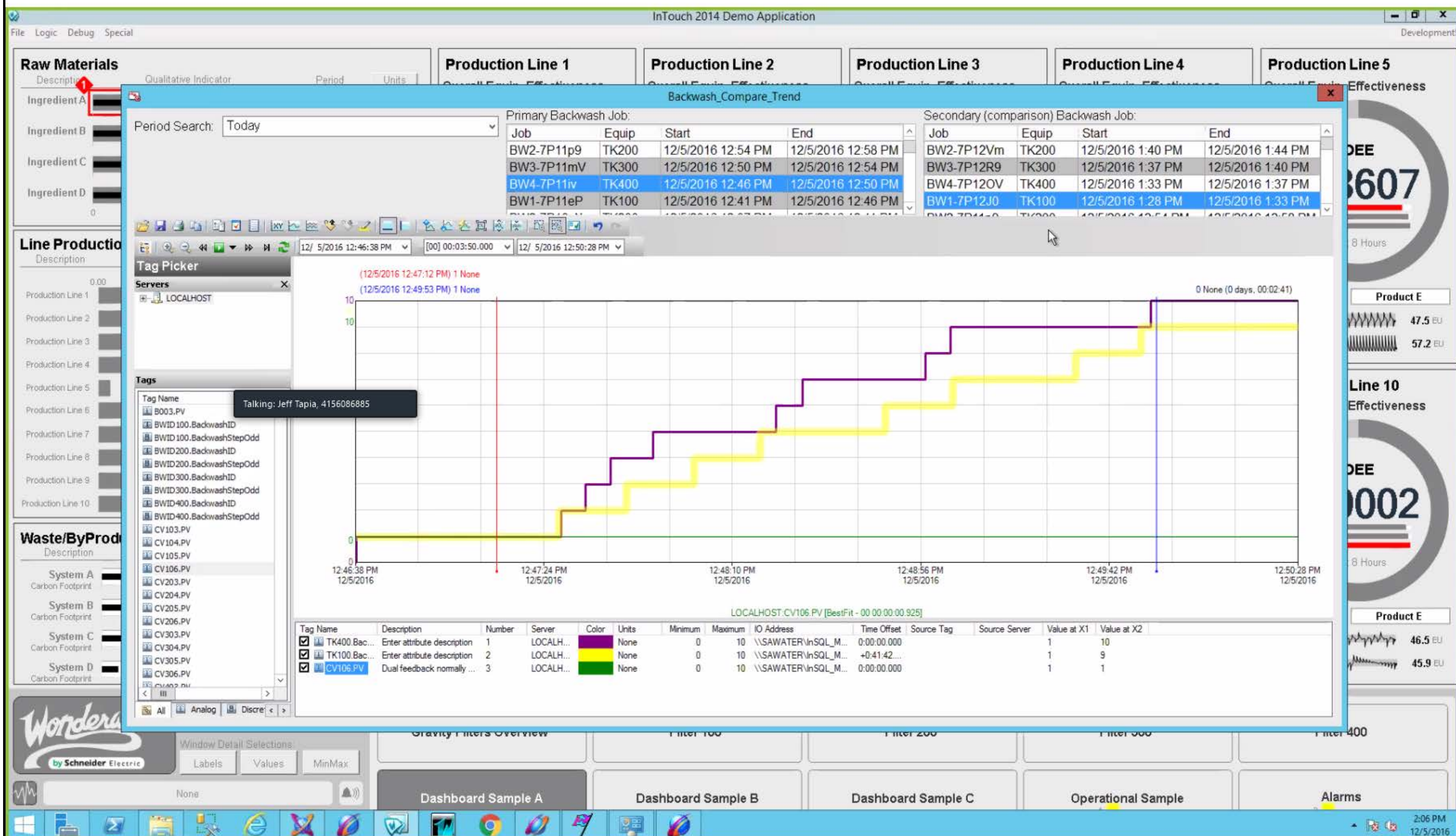
S300 Permit №	94526
Work Order №	123547
Finished Product Quantity This Batch [Grams]	2000

Sequence Group	Batch Step №	Description	Operator Confirmation	Step Status	Issues
A		PREPARATION & RAW MATERIAL LOADING		COMPLETE	
	1	All equipment cleaned & ready	☑	Complete	
	2	Equipment Configuration Confirmed	☑	Complete	
	3	Liquid raw materials pre-loaded & ready	☑	Complete	
	4	Solids raw materials pre-loaded & ready	☑	Complete	
	5	Process Secured & Remote Ops. Set	☑	Complete	
B		TRANSFER FIRST RAW			
	1	Initiate Transfer	☑	Complete	
	2	Agitation Confirmed	☐	Waiting	
	3	Totalized Transfer Confirmed	☐	Waiting	
C		TRANSFER SECOND RAW			
	1	Initiate Transfer	☐	Waiting	
	2	Agitation Confirmed	☐	Waiting	
	3	Totalized Transfer Confirmed	☐	Waiting	
D		TRANSFER THIRD RAW			
	1	Initiate Transfer	☐	Waiting	
	2	Agitation Confirmed	☐	Waiting	
	3	Totalized Transfer Confirmed	☐	Waiting	
E		AGITATE FINAL BATCH MIX			
	1	Initiate Agitation Timer	☐	Waiting	
	2	Agitation Confirmed	☐	Waiting	
	3	Agitation Time Completed	☐	Waiting	
F		TRANSFER BATCH TO QUENCH & QUENCH			
	1	Quench Reactor Charged & Ready	☐	Waiting	
	2	Initiate Transfer	☐	Waiting	
	3	Totalized Transfer Confirmed	☐	Waiting	
	4	Initiate Agitation Timer	☐	Waiting	
	5	Agitation Confirmed	☐	Waiting	
	6	Agitation Time Completed	☐	Waiting	
G		TRANSFER TO BAG FILTER & SEPARATION			
	1	Batch Tests Nominal Confirmed	☐	Waiting	
	2	Initiate Vacuum	☐	Waiting	
	3	Initiate Transfer from Synthesis Reactor	☐	Waiting	
	4	Totalized Transfer Confirmed	☐	Waiting	
	5	Initiate Vacuum Residence Timer	☐	Waiting	
	6	Vacuum Residence Time Completed	☐	Waiting	
H		BATCH COMPLETE			
	1	Remote Operations Cleared	☐	Waiting	
	2	Vacuum Shut-Down	☐	Waiting	
	3	Batch Completed	☐	Waiting	

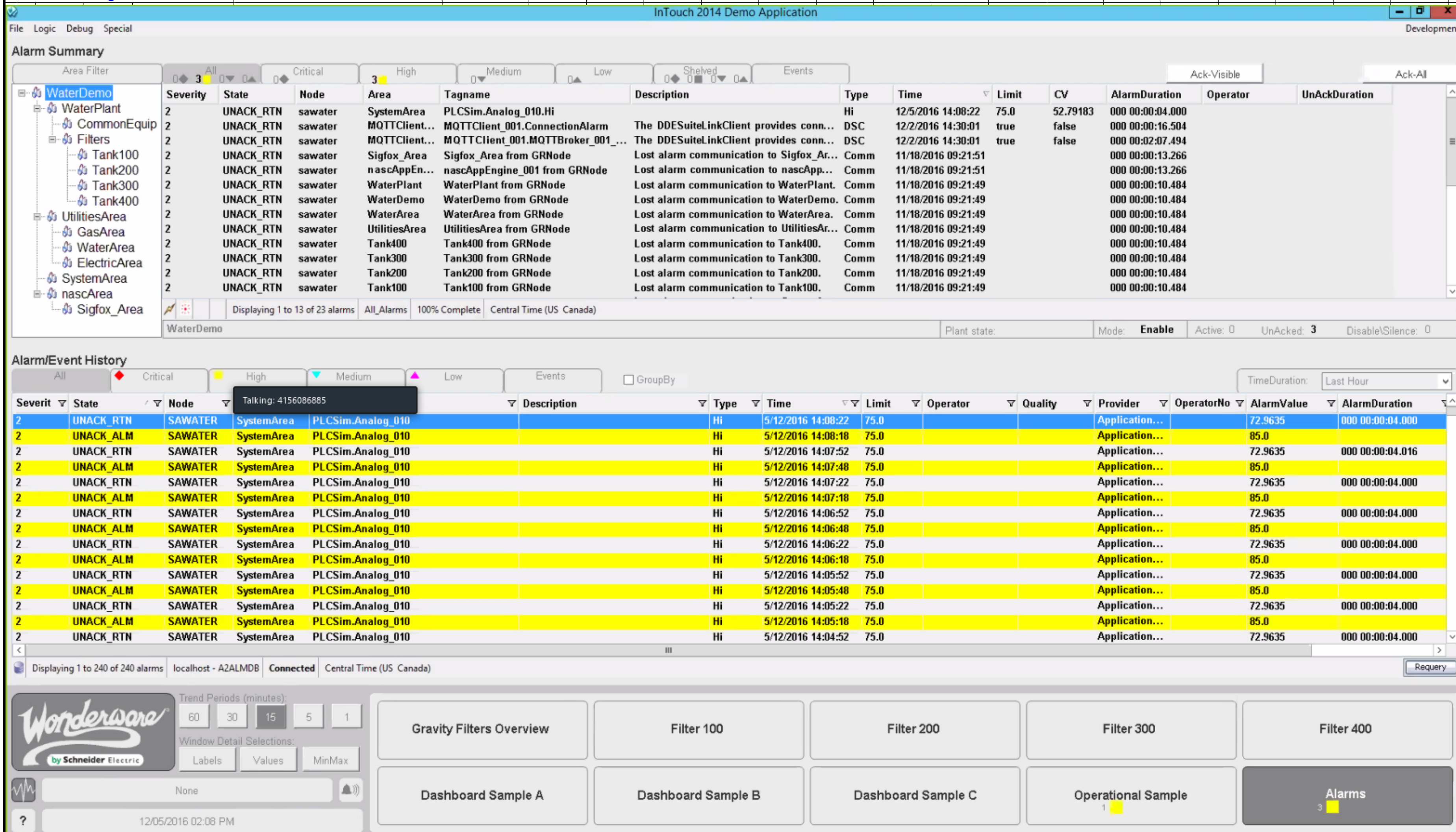
Total Batch Time:	1:05:34
Current Time:	13:30:55

Operator's Batch Log	
	TCM-5 down for maintenance. Running low on Gas 1, need to reorder. TCM-5 down for maintenance.

Process Variable Trend Screen



Process Warnings & Alarms



Recipe Scale-Up Transcription: Lab Scale→ Pilot Plant Scale		
Recipe:	101D	
Name:	Preparation of XYZ	
Sequence Group		Pilot Plant Transcription
A	Preparation:	
	R-0101 114L Synthesis Reactor	
		a) Verify Synthesis R-0101 clean and ready b) Verify Synthesis R-0101 tare net weight indicates zero kg c) Verify TCM-01 operating nominally at setpoint of 25° C. d) Verify TCM-xx operating nominally at setpoint of TBD° C. and connected to Reflux Condenser E-0101
		Equip Synthesis R-0101 with Type P analyzer
	R-0103 190L Quench Reactor	
		a) Verify Quench R-0103 clean and ready b) Verify R-0103 tare net weight indicates zero kg c) Verify TCM-03 operating nominally at setpoint of 25° C. d) Verify TCM-xx operating nominally at setpoint of TBD° C. and connected to Reflux Condenser E-0103
	F-0104 Process Filter	
		a) Verify Process Filter F-0104 clean b) Verify vacuum connection ot Process Filter F-0104 c) Verify Process Filter F-0104 connected to jacket heating cooling hose connections d) Verify TCM-0x operating nominally at setpoint of TBD ° C. e) Verify Process Filter F-0104 discharge connected to filtrate pump f) Verify Filtrate Pump discharge connected to waste filtrate catch tank
B	Raw Materials Loading:	
	T-0303 or T-0304 or T-0305 38L Liquid Addition Vessel	
		Charge available 38L Liquid Addition Vessel T-0303 / T-0304 / T-0305 with xxL / yy kg of Liquid RL4
	T-0303 or T-0304 or T-0305 38L Liquid Addition Vessel	
		Charge available 38L Liquid Addition Vessel T-0303 / T-0304 / T-0305 with xL / y kg of 100% Liquid RL5
	T-0303 or T-0304 or T-0305 38L Liquid Addition Vessel	
		Charge available 38L Liquid Addition Vessel T-0303 / T-0304 / T-0305 with xxL / y kg of Liquid RL20. Note: xL is used twice in Solid RS6 wash cycles.
	CNV-0101 2kg Dry Materials Loss-in-Weight Feeder Conveyor	
		Load x,xxx grams of Solid RS1 into Conveyor CNV-0101
	R-0103 190L Quench Reactor	
		Turn on process view camera in R-0103
		Verify R-0103 Quench Reactor jacket temperature setpoint to 25° C.
		Add xxkg / yyL deionized water R-0103
		Start R-0103 Agitator AG-0103 Set agitator speed to TBD% {100% ≡ most vigorous, or lesser speed %?} Verify R-0103 agitation is as expected via: a) Process view camera b) Agitator AG-0103 Motor % load current c) Agitator AG-0103 RPM speed feedback
		Charge Quench Reactor R-0103 with xkg of Solid RS2, Process-wise {by dumping bulk material?}
		Verify by process view camera
C	Transfer First Raw Liquid: Liquid RL4	
		Turn on process view camera in R-0101

		a) Verify load weight in T-0303 / T-0304 / T-0305 is 46.09kg b) Start TBD transfer means c) Transfer xxkg Liquid RL4 from T-0303 / T-0304 / T-0305 to Reactor Vessel T0101 {at any rate possible - what rate(s) are possible by the different transfer means?} d) At completion of transfer: Verify load weight in in T-0303 / T-0304 / T-0305 is zero kg Verify incremental load weight in R-1010 is zkg. e) Stop TBD transfer means
		Start R-0101 Agitator AG-0101 Set agitator speed to TBD% {100% ≡ most vigorous, or lesser speed %?}
		Heat/Cool temperature of Liquid RL4 in T-0101 to 25° C.
D	Transfer Second Raw Powder: Solid RS1	
		Verify R-0101 agitation is as expected via: a) Process view camera b) Agitator AG-0101 Motor % load current c) Agitator AG-0101 RPM speed feedback
		a) Verify load weight in CNV-0101 is xx grams b) Set R-0101 jacket temperature setpoint to 32° C. c) Set CNV-0101 delivery rate setpoint to xx grams/minute (= transfer of xx grams in 1-hour) d) Start CNV-0101 e) Confirm weight flow rate is at setpoint value f) Pause addition if R-0101 contents exceeds 32° C.; restart when 32° C., or less, is reached {Is there a lower minimum temperature for this reaction?} g) At completion of transfer: Verify load weight in CNV-0101 is zero grams Verify *incremental* load weight in R-1010 is zkg
		Using process view camera in T-0102, monitor the reaction mixture to ensure the Solid RS1 is disolved completely. If not, continue stirring until disolved.
E	Transfer Third Raw Liquid: 100% Liquid RL5	
		Set AG-0101 agitator speed to TBD% {100% ≡ most vigorous, or lesser speed %?} Verify R-0101 agitation is as expected via: a) Process view camera b) Agitator AG-0101 Motor % load current c) Agitator AG-0101 RPM speed feedback
		a) Verify load weight in Liquid Addition Vessel T-0303 / T-0304 / T-0305 is 5,144 grams b) Set R-0101 jacket temperature setpoint to TBD° (25°?) C. c) Set TBD transfer means delivery rate setpoint to 57.2 grams/minute (= transfer of xL or xxx grams in 1.5-hour (90-minute) d) Start TBD transfer means e) Confirm weight flow rate is at setpoint value f) Pause addition if R-0101 contents exceeds 45° C. and call the synthesis group Contents of R-0101 low temperature alarm at 20° C. g) At completion of transfer: Verify load weight in T-0303 / T-0304 / T-0305 is zero grams Verify *incremental* load weight in R-0101 is 5.14kg
		Upon verified completion of transfer, set R-0101 jacket temperature setpoint to 25° C.
		Set agitator speed to TBD% {100% ≡ most vigorous, or lesser speed %?} Verify R-0101 agitation is as expected via: a) Process view camera b) Agitator AG-0101 Motor % load current c) Agitator AG-0101 RPM speed feedback
		Set agitator AG-0101 Timer to 18 hours; start timer. {Does agitator stop if 18-hour timer exceeded?}
F	Transfer Synthesis Intermediate Product to Quench Reactor R-0103	

		Verify Quench R-0103 contents temperature is 25° C.
		Set AG-0103 agitator speed to TBD% {100% ≡ most vigorous, or lesser speed %?} Verify R-0103 agitation is as expected via: a) Process view camera b) Agitator AG-0103 Motor % load current c) Agitator AG-0103 RPM speed feedback
		a) Verify load weight in Quench Reactor R-0103 is 125kg b) Set R-0103 jacket temperature setpoint to TBD° (25°?) C. c) Set Synthesis Reactor R-0101 to Quench Reactor R-0103 Transfer Flow Delivery Rate setpoint to x grams/minute e) Enable flow control loop (opening flow control valve) f) Confirm weight flow rate is at setpoint value g) Confirm Quench Reactor contents remains at acceptable temperature range of 25°-30°C. h) Pause addition if Quench R-0103 contents exceeds TBD ° C. and call the synthesis group Contents of R-0103 low temperature alarm at TBD ° C.
		Upon verified completion of transfer, set R-0103 jacket temperature setpoint to 25° C.
		Set agitator speed to TBD% {100% ≡ most vigorous, or lesser speed %?} Verify R-0103 agitation is as expected via: a) Process view camera b) Agitator AG-0103 Motor % load current c) Agitator AG-0103 RPM speed feedback
		Set agitator AG-0103 Timer to 60 minutes; start timer. {Does agitator stop if 60-minute timer exceeded?}
G	Filter Finished Product & First Wash	
		Verify Quench R-0103 contents temperature is 25° C.
		Set AG-0103 agitator speed to TBD% {100% ≡ most vigorous, or lesser speed %?} Verify R-0103 agitation is as expected via: a) Process view camera b) Agitator AG-0103 Motor % load current c) Agitator AG-0103 RPM speed feedback
		Verify Process Filter F-0104 jacket temperature setpoint to TBD° (25°?) C.
		a) Turn on vacuum to F-010 b) Turn on Filtrate Pump
		Load 25kg (25L) of deionized water into Synthesis Reactor R-0101 {using spray ball?}
		Drain Synthesis Reactor R-0101 contents to Quench Reactor R-0103 to Process Filter F-0104 and process through Process filter cake to wash it. Collect wash water in filtrate catch tank.
H	Finished Product - Second Wash & Dry	
		Transfer xkg / xL Solid RL20 to Synthesis Reactor R-0101 from Liquid Addition Vessel T-0303 / T-0304 / T-0305
		Drain Synthesis Reactor R-0101 contents to Quench Reactor R-0103 to Process Filter F-0104 and process through Process filter cake to wash it. Collect wash water in filtrate catch tank.
		Continue the vacuum suctopm on Process Filter F-0104 for TBD minutes/hours
I	Finished Product - Third Wash & Dry	
		Load xxkg (yyL) of deionized water into Synthesis Reactor R-0101 {using spray ball?}
		Set AG-0101 agitator speed to TBD% for gentel stiring Verify R-0101 agitation is as expected via: a) Process view camera b) Agitator AG-0101 Motor % load current c) Agitator AG-01031RPM speed feedback

		Set Synthesis Reactor Jacket Temperature setpoint to 80° C. on TCM-01
		When Synthesis Reactor stirred contents is stable at 80° C., Turn-off vacuum on Process Filter F-0104; open hatch. Transfer wet cake RS6 from Process filter Process to Synthesis Reactor R-0101 with the help of water.
		Set agitator AG-0101 Timer to 60 minutes; start timer. {Does agitator stop if 60-minute timer exceeded?}
		Drain Synthesis Reactor R-0101 contents to Quench Reactor R-0103 to Process Filter F-0104 and process through Process filter cake to wash it. Collect wash water in filtrate catch tank.
		Verify Quench R-0103 contents temperature is 25° C.
		Verify Process Filter F-0104 jacket temperature setpoint to TBD° (25°?) C.
		a) Turn on vacuum to F-010 b) Turn on Filtrate Pump
J	Finished Product - Fourth Wash & Dry	
		Transfer xkg / yL Solid RL20 to Synthesis Reactor R-0101 from Liquid Addition Vessel T-0303 / T-0304 / T-0305
		Drain Synthesis Reactor R-0101 contents to Quench Reactor R-0103 to Process Filter F-0104 and process through Process filter cake to wash it. Collect wash water in filtrate catch tank.
		Continue the vacuum suction on Process Filter F-0104 for TBD minutes/hours
		Turn-off vacuum on Process Filter F-0104; open hatch. Remove washed wet cake and deliver to Room 101 for drying in electric dryer.

Human Machine Interface Design Guide
Common Control Systems

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CMU06-000176-AA

Prepared by: John Scarafiotti, Sr. Engineering Associate, DSED/DAG
Sam Montelongo, Engineer, DSED/DAG
Donald Jong, EE Engineer, DSED/DDG

Reviewed by: M A Hernández 10/5/06
Maurice Hernandez, CCS System Engineer

Concurred by: Patrick S. Dohoney 10/03/2006
Patrick Dohoney, NTS Control Systems Team Lead

Concurred by: 10.05.06
Adrian Godinez, HEAF Lead Electronics Engineer

Concurred by: 10/5/06
David Milhous, Site 300 Lead Electronics Engineer

Approved by: 10/5/06
Albert Lee, CCS Team Leader

TABLE OF CONTENTS

Preface

This document relies greatly on an earlier work completed for the Mixed Waste Management Facility by R. A. Weber and D.E. Petersen entitled, "Human Interface Design Guide for MWMF Instrumentation & Control Systems," Rev. 0. They have graciously allowed us to adapt their well written document for use as a style guide for the new B and N Program Common Control Systems. Their manuscript has provided the "backbone" for our document, served as a guide to good style, and is a source of valuable references and contacts. Any errors or omissions in this document are solely our own.

Commercial software and hardware have been selected for implementation of the Common Control Systems (CCS). InTouch (Wonderware Inc.) and LabView (National Instruments) are being used for the CCS HMI application running on the Windows operating system.

1.0 Introduction

1.1 Purpose

The purpose of this document is to establish uniform standards for the design of the Human-Machine Interface (HMI) for the new B and N Program Common Control Systems. These standards contribute to an HMI design that is:

- Consistent – aiding in operator cross-training;
- Efficient – contributing to ease of use and reduction of operator workload;
- Rules-driven – facilitating rapid development through pre-defined design decisions;
- Safe – low probability of inducing human error.

1.2 Intended Audience

This document is intended for use by individuals developing Graphical User Interface (GUI)-based, HMI screens for CCS.

1.3 Organization & Overview

The information contained in this document is grouped as described below:

Criteria – Section 2 contains descriptions of applicable Human Engineering Factors and preferred practices. Adherence to these criteria will result in an HMI design that closely conforms to the stated Purpose of this document.

Standard Practices – Section 3 contains the CCS working standards and design parameters.

Appendices – Relevant and useful information and attachments.

1.4 References

1. Weber, R.A. and Petersen, D.E., **Human Interface Design Guide for MWMF Instrumentation & Control Systems** Rev. 0

2. Banks, William W. and Weimer, Jon, Ph.D., **Effective Computer Display Design**. New Jersey, Prentice Hall, 1992.

3. **"Human Factors Engineering Design Criteria: Volume 1."** U.S. Department of Energy/Office of Nuclear Energy/Office of Nuclear Safety Policy and Standards, Jan. 1993.

4. "**MMI (Man-Machine Interface) Style Document.**" LLNL, Isotope Separation and Materials Processing Program / Computers, Networks, & Controls, Feb. 1, 1990.

5. Presentation document by the **Color Standards Working Group** / Laser Technology Program / Computers, Networks, & Controls, Aug. 21, 1990.

6. "**InTech**" - The International Journal for Measurement and Control, November, 1995

7. "**How to Design Effective Graphical User Interfaces**." Human Factors International Inc.

1.5 Abbreviations, Acronyms, & Definitions

Alarm Message – An alarm issued by CCS which requires immediate response or action. The alarm will be related to safety or equipment. Alarms are displayed on the main console screen.

ANSI – (**A**merican **N**ational **S**tandards **I**nstitute) A unique and diversified federation formed in 1918 and has become a premier source for information on national and international standards and conformity assessment issues.

Emergency Operation – Operation of equipment or a system outside its regularly anticipated parameters, where possible loss of safety functions are involved. Control system operation shall be available to allow appropriate emergency response and/or provide for safe and orderly shutdown.

GUI – (**G**raphical **U**ser **I**nterface) A method of implementing a Human-Machine Interface employing computer graphics.

HMI – (**H**uman-**M**achine **I**nterface) The means by which a human interacts or communicates with a machine.

Information Message – A message issued by CCS which is intended to provide benign information to the operator

CCS – (**C**ommon **C**ontrol **S**ystems) Taken collectively, all equipment necessary to operate or otherwise directly support experimentation at B and N Program Facilities.

ISA – (**I**nstrument **S**ociety of **A**merica) A nonprofit organization founded in 1945 that has developed the standards for instrumentation, measurement, and automation.

Normal Operation – Operation of equipment or a system within its regularly anticipated parameters.

Off-Normal Operation – Operation of equipment or a system outside its regularly anticipated parameters, loss of safety functions excluded. Off-normal operation may be the result of degraded equipment performance, loss of required utility services (electrical power, etc.) or malfunctions which affect system performance.

Operational State – The physical mode or position of a device or system. State is an absolute, quantitative value. State, in and of itself, is of neutral or undefined significance. Examples of state are: open, closed, on, off, opening, closing, in transition, energized, de-energized.

Operational Status – The condition of operational capability, normalcy, or functional health of a device or system. Status is a qualitative value that is dependent on a specific operational context. The state of a device or system results in its status, the determination of which is typically rules-driven and based on current operational context. Examples of status are: normal, caution, warning, out of range, safe, unsafe, danger.

SCADA – (**S**upervisory **C**ontrol **A**nd **D**ata **A**cquisition) A class of control system software which executes on a computer, and communicates to front-end-processors and/or remote terminal units which perform direct control of process equipment. The SCADA is typically configured to provide a graphical user interface which allows process monitoring, operator input, and data acquisition and supervisory control functions.

Warning Message – A warning issued by CCS which is intended to alert the operator to an off-normal condition. Warnings primarily relate to equipment or experiment status.

2.0 Criteria

2.1 HUMAN ENGINEERING FACTORS

2.1.1 General HMI Design

2.1.1.1 Standardization

The "look and feel" of the HMI must be uniform throughout all B and N Program Facilities. This requires consistency in the design of controls and displays, in coding and labeling, in window functionality and data entry syntax, in the use of colors, symbols, and icons, and in alarm presentation and response.

2.1.1.2 Human Error Tolerant Designs

Design must tolerate human error in those areas where failure could cause injury to personnel, damage to equipment, harm to the environment, or inadvertent operation of critical equipment. Feedback will be provided regarding the adequacy of human activity. Errors will be easily detected and corrected.

2.1.1.3 Simplicity of Design

The HMI will represent the simplest design consistent with functional requirements and expected service conditions. Personnel shall be capable of operating equipment with a minimum of training.

2.1.1.4 Process Monitoring & Control

Displays and controls shall allow the operator to monitor and control experiments over the full range of operating conditions including normal operation, off-normal operation, and emergency operation.

2.1.1.5 Safety

Design will reflect those factors applicable to personnel, public, environmental, and equipment safety. This shall include minimization of potential human error in the operation and maintenance of the system, particularly under off-normal or emergency operating conditions.

2.1.2 Control/Display Integration

2.1.2.1 Relationship

The relationship of a control to its associated display and the display to the control shall be immediately apparent and unambiguous to the operator.

2.1.2.2 Complexity and precision

The complexity and precision required for control manipulation and display monitoring must be consistent with the precision required for the system

2.1.2.3 Control System Feedback

Feedback to the operator demonstrating that the control system is responding properly shall be provided as rapidly as possible.

2.1.2.4 Control actuation and display indication

There shall be minimal time lag between system condition change and display indication of 0.5 seconds. When there is a time between control actuation and ultimate device or system state, there will be an immediate feedback indication of the progress and direction of parameter change.

2.1.2.5 Grouping of Controls and Displays

Related displays and controls shall be logically grouped to increase the ease and reliability of monitoring and control of processes. A grouping scheme shall make consistent use of the following methods, where appropriate: grouping by system, grouping by function, and grouping by sequence of operation. Without compromising the grouping scheme, the most important controls and displays shall be located in the most prominent and accessible area.

2.1.2.6 Consistency

Location of recurring functional groups and individual items shall be similar from screen to screen and arrangements of functionally similar controls and displays shall conform to the same conventions.

2.1.2.7 Emergency Use

Emergency displays and controls shall be located where they can be seen and reached with minimum delay.

2.1.2.8 Lack of Ambiguity

Display indicators shall clearly and unambiguously direct and guide the appropriate control response. The response of a display to control movements shall be consistent, predictable, and compatible with the operator's expectations and mental model of the system.

2.1.3 Visual Displays

2.1.3.1 Use

Visual displays shall be utilized to provide the operator with a clear indication of equipment or system conditions for operation under any eventuality commensurate with the operational and maintenance philosophy of the facility.

2.1.3.2 Content

The information displayed to an operator shall be sufficient to allow the operator to perform the intended task, but will be limited to information necessary to perform specific actions or to make decisions.

2.1.3.3 Precision

Information shall be displayed only within the limits and precision required for specific operator actions or decisions. The displayed precision shall not exceed the overall precision of the monitored system.

2.1.3.4 Format

Information shall be presented to the operator in a directly usable form. Requirements for transposing, computing, interpolating, or mentally translating into other units must be avoided.

2.1.3.5 Duration

Signals and display information shall be presented for a sufficient length of time to be reliably detected under expected operator workload conditions and operational environment.

2.1.3.6 Timeliness

Displays requiring updated information shall be refreshed to the degree of timeliness required for specific operator actions or decisions.

2.1.3.7 Advisory and Alerting

A display shall call the operator's attention to information within the display that is critical, out of normal range, or otherwise significant. Less-than-critical-information messages shall stand out from their surroundings to gain operator's attention. Warning messages and alarm messages shall be presented in a bold, attention-commanding manner. When necessary, sound or recorded messages will be used to enhance the alert procedure.

2.1.3.8 Redundancy

Redundancy in the display of information to a single operator shall be avoided unless it is required to achieve specified safety or reliability.

2.1.3.9 Display Failure

Failure of a display or its associated systems shall send immediate alarm conditions to the operator.

2.1.3.10 Contrast

Sufficient contrast shall be provided between all displayed information and the display background to ensure that the required information can be perceived by the operator under all expected lighting conditions. Under normal control room illumination, the use of dark characters on light background is preferred.

2.1.3.11 Analog/Digital Coding of Numeric Information

Information may be coded in analog, digital, or combination form. Digital displays are recommended for precise readings of quantitative values. Digital displays shall not be used as the only display when perception of the pattern of variation is important. Analog displays are recommended when values must be considered in relation to range or zones, or when trend information is required.

Analog displays shall not be used as the only display when the precise reading of quantitative values is important.

2.2 STATE VS. STATUS

General usage of the terms "state" and "status" is typically neither precise nor consistent. The terms are often used interchangeably or with meanings reversed. When it comes to information coding, there must be clear and consistent application of these concepts. Also, care must be taken not to interchange the common, imprecise conversational meaning of these terms with the following technical definitions.

2.2.1 Definitions

State – The physical mode or position of a device or system.
State is an absolute, quantitative value. State, in and of itself, is of neutral or undefined significance.

Status – The condition of operational capability, normalcy, or functional health of a device or system.

Status is a qualitative value that is dependent on a specific operational context.

2.2.2 Discussion

Examples of state: open, closed, on, off, opening, closing, transitioning, energized, de-energized.

Examples of status: normal, caution, warning, out of range, safe, unsafe, danger.

The state of a device(s) results in its status, the determination of which is typically rules-driven and based on current operational context.

Display of status allows an operator to perceive the condition of system normalcy. Indication of state allows an operator to diagnose the cause of off-normal conditions.

2.3 COLOR

Standards for color are established in order to (1) produce consistency in GUI displays; (2) minimize the time expended in making color choices for GUI functions; and (3) reduce the possibility of inducing error due to inappropriate application of color.

2.3.1 General

To avoid visual and perceptual overload, the maximum number of significant colors (colors which convey information) per screen display should be five or fewer. Four or fewer significant colors is preferred. Duplication of significant colors in titles, labels, and static or decorative graphics shall be avoided. The following colors are excluded from the count of significant colors: red and yellow as status colors; white and medium gray as binary state symbol fill colors.

Color coding of symbols or textual data to facilitate visual grouping, and the color coding of subsystems may be *sparingly* used, as long as the recommended maximum number of significant colors per display (discussed above) is not exceeded, and as long as the allocation of colors to such coding does not leave sub-optimal color choices for other functions.

There shall be sufficient contrast between background and text/graphics to assure legibility in all anticipated viewing conditions.

2.3.2 Colors and Color Combinations to be Avoided

Red will never be used to indicate anything normal. Moreover, red will not be incorporated into titles, labels, or static or decorative graphics *because its continuous presence tends to desensitize an operator's attention* to its significance as an alarm status indicator.

Primary blue and magenta are difficult to read on dark backgrounds.

Red/blue combinations produce a 3-D effect that can be visually disorienting.

Large areas of bright or saturated color produce retinal fatigue ghosting.

Blue shall not be used as a color for symbols. (There is a psycho-neurological problem in symbol recognition and interpretation when the color blue is involved.)

Depending on the display device, color coded lines may not be easily visible. Color convergence problems of some monitors will make interpretation difficult.

2.3.3 Color Coding of State

The large number of variables involved in coding state precludes extensive use of color. However, judicious use of color in coding the simple binary state of certain devices can aid an operator in quick interpretation of function. Care must be taken not to exceed the maximum number of significant colors (section 2.3.1) and not to use any color that could be misconstrued as indicating status.

2.3.4 Color Coding of Status

Color coding of status will conform to the American cultural stereotype of:

- red = "danger/unsafe/not correct for continued operation",
- yellow = "warning/caution", and
- green = "safe/normal".

Any other color coding scheme for status increases the possibility of misinterpretation. The application of color for status coding follows the above conventions, with the following exception: all information presented on the screen is presumed "normal" unless specifically flagged by red or yellow.

Therefore, "normal" status is not limited to, or indicated solely by, the color green

The distinction of "blinking" vs. "solid" may be incorporated into the coding of status, where blinking indicates the need for operator acknowledgment and solid indicates either benign information or acknowledged alarm or warning information.

2.4 FONTS

2.4.1 Legibility

A font style shall be chosen for maximum legibility. Aesthetics and artistic considerations are secondary to the ability to accurately read data.

A font style shall be used that does not impair discrimination of similar characters. The worst offending pairs of characters are the letter l and the number 1, the letter S and the number 5, the letter O and the number 0, and the letter Z and the number 2. If possible, a font style shall be used that has a slashed or center-dotted zero for character strings containing both letters and numbers.

A font style with serifs, variable stroke widths, or slanting shall not be used. These characteristics tend to impair legibility.

"Ariel" is a good model for a non-serif, high legibility, well-differentiated font style. Oh/Zero differentiation is accomplished by large difference in character width. El/One differentiation is by inclusion of a top serif on the One.

Proper sizing of text characters on the display screen is determined by the function of the text and the expected reading distance. Critical data shall be given the benefit of larger character sizes to increase legibility. Determination of expected reading distance shall take into account both seated and standing operators. See section 3.11 for information on text design parameters.

2.5 SYMBOLS

2.5.1 Conformance

The design and application of symbols will conform to applicable standards documents. Examples are shown below.

Graphical Symbols for Process Displays
ANSI/ISA-S5.5

Instrumentation Symbols and Identification
ANSI/ISA-S5.1

Graphical Symbols for Process Flow Diagrams
ANSI Y32.11

AAA93-105735 (P&ID Legend)

2.5.2 Consistency

Symbols shall be consistent and uniform in construction, style, and meaning throughout. Where possible, applications shall make use of common symbol libraries.

2.5.3 Size & Resolution

Symbol size and resolution shall be sufficient to allow the operator to perceive and interpret symbols under all expected lighting and viewing conditions.

2.6 OPERATING & WINDOWING ENVIRONMENT

2.6.1 Access

Access to computer system functions and to control functions shall be protected by login and password. The login account may be a personal or system account. In either case, the login account will determine subsequent capabilities and access privileges.

2.6.2 Attributes

A window containing a fixed-format display will not be resizable.

Each discrete window shall appear at the "default location" on the screen the first time it is invoked, and the "default location" should be customizable by the user. Where possible, window locations shall be designed to minimize obscuring data in other windows.

2.6.3 Interaction

Window activation shall be accomplished by clicking once on any part of the window. Dynamic window activation, based on pointer location alone, will not be used. When activated, a window shall become the top window. Where applicable, touch sensitive screens can be used in conjunction with a mouse or other pointing device.

Activated alarm message windows affecting personnel safety or high value data/equipment shall always rise to the top. Personnel safety alarm windows shall take precedence over high value data/equipment alarm windows. These types of alarm windows shall remain on top until appropriate operator response is received. All other types of alarms shall be queued, displayed, and acknowledged from an alarm summary window.

When a confirmation window appears in response to selecting a function, there shall be an unambiguous visual association between the selected function and its confirmation window.

Window hierarchies shall be constructed to reduce the possibility of the operator becoming lost within the structure of windows and menus (navigation errors). Either a quick return to the top level or an always-visible window navigation tool shall be provided.

"Hotkey" accelerators shall be provided where applicable for the benefit of experienced operators. In this case, the Windows reserved and commonly used keyboard hotkeys (Appendix C) shall not be reassigned, and in addition, mechanisms shall also be provided to print or display the existing hotkey list and to delete the selected hotkey.

The selection of a function will be the result of a click-and-release only within that function. It must never be possible to click down, drag through multiple functions, and release to select. Such a capability increases the possibility of inadvertent selection.

2.7 DATA ENTRY

2.7.1 General

When the control of a process requires the operator to enter numeric data, a data entry method shall be employed that clearly and unambiguously directs and guides the operator in making an appropriate entry. In addition to keyboard entry, data entry methods may include modifying a numeric value with increment buttons or a movable graphical device such as a slider or dial. The resultant numeric value shall be automatically restricted to an acceptable range and displayed in real time while the operator is adjusting the slider and/or dial.

When numeric data is entered from the keyboard, input error and range checking shall be employed. When erroneous or out-of-range data is encountered, the associated variable shall remain unaffected, and a warning dialog window shall appear which either explains the rejection of input data or prompts with the correct range and allows the operator to re-enter the data or cancel the transaction.

The format and precision required of entered data will be consistent with the function of the system.

The entry or modification of numeric data for a critical parameter shall produce a confirmation dialog window.

2.7.2 Data Entry Termination

Data entry fields (numeric or textual) shall be continuously modifiable by customary screen editing techniques until termination. Variables shall remain unaffected until termination. Termination shall be accomplished by pressing the RETURN, ENTER, or TAB key, by clicking outside the data entry area or by clicking on an ENTER button. A means will be provided for error recovery while entering or modifying the data field.

2.8 ALARMS

2.8.1 General

Visual and auditory alarms will be utilized to alert the operator to the existence of off-normal system status.

Visual and auditory alarms will be configured to be clearly discernible under all anticipated ambient lighting conditions and sound levels.

The methods employed to gain the operator's attention shall be in proportion to the severity of the condition. Warning messages and alarm messages pertaining to conditions which could cause injury to personnel, damage to equipment, or harm to the environment will employ the boldest practical combination of visual and auditory stimuli.

A warning or alarm message shall contain sufficient information to direct the operator to the appropriate response.

All unacknowledged messages will blink, indicating the need for acknowledgment by the operator. A method of acknowledging a blinking message shall be provided. When acknowledged, an alarm or warning message will cease to blink, but shall remain solid and illuminated in its status color until the underlying condition is rectified.

2.9 SOUND

2.9.1 General

An auditory alarm may be electromechanically produced (bell, horn, buzzer) or electronically produced (oscillator or digital sound effect) or a recorded voice message describing the alarm. An auditory alarm shall always be accompanied by a visual alarm message. There will be a clear and unambiguous association between an auditory alarm and its associated visual alarm message.

An auditory alarm shall be silenceable without canceling its associated alarm message.

No sound function will produce a sound pressure level that is uncomfortable or damaging to the hearing, or that violates existing occupational and safety regulations regarding sound pressure levels.

3.0 Standard Practices

3.1 Introduction

The standards defined in this section apply to the building and configuring of HMI control windows. The reader is assumed to be knowledgeable about HMI applications and their implementation. Much effort is spent defining colors and their specific use in the GUI; this is done to assure that the results will be a HMI that is consistent in appearance at all B and N Program experimental facilities.

3.2 Color Palette – General Usage & Prohibitions

Table 1 lists the color palette, and its recommended usage and prohibitions. This is consistent with section 2.3.4. All colors / color names are approximations only and are not strictly defined.

Table 1 General color usage / prohibitions

Color	General Usage / Prohibitions
Black	Background for setup & configuration windows
Gray	Transition state fill color for discrete state devices
Light Gray	Item not available
White	Closed / Off State fill color for discrete devices
Teal	Background color for windowing buttons
Green	Open / On State fill color for discrete devices
Yellow	Warning condition / message Error state fill color for discrete devices
Purple	
Red	Alarm condition / message
Cyan	Acknowledged message Benign information message
Blue	Do not use for symbols. Use on non-critical graphics only

3.2.1 Comments On Colors Used For Indicating State

There is much controversy concerning assigning colors to indicate the state of a discrete state device. This subject is discussed in section 3.1.2 of the document "Graphic Symbols for Process Displays" ANSI/ISA S5.5. In particular, point #8 permits a certain amount of leeway but stresses that **a standard must be set and adhered to for a particular project.**

Table 2 summarizes the use of colors for indicating state from a wide variety of organizations. Note that the trend is to use Green to indicate "on/open", yellow to indicate "transition" and white to indicate "closed/off". The color standards set of CCS for indicating state (see table 1 and table 4) are based to a large degree on this trend as well as other referenced documents.

Table 2 Summary of color assignments used by various organizations to indicate state. **This is for reference only**

Document / Organization	Date	Open / On	Transition	Closed / Off
Graphic Symbols for Process Displays ANSI/ISA S5.5 from section 3.3 structure of symbols: from section 3.2.1 color plan example:	2/86	 Black Green	 none Yellow	 White Red
HMI Style Document HMI Group, CNC, LED	2/90	Green	Yellow	White
Color Standards Working Group Laser Technology Program, CNC, LED	8/90	Green	Yellow	White
Human Factors Engineering Design Criteria DOE-STD-HFAC 1 UCRL-AR-108791 Vol. 1, Rev. 2 Draft	1/93	none	none	none
Design Criteria document Idaho National Engineering Laboratory	9/94	Lt. Green	Yellow	Gray

3.3 Color Palette – Text Legibility Chart

The following chart evaluates the legibility of text colors against background colors. Critical data shall utilize color combinations evaluated as "Best" or "Good". Under no circumstances shall a color combination evaluated as "Poor" be utilized for the display of data. This chart applies to the legibility of text only. It does not apply to the legibility of symbols or other graphics.

Table 3 Text legibility chart for all text and background color combinations.

Background \ Text	Black	Gray	Light Gray	White	Teal	Green	Yellow	Purple	Red	Cyan	Blue
Black		3	**1**	**1**		3	3		3		
Gray	3		3	3			3	3		3	3
Light Gray	3				3	3		3	3	3	3
White	**1**	3			3	3		3	3	3	**1**
Teal	3		3	**2**			3				
Green	3		3	3			3				
Yellow	3	3			3	3		3	3	3	3
Purple			3	3			3				
Red	3		3	3			3				
Cyan	3		3	3			3				
Blue		3	**1**	**1**			3				

1	Best
2	Good
3	Fair
	Poor

3.4 Colors for Coding State in Control Windows

The actual state of "discrete state devices" will be indicated by the fill color of the device symbol. Similarly, the requested state (i.e. the state of the final control element for the device) will be indicated by the fill color of its associated control button.

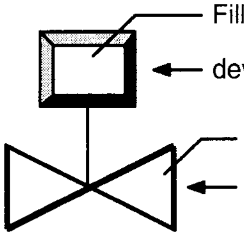


Table 4 Standard fill colors for discrete state device symbols and controls.

Control/Device State	Fill Color	Applicable to:
Close(d) / Off	White	device symbol & control button
Open / On	Green	device symbol & control button
Transition	Gray	device symbol
Error	Yellow	device symbol
Disabled	Light Gray	control button

3.5 Coding Status in Control Windows (text & symbols)

Table 5 Control Window types and their presentation.

Condition	Method
ALARM	Text or symbol enclosed within a red box (blinking when unacknowledged, solid when acknowledged but unrectified)
WARNING	Text or symbol enclosed within a yellow box (blinking when unacknowledged, solid when acknowledged but unrectified)
NORMAL	No box around text or symbol, or no text if parameter is in a normal range (note: the value may be presented only during alarm or warning condition)

3.6 Colors for Coding Status on Video Monitors

Alarm annunciators displayed on the video monitors at the control console will conform to the following standards for status color usage.

Table 6 Standard color usage for status indicators.

Color	Message Type	Implications
Red	Alarm	Critical parameter out of tolerance Immediate operator action required
Yellow	Warning	Marginal parameter value exists Corrective action may be required Parameter is changing but within boundary conditions
White	Information	Action not necessarily required, benign information
Green	Information	Parameter in expected state

3.7 Colors and General Configuration for Message Window

Message windows are used to report specified alarms and conditions of interest. Color usage and the other configurable parameters of the message windows shall conform to the following standards.

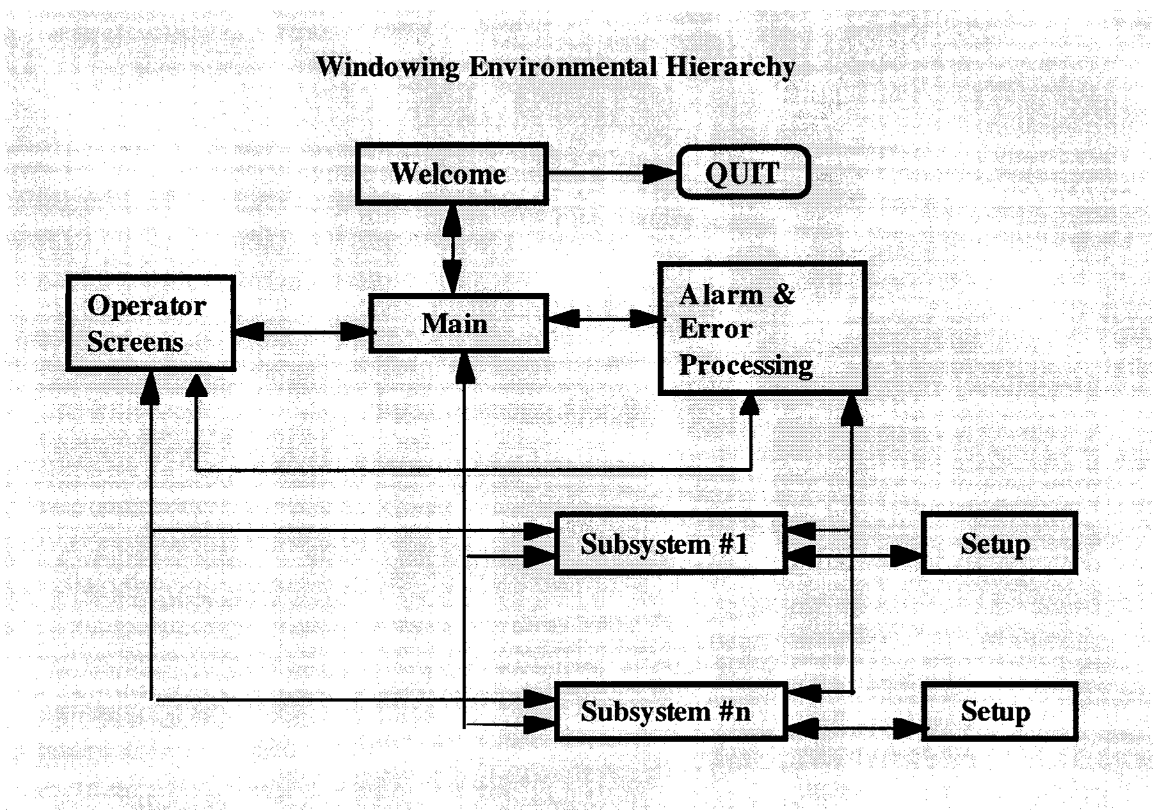
Table 7 Standard color usage for message windows

Border Color	Message Class	Implications / Usage
Red	alarm	Unacknowledged alarm Critical parameter out of tolerance Immediate operator action required
Yellow	warning	Unacknowledged warning Marginal parameter value exists Corrective action may be required Parameter is changing but within boundary conditions
Cyan	information	Acknowledged message and unacknowledged benign information Action not necessarily required
Light Gray	all classes	Item not available
Black	not applicable	Background color
Green	Information	Parameters in expected state

When a new alarm condition exists, a message window will be displayed with an appropriately colored border according to Table 7. Depending on the message class, operator action may or may not be required. i.e. An "alarm" message may require both an acknowledge and a reset whereas an "information" message may only require an acknowledge. In all instances the window is not cleared until appropriate action is taken.

3.8 Windowing Environment

The HMI windowing environment will have a hierarchical structure as shown in the example below. There are several levels; the highest is a "welcome" window that has a single button to open the "main" window. It's the only window that allows the operator, with appropriate authorization, to QUIT. Depending on the size and complexity of the experiment being controlled, there will be a "main", "operator", and "alarm & error monitor" window and one or more subsystem control windows ("subsystem #1" ... "subsystem #n"). The "subsystems windows will most likely have corresponding "setup" sub-windows.



3.8.1 Window Descriptions

The following are brief descriptions of the various predefined windows. The first two windows, welcome and main, will actually use these names. The operator, alarm and error processing, subsystem, and setup windows may be given names that best fit their intended use.

Welcome window

- This is the highest level window and the first window that opens after login.
- Has a welcome message. example: "Welcome to the Bunker 850 Control System"
- Has a button that opens the "main" window and closes the welcome window.
- Simple; no data
- This window is the only access point for quitting.

Main window

- Opens from "welcome" window.
- Highest level window used for monitoring and control, its function depends on the size and complexity of the process.
- For small/simple applications
  – has most or all data display and control functions for a given process
  – may have simple control subwindows
  – may have setup subwindows
- For larger more complex applications
  – is the top level control window, providing global control & monitoring
  – has access to the "subsystem" windows
  – has setup subwindow

Operator Screen window

- Opens from any window below the "welcome" level.
- Highest level window used for the experiment operation, monitoring and control.
- Displays status as related to the experiment.
- Has link to Main, Subsystems, and Alarm & Error processing windows .
- Uses selection, confirmation, and notify windows as necessary.

Alarm and Error Processing subwindows

- Opens from any window below the "welcome" level
- Highest level window used for alarm and error processing
- May have individual alarm/error acknowledge subwindows.
- Uses confirmation windows as necessary
- The alarm and error processing subwindows are linked to All windows

Subsystem windows

- Opens from "main" or higher level "control" window.

- Has display and control functions for a specific subsystem or component of the process.
- May have simple control subwindows.
- May have setup subwindows.

Setup windows
- Opens from respective "subsystem" window.
- Used for entering low usage setpoint, configuration or other parameters that are not appropriate to have reside on the associated subsystem window.

Selection and confirmation windows
- Pops up if a click action has multiple selections or for confirmation of a click action

Notify windows
- General purpose window used to present a benign message to the operator in a timely manor.
- Has configurable message and button

3.9 Buttons

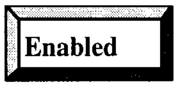
Buttons can have two shapes, square ends or rounded ends. The table below defines the usage for these two shapes. Security and lockout may be added to any button or control.

Table 8 Button shapes and usage.

Button Shape	Button Usage
square ends	control/configuration action
rounded ends	opens other windows (navigates between windows)

3.9.1 Control Buttons

Button legends and state indicators must be implemented so that there is no ambiguity with respect to their action or state. The button legend will indicate the action that will result when the button is pushed. The button's state indicator (if used) will display the current state.



Two-State buttons
- Used for benign operations/changes
- Single click toggles state
- Use "confirm" if extra error avoidance is needed

Multiple-State buttons
- Can be used for three or more states
- Pops up an "select" window from which a selection is made

3.9.2 Buttons That Open Other Windows

Opens and/or brings to the front the "main" window.

Selection pop-up, menu lists Trends available.

Selection pop-up, menu lists all available windows.

3.10 Symbols

A library of device symbols which is derived from ANSI/ISA S5.5 "Graphic Symbols for Process Displays" will be used . New symbols which follow the guidelines (see section 2.5) may be added as needed. Colors associated with symbols and control buttons have been defined in sections 3.4 & 3.5. Appendix B contains this symbol library.

3.10.1 Orientation of Symbol and Associated Controls & Readouts

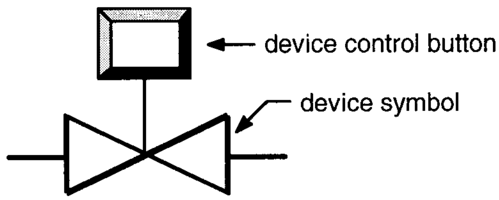
Symbols may be rotated to accommodate the layout of the process (preferable 90° increments). The preferred layout has process flows going from left to right.

Control buttons, setpoint controls and readouts shall be above or to the right of the symbol. Control buttons and setpoint controls shall have a thin line connecting to the symbol. Numeric controls shall be enclosed in a shadowed box to distinguish them from readouts.

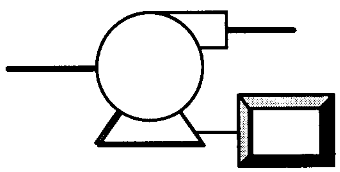
3.10.2 Examples

The following are a few examples of symbols with their associated control buttons, setpoint controls and readouts.

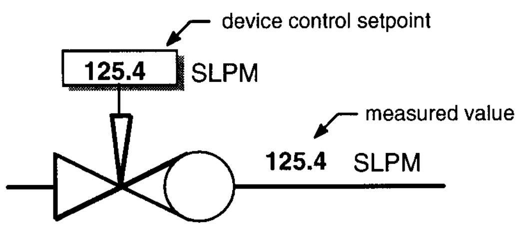
Valve



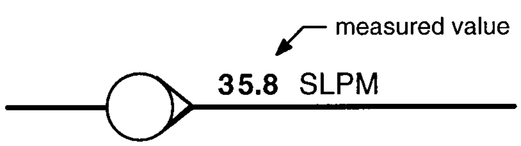
Pump



Mass Flow Controller



Flow Sensor



Common Control System

Programmer's Software Guide

Document Number: CMU06-000175 Rev AB

Review 3

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Authors:

Donald Jong, LLNL
Patrick Dohoney, LLNL

Concurred By:

Dave Milhous, LLNL
S300 Controls Point of Contact

Date 6-16-08

Adrian Godinez, LLNL
HEAF Controls Point of Contact

Date 06/13/08

Patrick Dohoney, LLNL
NTS Controls Point of Contact

Date 06/09/2008

Approved By:

Albert Lee, LLNL
Common Control System Coordinator

Date 6/16/08

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1.0 Introduction

1.1 Purpose

The purpose of this document is to guide the procurement, design, and development of software for the Common Control Systems (CCS). The use of this Guide is intended to help the programmer develop clear, high quality code, which in turn will aid subsequent maintenance efforts. This Guide focuses on establishing a consistent tool set and programming style (especially in how the code is documented), that is to be applied across all CCS systems. Code that predates the release of version AA of this document may be exempted or partially exempted from the guidelines. The CCS Configuration Change Board (CCB) will decide whether an existing code should be exempted from the guidelines.

This version is a major update of the *Programmer's Software Guide* BMCS 99-001 Version 2.1 originally written by John Scarafiotti and revised by Paul Shaich and Sam Montelongo in August of 1999. Stringent rules remain in this revision and are broadened as the guideline for the CCS software developed for the B Program and JNPO facilities. The commercial software list has been extended to include the packages currently being used by the CCS development. Variable and file naming conventions have also been updated to accommodate the current needs. In addition, the format and sections have been reorganized for easy reading and editing in the future.

All B Program and JNPO facilities will be referred to hereon as Facilities

1.2 Intended Audience

The document is written for all levels of personnel who work on and/or manage software or firmware for the Common Control Systems (CCS).

1.3 Configuration Change Board

The CCS Configuration Control Board (CCB) has general oversight responsibility for software used in the development of CCS. See the following document *CCS Configuration Management Plan - CMU07-000018 for more information on the CCS CCB*.

1.3.1 The CCB consists of the CCS Team Leader and the representatives from each Facility.

1.3.2 The CCB has jurisdiction over *CCS Programmer's Software Guide* and its interpretation.

1.4 Restrictions on Software

1.4.1 Software that is purchased shall meet the following minimal requirements:

1.4.1.1 The software will be a company-supported, off-the-shelf product. Whenever possible, the application will be a mature, established product with a known track-record in the software industry.

1.4.1.2 CCB must approve the use of software that is to be procured for use in CCS. The approval process is defined in the CCB charter.

1.4.2 When no commercial product is available or appropriate, software will be developed in-house, subcontracted, or found as open-source. All such software and firmware shall conform to provisions contained in *CCS Quality Assurance Plan - CMU07-000017*. The software shall also conform to the provisions of this document, as well as the *CCS HMI Design Guide -CMU06-000176* or equivalent document(s).

1.5 Organization & Overview

In addition to the LLNL institutional requirements, this document contains requirements on procurement, development, programming, and maintenance of software and firmware. It also contains recommendations for efficiently satisfying the requirements.

Standard Practices – Section 2 contains working standards for software code developed for the Facilities.

Appendices – Some of the appendices contain firm requirements that are not stated in the body of the document. Requirements in the appendices are grouped there for two reasons. (a) They are easy to find while programming – without having to search through extraneous material. For example, program headers are described in appendices. (b) Fine grained detail occurs in appendices – enabling a reader to view the body as a more unified document.

1.6 Project Reviews

Any projects that claim compliance with this document shall include a member of the CCS team or a designee (choosen by the CCS team) on all their reviews. This inclusion is meant to assure the oversight by CCS and insure compatibility across B-Program and JNPO Facilities. The reviewer should not be a member of the project team.

2.0 Standards

2.1 General Standards for All Software

2.1.1 Software developed for use in Facilities is operated and maintained for anywhere from 5 to 15 years. The developer must design the code such that personnel who were not part of the original development team can maintain it. The developer must therefore use clear, concise constructs in the source code, and provide full explanations of any advanced algorithms or techniques.

2.1.2 The software developer shall strive to produce applications that can be installed, used, and maintained in a straightforward, consistent manner. This includes supplying clear, meaningful messages in the event of an application error. Such messages shall minimally identify the location (source code file), possible causes and results, and options for subsequent actions.

2.1.3 Software packages often have reserved identifiers that have specific interpretations. Use of such reserved words is generally required to make efficient use of the software package. A common example is the C language reserved words stdin, stdout, and stderr which are #define macros of type pointer to FILE. Many vendor C/C++ libraries will #define literals, variables, functions, procedures, and methods with shorter and easer to use reserved words which: eliminate magic numbers; make your code look less complex and easier to read. These reserved words are usually replaced with their actual text prior to lexical analysis and are completely evaluated at compile time. If such identifiers are used in software development, the identifier and its meaning must be documented as part of the main file header.

2.1.4 Global user-defined functions/MACROs must be defined in the file where global variables are declared and defined. While use of such code is very efficient, without clear, easy to understand documentation, the meaning of this code can be obscure. An example of such code is: FOREVER, which is a global user-defined function/macro that is essentially a "Repeat Forever" statement. In the event that the global definition file becomes large enough that a printed copy exceeds two pages in length, the developer must break up the file into a number of smaller files. Entries into each individual “sub-file” must be grouped according to related functions or other reasonable criteria. An “include” statement for each of the smaller files must be part of the original global definition file. With this structure, all global variables, user-defined functions and MACROs can be found by following links from the single global file.

2.1.5 LLNL and NSTec projects often include vendor supplied software. If this vendor supplied software is used unmodified, then it need not follow the format guidance of this document. This code must be blocked off to show where it starts and where it ends. It shall have a header alerting the reader that it is vendor supplied code and therefore it may not adhere to this document. If minimal code changes to this vendor code are required to adapt it to B Program use, it shall have in-line comments to show what changes were made, where they are and why changes have been made. Any new code shall adhere to this document, i.e., global declarations, variable names, function names, headers, etc. Any vendor supplied code that requires significant changes to meet the needs of B Program and JNPO, shall have a full header and format as outlined in this document.

2.1.7 Use of programmer defined abbreviations should be minimized. In the event a new abbreviation must be used, programmer defined abbreviations must be defined in a main file header. These abbreviations are to be submitted to the CCB for inclusion into the Standard Abbreviations List (see Appendix A).

2.1.8 Delivery of all developed software is to be accompanied by hard copy and electronic copy of source code. In addition, the required tools and procedures, especially for generating executables and/or object code, shall also be included.

2.1.9 Software intended for use in the new CCS will be reviewed for compliance with the guidance given in this document. The personnel who will review this software will be drawn on a rotating basis from the members of the project team. Project team members will not review their own code for compliance.

2.1.10 The quality assurance plan for the project requires that code walk-throughs be performed on software developed for the project. Code walk-throughs and their associated results are required to be presented at the final design review. One of the agenda items for the code walk-through is to review for compliance with this document. While this review will suffice for the compliance to this Guide, it is recommended that such compliance reviews be conducted earlier in the development cycle. This will ensure that changes required to comply with this document are minimized.

2.1.11 It is permissible for the reviewer performing a compliance review to sample the code being reviewed. The table itemized in the appendix to the S300 quality assurance plan "LLNL B-Division S-300 Quality Assurance Plan (M-078-144)" will govern the size of the sample reviewed. Code modules will be the items counted to determine the sample size (that is as opposed to lines of code). If random guidance violations are found in the sample, these should be corrected and the software engineer should examine their code to find other violations. If significant guidance violations are found in the sample, then the entire body of code should be reviewed. Once the initial compliance review is performed, the software engineer is required to modify the code to be compliant. Additional periodic reviews of this code are required until the code successfully passes the compliance review.

2.2 Code Header

CCS software development will employ multiple languages. The following list of requirements shall apply for source code headers in all languages used.

2.2.1 A file header will appear at the top of every file. The header shall be written and in place before final testing of the software begins.

2.2.2 For a given language the header shall be in the form of an extended comment whose beginning and ending use different symbols to demarcate the header. The header shall not have symbols in the right or left columns to signify that a line belongs to a header.

2.2.3 For a given language such as C, different kinds of headers are defined for files with different kinds of contents (see appendices).

2.2.4 For a given language, headers must be consistent. The information must be presented in the same order for all files or modules of the same kind.

2.2.5 Topical labels (or header topics) which are empty or blank shall not be deleted – the reader must always see the same layout for any header.

2.2.6 The following is a minimal set of topics is to be included in any source code header. In some programming languages more topics will be needed.

2.2.6.1 Name of function, routine, procedure, or script
2.2.6.2 Author
2.2.6.3 How it is used
2.2.6.4 Purpose of the code
2.2.6.5 Global variables (or equivalents in other languages, e.g. tagnames in *InTouch*)
2.2.6.6 Inputs
2.2.6.7 Outputs
2.2.6.8 Limitations
2.2.6.9 Assumptions
2.2.6.10 History of code

2.2.7 The preceding set of topics is used to define headers for C/C++, *InTouch*, and *LabVIEW* (see appendices). The differences between the headers for the three languages follow directly from the different nature of the languages.

2.2.8 Using the diverse set of headers in the appendices as examples, a developer shall define a set of headers relevant to other program languages used. Consultation with the CCB is required. The CCB must approve proposed headers for other languages.

2.3 Code Documentation

2.3.1 Internal code documentation must be finished or updated promptly after the code is working correctly.

2.3.2 For each application a user's guide, tutorial, or functional manual must be written.

2.3.3 The written documentation must be supplied in hard copy and electronically. Electronic textual documentation shall be supplied in Microsoft Word format, using the currently accepted version listed in Appendix M.

2.3.4 For each application the documentation shall include two lists of directories and files. One list provides the directory hierarchies and does not include a list of (non-directory) files. The second list provides file names in each directory.

2.3.5 Any non-standard developer packages, C or other libraries, or editors that are required to view, compile, or link the source or executable files must be supplied.

2.3.6 All source code for any application developed or modified for the Facilities, as well as other information useful for maintenance, shall be supplied on disk or preferably, CD-ROM media.

2.3.7 When any significant software changes are made the hard copy documentation must be updated in a timely fashion as defined in the applicable configuration control document.

2.3.8 The compiler type and compiler version shall be called out in the document. The date and version number of any compiler updates or changes shall be clearly stated in the written document. Any special software support or special compiler requirements shall be specified in the written documentation, as well as in the internal code documentation.

2.3.9 For each application the documentation shall include an Adobe Acrobat (pdf) of front panels for LabVIEW, InTouch. Also, an Adobe Acrobat (pdf) of the LabVIEW vi wiring diagrams is required.

2.3.10 ASCII editor templates must be supplied in electronic format.

2.3.11 For each PLC application, a list of its variable names and register locations must be provided.

2.3.12 For each *InTouch and IAS* application,

2.8.12.1 A list of tagnames will be provided.

2.8.12.2 Scripts must be supplied in Adobe Acrobat (.pdf) format. This will require that a fully functioning copy of Adobe Acrobat be installed on the Intouch development system. The developer may then "print" the script listings to an Acrobat file for distribution.

2.3.13 LabVIEW VI's, including wiring diagrams, are to be supplied as source code.

2.4 Coding Practice for Developing C/ C++ and PLC Software

2.4.1 Executable File Name

When compiling and linking source code to create the executable file, the developer shall adopt the convention of using the same name for both the main source code file name, and the executable file name. For example: BeamBug.cpp and BeamBug.exe.

2.4.2 Function/Routine Name

Algorithms and routines should be written and implemented to reflect the, operational aspects of Facilities, especially in the selection of function and variable names. The names and terms used within developed software should reflect their relationship with facility components or operations. When applicable, variable names shall be the same as hardware names.

2.4.3 Code Style

All C Code must be written to conform to the applicable ANSI Standard for C++ Programming. (ANSI Document Number: ISO/IEC 14882:1998, Title: Programming languages - C++) All software shall be written in a consistent, clean style that aids a reader. This includes indenting each new code block, consistent use of braces, and uniform methods of naming variables.

2.4.4 Code Validation

Software developers must validate all C and C++ source code for syntactical compliance to the applicable standard, through use of a commercially available validation tool. See Appendix M for a list of acceptable validation tools.

2.4.5 Run-time Error Check

Software developers must check all C and C++ executable code for run-time or memory-access errors, through use of a commercially available detection tool. See Appendix M for a list of acceptable detection tools.

2.4.6 Case/Switch Nesting Limit

Avoid nesting case or switch more than two layers deep, as much as is practical.

2.4.7 Use of Global Variables

The use of global variables in C/C++ and Pascal shall be minimized and if used, shall be documented as described in the later “Header Definitions”.

2.4.8 Naming Variables

The naming conventions for software that is currently in use by facilities is acceptable and shall not have to be modified unless they are required to follow the following CCS standard. The following variable naming pattern will be used:

Variable Name Pattern:

[<local>_[[<external>_]*|<area>_]]**<description>**[<IO>][_C[onst]|_G[lobal]|_N[ot]|_<pointer>|_<units>]*

Where:

[] :	Bracketed items are optional based on the programming language used and in what context it is used.
| :	A vertical bar represents an logical exclusive OR.
* :	Stared items indicate their use zero or more times as needed.
<local> :	Approved system, device, or component abbreviation (usually three letters/numbers, all capitals).
<external> :	Approved system, device, or component abbreviation (usually three letters/numbers, all capitals).
<area> :	Approved area or bunker abbreviation (usually three letters/numbers, all capitals).
<description> :	Meaningful description of the variable name (use approved abbreviations as needed).
<IO> :	Input or output data direction designation (usually an approved abbreviation).
<pointer> :	Pointer abbreviation.
<units> :	Engineering unit abbreviation.

Examples: (additional examples can be found in the following sections)

Internal Variable:	`allInterlocksMade`
Pointer Variable:	`dataRecord_stptr`
Constant Variable:	`pie_Const`
Global Variable:	`state_Global`
Negative Logic Variable:	`targetInsertedSw_Not`
Variable with Units:	`atmPressureGage_psi`
PLC Local Variable:	`SYS_allInterlocksMade`
PLC External IO Variable:	`SIS_FAC_BunkerDoorIntlkAsw`

The following additional general rules shall be applied when naming variables:

2.4.8.1 Names shall be meaningful in the control or monitoring context of Facilities. They shall not be arbitrary. They shall be names of things (i.e.: systems, subsystems, assemblies, devices components, etc.), events, and actions in the control and monitoring scenario of the facility or complex.

2.4.8.2 The description field is a required variable name field. All other variable name fields will only be used when the context requires it. The variable description field will be mixed case, and for other than exception cases, the first term will begin with a lowercase letter and each following term will begin with a capital letter; e.g., driverCurrent. Exception cases are: when convention dictates the use of uppercase letters for an acronym or abbreviation, a single letter term, and any other case where the result could be misinterpreted (for example: FXRinjectorKey, remoteHVpermRelay, coverIntlkBsw, door1intlkAsw, and laser1onRelay, etc.).

2.4.8.3 The variable description field should consist of non-abbreviated words (with the exception of words appearing on the approved CCS Abbreviation List [Appendix A])

(a) Unless the abbreviations are standard (e.g. 'KV' for 'kilovolts'), or

(b) Unless the name is too long, as dictated by the buffer size or by human judgment.

2.4.8.4 Use of underscores in variable names is covered in section 2.4.9.

2.4.8.5 Additional variable naming rules for PLCs are covered in section 2.4.12.

2.4.8.6 When an acronym is used in the description field of a variable name, the acronym will be entered in capital letters.

2.4.8.7 Variables used for inputs and outputs will include the IO field in their name. Input variable examples are: Ain, Din, Intlk, Req, or Sw. Output variable examples are: Aout, Dout, Perm, Ind, Lt, Soln, Relay, or Cntl. In the special case of an input and output variable (i.e.: shared memory), use: Aio or Dio. This provides a distinction between logic variables and I/O variables. For example, a variable referring to the T&FS CDU trigger crowbar relay would be: TFS_CDU_triggerCrowbarRelay.

2.4.8.8 Variables int i, j, and k are conventionally used for loop control variables and are acceptable in that context. However, i1, il, l and similar typographically obscure variable names must be avoided.

2.4.8.9 Variable names such as tmp, temp, flag, buf, and the like are poor names because they do not reflect their use in the facility operational context, and thus shall not be used.

2.4.8.10 The Hungarian naming convention will not be used in the CCS software (see McConnell, p. 203).

2.4.8.12 Sometimes it is necessary to use a negative logic variable. Variables that represent a negative logic value should be identified as such by using the _Not suffix. It is recommended that negative logic variables be converted to positive logic in one place in the code and the positive logic variable be used everywhere else.

2.4.8.11 All variables communicated between a controller and its HMI should match exactly (i.e.: the variable name defined on the controller should be exactly the same as the variable name defined on the HMI). This makes controller and HMI variable naming special. Variables communicated between a controller and an HMI will always use the controller's local field designation. The only time the external field of a variable needs to be HMI_ is when the HMI is writing to a variable for a specific control function or the HMI is reading from a variable for a specific display function. Developers may communicate any non HMI specific control or display function variable to the HMI for debugging, diagnostic, or testing purposes as long as the variable names match.

2.4.9 Use of Underscore(s) in Variable Name

The following conventions will apply in the use of underscores in variable names:

2.4.9.1 Underscores are not used instead of mixed case expressions: that is, write driverCurrent, not driver_current. Underscores are reserved for special roles in variable names.

2.4.9.2 Underscores are used to improve readability in mixed case naming. In particular, underscores can be especially effective between acronyms. (For example, the expression IPIOaddress can be written IP_IOaddress to preserve the capitalization of IP and of IO without producing what at first glance appears to be a strange abbreviation.) This use is at the discretion of the engineer. Engineers are encouraged to minimize the use of underscores for this application and the guidance presented below should be followed as closely as possible. The engineer is cautioned that underscores are included in the count of characters in variable names. There are several software tools used in this project that limit the length of variable names to 32 characters.

2.4.9.3 Underscores are used for variable name suffixes to identify constants, globals, negative logic, pointers, and units to make it easier to locate occurrences of these items. Pointer variables are expressed in the form varName_tptr for a pointer to varName. Here t is a one or two letter abbreviation of some C/C++ storage type, such as int (i), float (f), double (d), char (ch), or object (o). For example, a pointer to a float FXRpowerSupplyVoltage is written FXRpowerSupplyVoltage_fptr.

2.4.9.4 Multiple indirection of pointers is indicated by the suffix form _typeptrN, where N is an integer signifying the level of indirection. For example given struct FXRdataRecord, FXRdataRecord_stptr2 signifies a pointer to the struct pointer FXRdataRecord_stptr. The default value of N in _typeptrN is 1. Thus we write FXRdataRecord_stptr, not FXRdataRecord_stptr1

2.4.9.5 A pointer to a function is signified by adding the suffix '_funcptr'.

2.4.9.6 Underscores are used in variable name prefixes to identify the local system and if necessary an external system. In some instances, the developer may need to resolve ambiguities in variable names that refer to similar items in different systems. In this case, underscores shall be used to prepend a local system and external system identifier to the beginning of the variables. For example, TFS_CDU_varDescription and SIS_PDV_varDescription.

2.4.9.7 Underscores will be used in all variables referring to PLC variables in a standard name format as shown at the beginning of section 2.4.8. See Appendix A for a list of the approved abbreviations.

2.4.9.8 Underscores may be used for internal purposes by some compilers. Avoid expressions such as _vname, _vname_, and vname_.

2.4.10 Naming Functions

The following specific rules shall be applied when naming functions:

2.2.10.1 Function names are to be mixed case.

2.2.10.2 In order to be easily distinguished from variable names, function names begin with a capital letter; e.g., ReceivedData(), ConnectedTo(VCO).

2.2.10.3 Underscores play roles in function names similar to roles in variable names.

2.4.11 Use of Underscore(s) in Global Variable Name

The following conventions shall be applied in the use of underscores for global variables.

2.4.11.1 Underscores are used to make global or module variables in C easy to locate.

2.4.11.2 Postfix the expression '_Global' or '_G' to each global variable in C/C++. To illustrate syntax, one would write numberFXRports_Global to declare a global variable numberFXRports.

2.4.11.3 Define the global variable only once, and use extern declarations for it everywhere else. Define all global variables for C/C++ in a special file C_globals.h; similarly for Pascal.

2.4.11.4 Global variables in the C_globals.h file must be grouped according to function or other reasonable criteria.

2.4.11.5 For pointers to global variables, the order of precedence is illustrated as follows. A pointer to the global struct FXRdataRecord_Global is written FXRdataRecord_Global_sptr.

2.4.12 Naming PLC Variables

In addition to the standards described above, the following practices shall be applied when naming PLC variables:

2.4.12.1 PLC variable names are required to use the local field and when necessary the external field and area field. PLC variables will not use the global and the pointer variable name fields. All PLC variables are in effect global and it makes no sense to use the global field. PLC programming languages have no pointer construct making the pointer field of no use.

2.4.12.2 The description field of the PLC variable is in the standard mixed case variable format. The approved abbreviations listed in Appendix A may be used in this section of the PLC variable.

2.4.13 C Code Header

Code shall begin with a standard header. The kinds of headers to be used are defined in the Appendix D ("Templates for C Headers.").

2.4.14 C Code Layout

2.4.14.1 The order in which source code elements shall appear is as follows:

- Header
- #include statements (when applicable)
- #define statements (when applicable)
- External functions (when applicable)
- Local functions (when applicable)
- External variable declarations (when applicable)
- Local variable declarations
- Source code with comments

2.4.14.2 Use white space liberally to separate different regions within the code.

2.4.14.3 The maximum number of statements per line is one, except for the loop control statements.

2.4.14.4 Mathematical expressions shall be easy to read with space on each side of binary or ternary operators. For example, instead of 'j=0;', write 'j = 0;' or 'j = 0 ;'.

2.4.14.5 The following rules shall be applied in the placement of braces in indented statements:

- Braces shall appear by themselves on a line.
- On a hard copy printout, matched braces shall line up in the same column. Note that this requires the use of a non-proportional spaced font for printing. It is recommended that a non-proportional spaced font be used for development, as well.
- The indentation shall be a minimum of 3 columns to the right of the previous statement, with the amount of indentation to remain consistent throughout the source code. For example, if the developer chooses to indent 4 columns, all indents must be 4 columns.
- The indentation requirement holds for (a) an isolated opening brace in the previous line and (b) optionally, the first letter on the line after an opening brace (if this option is selected, it must be consistently applied).
- The brace matching convention to be used in C/C++ coding is shown in the following scheme. A similar scheme shall be used for Pascal blocks.

```
Begin_Block
    {
    Block_Contents
    }
```

OR

```
    {
       Block_Contents
    }
```

- Indentations shall be iterated into nested blocks as follows. Empty lines are permitted to enhance readability.

```
Begin_Blocks
   {
```

```
Statement 1
Statement 2
    {
    Statement 3
    Statement 4
    }
}
```

2.5 Coding Practice for Wonderware's *InTouch* and *Industrial Application Server (IAS)*

Note: *IAS* is a off-the-shelf process controls application development product for supervisory control and data acquisition. Detailed product information is available on the Wonderware web site at www.wonderware.com.

2.5.1 Adopting Wonderware/*IAS/InTouch* Conventions

Coding shall follow Wonderware's suggested practices wherever feasible. Wonderware's suggestions can make code verification easier.

2.5.2 Tagnames

Tagnames shall be the same as PLC labels and hence hardware names, so far as possible or practical. Known exceptions include hardware names that do not begin with an alpha character (A-Z or a-z) and names longer than 32 characters.

2.5.3 Script Header

Every *InTouch* script shall have a standard header. Use Appendix F ("Templates for *InTouch* Headers") and Appendix G ("Sample InTouch Script") as the guideline. These appendices also illustrate the use of the headers.

2.5.4 Adopting C/C++ Code Practice

C/C++ coding practices insofar as relevant and practical to InTouch scripts shall be adopted for *InTouch* scripts, except that hyphens and underscores may be used (as opposed to underscores only) for compound names. In addition, For any in-house or subcontracted supplied C code that *InTouch* calls, the guidelines previously described for C/C++ shall be adhered to. The requirement applies to use of Wonderware's *DDE Server Toolkit for Microsoft Windows*. Beware of Wonderware's environment which may restrict the developer to comply with the general programming guidelines.

2.6 Coding Practice for *LabVIEW*

2.6.1 Global Variables

The following rules shall be applied in using global variables in a *LabVIEW* application.

2.6.1.1 All global variables that are declared in *LabVIEW* shall be collected into one VI (Virtual Instrument). Global variables declared as part of a VI obtained from a commercial, third party source are an exception.

2.6.1.2 *LabVIEW* global variables shall be indicated by the postfix '_Global'. For example, *varName_Global*.

2.6.1.3 C global variables that are passed to *LabVIEW* retain their postfix '_Global' during their occurrence in the *LabVIEW* environment.

2.6.2 Adopting C/C++ Guidelines

Developers shall comply with the guidelines previously described for C/C++ software for any in-house or subcontractor supplied C code that *LabVIEW* calls (for example, as part of a Code Interface Node (CIN) function).

2.6.3 VI Header

LabVIEW VI's shall include a standard header. Use Appendix H ("Templates for *LabVIEW* Headers") and Appendix I ("Sample *LabVIEW* Code") as guidelines. These appendices also show other required documentation.

2.7 Conventions for Directory, Folder and File Name Extensions

2.7.1 C/C++ developers shall use Visual C/C++ conventions, as illustrated in Appendix C, for top-level folder and directory names.

2.7.2 Developers shall use the conventions as described in Appendix B for file extension names.

2.7.3 Current Facility software employs its own convention for directory structures. This structure is explained in the *LLNL Modicon Compiler and Utilities User Guide*, which is available from the CCB. Developers who must add to or modify this existing code shall follow the established convention.

2.8 Commercial Software

2.8.1 CCB must approve all CCS (B-Program and JNPO) control system related software proposed for use in a Facility.

2.8.2 For the current versions of the programs in use, see the Appendix M, "Current Versions of CCS Software." Both the starting version and the current version of each piece of software in use is stated. The appendix shall be kept current.

2.9 Non-commercial Tools and Standards

LLNL compiler and utilities for Modicon

DAS (Data Acquisition System) (See the Appendix L "DASFile Specifications.")

2.9 Safety Software Standards

The following rules apply to safety interlock systems (SISs).

2.9.1 Variable Names

Safety software variables will include their safety function in their description field (see section 2.4.8). Variables representing safety interlocks, safety requests, safety permissives, and safety Indicators will use interlock, request, permissive, indicator, or an approved abbreviation.

Examples:

Safety Interlocks: `SIS_FAC_BunkerDoorIntlkAsw & SIS_LSR1_coverDoorIntlkBsw.`

Safety Requests: `SIS_HMI_fireTableSweepReqBtn & SIS_FAC_safetyKeyReqSw.`

Safety Permissives: `SIS_LSR1_CWlaserPermArelay & SIS_LSR2_shutterPermBrelay.`

Safety Indicators: `SIS_FAC_HEdangerIndHorn & SIS_TFS_HVwarningIndBeacon`.

2.9.2 Looping Structures
The SIS software should be as simple and linear as possible. Safety software will refrain from using non-deterministic looping structures such as FOR, REPEAT, and WHILE. This will ensure the SIS PLC scan times will be consistent and repeatable and will also assure the safety software will not get hung in an infinite loop.

2.9.3 Latching Permissives
Safety software will refrain from latching safety permissives in a permitted state. This assures that if the correct interlock chain is broken the permissive will be dropped and the hazard disabled.

2.9.4 HMI Logic
All safety logic calculations will be performed by a PLC, which is more reliable than a PC. No HMI will perform safety logic calculations. If all safety function logic calculations are made by the PLC then these functions will continue to function even if the HMI has crashed.

2.9.5 Variable Protection
A safety system HMI has "write access" to all of the safety PLC's addressed variables. To guard against inappropriate use of these addressed variables the PLC programmer will protect the memory of all addressed variables that do not have a specifically identified HMI control function (i.e.: variables that are only displayed on the HMI for monitoring, debugging, diagnostic, or testing purposes). The HMI and PLC programmer will identify all variables that have a specifically identified HMI control function and set the local field to SIS and the external field to HMI (for example: `SIS_HMI_fireTableSweepReqBtn`).

2.10 Software Version Numbering

Version numbers consist of three numbers separated by dots. The three numbers represent the Major Revision, the Minor Revision, and the Patch Level as shown in the following syntax.

<Major Revision>.<Minor Revision>[.<Patch Level>]

The Major and Minor Revisions are tied to a specific feature set. The Patch Level is optional if there is only one version of the system with that specific feature set.

2.10.1 The Major Revision
A change in Major Revision should be made whenever major effort is used in the modification to the feature set of a system. The determination of what separates a Major Revision change from a Minor Revision change is somewhat subjective. The system developer or project team should determine whether a change should qualify as major. However, a change in Major Revision should generally be used if any of the following is true.

1) A configuration file format is modified such that old versions of the system cannot use the new file format.
2) The User Interface would require training or practice for someone who is familiar with the old version.

3) A protocol used for communication with another system changes such that systems able to talk to the old version would not be able to talk to the new version without modification.

The Major Revision should not change if any of the following is true, even if the change meets one of the above conditions.

1) The change is only in fixes to the systems original intended operation, such as if the system did not meet all of the requirements and had to be fixed in order to do so.
2) The operation of the system has little discernible difference from the old version from the perspective of an operator or user.

For the Major Revision it is recommended to use numbers starting with 1 and incrementing by 1.

2.10.2 The Minor Revision

A change in Minor Revision should be made whenever the feature set of a system is changed, but the change is not considered to be a major change. Two versions of a system which differ only by Minor Revision should be seen by users and operators as the same system, albeit with some differences in features.

The Minor Revision should not change if the changes are only fixes to the systems original intended operation, such as if the system did not meet all of the requirements or a feature was not working correctly.

For the Minor Revision it is recommended to use numbers starting with 1 and incrementing by 1.

2.10.3 The Patch Level

A change in Patch Level should be made whenever the change to system is limited to fixes to the systems original intended operation. This category contains software bug fixes, changes to labeling, etc. Two versions should be seen by users and operators as the same system, albeit one has fewer bugs or issues.

For the Patch Level it is recommended to use numbers starting with 1 and incrementing by 1.

2.10.4 Target Versions

During system development, it is common for a group of requirements, goals, or issues to be targeted for a specific revision number in the future. When this is the case, the Patch Level is not needed. Instead, an indication that the version is targeted for a specific Major and Minor Revision is used. The indication is to use the Patch Level and precede the level with "RC" where the letters stand for Release Candidate. Thus, a feature set targeted for a version of "3.5" would have release candidates starting with 1, which would be represented as "3.5.RC1". Should that version of the system be accepted and released as version "3.5", it could be referred to as "3.5" or "3.5.0". If the system is patched, the next released version may be "3.5.1" or, if multiple versions were created before "3.5" could be released again, it could be something higher, such as "3.5.6".

It is not recommended to use a sequencing scheme that is confusing when preceded by the release candidate marker ("RC").

Acknowledgments

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Appendix A: Approved Abbreviations

Abbreviations for the Local and External Variable Name Fields

Note: The table below does not provide a complete list of Local and External abbreviations. Additional Local and External abbreviations may be approved by facility project management.

Abbreviations for the Local and External Variable Name Fields	
ANM	Analog Monitoring System
AUX	Auxillary Subsystem
CDU	Capacitor Discharge Unit Subsystem
CS	Command System
DLY	Digital Delay Subsystem
DIG	Digitizer Subsystem
FBR	Fabry Perot Subsystem
FAC	Facility (where the Facility is considered the system)
FXR	Flash X-Ray
GIG	Gigalumen Subsystem
HMI	Human Machine Interface (only used as an external field)
HPX	Hewlett-Packard (HP) X-ray
HSC	High Speed Camera Subsystem
HYD	Hydraulic Subsystem
LIN	Linear Accelerator (LINAC)
MS	Monitor System
OPT	Optic Subsystem
PEG	Portable Electric Gun Subsystem
PIN	Pin Diagnostic Subsystem
PXR	Portable X-Ray
SIS	Safety Interlock System
SYS	System Specific
TFS	Timing & Firing System
RSS	Run/Safe Subsystem
XRY	X-Ray Subsystem
VAC	Vacuum Subsystem
ZZZ	(place holder)

Abbreviations for the Area Variable Name Field

Note: This is not a complete list of Area abbreviations. Additional Area abbreviations may be approved by facility project management.

801, 850, 851	SITE 300 Bunker
GUN, SPH, 1KN, 1KS, SMN	HEAF Bldg.191 Area
CER, CTR, CP9, FAR, FLR, HLR, IMR, RLR, XRR, ZRA, ZRB, ZRC, ZRD	U1A Subcritical Experiments

Appendix A: Approved Abbreviations

Abbreviations for the Description and IO Variable Name Fields

Note: The table below does not provide a complete list of the description and IO abbreviations. Additional description and IO abbreviations may be approved by facility project management.

Abbreviations for the Description and IO Variable Name Fields	
Ain	Analog Input
Aio	Analog Input & Output
Alrm	Alarm
Alrt	Alert
Aout	Analog Output
App	Application
Bnkr	Bunker
Bnkrtt	Bunkerette
Bx	Box
Byp	Bypass (Not used in Safety Systems)
Cam	Camera
Ccp	Central Control Post
Chrg	Charge
ClLt	Close Light
Cls	Close
ClSoln	Close Solenoid
ClSw	Close Switch
Cmplt	Complete
Cntl	Control
Coinc	Coincidence
Crwbr	Crowbar
Din	Digital Input
Dio	Digital Input & Output
Dly	Delay
Dmpr	Damper
DnSelect	Down Select
DnSoln	Down Solenoid
DnStart	Down Start
DnSw	Down Switch
Dout	Digital Output
Dr	Door
DrSw	Door Switch
Dwn	Down
EStop	Emergency Stop
Extnl	External
Fid	Fiducial
Flt	Fault
FO	Fiber-Optic

Appendix A: Approved Abbreviations

Abbreviations for the Description and IO Variable Name Fields	
Func	Function
Gen	Generator
HV	High Voltage
HyCam	Electric Driven Camera
Hyd	Hydraulic
Ind	Indicator
Inh	Inhibit
Inp	Input
Intlk	Interlock
Intnl	Internal
Intr	Interrupt
Loc	Local
LS	Limit Switch
Lt	Light
Man	Manual
Mech	Mechanical
Misc	Miscellaneous
Mon	Monitor
Neg	Negative
Nor	North
OnLt	On Light
OpLt	Open Light
Opn	Open
OpSoln	Open Solenoid
OpSw	Open Switch
Outp	Output
Perm	Permissive
Pers	Personnel
Ptr	Pointer
Pos	Positive
PS or ps	Power Supply
Pwr	Power
Rdy	Ready
Rem	Remote
Rep	Repetition
Req	Request
RET	Restricted Entry Time
Rly	Relay
Rm	Room
Rtr	Rotor
Rxcv	Receive
Sel	Select
Shtdwn	Shutdown

Appendix A: Approved Abbreviations

Abbreviations for the Description and IO Variable Name Fields	
Shut	Shutter
Soln	Solenoid
Sou	South
Stp	Stop
Strt	Start
Sw	Switch
Sync	Synchronize
Tbl	Table
Tek	Tektronix
Trig	Trigger
Tst	Test
Txmt	Transmit
UpSw	Up Switch
VAC	Volts AC
VDC	Volts DC
Vlv	Valve

Words that Should Never be Abbreviated

The words contained in the table below are those that should never be abbreviated when used in the context of software source code for the Facilities. In general, they have been determined to be either a) of such a critical nature that they merit the attention of a full spelling; b) no suitable abbreviation can be made; or c) both.

Words that Should Never be Abbreviated	
Area	
Arm	
Beam	
Blast	
Confirm	
Done	
Enable	
Fire	
Fireset	
Front	
Gate	
Glitch	
Injector	
Laser	
Latch	
Main	
Master	
Muster	

Appendix A: Approved Abbreviations

Words that Should Never be Abbreviated	
Mode	
Patch	
Pulse	
Rear	
Reset	
Safety	
Scram	(Not used anymore, see EStop)
Secure	
Sparkgap	
Unsafe	
Target	
Up	
Warning	

Appendix B: File Extensions

C /C++ file extensions (derived from *Microsoft Visual C++ 4.0*)

.c	C source file
.cpp	C++ source file
.cfg	Configuration file
.dat	Data file
.dll	Dynamic link file
.drv	Driver file
.err	Error file
.exe	Executable file
.h	Include file
.hlp	Help file
.i	Bitmap file
.lib	Library file
.mak	Make file for C or C++ source file
.obj	Object file
.r	Resource file
.ar	Archive File

***LabVIEW* file extensions**

.ctl	Control Label file	(LV Guide, p. 29, 30)
.inlv	*LabVIEW* input data file	
.llb	VI library file	
.outlv	*LabVIEW* output file	
.txt	Text file for VI of same file name	(LV Guide, p. 29)
.vi	VI file	

CINTOOLS (*LabVIEW*) file extensions

.a	Assembly language file
.app	Application file
.lsb	Library file
.make	Make file for CIN source file
.tool	File of tools

***Modicon* file extensions**

The file extensions appear either in the *LLNL Modicon Compiler and Utilities User Guide*, which is available from Site 300 if needed, or in the *Concept* documentation.

***InTouch* file extensions**

The file extensions are attached by *InTouch*. The following listed is extracted from an *InTouch* training manual appendix, “Data Files Created and Used by *InTouch*.”

Appendix B: File Extensions

***InTouch* file extensions**

*.aeh	Error log file
*.alg	Logged alarm file
*.avl	Information file for DDEx or tagname directory
*.bin	Binary file for password information or DDE access names and nodes
*.cfg	Configuration information (binary) file
*.csc	Condition script (binary) file
*.csv	Recipe file
*.dat	Binary data file
*.dch	Data change script (binary) file
*.def	Information file for tagname alarm groups
*.h	Binary file of retentive values for the application
*.idx	Index file for .lgh file
*.inf	File of InTouch information (ds.inf, vers_res.inf)
*.ini	initialization file
*.lgh	Logged data (binary) file
*.ndx	Information file for tagname directory
*.tbk	InSupport toolbox file (do not delete when deleting *InTouch* backup files)
*.trn	Trend information file for a window or file of serial numbers for all real trends in application
*.txt	Text file such as help file
*.ver	Application version file
*.wav	MS sound file for InTouch sound function
*.win	WindowMaker file (win#####.win contains detailed description of each window)
*.www	File for compiled form of a .win file of the same name, or
*.x	Information file for tagname directory or for retentive values for the application
?.bk	Backup file (for any edited *InTouch* file)

Additions from *InTouch 9.0*

*.wvw	When a window is first loaded by WindowViewer, it is “compiled” and saved into a WVW file. This substantially improves the window loading time in WindowViewer.
*.ksc	Key script file (binary)
*.csv	Text file in Comma Separated Variable format
*.bmp	Graphics/image files containing a bitmap object of the bitmap has a String Value Display link.
*.jpg	See *.bmp
*.pcx	See *.bmp
*.tga	See *.bmp
*.pal	Windows Palette file created by exporting a palette from the WindowMaker color palette or by a 3rd party utility.
*.neh	Text file created by the Wonderware NT Conversion Logger when a 16-bit InTouch application is converted to 32-bit. Contains a log of the conversion process, including any errors that are encountered.
*.nmd	A binary file containing a Quick Function script.

Appendix B: File Extensions

*.oes	A binary file containing an ActiveX event script.
*.wdf	InTouch Script Extension Files

Archestra IDE data is stored in the Galaxy Repository, which is an MS SQL database. However, there are a few important files:

*.aaPKG	XML file containing an exported Galaxy object
*.aaPDF	Same as *.aaPKG
*.csv	Comma-delimited files are used for Galaxy dumps (backups)
*.aaSLIB	Script Function Library
*.dll	Can be used for Script Function Libraries
*.tlb	Same as *.dll
*.olb	Same as *.dll
*.exe	Same as *.dll

Appendix C: Directory Structures

Folder (or directory) names within a C/C++ program folder for a program called x

x_Bin
x_Help
x_Include
x_Lib
x_Project
x_Template

Appendix D: Templates for C Headers

1. File Header for a C Program

A standard header, containing the information described below, must appear at the top of each C program [main()] file. C++ comment symbols ‘//’ are used to mark descriptions of variables and so forth, in order to avoid nested occurrences of C comment symbols ‘/*’. If a field is irrelevant or not applicable, the entry will be ‘NA’ or ‘None’. Headers for C++ programs include all the information in a C program, but additional headers specific to classes, templates, etc. are required.

1.1 File Name
It is the full name of the file, including extension. The name without extension, by convention, must be the same as the corresponding executable. A descriptive name should follow, e.g., LvinputIO.c // Input I/O process to read FXR experimental record.

1.2 Synopsis of Program Usage
Including argument list, which summarizes the methods for invoking the executable file. This should include the Program Name (executable file name), and command arguments. The command argument list should include a description of the argument’s effect on program execution, or the program’s effect on the argument. Optional arguments are shown in square brackets. For example:

```
Synopsis:
    BeamBug inFile outFile [outputFileType]
Arguments:
    inFile - name of file to open and proces
    outFile - name of file written to disk that contains
    processed data
    outputFileType - type of file; default is Excel spreadsheet
```

1.3 Purpose
What the program does or why it is needed, including a brief description of the processes applied to the inputs to produce the desired outputs.

1.4 Functions contained in this file
A brief description of each function in the list.

1.5 Functions/Modules the program calls
Includes any non-C code foreign modules with C wrappers.

1.6 Inputs
Namely ports, files read, standard input, etc.

1.7 Outputs
Namely files, windows, standard output, global variables modified, environmental variables modified which the program produces.

1.8 Global variables modified
an annotated list of the global variables modified by the program. The annotations describe how each variable is changed.

1.9 Interfaces and Resources Used
A list of external interfaces and resources that are used by the application. For example, the use of Intouch as the HMI, data sharing with a named LabVIEW application, or Windows NT resources.

Appendix D: Templates for C Headers

1.10 Limitations
list of application processing restrictions (e.g. the program requires 32 MB of RAM, is the only process that can be active on the workstation, is not active when FXR is ready, etc.)

1.11 Assumptions
Concerning the execution environment (e.g. InTouch is running, LabVIEW CIN x.a is active, the xxx workstation display is in state S, global variable xxx passed into program has value 3.0, etc.)

1.12 History
A table supplying the complete software installation and maintenance history of the functions in the file. New entries are appended to existing history entries. The first entry in the history must be the original field installation of the released code, and shall be version 1.0. Version changes for fixes to the code, according to the extent of the modification, are of the form x.y, or x.x.z (e.g. from 1.0 to 1.0.1, 1.1 or 2.0). The dates of the fixes and what was done to the code are to be internally commented at the point of modification in the code, as cross-references to the History. These internal comments must contain sufficient detail for a complete understanding of the change, and the purpose of the change.

1.13 Notes
It provides relevant information not listed elsewhere in the header. The Notes topic is where information about compiler requirements would be put if the code requires a special compiler.

1.14 File Header Example for C Program

```
/********************************** File Header for C Program *******************************************

File Name: filename.c[.cpp]   // descriptive name

Synopsis of Program Usage:

ProgramName arg1 arg2 arg3 [arg4 arg5] // Note: by convention, ProgramName ≡ filename
Arguments:
    arg1        // some description of effect of argument on program’s processing, or vice versa
    arg2        // some description
    arg3        // some description
    [arg4]      // some description
    [arg5]      // some description

Purpose:
    What the program does and why, including processes applied to the inputs to produced the desired outputs.

Functions contained in this file:
    function1    // some description
        . . .
    functionN    // some description

Funtions/Modules the program calls:

Inputs:
    Files read:
    Standard input:
    Etc.

Outputs:
    Output files:
    Windows:
    Standard output:

Global variables modified: (e.g. ErrorLog)
    Environment variables modified:
    Etc.

Interfaces and Resources:
    application function used             // service provided
    application function used             // service provided
```

Appendix D: Templates for C Headers

```
Limitations:

Assumptions:

History:
Version     Date              Author                          Description
___________________________________________________________________________
1.0         mm/dd/yy          Joe Developer                   Initial Release
1.0.1       mm/dd/yy          Jane Programmer                 Description of fix or modification

Notes:

**********************************End of File Header for C Program **************************************/
```

2. File Header for a File of C Functions

A standard header must appear at the top of each file of C functions that does not contain a function main(). A header template is shown after the following header description. In addition, each function within the file must contain a standard header (see Appendix E, Section 3).

2.1 File Name
It is the full name of the file, including extension.

2.2 Functions
A sequential list of functions in the file, each function name followed by a description of the function.

2.3 Description
Describes the group of functions in the file.

2.4 History
A table supplying the complete software development and maintenance history of the bundle. Other comments under History in File Header for C Program apply.

2.5 Notes
It provides relevant information not listed elsewhere in the header. The Notes topic is where information about compiler requirements would be put if the code requires a special compiler.

2.6 File Header Example of C Functions

```
/************************** File Header for File of C Functions ****************************

 File Name: Filename.c[/.cpp]     // descriptive file name

 Functions: function 1's name     // description
            function 2's name     // description
                  . . .
            function N's name     // description

Description:
   General description of the group of functions.

History:
Version     Date              Author                      Description
_________________________________________________________________________
x.x.x       mm/dd/yy
Notes:

***********************End of File Header for File of C Functions *************************/
```

Appendix D: Templates for C Headers

3. Function Header for a C Function within a File

A standard header must appear at the top of each C function. This header applies whether the function is part of a program file (Appendix E, Section 1) or is contained in a file of functions (Appendix E, Section 2). A header template is shown after the description of the header. If a field is irrelevant or not applicable, the entry will be NA or None.

3.1 Synopsis of Function Usage
Including argument list, which summarizes the methods for invoking the function. This should include the Function Name, function type, and passed arguments. The argument list should include a description of the argument's effect on function execution, or the function's effect on the argument. Optional arguments are shown in square brackets. For example:

```
Synopsis:
    bool PSstatus (int PSnumber, [bool onStat, bool faultStat])
Arguments:
    PSnumber - identifier for selected power supply
    onStat - if present, returns the on/off status of the supply
    faultStat - if present, returns the fault status of the
    supply
```

3.2 Purpose
Statement of what the function is for, including processes applied to the inputs to produce the desired outputs.

3.3 Functions or modules called
A list of all the functions called by the function characterized by the header.

3.4 Inputs
Namely ports, files read, standard input, etc.

3.5 Outputs
Namely files, windows, standard output, global variables modified, environmental variables modified by the function.

3.6 Global variables modified
An annotated list of the global variables modified by the file. The annotations describe how each variable is changed.

3.7 Interfaces and Resources Used
A list of external interfaces and resources that are used by the function. For example, the use of Intouch as the HMI, data sharing with a named LabVIEW application, or Windows NT resources.

3.8 Limitations
A list of application processing restrictions (e.g. the program requires 32 MB of RAM, is the only process that can be active on the workstation, is not active when FXR is ready, etc.)

3.9 Assumptions
Concerning the execution environment (e.g. InTouch is running, LabVIEW CIN x.a is active, the xxx workstation display is in state S, global variable xxx passed into program has value 3.0, etc.)

Appendix D: Templates for C Headers

3.10 History

A table supplying the complete installation and maintenance history of the functions in the file. Other comments under History in File Header for C Program apply.

3.11 Notes

It provide relevant information not listed elsewhere in the header. The Notes topic is where information about compiler requirements would be put if the code requires a special compiler.

3.12 Function Header Example for a C Function within A File

```
/********************** Function Header for a C Function within a File **********************

Synopsis:
bool PSstatus (int PSnumber, [bool onStat, bool faultStat])
Arguments:
PSnumber - identifier for selected power supply
onStat - if present, returns the on/off status of the supply
faultStat - if present, returns the fault status of the supply

Purpose:
    What the function does and why, including processes applied to the inputs to produced the desired outputs.

Functions/modules called:

Inputs:
    Files read:
    Standard input:
    Etc.

Outputs:
    Output files:
    Windows:
    Standard output:

Global variables modified: (e.g. ErrorLog)
    Environment variables modified:
    Etc.

Interfaces:
    application function used        // service provided
    application function used        // service provided

Limitations:

Assumptions:


History:
Version     Date              Author                        Description
_________________________________________________________________________
x.x.x       mm/dd/yy

Notes:

******************* End of Function Header for a C Function within a File ********************/
```

4. File Header for a C Header File

A standard header must appear at the top of each C header file. It will contain the following information. If a field is irrelevant or not applicable, the entry will be NA or None.

4.1 File Name

It is the full name of the file, including extension.

Appendix D: Templates for C Headers

4.2 Include Name
The full node\volume\directory pseudo name or alias, which appears after '#include' in the files that include the header file.

4.3 Description
A description of the contents of the header file, and where it is meant to be used.

4.4 Global variables Declared
An alphabetical list of global variables declared. The list shall be empty unless the file is a header specifically used to create global variables (see the C Coding Practices section).

4.5 History
A table supplying the complete installation and maintenance history of the headers in the file. Other comments under History in File Header for C Program apply.

4.6 Notes
It provides relevant information not listed elsewhere in the header. The Notes topic is where information about compiler requirements would be put if the code requires a special compiler.

4.7 Conditional Include
The preprocessor (#ifdef …#endif) conditional check verify the C header file is only included once.

4.8 File Header Example for a C Header File

```
/***************************** File Header for a C Header File *****************************

File Name: headerfile.h

Include Name: Node\directory-path\FileName.h        // as it would appear in the # include
statement in the applicable files

Description:
    Description, of the contents of the header file, and where it is meant to be used.

Global variables declared:

History:
Version     Date              Author                      Description
_________________________________________________________________________
x.x.x       mm/dd/yy

Notes:

************************** End of File Header for a C Header File **************************/
#ifndef _HEADERFILE_H_/* If headerfile.h has not been defined then */
#define _HEADERFILE_H_/* define it. */

    <C header file contents>

#endif  /* _HEADERFILE_H_ */
```

Appendix E: Sample C Code

```
/*****************************************************************************************

File Name: CDU.cpp // Main (executable) source code file for CDU control and monitoring.

Synopsis of Program Usage:

CDU logFile [configFile]    // Note: by convention, ProgramName = main () source filename
Arguments:
    logFile        // File name, including optional path, to receive logged data.
                      Path defaults to c:\cdu\. If file exists, data is appended.
    configFile     // File name, including optional path, from which to read configuration
                      data. Path defaults to c:\cdu\. File name defaults to CDUconfig.inf.

Purpose:
This program implements the main control and monitoring for the bunker CDUs. It spawns the
necessary number of processes for the number of CDUs specified in the config file. Other config
file input is used for unit addressing and scaling. Once initialization has been verified, CDUs
are charged, discharged, and fired through interaction with the operator and the Quantum PLC. CDU
operations and voltage settings are logged to a specified log file. Upon exit, CDU charging is
disabled and voltages are set to zero.

Functions contained in this file:
BHiveComm (string %inString, string %outString, int BHcommStatus); // Handles serial I/O with
                                                                       Bhive controller.
CDUstatus (CDU thisCDU); // Gathers inputs from PLC and A/D for transfer to Intouch for display.

Funtions/Modules the program calls:
ptacc (tagname %thisTag); // Intouch SDK call to move data into and out of the
                             tagname dictionary.

Inputs: Voltage values read from CDU monitor A/Ds; Quantum CDU status bits.
Files read: c:\cdu\CDUconfig.inf (or user specified replacement).
Standard input: N/A
Intouch inputs: For each CDU: Charge, Discharge, Voltage setting

Outputs: N/A
Output files: c:\cdu\logFile.log (or user specified replacement)
Standard output: N/A
Intouch Windows: CDU Control, CDU Monitor Status
Intouch outputs: For each CDU: Voltage reading, bit status

Global variables modified: N/A
Environment variables modified: N/A

Interfaces and Resources:
    Quantum Ethernet I/O     // Communications to/from Quantum PLC
    Com Port 1               // Communications to/from BHive controller

Limitations: N/A

Assumptions:
Proper connections and network definitions for communication to Quantum PLC
BHive controller properly connected to com port 1
CAMAC A/D modules proper connected and addressed
DLLs for Quantum communication and Intouch libraries properly located

History:
Version     Date              Author                       Description
____________________________________________________________________________
1.0         05/28/99          M. A. Hernandez              Initial Release

Notes:
The following example is bogus, of course.
```

Appendix E: Sample C Code

```
****************************************************************************************/

#include "CDUglobals.h";
#include "CDUclassDef.cpp";
#include <stdlib.h>;

main ();
{
    /* If file doesn't already exist, then exit with an error message */
    CconfigFile file;
    CconfigFileStatus status;
    if (!file.GetStatus(configFile, status))
    {
        CintouchTag errorStatus;
       errorStatus.UpdateTag (CANNOT_OPEN_CONFIG_FILE);
        file.Close();
    }
    else
      OpenDocumentFile(configFile);  // Open the file now that it has been found.
   blah;  /* The rest of the CDU control application */.
   blah;  /* The rest of the CDU control application */
   blah;  /* The rest of the CDU control application */
}
```

Appendix F: Templates for *InTouch* Headers

InTouch scripts are rich in complexity, which in fact compounds the difficulty of describing a header. This appendix is therefore admittedly abstract and difficult to understand. A developer might start an InTouch demonstration program and examine its scripts while studying the discussion of script headers. The developer would then also gain greater appreciation of the InTouch Script Editor. See also the InTouch sample script in the next appendix.

1. Script Header for an InTouch Script

A standard header must appear after the *InTouch* supplied preamble at the top of each *InTouch* script. If a field is irrelevant or not applicable, the entry will be “NA” or “none”.

When printed as part of the documentation built in to *Intouch*, a script will have a header in two parts. The first part is formatted automatically by *InTouch* with information, which is derived from the way that the developer implements the script. No further developer action is necessary for this part.

The developer enters the second part in the large script window. The format for the developer supplied header is given next. The first line for the developer supplied header in the script window is

```
{*****************************************************
```

which indicates the start of the developer’s header, and the last line of the header is

```
*-----------------------------------------------------*}
```

Note that *InTouch* scripts do not occur in files as C programs do. Thus the category of Header for a File of *InTouch* Scripts is irrelevant.

1.1 Preambles

Only one of the five *InTouch* preambles described below appears in the script print out:

1.1.1 Application Script, No input is required. This type of script is associated with the application.

1.1.2 Window Script, WindowName, is the developer-supplied name of the window (for window scripts only).

1.1.3 Key Script, Key, the developer-supplied “hot” key(s) for the keyboard activation script action (for key scripts only).

1.1.4 Condition Script: Condition, the developer-supplied tagname(s) on which a conditional action is based (for condition script only). The developer selects the conditional action from one of the following condition types: On False, While False, On True, or While True. The condition type selected for application, window, or key scripts does not appear in the InTouch-supplied header. (Data change scripts have no condition types.)

Condition Script: Comment, the developer-written comment, which needs to be a terse, general description of what the script affects (for condition script only).

1.1.5 Data Change Script: Tagname[.field], the developer-defined name assigned to a variable in the InTouch database (for data change script only).

1.2 ApplicationName

Appears at the top of the developer’s own header for the first script in the set of scripts. It does not appear in headers for the following scripts. Thus if there are five kinds of scripts in the InTouch application, it appears five times, once at the top of each of kind of script.

Appendix F: Templates for *InTouch* Headers

1.3 Purpose

A statement of the general purpose of the script. Algorithmic details are stated under Script Algorithm.

1.4 Script Algorithm

A description of what happens according to the script for whenever each condition type is satisfied by the control and monitor systems. The list shall be in the order in which InTouch cycles through the condition types. For condition types that are not used in a script, the header entry shall be marked “NA” or “None.” Condition types for the various kinds of scripts are as follows. An application script can have any or all of the condition types: While Running, On Startup, or On Shutdown; a window script: On Show, While Showing, or On Hide; a condition script: On False, While False, On True, or While True; and a key script: On Key Down, While Down, or On Key Up. A data change script has no condition type. The description of what happens for a condition type must be presented in terms of the everyday language of bunker operations.

1.5 Tagnames

A list of all tagnames that are modified by the script, with a particular notation for those tagnames used to activate Condition or Data Change scripts. Entries must also show the data type for each tagname.

1.6 Inputs

A list of files read are cited by node, disk, directory, file name and extension, followed by ‘/’ and the name of the application; a list of external applications which provide data to the script, such as Excel, IndustrialSQL Server, etc.

1.7 Outputs

A list of files written are cited by node, disk, directory, file name and extension, followed by ‘/’ and the name of the application, and a list of external applications to which the script writes.

1.8 Interfaces and Resources

A list of interfaces and resources with which the script interacts. (e.g. LabVIEW VIs, NT Windows, etc.)

1.9 Limitations

List of application processing restrictions (e.g. the program requires 32 MB of RAM, is the only process that can be active on the workstation, is not active when FXR is ready, etc.)

1.10 Assumptions

Concerning the execution environment (e.g. Excel has data in spreadsheet S1, LabVIEW CIN x.a is active, the xxx workstation display is in state S, global variable xxx passed into program has value 3.0, etc.)

1.11 History

A table supplying the complete installation and maintenance history of the script. The guidelines for the History section in C Program File Header apply.

1.12 Notes

provides relevant information not listed elsewhere in the header.

Script Header for *InTouch* Scripts

[Exactly one of the following five preambles constructed by *InTouch* appears
before the header constructed by the developer.]

Appendix F: Templates for *InTouch* Headers

```
Application Script:
OR

Window Scripts for "WindowName":
OR

Key Script:
   Key:          // Hot key or key combination selected by developer
OR

Condition Script:
   Condition:   // Boolean operation on one or more tagnames in the program
   Comment:     // Developer written general comment about the condition script
OR

Data change script:
   On Changes to Tagname.[field]:

{* *********************************************************************
ApplicationName – for the first script in the set of scripts.

[Topic labels such as 'Purpose:' appear on separate lines, to
work around syntax limitations in the Script Editor.]

Purpose:
   General statement of purpose of the script.

Script Algorithm:
   What happens in the script.
   e.g. in condition scripts, details of actions taken for each of the conditions:
   On False, While False, On True, While True.

Tagnames Used:
   TagType1 Tagname1      * Triggers Data Change script X
   TagType2 Tagname2
   TagType3 Tagname3      * Triggers Condition script Y
       . . .
   TagTypeM TagnameM

Inputs:
    Files:
       node\\diskName\directory\inFileName1.ext
           . . .
       node\\diskName\directory\inFileNameK.ext

   External Applications:

Outputs:
    Files:
       node\\diskName\directory\outFileName1.ext    / application used
           . . .
       node\\diskName\directory\outFileNameL.ext    / application used

   External Applications:

Interfaces and Resources used:

Limitations:

Assumptions:

History:
Version     Date              Author                          Description
________________________________________________________________________
x.x.x       mm/dd/yy

Notes:

*------------------------------------------------------------------------------------*}
```

Appendix F: Templates for *InTouch* Headers

2. Condition Type Header in an InTouch Script

Condition types in a script each require a condition type header provided that

(1) The script is longer than one page (The script header itself does not count against the one page limit), and
(2) The script defines more than one condition.

The condition type header helps compensate for the fact that pages for a script do not print out with page numbers, appear in large print, and generally disheveled in appearance.

2.1 Window name (for Window script only)
The name of the window whose behavior is defined in the window script.

2.2 Key (for Key script only)
The name of the key or key combination that is hot-wired in the key script.

2.3 Condition (for Condition script only)
The Boolean operation on one or more tagnames in the program used to decide actions in a condition script.

2.4 Condition type
The specific condition type (i.e., On True, On False, On Open, etc.) defined in the next block of the script, for application, window, key, or condition scripts. (See previous section, Script Header for an InTouch Script, for permissible kinds of condition types for different kinds of scripts.) Data change scripts have no condition types; hence they have no condition type blocks of script and no condition type headers. Condition type headers are required for Application scripts, Window scripts, Key scripts, and Condition scripts.

2.5 Purpose
General statement of purpose for the specific condition type defined in the next block of script (the developer can copy and paste from his statement of purpose for the relevant condition type in his script header).

Condition Type Header in *InTouch* Scripts
(Use one of the following, depending on type of script.)

```
Application  Script:
{* ************************************************************************

Condition type:

Purpose:

* ----------------------------------------------------------------------------------*}
```

OR

```
Window Script:
{* ************************************************************************

Window name:

Condition type:

Purpose:

* ----------------------------------------------------------------------------------*}
```

OR

Appendix F: Templates for *InTouch* Headers

```
Key Script:
{* ***********************************************************************

Key:

Condition type:

Purpose:

* ----------------------------------------------------------------------------------*}
```

OR

```
Condition Script:
{* ***********************************************************************

Condition:

Condition type:

Purpose:

* ----------------------------------------------------------------------------------*}
```

Appendix G: Sample *InTouch* Script

First header is the script header for an *InTouch* script.

```
Condition Script:
        Condition:    Mod_Slot_3-7
        Comment:          Script is tied to CCP In Reader On Hook bit

{* ***********************************************************************

Purpose: Monitor Mod_Slot_3-7 bit to see whether the wand at CP gate is on or off hook.
       (The 3-7 bit happens to be tied to a PLC bit, the CCP In Reader On Hook bit,
       which is defined internally to the PLC and does not appear in the Tagname
       Directory. The PLC bit is represented in the InTouch database by the
       tagname 'Mod_Slot_3-7'.)

Script Algorithm:
       On FALSE   log a message to WWLogger,
                           notify Personnel Tracking System (TRACKR), and
                           send reminder message to display at Entry Gate monitor.

       On TRUE    log a message to WWLogger and
                          notify Personnel Tracking System (TRACKR).

       On WHILE TRUE  NA.

       On WHILE FALSE  NA.

Tagnames Used:
    Discrete Mod_Slot_3-7       *triggers GateOpen condition script
    String   PTS_CPE_Cmd

Inputs:
    Files:
        None

    External Applications:
        TRACKR  (LLNL Visual Basic application)

Outputs:
    Files:
        None

    External Applications:
        TRACKR  (LLNL Visual Basic application)
Interfaces and Resources used:
    Modbus Server with DDE access name Modbus_984
    Modbus_984
    Personnel Tracking System

Limitations:
    None
Assumptions:
    TRACKR is up and running.
    Modbus server between PLC and code is up and running.
    Wonderware can talk to Personnel Tracking System code (TRACKR), i.e., I/O link
    is established.
    CP entry gate personal computer is up and running.
History:
Version   Date              Author                       Description
_________________________________________________________________________
1.0       06/15/95          Sam Montelongo               Release for production.

Notes:
    The tagname 'Mod_Slot_7-3' was used only because the InTouch shell was written
    before the PLC slots were assigned components in the communications systems. Were
    PLC aspect of the design finished before the shell was programmed, then the condition
    name would be something like 'CCP In Reader On Hook' instead of  'Mod_Slot_7-3'.

*-------------------------------------------------------------------------------------*}
```

Appendix G: Sample *InTouch* Script

Second header is the condition type header for the first block of condition type script.

```
{* *********************************************************************

Condition: Mod_Slot_3-7

Condition type:    On FALSE

Purpose:   Monitor Mod_Slot_3-7 bit to see whether the wand at CP gate is on or off hook.
           Log a message to WWLogger, notify Personnel Tracking System (TRACKR),
           and send reminder message to display at Entry Gate monitor.

* ----------------------------------------------------------------------------------*}
    On False:

        LogMessage (  "MODICON  :  CCP  In Reader on Hook  :  CLEARED"  ) ;

        {Notify PTS}
        PTS_CPE_Cmd = "CP-ENTER 0";  {OFF HOOK}
        WWExecute ("TRACKR","DSPLY",PTS_CPE_Cmd);

        {Send reminder message}
        PTS_CPE_Cmd = "MSG-CPE ***  REPLACE  BAR CODE READERWHEN FINISHED.   ***";
        WWExecute ("TRACKR", "DSPLY",PTS_CPE_Cmd);
```

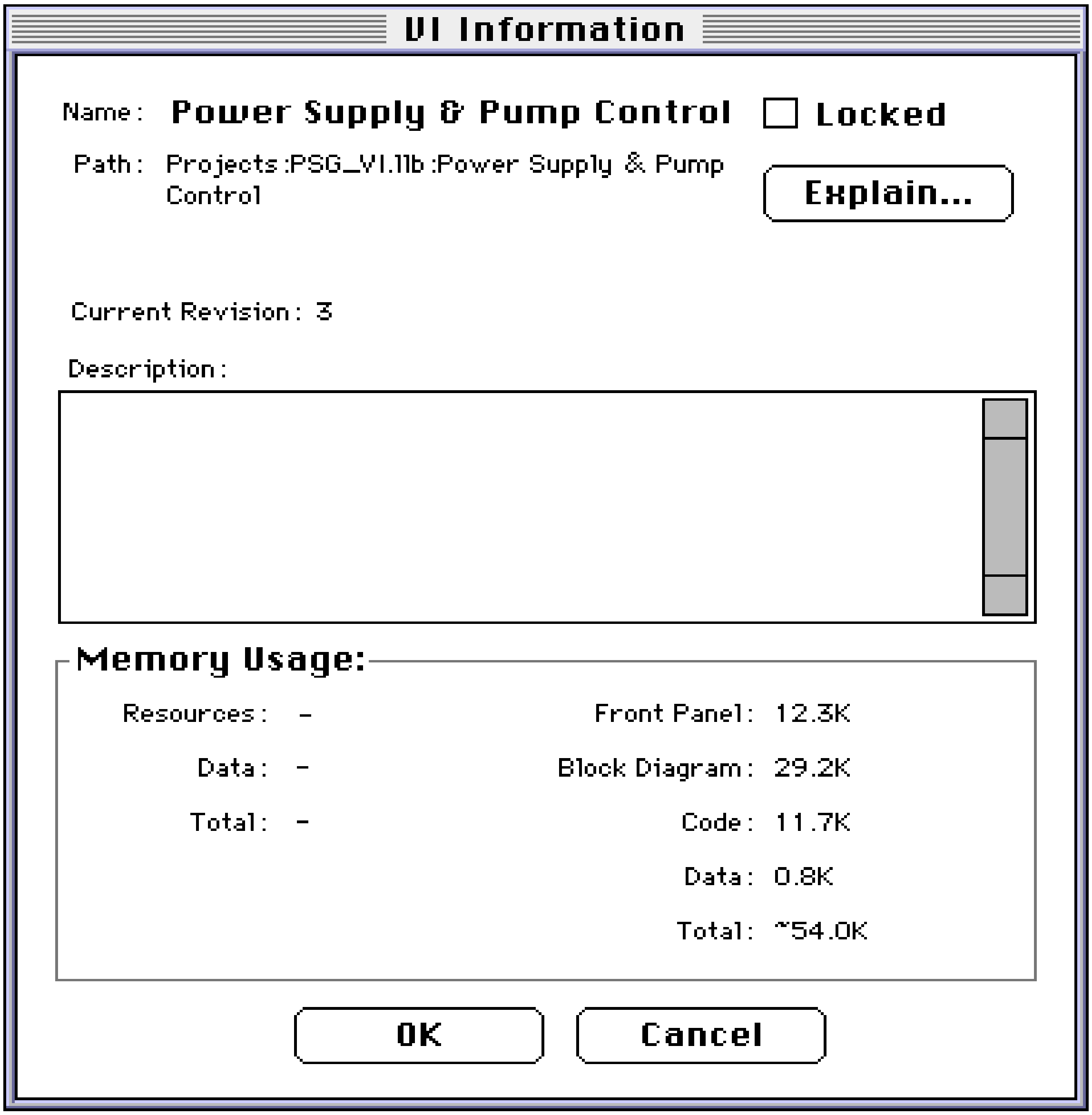
Third header is the condition type header for the second block of condition type script.

```
{* *********************************************************************

Condition: Mod_Slot_3-7

Condition type:    On True

Purpose:    Monitor Mod_Slot_3-7 bit to see whether the wand at CP gate is on or off hook.
            Log a message to WWLogger and notify Personnel Tracking System (TRACKR).

* ----------------------------------------------------------------------------------*}
    On True:

        LogMessage (  "MODICON  :  CCP  In Reader on Hook  :  SET"  );

        {Notify PTS}
        PTS_CPE_Cmd = "CP-ENTER 1"  {ON HOOK}
        WWExecute ("TRACKR", "DSPLY",PTS_CPE_Cmd);
```

Appendix H: Templates for *LabVIEW* Headers
(by Greg Mack)

1. File Header for a *LabVIEW* Virtual Instrument

A standard header must be defined for each LabVIEW[1] Virtual Instrument (VI) file and the header must be defined using the “Show VI Info” command under the “Window” pulldown menu. The header text is entered into the scrollable section called “Description." Alternatively, a text editor may be used to generate the header file and the header can then be pasted into the “Description” section.



LabVIEW developers, when using the “Show Help” command under the “Help” pulldown menu, have immediate access to the header information simply by pointing the mouse cursor to the icon of

[1] Familiarity with LabVIEW will make this appendix section easier to understand.

Appendix H: Templates for *LabVIEW* Headers

the VI under development. A collection of VI headers defined using the "Show VI Info" feature may all be printed using a single "Print Documentation" command from the "File" pulldown menu.

Sections 1.1 - 1.19 describe the information contained in a LabVIEW header. A LabVIEW header template has been provided to simplify maintenance and is illustrated in Figure 1. If a field is irrelevant or not applicable, the entry will be 'NA' or 'None'.

1.1 File Name

It is the full name of the file, including extension. The name without extension, by convention, must be the same as the corresponding executable. A descriptive name should follow, e.g., LVinputIO.vi // Input I/O process to read FXR experimental record.

1.2 Synopsis of Program Usage

Including argument list, which summarizes the methods for invoking the executable file. This should include the Program Name (executable file name), and command arguments. The command argument list should include a description of the argument's effect on program execution, or the program's effect on the argument. Optional arguments are shown in square brackets. For example:

```
Synopsis:
     BeamBug inFile outFile [outputFileType]
Arguments:
     inFile - name of file to open and process
     outFile - name of file written to disk that contains processed
     data
     outputFileType - type of file; default is Excel spreadsheet
```

1.3 Purpose

What the program does or why it is needed, including a brief description of the processes applied to the inputs to produce the desired outputs.

1.4 Sub-vi's

A list of sub-vi's contained in this file, including prototypes, and a brief description of each sub-vi in the list.

1.5 Sub-vi's the program calls

The called modules can be LabVIEW VIs, or C Code Interface Nodes (CIN) that are designed to specifically link to LabVIEW VIs, or external applications.

1.6 Inputs

Namely ports, files read, standard input, etc.

1.7 Outputs

Namely files, windows, standard output, global variables modified, environmental variables modified the at the program produces.

1.8 Global variables modified

An annotated list of the global variables modified by the program. The annotations describe how each variable is changed.

1.9 Interfaces and Resources Used

A list of external interfaces and resources that are used by the application. For example, the use of Intouch as an HMI, data sharing with another named LabVIEW application, or Windows NT resources.

Appendix H: Templates for *LabVIEW* Headers

1.10 Limitations

List of application processing restrictions (e.g. the program requires 32 MB of RAM, is the only process that can be active on the workstation, is not active when FXR is ready, etc.) If no restrictions exist, leave topic blank.

1.11 Performance

Items affecting execution speed including Input/Output, Screen Display, and Memory Management. [Necessary? Part of limitations and / or assumptions?]

1.12 Assumptions

Concern the execution environment (e.g. InTouch is running, LabVIEW CIN x.a is active, the xxx workstation display is in state S, global variable xxx passed into program has value 3.0, etc.)

1.13 History

A table supplying the complete software installation and maintenance history of the application. New entries are appended to existing history entries. The first entry in the history must be the original field installation of the released code, and shall be version 1.0. Version changes for fixes to the code, according to the extent of the modification, are of the form x.y, or x.x.z (e.g. from 1.0 to 1.0.1, 1.1 or 2.0). The dates of the fixes and what was done to the code are to be internally commented at the point of modification in the code, as cross-references to the History. These internal comments must contain sufficient detail for a complete understanding of the change, and the purpose of the change.

1.14 Notes

It provides relevant information not listed elsewhere in the header.

1.15 File Header Example for *LabVIEW* Program

```
************************************************************************

File Name:    filename.vi         // descriptive name

Program Name: ProgramName         // descriptive name, by convention, should match "filename"

Synopsis:  ProgramName [param1, . . . , paramN]
    Graphical Parameter List:
        param1              // some description of effect of parameter on program's processing
        . . .
        paramN              // some description of effect of parameter on program's processing

Purpose:

Sub-vi's contained in this file:
    Sub-vi1                 // some description
    . . .
    sub-viN                 // some description

subVIs the program calls:

Inputs:
    Files read:
    Standard input:
    Etc.

Outputs:
    Output files:
    Windows:
    Standard output:

Global variables modified: (e.g. ErrorLog)
    Environment variables modified:
    Etc.

Interfaces and Resources Used:
    application function used             // service provided
    application function used             // service provided
```

Appendix H: Templates for *LabVIEW* Headers

```
Limitations:

Performance:

Assumptions:

History:
Version     Date            Author                      Description
__________________________________________________________________________
x.x.x       mm/dd/yy

Notes:

* -------------------------------------------------------------------------------------------------------*/
```

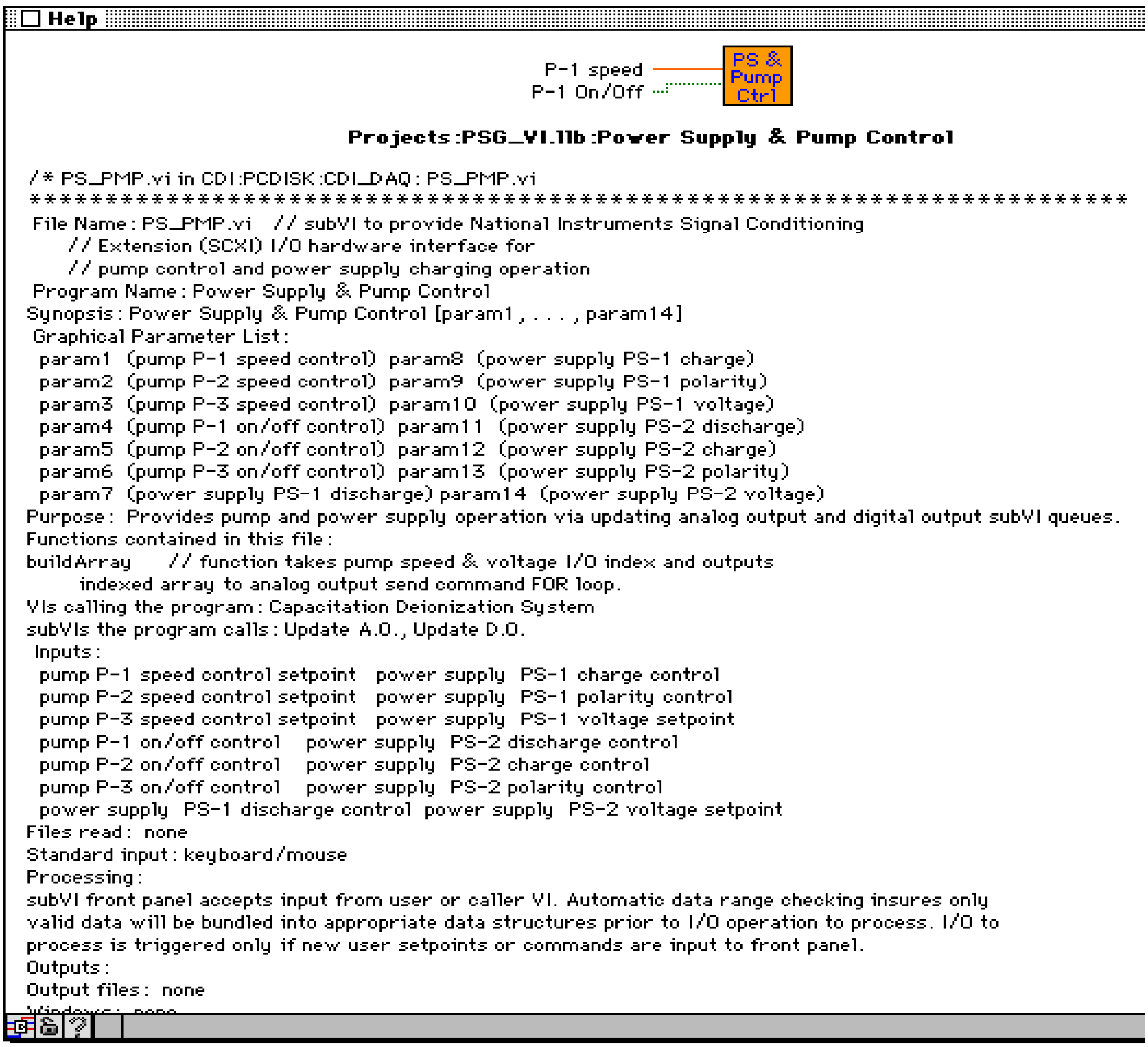
2. File Header for C Code Interface Node (CIN) Program

Code in C Code Interface Node (CIN) shall be treated in the same manner as a C function contained within it's own file. Therefore, the guidelines described in Appendix E, Sections 2 and 3 shall apply.

Appendix I: Sample *LabVIEW* Code
(by Greg Mack)

The following LabVIEW VI, Power Supply & Pump Control, was developed for a desalination project and has been included as a representative example.

Figure 1 illustrates use of the LabVIEW program "Show Help" command under the "Help" pulldown menu. The figure is a bit-mapped and looks much better on screen than in print. However, the figure conveys a sense of how the header appears.




```
/* PS_PMP.vi in CDI:PCDISK:CDI_DAQ: PS_PMP.vi
*************************************************************************
 File Name: PS_PMP.vi   // subVI to provide National Instruments Signal Conditioning
     // Extension (SCXI) I/O hardware interface for
     // pump control and power supply charging operation
 Program Name: Power Supply & Pump Control
Synopsis: Power Supply & Pump Control [param1, . . . , param14]
 Graphical Parameter List:
  param1  (pump P-1 speed control)  param8  (power supply PS-1 charge)
  param2  (pump P-2 speed control)  param9  (power supply PS-1 polarity)
  param3  (pump P-3 speed control)  param10  (power supply PS-1 voltage)
  param4  (pump P-1 on/off control)  param11  (power supply PS-2 discharge)
  param5  (pump P-2 on/off control)  param12  (power supply PS-2 charge)
  param6  (pump P-3 on/off control)  param13  (power supply PS-2 polarity)
  param7  (power supply PS-1 discharge) param14  (power supply PS-2 voltage)
Purpose:  Provides pump and power supply operation via updating analog output and digital output subVI queues.
Functions contained in this file:
buildArray     // function takes pump speed & voltage I/O index and outputs
       indexed array to analog output send command FOR loop.
VIs calling the program: Capacitation Deionization System
subVIs the program calls: Update A.O., Update D.O.
 Inputs:
  pump P-1 speed control setpoint   power supply  PS-1 charge control
  pump P-2 speed control setpoint   power supply  PS-1 polarity control
  pump P-3 speed control setpoint   power supply  PS-1 voltage setpoint
  pump P-1 on/off control    power supply  PS-2 discharge control
  pump P-2 on/off control    power supply  PS-2 charge control
  pump P-3 on/off control    power supply  PS-2 polarity control
  power supply  PS-1 discharge control  power supply  PS-2 voltage setpoint
Files read:  none
Standard input: keyboard/mouse
Processing:
subVI front panel accepts input from user or caller VI. Automatic data range checking insures only
valid data will be bundled into appropriate data structures prior to I/O operation to process. I/O to
process is triggered only if new user setpoints or commands are input to front panel.
Outputs:
Output files:  none
```

Figure 1. Power Supply & Pump Control VI Header

Appendix I: Sample *LabVIEW* Code

Figure 2 illustrates the front panel for the example VI.

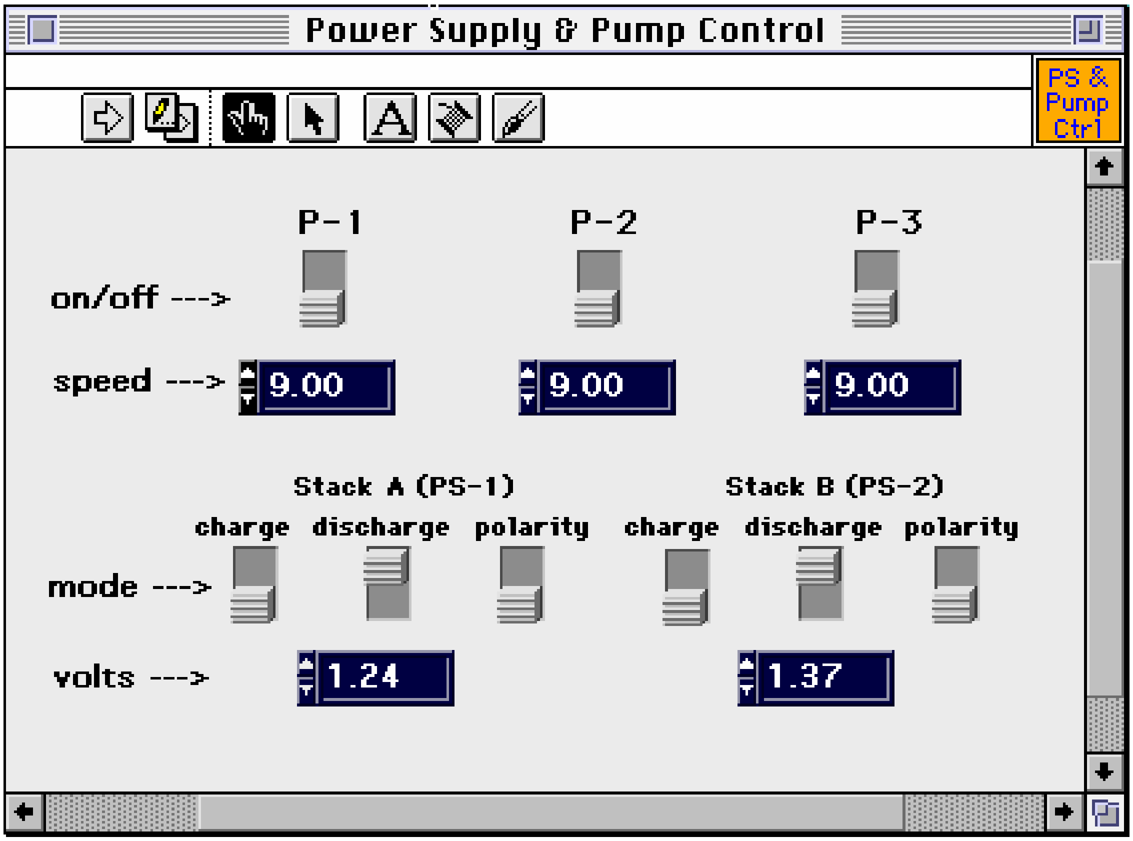


Figure 2. Power Supply & Pump Control VI - Front Panel

Appendix I: Sample *LabVIEW* Code

Figure 3 illustrates the wiring diagram for the example VI.

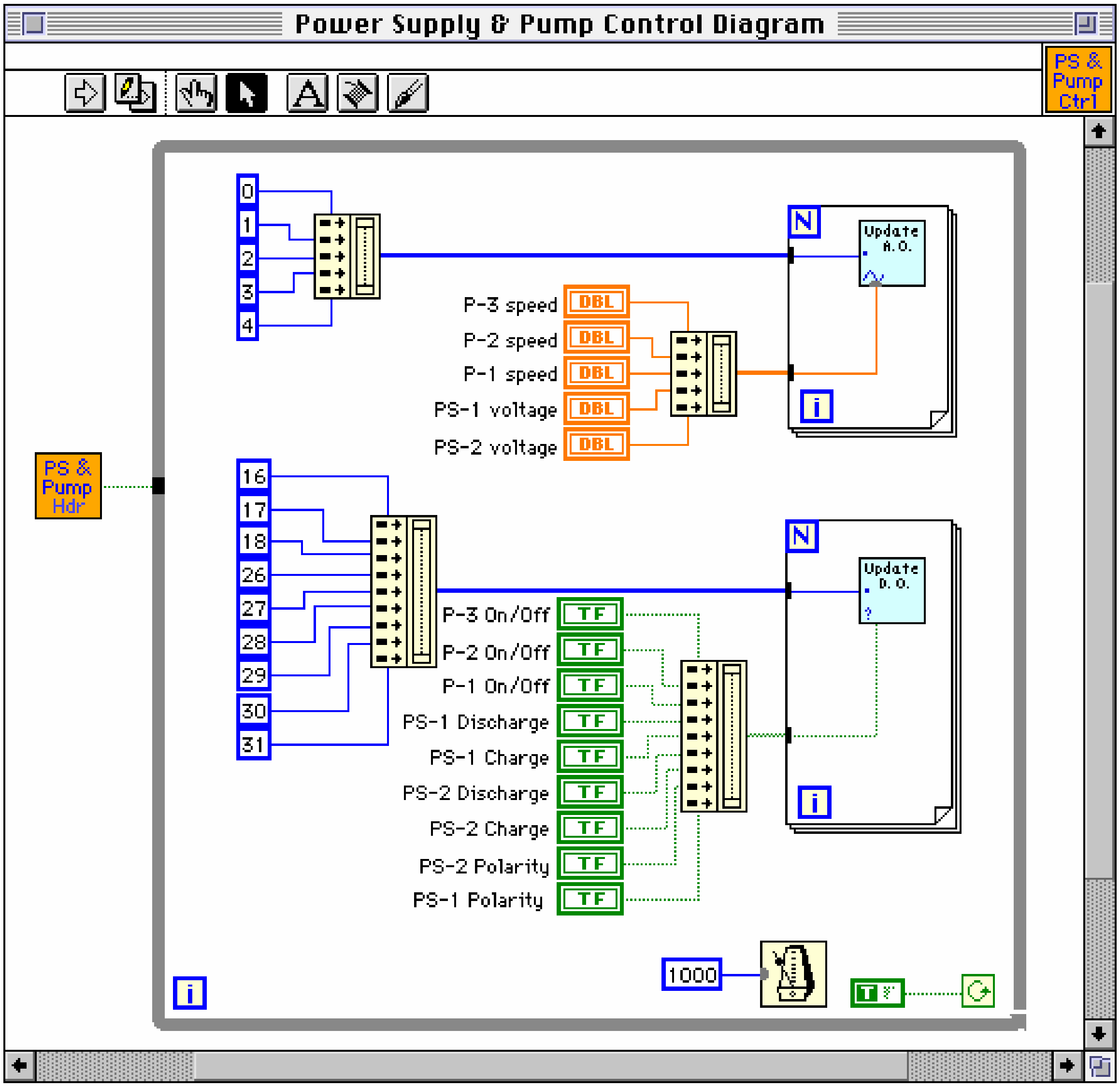


Figure 3. Power Supply & Pump Control VI - Wiring Diagram

Appendix I: Sample *LabVIEW* Code

Figure 4 illustrates the hierarchy of the example VI in the context of the overall project.

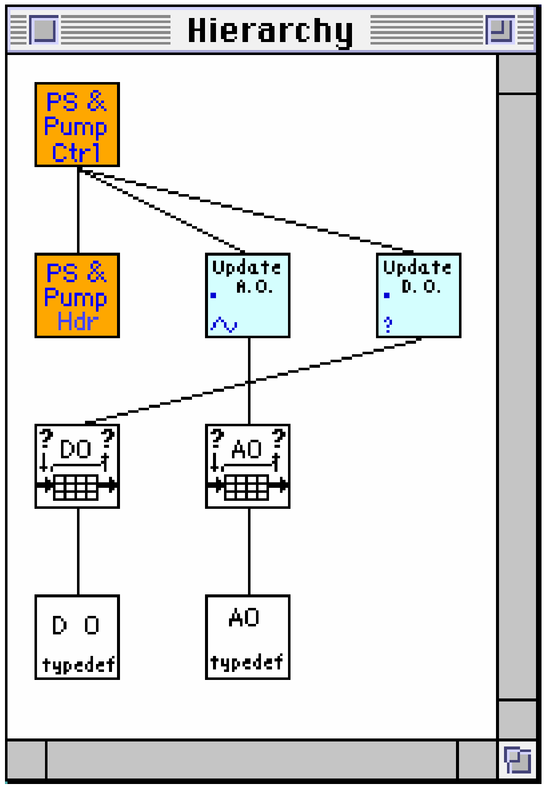


Figure 4. Power Supply & Pump Control VI Hierarchy

Appendix J: *LabVIEW* Style Guide

LabVIEW Style Book (Prentice Hall, ISBN-13: 978-0131458352), by Peter A. Blume (National Instruments).

Appendix K: *CONCEPT* Style Guide

PLC software for CCS systems is developed using the *CONCEPT* application development environment. *CONCEPT* supports five programming languages defined in the IEC 61131 part 3 standard. The Structured Text programming language is the preferred choice for CCS software, however, use of alternative IEC 61131 languages is allowed. Justification for the choice of an alternative language is expected to be part of the software review cycle. The developer may choose to select an alternative language for one of following reasons: 1) the chosen language portrays the problem in a more efficient and understandable manner, or 2) the required operation is available solely in the chosen language.

Regardless of the language chosen for software development in the *CONCEPT* development system, headers are expected for each segment in the PLC software system. In the Structured Text or Instruction List languages, the header can be included directly within the segment code. In the other languages, which are more graphical in representation, the header will be included in the segment description. All *CONCEPT* headers will follow the content and format described for C headers in Appendix E.

Appendix L: DASFile Specification

1. Introduction

This document defines the binary file structure used to record digital data recorded by various data systems used to support B Program. Structure Level is an entry in the file header specifying the version of the file format this file conforms to. This document describes Structure Level 4. All DAS file processors will use this file structure to manipulate, display, and transport experimental data between personnel and/or facilities supporting B Program. Several compute platforms are used within B Program. In order to define a single format, this standard uses a single floating point format and byte order. That makes the files natively compatible with some platforms. Other platforms will have to adjust the data and headers in order to interpret them correctly.

2. Basic File Format

The data file format is organized in 512 byte blocks. There are four basic block structures defined: 1) Primary Header Block; 2) Element Header Block; 3) Extension Header Block; 4) Data Block. The Primary Header Block contains information that is global to all data recorded by a single recording device. The Element Header Block contains information on each channel from a particular recording device stored in this file. Element Header Blocks are discussed in more detail in the following paragraph. The Extension Header contains information that is specific to the recording device and to the specific type of recording device (eg a LeCroy 8828 , a Tektronix RTD 720, or any other recording instrument). The Data Block contains the actual recorded data.

Recording devices often have more than a single channel. For example, the RTD 720 has up to four channels. Some or all of these channels are used to record a specific experiment. The recorder channels that are used for recording are mapped to a specific element in the file. This mapping is one-to-one between channels and elements however any channel may be mapped to any element. For example, this allows channels 2 and 4 (if these are the only ones used) to be mapped to elements 1 and 2 in the file. The Element Header Blocks contain an element records for each element recorded by that recording device. Each element record contains the information that is specific to the elements in the file. The element records for the first eight elements are contained in the first Element Header Block. If a recording device has more than eight elements, the next block in the file is also an Element Header Block and contains the element records for the next eight elements. This continues until there are element records for each element in the recording device. For example, if a 24 channel recording instrument used 20 channels to record an experiment and all 20 channels were stored in a single DAS file, there would be three Element Header Blocks in that file. The channels containing recorded data would be mapped to 20 elements. The first Element Header Block would contain the element records for the first eight elements, the second Element Header Block would contain the element records for the second eight elements, and the third Element Header Block would have only four element records, those for the last four elements.

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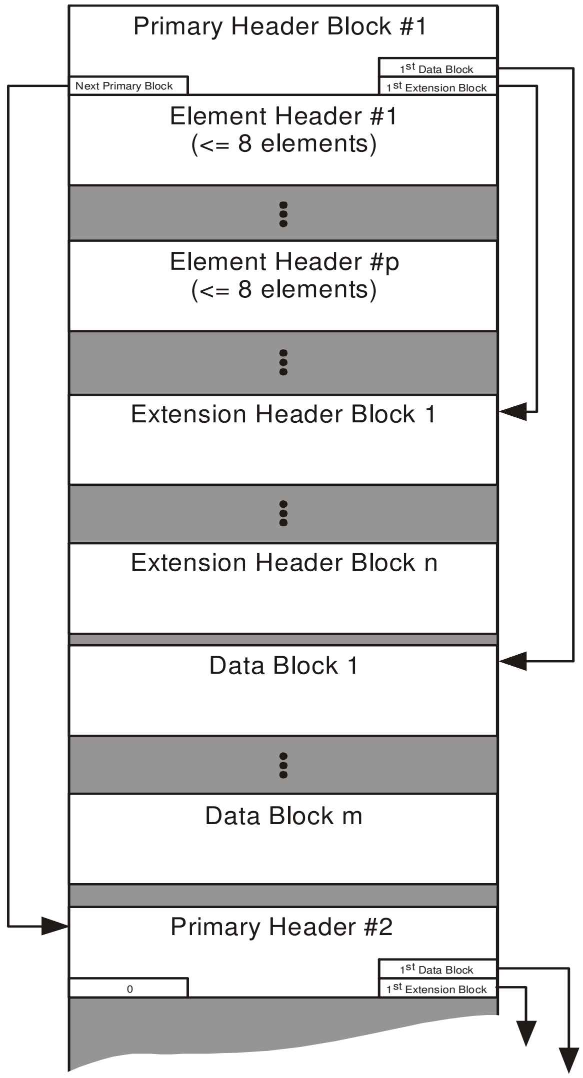

Figure 1: Diagram of DAS File Structure

These basic blocks are laid out as shown in Figure 1. The Primary Data Block is the initial block in the file. The file specification allows for data from multiple recording devices in a single file. The first Primary Data Block has a block pointer that points at the next Primary Data Header in the file. If this pointer is 0, there is data from only one recording device in the file. The Element Header Block follows the Primary Header Block. This block has room for eight element records. Each record describes an element in the file. If more than eight elements are used for this recording device, additional Element Header Blocks are added. As noted above, each element has a one-to-one mapping with a channel in the recording device. Following the Element Header Block(s), are the Extension Blocks. There is a pointer in the Primary Header Block that points at the first Extension Header Block for that file. If that pointer is zero (0), there are no Extension Header Blocks for this recording instrument. The number of Extension Header Blocks is specific to the recording device for that data set. The final portion of each data set is the data. The data is arranged as a set of Data Blocks. The first Data Block is pointed to by an entry in the Primary Header Block. The data follows

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in sequence until all data samples have been stored. The sections that follow describe the format of the blocks that make up the DAS file.

2.1 Data Formats

The data formats for each field in the DAS file is specified in the tables describing all of the blocks used in the DAS file. Single byte fields are stored in a single byte. There are single byte enumerated types in the specification. The defined types available are listed in the footnotes for each enumerated type. If the field refers to the first of the enumerated types, the value of the field is a 1. If the field refers to the second of the enumerated types, the value of the field is a 2, and so on. Packed ASCII fields are stored one byte per character, one after another until the end of the string. The first byte holds the left-most character of the string, the final byte holds the right-most character in the string. If the string is shorter than the field in the header, the remaining bytes are filled with nulls. Integer values are generally two or four byte signed integers. These are stored as big-endian integers (ie the first byte in the file holds the most significant bits of the integer, the second byte in the file holds the next most significant bits, and the last byte holds the least significant bits in the integer. Floating point values are stored in IEEE floating point format. The IEEE floating point format is described in Appendix A. Note that the IEEE floating point format specifies the contents of each byte in the number. It does not specify how the bytes are stored in the machine or in a file created by the machine. Since this DAS file specification uses the big-endian convention, the bytes are stored as shown in Section M.1.

2.2 Standard Strings

The DAS file specification has several fields that are names of units. Examples of these fields are the ModelName in the RecorderAddress, AmplifierAddress, TriggerAddress, and ClockAddress fields of the Primary Header Block and the MemoryNameString field in the LeCroy Extension Block. The content of these strings often determine how additional information in the block is interpreted. Therefore standard strings have been defined for the hardware supported by the DAS format.

The DAS file specification is designed to support a number of different recorder types. There is a field in the Primary Header Block, the RecorderAddress field that specifies the type of recorder that recorded the data enclosed in the file. While this field is a variant record (ie the contents of the field are interpreted differently depending on the contents), the initial subfield of this field is common to all variants. This subfield, the ModelName, contains the characters that identify the recorder type for this file.

Some recording systems make use of amplifier modules. There is a field in the Primary Header Block, AmplifierAddress, that describes the physical address of the amplifier modules. The ModelName subfield of the AmplifierAddress field indicates what amplifier is being used. Two amplifiers have been defined: the LeCroy 6102 and the LeCroy 6103. If no amplifier is being used, this field is null-filled.

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Some recording systems require use of additional units that contain the recorder memory. The following memory units have been defined:

LeCroy 8105, 128Kbyte, minimum of 2 required for a LeCroy 8828
LeCroy 8104, 32Kbyte, minimum of 1 required for a LeCroy 8828
LeCroy 8103, 32Kbyte, minimum of 2 required for a LeCroy 8828
LeCroy 8800, 32Kbyte, minimum of 1 required for a LeCroy 8212;
The standard strings for the defined units are sumarized in the table below:

Unit designation	Standard String [a]
LeCroy 6102	LeCroy6102
LeCroy 6103	LeCroy6103
LeCroy 6880	LeCroy6880
LeCroy 8103	LeCroy8103
LeCroy 8104	LeCroy8104
LeCroy 8105	LeCroy8105
LeCroy 8800	LeCroy8800
LeCroy 8212	LeCroy8212
LeCroy 8828	LeCroy8828
Tektronix RTD 720	TekRTD720

Note:
a: the standard string is stored in a 16 byte packed array of characters. The standard strings are generally less than sixteen characters. The standard strings are filled in placing the left-most byte of the string in the first byte of the array, the next byte of the string in the second byte of the array and so on until the entire string is in the array. Any remaining bytes of the array are filled with nulls.

3. Primary Header Block – DAS Header Block:

Field Definition	Variable Name	Field Type	Start	End
Identifies the file structure version	StructureLevel[a]	2 byte signed integer	0	1
Unique identifier for each recorder	RecorderUnitNumber	2 byte signed integer	2	3
Name of recorder used by operator	RecorderUnitName	16 byte packed array of char	4	19
Time when data recorded: Year: full 4 digit year	TimeStamp.Year	2 byte signed integer	20	21
Time when data recorded: Month : 1-12	TimeStamp.Month	2 byte signed integer	22	23
Time when data recorded: Day: 1-31	TimeStamp.Day	2 byte signed integer	24	25
Time when data recorded: Hour: 0-23	TimeStamp.Hour	2 byte signed integer	26	27
Time when data recorded: Minute: 0-59	TimeStamp.Minute	2 byte signed integer	28	29
Time when data recorded: Second: 0-59	TimeStamp.Second	2 byte signed integer	30	31
Name of experiment creating data	DataSetName	8 byte packed array of char	32	39
Time when setup completed	SetupTimeStamp	64 byte packed array of char	40	103

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Field Definition	Variable Name	Field Type	Start	End
Comment field: short experiment description	DataSetComment	64 byte packed array of char	104	167
Time in seconds corresponding to first sample	ZeroTime	4 byte real	168	171
Time in seconds between samples	DeltaTime	4 byte real	172	175
Total number of samples in each element [b]	SampleCount	4 byte signed integer	176	179
Minimum dynamic binary value of ADC	MinADC	2 byte signed integer	180	181
Maximum dynamic binary value of ADC	MaxADC	2 byte signed integer	182	183
Number of elements contained in file [b]	ElementCount	2 byte signed integer	184	185
Size in bytes of an individual sample [b]	ElementSize	2 byte signed integer	186	187
Data type of element	ElementFormat	1 byte – enumerated type [c]	188	
Format of file	FileFormat	1 byte – enumerated type [d]	189	
Name of task that created this file	TaskName	16 byte packed array of char	190	205
Relative block address of first header extension block [e]	FirstExtensionBlock	2 byte signed integer	206	207
Relative block address of first data block [f]	FirstDataBlock	2 byte signed integer	208	209
Absolute block address of next DAS_Header block [g]	NextHeaderBlock	2 byte signed integer	210	211
Information needed to address physical recorder	RecorderAddress	64 byte variant record [h]	212	275
Information needed to address physical amplifier	AmplifierAddress	64 byte variant record [h]	276	339
Information needed to address physical trigger device	TriggerAddress	64 byte variant record [h]	340	403
Information needed to address physical clock	ClockAddress	64 byte variant record [h]	404	467
Name of time unit [i]	TimeUnitName	16 byte packed array of char	468	483
Padding	<undefined>	28 bytes	484	511

Notes:

[a]: This document specifies Structure Level = 4.

[b]: Samples are the individual data gathered by the digitizer (eg a byte in an 8-bit digitizer). Elements are made up of a number of samples (eg 128Kbytes in a four channel RTD720 with 512K of memory). Channels from a recording unit are mapped one-to-one to elements. Unused channels may not be mapped to an element (saving space in the resulting data file). Channels may be mapped in any order to any element.

[c]: Defined types: (DAS_SignedValue, DAS_UnsignedValue)

[d]: Defined types: (DAS_RawData, DAS_CalData, DAS_SetUpFile, DAS_ConfigFile, DAS_ComplexData, DAS_ScanData);

[e]: First block of file = 1. Absolute block address of first extension header block: CurrentHeaderBlock – 1 + FirstExtensionBlock

[f]: Absolute block address of first data block: CurrentHeaderBlock – 1 + FirstDataBlock

[g]: Used to thread a list of headers in configuration and data files. A zero value terminates the list.

[h]: This variant type is defined in the table: **DAS Device Address Record**

[i]: Generally **Seconds**, but could be **Hertz** (in case of FFT data).

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3.1 DAS Device Address Field:

This data type is used in several fields in the Primary Header Block (they are indicated by the superscript [g]). This is a 64 byte variant record in Pascal, meaning that there are a number of interpretations of the field depending on the value of the tag used to access the field. Currently, there are seven variants of this field. Each is defined below:

3.1.1 Tag: DAS_Null_Device **(integer = 1)**

Field Definition	Variable Name	Field Type	Start	End
Model of device	ModelName	16 byte packed array of char	0	15
Serial number of device	SerialNumber	16 byte packed array of char	16	31
Padding	RSX_Extra	2 byte signed integer	32	33
Padding	<undefined>	30 bytes	34	63

3.1.2 Tag: DAS_Strange_Device **(integer = 2)**

Field Definition	Variable Name	Field Type	Start	End
Model of device	ModelName	16 byte packed array of char	0	15
Serial number of device	SerialNumber	16 byte packed array of char	16	31
Padding	RSX_Extra	2 byte signed integer	32	33
Array of device specific stuff	Stuff	22 byte array of 2 byte signed integer	34	55
Relative block address of next DeviceExtensionBlock [a]	DeviceExtensionBlock	2 byte signed integer	56	57
Name of task containing all device specific code	DeviceTaskName	6 byte packed array of char	58	63

Note:

a: Absolute block address of next device extension block: CurrentHeaderBlock – 1 + DeviceExtensionBlock

3.1.3 Tag: DAS_CAMAC **(integer = 3)**

Field Definition	Variable Name	Field Type	Start	End
Model of device	ModelName	16 byte packed array of char	0	15
Serial number of device	SerialNumber	16 byte packed array of char	16	31
Padding	RSX_Extra	2 byte signed integer	32	33
Address of crate containing CAMAC module	Crate	2 byte signed integer	34	35
Number of slot containing CAMAC module	Slot	2 byte signed integer	36	37
Channel address within CAMAC module	Channel	2 byte signed integer	38	39
Padding	<undefined>	24 bytes	40	63

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3.1.4 Tag: DAS_GPIB **(integer = 4)**

Field Definition	Variable Name	Field Type	Start	End
Model of device	ModelName	16 byte packed array of char	0	15
Serial number of device	SerialNumber	16 byte packed array of char	16	31
Padding	RSX_Extra	2 byte signed integer	32	33
Address of GPIB bus the device is connected to	Bus	2 byte signed integer	34	35
Primary GPIB address for device	Primary	2 byte signed integer	36	37
Secondary GPIB address for device	Secondary	2 byte signed integer	38	39
Padding	<undefined>	24 bytes	40	63

3.1.5 Tag: DAS_ADAC **(integer = 5)**

Field Definition	Variable Name	Field Type	Start	End
Model of device	ModelName	16 byte packed array of char	0	15
Serial number of device	SerialNumber	16 byte packed array of char	16	31
Padding	RSX_Extra	2 byte signed integer	32	33
Address of unit within module	AD_Unit	2 byte signed integer	34	35
Padding	<undefined>	28 bytes	36	63

3.1.6 Tag: DAS_Biom ation **(integer = 6)**

Field Definition	Variable Name	Field Type	Start	End
Model of device	ModelName	16 byte packed array of char	0	15
Serial number of device	SerialNumber	16 byte packed array of char	16	31
Padding	RSX_Extra	2 byte signed integer	32	33
Address of BI-Bus the device is connected to	BI_Bus	2 byte signed integer	34	35
Biomation unit address of device	BI_Unit	2 byte signed integer	36	37
Padding	<undefined>	26 bytes	38	63

3.1.7 Tag: DAS_WaveSaver **(integer = 7)**

Field Definition	Variable Name	Field Type	Start	End
Model of device	ModelName	16 byte packed array of char	0	15
Serial number of device	SerialNumber	16 byte packed array of char	16	31
Padding	RSX_Extra	2 byte signed integer	32	33
Address of WaveSaver bus the device is connected to	WS_Bus	2 byte signed integer	34	35
WaveSaver unit address of device	WS_Unit	2 byte signed integer	36	37
Padding	<undefined>	26 bytes	38	63

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4. Element Header Block – DAS Element Record:

Field Definition	Variable Name	Field Type	Start	End
The number of the channel associated with element #1	[1]ChannelMap	2 byte signed integer	0	1
The name of the signal recorded in element #1	[1]SignalName	16 byte packed array of char	2	17
The name of the units on the y axis	[1]SignalUnitName	16 byte packed array of char	18	33
The integrated gain of the recording system	[1]Gaina	4 byte real	34	37
The integrated offset of the recording system	[1]Offset	4 byte real	38	41
Conversion factor to create engineering units	[1]EngrUnitb	4 byte real	42	45
Maximum data value occuring in element #1	[1]DataMaxc	4 byte real	46	49
Minimum data value occuring in element #1	[1]DataMin	4 byte real	50	53
Binary value cooresponding with 0 VDC input	[1]BaseLine	2 byte signed integer	54	55
The number of the channel associated with element #2	[2]ChannelMap	2 byte signed integer	56	57
The name of the signal recorded in element #2	[2]SignalName	16 byte packed array of char	58	73
The name of the units on the y axis	[2]SignalUnitName	16 byte packed array of char	74	89
The integrated gain of the recording system	[2]Gain	4 byte real	90	93
The integrated offset of the recording system	[2]Offset	4 byte real	94	97
Conversion factor to create engineering units	[2]EngrUnit	4 byte real	98	101
Maximum data value occuring in element #2	[2]DataMax	4 byte real	102	105
Minimum data value occuring in element #2	[2]DataMin	4 byte real	106	109
Binary value cooresponding with 0 VDC input	[2]BaseLine	2 byte signed integer	110	111
The number of the channel associated with element #3	[3]ChannelMap	2 byte signed integer	112	113
The name of the signal recorded in element #3	[3]SignalName	16 byte packed array of char	114	129
The name of the units on the y axis	[3]SignalUnitName	16 byte packed array of char	130	145
The integrated gain of the recording system	[3]Gain	4 byte real	146	149
The integrated offset of the recording system	[3]Offset	4 byte real	150	153
Conversion factor to create engineering units	[3]EngrUnit	4 byte real	154	157
Maximum data value occuring in element #3	[3]DataMax	4 byte real	158	161
Minimum data value occuring in element #3	[3]DataMin	4 byte real	162	165
Binary value cooresponding with 0 VDC input	[3]BaseLine	2 byte signed integer	166	167
The number of the channel associated with element #4	[4]ChannelMap	2 byte signed integer	168	169

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Field Definition	Variable Name	Field Type	Start	End
The name of the signal recorded in element #4	[4]SignalName	16 byte packed array of char	170	185
The name of the units on the y axis	[4]SignalUnitName	16 byte packed array of char	186	201
The integrated gain of the recording system	[4]Gain	4 byte real	202	205
The integrated offset of the recording system	[4]Offset	4 byte real	206	209
Conversion factor to create engineering units	[4]EngrUnit	4 byte real	210	213
Maximum data value occuring in element #4	[4]DataMax	4 byte real	214	217
Minimum data value occuring in element #4	[4]DataMin	4 byte real	218	221
Binary value cooresponding with 0 VDC input	[4]BaseLine	2 byte signed integer	222	223
The number of the channel associated with element #5	[5]ChannelMap	2 byte signed integer	224	225
The name of the signal recorded in element #5	[5]SignalName	16 byte packed array of char	226	241
The name of the units on the y axis	[5]SignalUnitName	16 byte packed array of char	242	257
The integrated gain of the recording system	[5]Gain	4 byte real	258	261
The integrated offset of the recording system	[5]Offset	4 byte real	262	265
Conversion factor to create engineering units	[5]EngrUnit	4 byte real	266	269
Maximum data value occuring in element #5	[5]DataMax	4 byte real	270	273
Minimum data value occuring in element #5	[5]DataMin	4 byte real	274	277
Binary value cooresponding with 0 VDC input	[5]BaseLine	2 byte signed integer	278	279
The number of the channel associated with element #6	[6]ChannelMap	2 byte signed integer	280	281
The name of the signal recorded in element #6	[6]SignalName	16 byte packed array of char	282	297
The name of the units on the y axis	[6]SignalUnitName	16 byte packed array of char	298	313
The integrated gain of the recording system	[6]Gain	4 byte real	314	317
The integrated offset of the recording system	[6]Offset	4 byte real	318	321
Conversion factor to create engineering units	[6]EngrUnit	4 byte real	322	325
Maximum data value occuring in element #6	[6]DataMax	4 byte real	326	329
Minimum data value occuring in element #6	[6]DataMin	4 byte real	330	333
Binary value cooresponding with 0 VDC input	[6]BaseLine	2 byte signed integer	334	335
The number of the channel associated with element #7	[7]ChannelMap	2 byte signed integer	336	337
The name of the signal recorded in element #7	[7]SignalName	16 byte packed array of char	338	353
The name of the units on the y axis	[7]SignalUnitName	16 byte packed array of char	354	369
The integrated gain of the recording system	[7]Gain	4 byte real	370	373

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Field Definition	Variable Name	Field Type	Start	End
The integrated offset of the recording system	[7]Offset	4 byte real	374	377
Conversion factor to create engineering units	[7]EngrUnit	4 byte real	378	381
Maximum data value occuring in element #7	[7]DataMax	4 byte real	382	385
Minimum data value occuring in element #7	[7]DataMin	4 byte real	386	389
Binary value cooresponding with 0 VDC input	[7]BaseLine	2 byte signed integer	390	391
The number of the channel associated with element #8	[8]ChannelMap	2 byte signed integer	392	393
The name of the signal recorded in element #8	[8]SignalName	16 byte packed array of char	394	409
The name of the units on the y axis	[8]SignalUnitName	16 byte packed array of char	410	425
The integrated gain of the recording system	[8]Gain	4 byte real	426	429
The integrated offset of the recording system	[8]Offset	4 byte real	430	433
Conversion factor to create engineering units	[8]EngrUnit	4 byte real	434	437
Maximum data value occuring in element #8	[8]DataMax	4 byte real	438	441
Minimum data value occuring in element #8	[8]DataMin	4 byte real	442	445
Binary value cooresponding with 0 VDC input	[8]BaseLine	2 byte signed integer	446	447
Padding	<undefined>	Bytes	448	511

Notes:

a; The element value, gain and offset are defined so that the actual voltage seen by the digitizer channel is: true voltage (volts) = (Gain * Element Value) + Offset. All gains and offsets from all amplifier, preamplifier, and/or internal digitizer amplifier stages rolled into the two values, Gain and Offset.

b; Actual engineering units = EngrUnit * true voltage; may include gains from amplifier(s) or sensors not included in Gain

c; With raw data, minimum and maximum are raw binary values; For converted files, all data values as well as the maximum/minimum are expressed in engineering units: value = EngrUnit * ((Gain * binary value) + Offset)

5. Extension Header Block

Extension Header Blocks are specific for each type of recording instruments. This specification describes the Extension Header Blocks for the LeCroy 8828 and the Tektronix RTD720.

5.1 LeCroy Extension Block

The LeCroy Extension Block is a variant record. It can describe either a recorder and its memory or an amplifier. Variants for three digitzers and two amplifiers have been defined. Only the Extension Blocks for the LeCroy 8828 digitizer and the LeCroy 6103 amplifier have been described. The others are placeholders for future use.

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5.1.1 LeCroy 8828 Extension Block:

Field Definition	Variable Name	Field Type	Start	End
Header specification version [a]	LeC_VersionNumber	2 byte signed integer	0	1
Type of memory module	MemoryModule	1 byte – enumerated type [b]	2	
Padding	ExtraByte	1 byte	3	
Number of memory modules	NumOfMemModule	2 byte signed integer	4	5
Name of memory type [c]	MemoryNameString	16 byte packed array of char	6	21
Amount of available memory in Kbytes	AvailMemory	2 byte signed integer	22	23
Amount of active memory in Kbytes	ActiveMemory	2 byte signed integer	24	25
Amount of pre-trigger in samples	PreTriggerSize	2 byte signed integer	26	27
Length of sample period in ns	SamplePeriod	2 byte signed integer	28	29
Digitizer offset in mv	DigitizerOffset	2 byte signed integer	30	31
Padding	<undefined>	480 bytes	32	511

Notes:

a: The curent version of the LeCroy Extension Header Block. Currently = 1.

b: Defined types: (LeCroy8105, LeCroy8104, LeCroy8103, LeCroy8800)

c: See the section **Standard Strings** for accepted values

5.1.2 LeCroy 6103 Extension Block**:**

Field Definition	Variable Name	Bytes	Field Type	Start	End
Dummy version padding	DummyVersion3	2	2 byte signed integer	0	1
Padding [a]	Dummy6103	480	480 bytes	2	481
Channel A: Input Coupling	Amp_6103_A.InputCoupling	2	2 byte signed integer	482	483
Channel A: Sensitivity	Amp_6103_A.Sensitivity	2	2 byte signed integer	484	485
Channel A: Offset	Amp_6103_A.Offset	2	2 byte signed integer	486	487
Channel A: Bandwidth	Amp_6103_A.Bandwidth	2	2 byte signed integer	488	489
Channel A: Enable	Amp_6103_A.Enable	2	2 byte signed integer	490	491
Channel B: Input Coupling	Amp_6103_B.InputCoupling	2	2 byte signed integer	492	493
Channel B: Sensitivity	Amp_6103_B.Sensitivity	2	2 byte signed integer	494	495
Channel B: Offset	Amp_6103_B.Offset	2	2 byte signed integer	496	497
Channel B: Bandwidth	Amp_6103_B.Bandwidth	2	2 byte signed integer	498	499
Channel B: Enable	Amp_6103_B.Enable	2	2 byte signed integer	500	501
Trigger: Source	Trig_6103.Source	2	2 byte signed integer	502	503
Trigger: Level	Trig_6103.Level	2	2 byte signed integer	504	505
Trigger: Slope	Trig_6103.Slope	2	2 byte signed integer	506	507
Trigger: Coupling	Trig_6103.Coupling	2	2 byte signed integer	508	509
Trigger: Enable	Trig_6103.Enable	2	2 byte signed integer	510	511

Notes:

a: This padding is used to force the Channel A, Channel B and Trigger information to the end of the block.

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5.2 Tektronix RTD 720 Extension Block:

The RTD 720 Extension Block is not a field oriented block, but is a series of blocks, each filled with 512 ASCII characters. The characters are the results of queries to the RTD from the computer controlling it. The queries used are “SET?”, “WFMPRE?”, “TRFRACT?” and “UID?”. The RTD is set to verbose mode and the answers received from the queries are copied unmodified into the Extension Header Blocks in the order listed above. The description of the response for each of these queries follows. The Tektronix RTD Extension Header Block ends with the ASCII characters: “BLOCK ENDS.”.

5.2.1 The SET? Query:

The SET? query prompts the RTD for all current instrument settings. The response of the RTD is a comma delimited sequence of settings with an ASCII abbreviation for the name of the setting, followed by a colon, followed by the value of the setting itself, expressed in ASCII. An example of the RTD response for the SET? query is:

```
SET CH1 RANGE:1,OFFSET:10, ...
```

5.2.2 The WFMPRE? Query:

The WFMPRE? query prompts the RTD for the settings in the waveform preamble for all channels in the instrument. The instrument can be set up as a 1, 2, or 4 channel recorder. The response of the RTD for the WFMPRE? query is a comma delimited sequence of settings, with an ASCII abbreviation for the name of the setting followed by, a colon, followed by the value of the setting (in ASCII). For example, the response for the WFMPRE? query for an RTD setup in two channel mode is:

```
WFMPRE BIT/NR:8,BN.FMT:R1,BYT/NR:1,CRVCHK:
NULL,ENCDG:BINARY,NR.PT:512,PT.FMT:Y,PT.OFF:64,
WFID: "CH1, REC7”,XINCR:1E-9,XUNIT:SECONDS,XZERO:0,
YMULT:CH1:3.91E-3,YMULT:CH2:3.91E-3,
YOFF:127,YUNIT:CH1:VOLTS,YUNIT:CH2:VOLTS,YZERO:CH1:100
E-3,
YZERO:CH2:100E-3
```

5.2.3 The TFRACT? Query:

The TRFRACT? query prompts the RTD for the fraction of the sample interval in which the trigger event occurred for all records. TRFRACT? is used to determine the trigger point where: trigger point = ((PT.Off – TRFRACT) * XINCR). The response of the RTD is a comma delimited sequence of settings with an ASCII abbreviation for the name of the setting, followed by a colon, followed by the value of the setting itself, expressed in ASCII. An example response for the TRFRACT? query for an RTD set up in four channel mode is:

```
TRFRACT 1:.5,2:.25,3:.75,4:0
```

5.2.4 The UID? Query:

The UID? query prompts the RTD for a user-settable string. This string is used by the Bechtel Nevada personnel to identify the particular RTD in question. The response of the RTD is a comma delimited sequence of settings with an ASCII abbreviation for the

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name of the setting, followed by a colon, followed by the value of the setting itself, expressed in ASCII. An example of the RTD's response to the UID? query is:

```
UID "RTD72087"
```

6. DATA Blocks

The data for both the LeCroy 8828 and the Tektronix RTD720 are eight-bit values. They are packed one value to a byte, in 512-byte blocks until all samples for all channels of the instrument are stored. The sample recorded at the earliest time for the first element is stored first, then the next sample in time for the first element, until the last sample in time is stored for the first element. The next byte in the file is used to sample recorded at the earliest time for the second element, followed by the next sample in time for the second element, until the last sample in time is stored for the second element. This pattern is continued until all elements are stored. At this point, the data for this recorder is complete and the final block is written to the file.

7. Section L.1: IEEE Floating Point Format

The IEEE (Institute of Electrical and Electronics Engineers) has produced a standard for floating point arithmetic. This standard specifies how single precision (32 bit) and double precision (64 bit) floating point numbers are to be represented, as well as how arithmetic should be carried out on them. The values for the DAS file are all single precision IEEE floating point values.

Single Precision Format

The IEEE single precision floating point standard representation requires a 32 bit word, which may be represented as numbered from 0 to 31, left to right. The first bit is the sign bit, S, the next eight bits are the exponent bits, 'E', and the final 23 bits are the fraction 'F':

```
S EEEEEEEE FFFFFFFFFFFFFFFFFFFFFFF
0 1      8 9                    31
```

The byte with the lowest address contains the sign bit (bit 7, the most significant bit of the byte) and the upper 7 bits of the exponent (2^8 in bit 6 thru bit 2^1 in bit 0). The byte with the next highest address contains the least significant bit of the exponent (2^0 in bit 7) and the most significant bits of the fraction (2^{-1} in bit 6 thru 2^{-7} in bit 0). The byte with the next highest address contains the next most significant bits of the fraction (2^{-8} in bit 7 thru 2^{-15} in bit 0). The byte with the higest address contains the least significant bits of the fraction (2^{-16} in bit 7 thru 2^{-23} in bit 0).

The sign bit, bit 7 of the first byte, is 1 for negative, 0 for positive. The fraction is normalized and the radix point assumed to be to the left of the MSB, hence $0.5 <= f < 1.0$. The MSB, always being 1, is not stored. The binary exponent is stored with a bias of 127. This leads to all valid exponents being positive values. A chart of this format is below:

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Order of parts and bits in IEEE floating point format																															
FS	Exponent								Fraction																						
0	7	6	5	4	3	2	1	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14	-15	-16	-17	-18	-18	-20	-21	-22	-23

7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
Byte 0								Byte 1								Byte 2								Byte 3							
Byte and bit order in machine																															

Where:

FS is the sign bit, indicating the sign of the number.
Exponent bits 0 thru 7 are bits 2^0 thru 2^7 of the exponent.
Fraction bits –1 thru –23 are bits 2^{-1} thru 2^{-23} of the fraction.

Note that the byte order specified in this chart follows the big-endian convention. Little-endian machines have bytes with the same format, but store those bytes in a different order. These bytes must be re-ordered to match this DAS specification in order to meet the specification. Little-endian machines store the bytes shown in the chart in the following order: Byte 1, Byte 0, Byte 3, Byte 2.

The value V represented by the word may be determined as follows:

If	E=255	and	F is nonzero	then	V=	NaN ("Not a number")
If	E=255	and	F is zero and S is 1	then	V=	-Infinity
If	E=255	and	F is zero and S is 0	then	V=	Infinity
If	0<E<255			then	V=	(-1)**S * 2 ** (E-127) * (1.F)

where "1.F" is intended to represent the binary number created by prefixing F with an implicit leading 1 and a binary point.

If	E=0	and	F is nonzero	then	V=	(-1)**S * 2 ** (-126) * (0.F)

These are "unnormalized" values.

If	E=0	and	F is zero and S is 1	then	V=	-0
If	E=0	and	F is zero and S is 0	then	V=	0

In particular,

0 00000000 00000000000000000000000 = 0
1 00000000 00000000000000000000000 = -0

0 11111111 00000000000000000000000 = Infinity
1 11111111 00000000000000000000000 = -Infinity

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0 11111111 00000100000000000000000 = NaN
1 11111111 00100010001001010101010 = NaN

0 10000000 00000000000000000000000 = +1 * 2**(128-127) * 1.0 = 2
0 10000001 10100000000000000000000 = +1 * 2**(129-127) * 1.101 = 6.5
1 10000001 10100000000000000000000 = -1 * 2**(129-127) * 1.101 = -6.5

0 00000001 00000000000000000000000 = +1 * 2**(1-127) * 1.0 = 2**(-126)
0 00000000 10000000000000000000000 = +1 * 2**(-126) * 0.1 = 2**(-127)
0 00000000 00000000000000000000001 = +1 * 2**(-126) *
0.00000000000000000000001 = 2**(-149) (Smallest positive value)

8. Section L.2: A LeCroy 8828 Example

This appendix describes what a DAS file would look like for a LeCroy 8828 digitizer. In this case, we will also presume that there is an amplifier with this digitizer. If one were to construct a DAS file for the LeCroy 8828 following this specification, the file would have four header blocks followed by as many data blocks as needed to hold the data. The blocks are as follows: Block 1: Primary Header Block; Block 2: Element Header Block; Block 3: Extension Header Block (for the 8828); Block 4: Extension Header Block (for the 6103); Block 5 thru EOF: Data blocks;. A file for this recorder, following the DAS specification would have the following format:

Primary Header Block

The fields of the Primary Header Block would be filled in with the appropriate information for this recorder. Most of the fields are self explanatory. The RecorderUnitNumber is the unit number assigned by the facility for the digitizer. The DeltaTime for an 8828 at full speed is 5ns, so the number here should be 5.0e-9. There is an 8-bit ADC in the 8828, so the MaxADC is 255 and the MinADC is 0. This is a single channel device, so the ElementCount is 1, the ElementSize is 1 (one byte equal to 8 bits). With a single element, one Element Header Block is all that is needed, so the FirstExtensionBlock, the relative block address of the Extension Header Block, which occurs in the file after the Element Header Block, is 3. Two Extension Header Blocks will be needed, one for the LeCroy 8828 and a second for the LeCroy 6103 amplifier. The FirstDataBlock, the relative block address of the first data block is 5. We will use a single recorder in this file, so the NextHeaderBlock, pointing to the next Primary Header Block is 0, indicating none follows.

The RecorderAddress will use the DAS_CAMAC variant, with the ModelName being LeCroy8828 and the appropriate information in the other fields. The AmplifierAddress will also use the DAS_CAMAC variant, with the ModelName being LeCroy6103 and the appropriate information in the other fields. The TriggerAddress will also use the DAS_CAMAC variant, with the ModelName being LeCroy6103, as the LeCroy 6103 is both an amplifier and a trigger source. The other fields are filled with the appropriate information. The final field, TimeUnitName will be ns.

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Note that the kind of recorder used for this data is defined by the ModelName in the RecorderAddress field. The amount of data in the file is determined by the ElementCount (number of elements in the file) * SampleCount (the number of samples in an Element) * ElementSize (the number of bytes in an individual sample). Note also, that the start of the data in the file is at the block boundary pointed to by the FirstDataBlock. The absolute block address of the first data block is calculated by the CurrentPrimaryHeaderBlock (1 if the first Primary Header Block in the file) –1 + FirstDataBlock.

Element Header Block

This is a single channel device which can be mapped to a single element. While there is no requirement to map it to the first element, we will map it to the first element in this example. The first nine fields of the Element Header Block deal with the first element. Those fields should be filled with the appropriate values.

Extension Header Blocks

As mentioned above there are two extension header blocks for this example, one for the LeCroy 8828 and one for the LeCroy 6103. [There is a possibility that both header are residing in the same 512 block. This should be verified.]

The Extension Header Block for the LeCroy 8828 comes first. The fields in this header block are filled in with the appropriate values.

The Extension Header Block for the LeCroy 6103 amplifier comes next. The fields in this header block are filled in with the appropriate values. Note that all fifteen fields are at the end of the header block. There is nothing but padding at the beginning of the block.

Data blocks

The data blocks start at the block pointed to by FirstDataBlock (using this to calculate the absolute block #: CurrentPrimaryHeaderBlock (1 if the first Primary Header Block in the file) –1 + FirstDataBlock). There are as many blocks used as it takes to provide the following number of bytes (note that each block contains 512 blocks): ElementCount (number of elements in the file) * SampleCount (the number of samples in an Element) * ElementSize (the number of bytes in an individual sample).

9. Section L.3: A Tektronix RTD 720 Example

This appendix describes what a DAS file would look like for a Tektronix RTD 720 digitizer. The amplifier for this unit is built into the unit so it is not included in the file. If one was to construct a DAS file for the Tektronix RTD 720 following this specification, the file would have four to five header blocks followed by as many data blocks as needed to hold the data. The blocks are as follows:

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Block 1: Primary Header Block; Block 2: Element Header Block; Block 3 (to as many as Block 5): Extension Header Blocks; Block 5 (or 6 or 7, depending on the length of the Extension Header Blocks) thru EOF: Data blocks;. For this example, we will presume that the RTD 720 is in four-channel mode. A file for this recorder, following the DAS specification would have the following format:

Primary Header Block

The fields of the Primary Header Block would be filled in with the appropriate information for this recorder. Most of the fields are self explanatory. The RecorderUnitNumber is the unit number by the facility for the digitizer. The DeltaTime for an RTD 720 at full speed in four channel mode is 2ns, so the number here should be 2.0e-9. There is an 8-bit ADC in the RTD 720, so the MaxADC is 255 and the MinADC is 0. This is a multiple channel device, set up in four chanel mode, so the ElementCount is 4, the ElementSize is 1 (one byte equal to 8 bits). With a four elements, one Element Header Block is all that is needed, so the FirstExtensionBlock, the relative block address of the Extension Header Block, which occurs in the file after the Element Header Block, is 3. Two to three Extension Header Blocks will be needed for the RTD 720. Recall that the RTD 720 Extension Header Blocks are free-form text blocks that contain the results from four commands to the RTD 720. The number of bytes returned from the RTD 720 is dependent on the settings in the RTD. Therefore, to find the first data block, one must follow the pointer kept in the FirstDataBlock field. In this example, depending on the number of bytes returned from the RTD 720, the relative block address of the first data block is either 5 or 6. We will use a single recorder in this file, so the NextHeaderBlock, pointing to the next Primary Header Block is 0, indicating none follows.

The RecorderAddress will use the DAS_GPIB variant, with the ModelName being TekRTD720 and the appropriate information in the other fields. The AmplifierAddress will be null, as there is no amplifier. The TriggerAddress will also be null.

Note that the kind of recorder used for this data is defined by the ModelName in the RecorderAddress field. The amount of data in the file is determined by the ElementCount (number of elements in the file) * SampleCount (the number of samples in an Element) * ElementSize (the number of bytes in an individual sample). Note also, that the start of the data in the file is at the block boundary pointed to by the FirstDataBlock. The absolute block address of the first data block is calculated by the CurrentPrimaryHeaderBlock (1 if the first Primary Header Block in the file) –1 + FirstDataBlock.

Element Header Block

This is a multiple channel device, set up in four-channel mode. These four channels can be mapped into any of the eight elements in the first Element Header Block. For this example, we will map Channel 1 to Element 1, Channel 2 to Element 2, and so on. The first nine fields of the Element Header Block deal with the first element. Those fields should be filled with the appropriate values for Channel 1. The next nine fields of the Element Header Block deal with the second element. Those fields should be filled with the appropriate values for Channel 2. This continues until the first four elements are filled with the information from the four channels in the RTD.

Extension Header Blocks

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As mentioned above there are multiple Extension Header Blocks for the RTD 720. These blocks are filled with the ASCII characters returned by the RTD 720 in response to four commands. The following four commands are given in the following order: **SET?, WFMPRE?, TFRACT?, UID?.** Each command is a query to the RTD 720 for various parameters. The RTD 720 responds with a string of ASCI characters. These characters are copied directly into the Extension Header Block until it is full, and then continues into the next Extension Header Block. When the four commands are complete and the responses have been written to the Extension Header Blocks, the string : “BLOCK ENDS.” is written to the last Extension Header Block.

Data blocks

The data blocks start at the block pointed to by FirstDataBlock (using this to calculate the absolute block #: CurrentPrimaryHeaderBlock (1 if the first Primary Header Block in the file) –1 + FirstDataBlock). There are as many blocks used as it takes to provide the following number of bytes (note that each block contains 512 blocks): ElementCount (number of elements in the file) * SampleCount (the number of samples in an Element) * ElementSize (the number of bytes in an individual sample).

Appendix M: Current Versions of CCS Software

1. CCS Server Software

Software Title	Starting Version	Current Version	Vendor URL
Subversion for Source Code Revision Control and Document Repository Sharing	N/A	v 1.3	http://subversion.tigris.org/
MASS AutoSave*(Windows)* for Modicon Concept File Revision Control	N/A	v 5.01	http://www.mdtsoft.com/products/autosave/
Requisite PRO for Project Management	N/A	v 2003.06.15	http://www-306.ibm.com/software/awdtools/reqpro/
Jira for Project Management to replace Microsoft Project	N/A	v 3.6.1	http://www.atlassian.com/software/jira/
License Server for *Requisite Pro* and other Rational Software	N/A	v 9.2	http://www-306.ibm.com/software/rational/support/licensing/index.html
TWiki for Web Content Management and Collaborative Environment	N/A	v 4.0	http://twiki.org/

2. CCS Client Software

Software Title	Starting Version	Current Version	Vendor URL
Adobe Acrobat 7.0 *Professional* for creating PDF files	N/A	v 7.0	http://www.adobe.com/products/acrobatpro/
Beyond Compare Tool for File and Directory Comparison	N/A	v 2.4.3	http://www.scootersoftware.com/
Eclipse for Java and other Code Development	N/A	v 3.2	http://www.eclipse.org/
IAS Archestra IDE for HMI Object Development	N/A	v 2.1	http://www.wonderware.com/Products/appserver/
LabVIEW for HMI Code Development	N/A	v 8.20	http://www.ni.com/labview
Modicon Concpt for PLC Code Development	N/A	v 2.6	http://www.squared.com/
MS Visual Studio.NET for Wonderware and other Object Code Development	N/A	v 2003	http://www.microsoft.com
MS Office 2003 for Word, Excel, And Power Point	N/A	v 2003	http://www.microsoft.com
MS Visio2003 for flowchart, and simple graphic symbols	N/A	v 2003	http://www.microsoft.com

Appendix M: Current Versions of CCS Software

Software Title	Starting Version	Current Version	Vendor URL
TOCBuilder Tool for Creating Table of Contents from the Bookmarks of PDF document	N/A	v 1.5	www.organicsw.com
TortoiseSVN Tool for General Purpose Subversion Management	N/A	v 1.3.5	http://tortoisesvn.tigris.org/
Wonderware InTouch for HMI Code Development	N/A	v 9.5patch01	http://www.wonderware.com/products/intouch/
XMLSpy XML File Editor	N/A	v 2006	http://www.altova.com/products_ide.html

Appendix N: Known Program or Application Limitations

InTouch (as of Oct., 2006)

Tagnames can be up to 32 characters long.
Tagnames must begin with an alpha in A-Z or a-z.
Effect: Potential conflict with legacy hardware names and PLC labels.

LabVIEW (as of Oct., 2006)

No known limitations.

Annotated Bibliography

Chang, Paul, Jeff Deutsch, Danny Teaff, and Terry Tyler, *High Performance Storage System Developer's Guide*, *Draft 3.0*. (IBM Federal System Company, Houston; LANL, LLNL, NERSC, SNL Joint Private Publication: December 19, 1996).

LLNL Internal Use Only.

Eckel, Bruce, *Thinking in C++* (Englewood Cliffs, N.J.: Prentice-Hall, 1995) ISBN 0 - 13 - 917709 - 4.

Books on C++ published before 1995 or 1996 are unreliable because the ANSI draft for C++ continues to evolve. Eckel's book is written from the point of view of multiple developers working on a joint project, and indicates how C++ can be superior for large software projects. Eckel's book is already out of date but so are all others. (As of February 22, 1997, latest issue date of an ANSI draft for C++ had been December, 1996. Some syntax in earlier ANSI drafts for C++ were revisited and then revised. Private communications with Professor J. Zelenski, Computer Science Department, Stanford University, January 7, 1997.) The evolution of the standard for C++ implies that the compilers are not fully compliant with the latest draft.

Harbison, Samuel P. and Guy L. Steele, Jr., *C: A Reference Manual*, 4th ed. (Englewood Cliffs, N.J.: Prentice-Hall, 1995) ISBN 0 - 13 - 326224 - 3.

We use Harbison's book to referee C code and will use later editions, as they become available. Earlier editions of Harbison's book are obsolete and not ANSI/ISO compliant with the latest ANSI C, due in part to errors in Harbison's book. The fourth edition is useful to contrast syntactical differences between C and C++. The comparisons in the fourth edition of divergences of C and C++ syntax may become inaccurate as the ANSI draft for C++ continues to evolve.

Hunt, David N., *Quality Assurance for B Program Monitoring and Control System.*
B/S300 97 - 006.

The document is available on the Site 300 server.

Johnson, Gary W., *LabVIEW Graphical Programming: Practical Applications in Instrumentation and Control*. (New York: McGraw-Hill, 1994). ISBN 0 - 07 - 032692.

The book is a definitive user's guide. The book appeared before *LabVIEW 4.0*, which is palette-oriented rather wholly dependent on menus. The methodology and design principles in the book remain valid. The book still receives praise from National Instruments, although some of their engineers say that it ought to be updated.

Annotated Bibliography

Mansfield, Ann and Thomas Coradettei, *LLNL Modicon Compiler and Utilities User Guide*, Revised ed. (LLNL: Livermore, CA, 1983, 1986).

McConnell, Steve, *Complete Code: A Practical Handbook of Software Construction*. (Redmond: WA: Microsoft Press, 1993). ISBN 1 - 55615 - 484 - 4.

McConnell collects research and programming experience to help the reader write high quality programs. The book seeks to narrow the gap between "the knowledge of industry gurus and professors on the one hand and common commercial practice on the other. Many programs are still buggy, late, and over budge, and many fail to satisfy the needs of users." Parts of McConnell's book are strongly recommended as supplemental reading to *Programmer's Software Guide*.

Miller, Lawrence H. and Alexander E. Quilici, *The Joy of C: Programming in C,* 2nd ed. (New York: Wiley, 1993). ISBN 0 - 471 - 51333 - 4.

This very good book illustrates how to be tricky in coding practice and serves very well to show what we are not looking for. Increasingly sophisticated approaches are taken to coding the same problem. Often enough the most efficient implementations are obscure.

Software Guidelines Committee for Applications Development Department at LLNL, "Software Guidelines - Standards, Practices, and Conventions," Final Draft (Livermore, CA: LLNL, August 10, 1992).

General guidelines for project management activities and for software life cycle. Project management activities include project planning and management, risk management, configuration management, verification and validation, and metrics. Phases of software life cycle comprise requirements, analysis, design, implementation, testing, installation, maintenance, and operation. The guidelines are more general than those in *Programmer's Software Guide*.

Stroustrup, Bjarne, *The C++ Programming Language*, 3rd ed. (Reading, Mass: Addison-Wesley, 1997).

Stroustrup's book is the canonical reference for C++ until the ANSI standard is finalized and released. The publication date of Stroustrup's second edition is 1991.

Wind River Systems, "Appendix G, Coding Conventions" in *User's Guide: Tornado 1.0 (Windows Version)*, pp. 473-505.

The Wind River Systems' standard for C and C++ code is articulated. Their standards differ from those defined in *Programmer's Software Guide*, and their definition of 'module' as "any unit of code that resides in a single source file" differs. Some of the standards may be due to idiosyncrasies required for Wind River C compilation.

Revision Record

Rev.Dft	Date	By	Sections Changed	Description of / Reason for change
2.1	08/25/99	John Scarafiotti, Sam Montelongo, et al.	N/A	Revision Release: B/MCS 99-001 Programmer' Software Guide (B-Program)
AA.0	10/30/06	Donald Jong	All	1. Changed document name to "Common Control Systems Programmer's software Guide", 2. Replaced "Monitoring and Control System" (MCS) With "Common Control Systems" (CCS), 3. Deleted "Change Control Board" and Appendix A "BMCS Software Committee Charter". Charter issues are referring to a separate document "CCS Configuration Change Board (CCB)", 4. Re-worked, Re-organized, and re-formatted sections for easy reading and future editing. This has eliminated some descriptions that can be found in the vendor's software manual and also allows "table of contents" to be generated automatically, 5. Updated Appendix B "File Extensions" and Appendix M "Current Versions of CCS" to Accommodate the latest software being used (info provided by Matt Brown), 6. Added this Revision Record to comply with the CCS documentation format
AB.0	04/05/07	Pat Dohoney	Title §2.4 Appendex A	1. Updated cover page, signature block, and headers and footers throughout the document 2. Updated variable naming rules 3. Added IO abbreviations: Ain, Aout, Din, & Dout,
AB.1	05/20/08	Pat Dohoney	§1.3 §2.1.3 §2.4 §2.9 §2.10 Acknow… Appendix A	1. Provided "TBD" CMP reference information. 2. Provided an example to replace "???". 3. Revised variable naming rules. 4. Added Safety Software Standards. 5. Added Software Version Numbering. 6. Updated the Acknowledgments. 7. Added system abbreviations CS, MS, & TFS, Added IO abbreviations: Ind, Req, Rxcv, & Txmt.
AB.2	05/22/08	Pat Dohoney	All AB modified § §1.4.2 §2.6.1 Appendix D Appendix K	1. Made review and comment driven changes - Gary Armstrong, Matt Brown, Martin Burk, Robert Hazy, Fritz Rene, & Dmitriy Voloshin. 2. Corrected QAP reference and added open-source reference. 3. Revised LabVIEW Global variable name usage. 4. Updated template: File Header for a C Header File. 5. Corrected the IEC PLC programming language reference.
AB.3	06/09/08	Pat Dohoney	§1.5, §1.6, §2.1.5, §2.1.10, §2.3.9, §2.3.12, §2.4.8, §2.8.1 §1.1, App. J, App. L-§2.2	1. Made review and comment driven changes – Adrian Godinez. 2. Made review and comment driven changes – Dave Milhous.