Using Vertigo™

Workbook and Study Guide

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Introduction

This workbook and study guide is an integral part of the Using Vertigo™ training module. The Using Vertigo™ training module provides a detailed discussion of the use of the Vertigo™ software for the lifecycle management of the Safety Instrumented Systems (SIS). The training course presents a discussion how Vertigo™ can be used to perform analysis, design, and documentation of all phases of the SIS safety lifecycle including SIL verification calculations, safety requirements specifications, managing and

documenting SIS testing, managing and documenting bypasses, and managing, documenting, and reporting activation of the SIS.

About Kenexis

Kenexis is an independent engineering consulting firm. We ensure the integrity of instrumented safeguards and industrial networks. Using skills in risk analysis, reliability engineering, and process engineering, we help establish the design and maintenance specification of instrumented safeguards, such as safety instrumented systems (SIS), alarm systems, fire and gas systems. We use the same skills for industrial control systems (ICS) network design, cyber security assessments, and industrial network performance analysis.

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Section 0 – Scope and Roadmap

Safety instrumented systems (SIS) are one of the most flexible and common safeguards used in the process industries to reduce risk to a tolerable level. Design and implementation of SIS occurs using a lifecycle process that includes numerous analysis and documentation steps. Vertigo™ is the best-in-class software tool that is utilized to facilitate this process. This training course will provide detailed instruction for how to utilize the Vertigo™ software tool to perform SIS lifecycle activities.

Course Objectives

The overall objective of this training course is to explain how to use the Vertigo™ software application to perform SIS lifecycle activities.

- Logging in to the Kenexis Integrated Safety Suite (KISS), creating, and managing studies
- Understand the overall interface employed by Vertigo including the navigation ribbon that allows switching between sections of the application and interacting with grids
- Interacting with the IPF list page
- Working with the SIL Verification Details Form
- Understanding how to use failure rate data in different formats and from different locations, including failure rate databases
- Learn to apply the different terms of the probability of failure on demand calculations
- Understand the structure of SIL verification data, including instrument types, instruments, and complete IPF
- View the range of calculations results for SIL verification
- Understand the structure of SRS data, including general requirements, instrument worksheets, and cause-and effect diagrams
- Learn how to track and document SIS testing, including statistical review of testing results
- Understand how to implement event tracking and monitoring
- Learn to track and document and track the authorization of bypasses
- Learn to work with the full range of reports that are available in Vertigo™
- Understand the available study settings and their impact on calculation and reporting

Section 0 – Scope and Roadmap

Course Roadmap

The training course is divided into the following sections:

- Section 0 Scope and Roadmap
- Section 1 Getting Started
- Section 2 Interface
- Section 3 SIL Verification
- Section 4 Safety Requirements Specifications
- Section 5 Test Tracking
- Section 6 Event Tracking
- Section 7 Bypass Tracking
- Section 8 Reporting
- Section 9 Study Settings

Course Limitations and Prerequisites

This training course only provides instruction on how to implement SIS safety lifecycle tasks, it does not provide background on the theory behind how safety lifecycle tasks are performed, including the details of risk analysis, reliability engineering for SIL verification, and statistics related to development of failure rates and confidence intervals for failure rates. For the student to develop an understanding of the theory behind SIL verification and the rationale for the SIS safety lifecycle the authors recommend that prior to taking this training course the student should first attend the following Kenexis Training Courses.

1. Safety Instrumented Systems – Overview and Awareness
2. Safety Integrity Level Verification

Also, this course assumes that the user understands how to navigate around the Kenexis Integrated Safety Suite (KISS) Project Manager section. More information on the KISS Project Manager can be found in the following Kenexis Training Course.

1. Using Kenexis Integrated Safety Suite (KISS) Project Manager

Section 1 – Getting Started

Section 1 – Getting Started

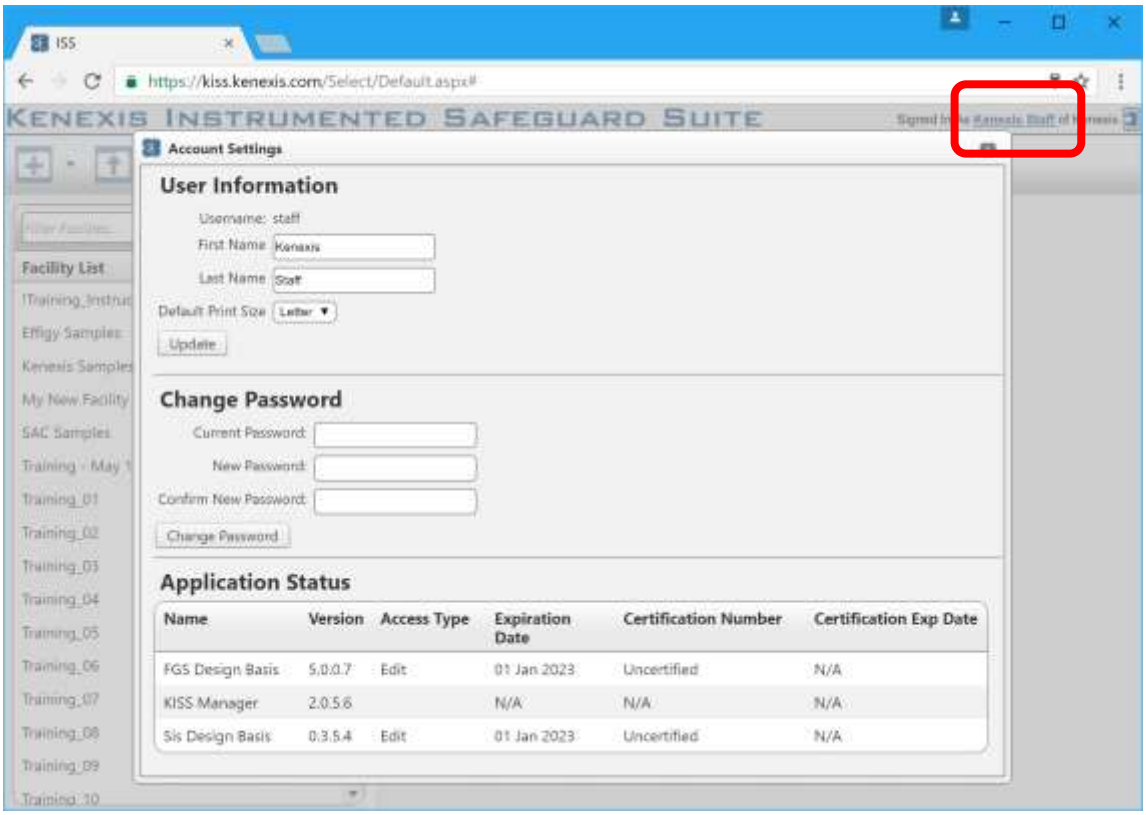
This section will provide information on logging into the Kenexis Integrated Safety Suite (KISS) of applications and how to navigate the Project Manager portion of the suite in enough detail to allow Vertigo studies to be opened and created. More detailed instruction on use of the KISS Project Manager is contained in the Using KISS Project Manager training course.

1.1 Login and Account Information

KISS is accessed through a web browser connected to the internet. The user should direct the browser to https://kiss.kenexis.com for the public instance of KISS. Users that are to access a private instance of KISS will need to receive the URL from their software administrator. The login page provides access to the suite of software after entering your username and password. If login information is lost, either username or password, this information can be retried by clicking on the "Forgot Password?" hyperlink. Also, additional assistance can also be obtained from Kenexis support via e-mail at support@kenexis.com.

Section 1 – Getting Started

After logging in you will be directed the Study Manager Page where clicking on your name in the title bar will bring up your account settings. In the account settings page you will be able to change your password and check the status of your licenses.

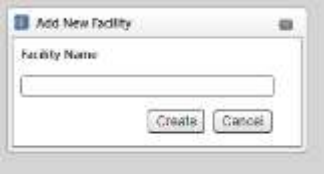


1.2 Create New Facility and Study

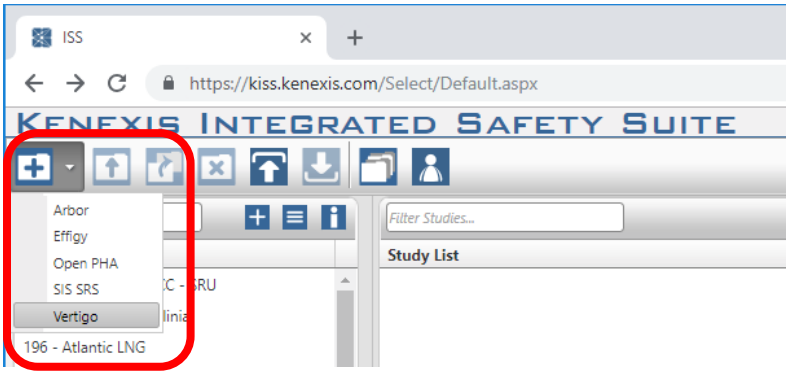
New Facilities and studies are created in the Project Manager portion of KISS. A new facility can be created by clicking on the "+" icon at the top of the facilities list.

This brings up a dialog box requesting a Facility Name as shown below.

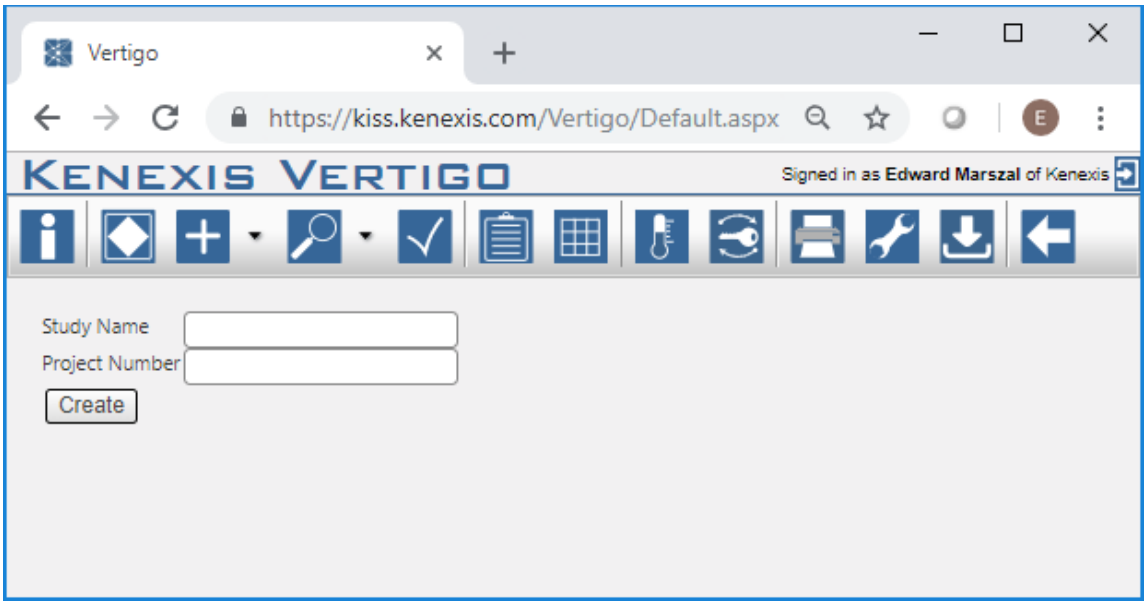
Section 1 – Getting Started



After entering the facility name the Study Manager will show a blank Study List for the new facility. A new study is created by clicking on the "Add Study" Button and selecting Vertigo.

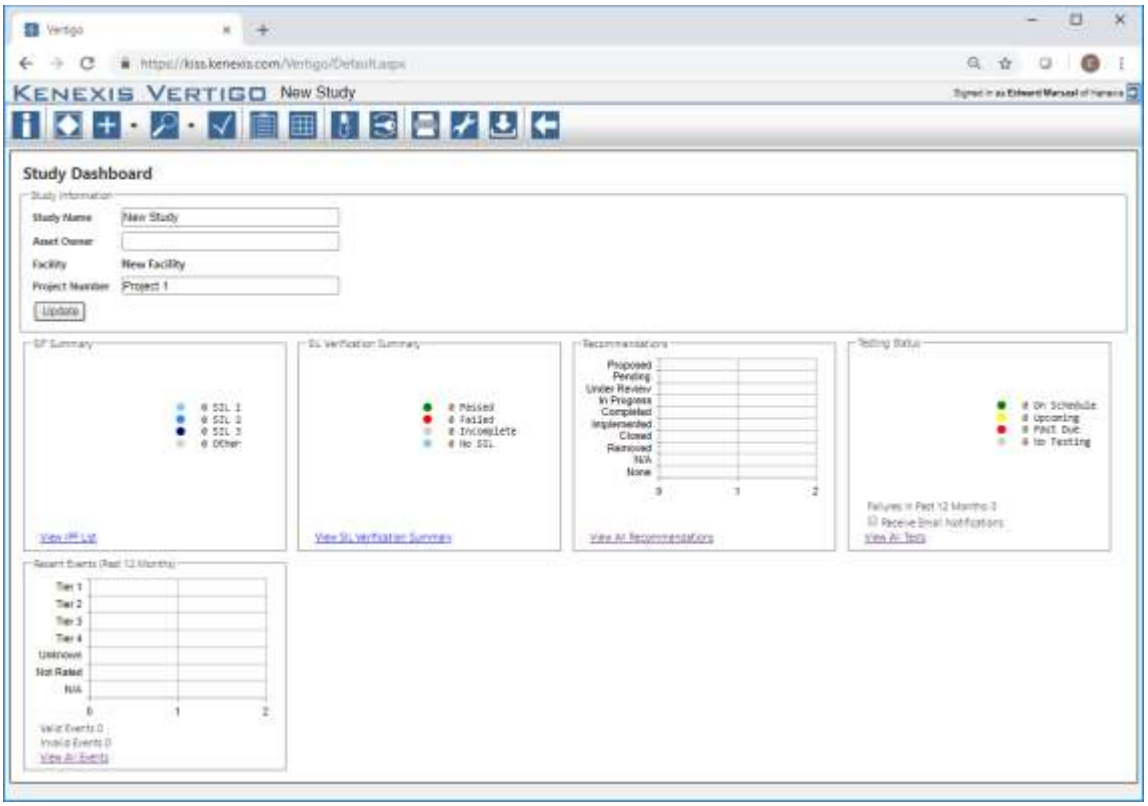


The new study is created and a study information page, requesting a study name and project number, is shown prior to launching into the Vertigo application with the new study.



Section 1 – Getting Started

Once the new study is created the Vertigo application is launched and the user is moved to the Study Dashboard page of the application where the Asset Owner can also be added to the study information.



1.3 Exercise #1 – Create a Facility and Study

For exercise #1, you are required to create a new facility and a new study that will be used throughout the rest of the course. *Appendix 1* of this Workbook and Study guide contains information regarding a sample process that will be the basis for this training course. You should read through *Appendix 1* to familiarize yourself with the sample plant and the log into Vertigo and create a facility and study.

Facility Name – General Oil and Gas Operating Company – Texas City

Study Name – Gas Production Facility

Project Number – P-2004

Section 2 – Interface

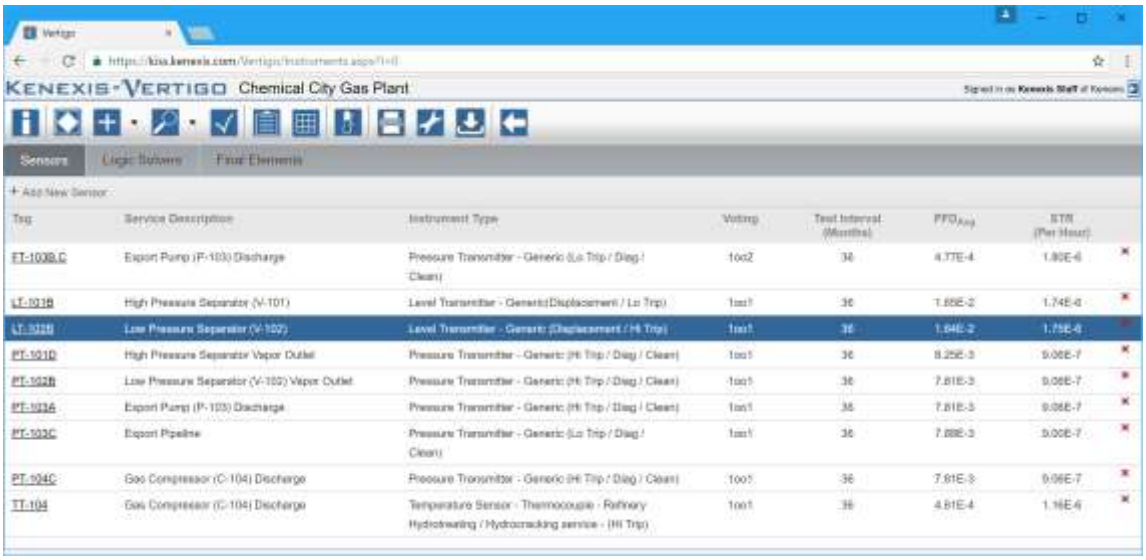
Section 2 – Interface

This section will provide a detailed explanation of the interface employed by Vertigo including a discussion of the navigation bar for switching between application sections and the grid controls that are prevalent throughout the application.

2.1 Navigation Toolbar

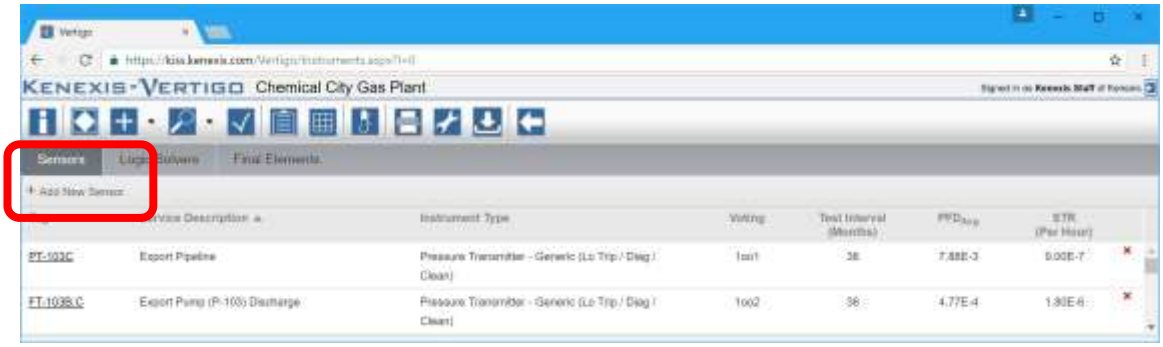
The navigation toolbar is the primary means for navigating between application sections and tools.

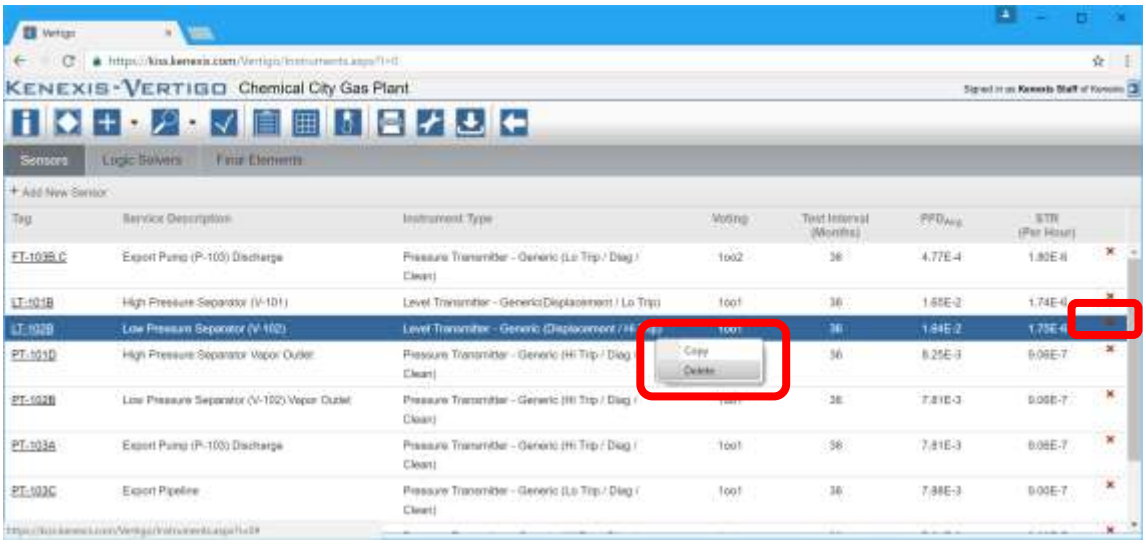
2.2 Working with Grids – Add, Edit, Delete



Grids are the primary tool that are used in Vertigo to interact with project data. There are data grids associated with SIS equipment items, SIS equipment types, safety requirements specifications requirements, tests, bypasses, and a variety of other items. New records can be added by clicking on the "+ Add" button that is shown for all grids. When a grid is displayed, each record in the grid can be opened for editing or deleted.

Section 2 – Interface

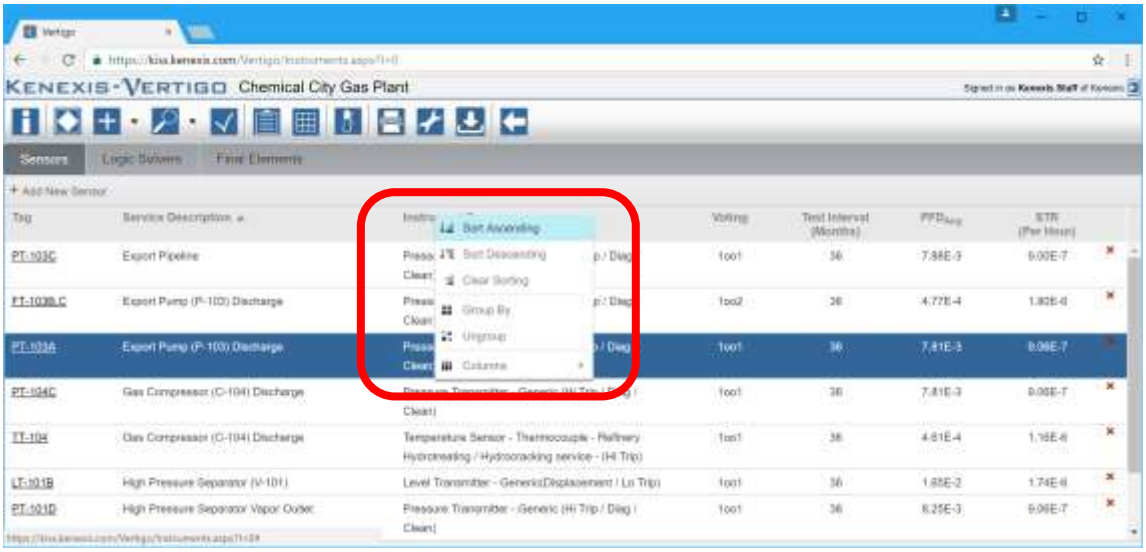




2.3 Working with Grids – Sorting

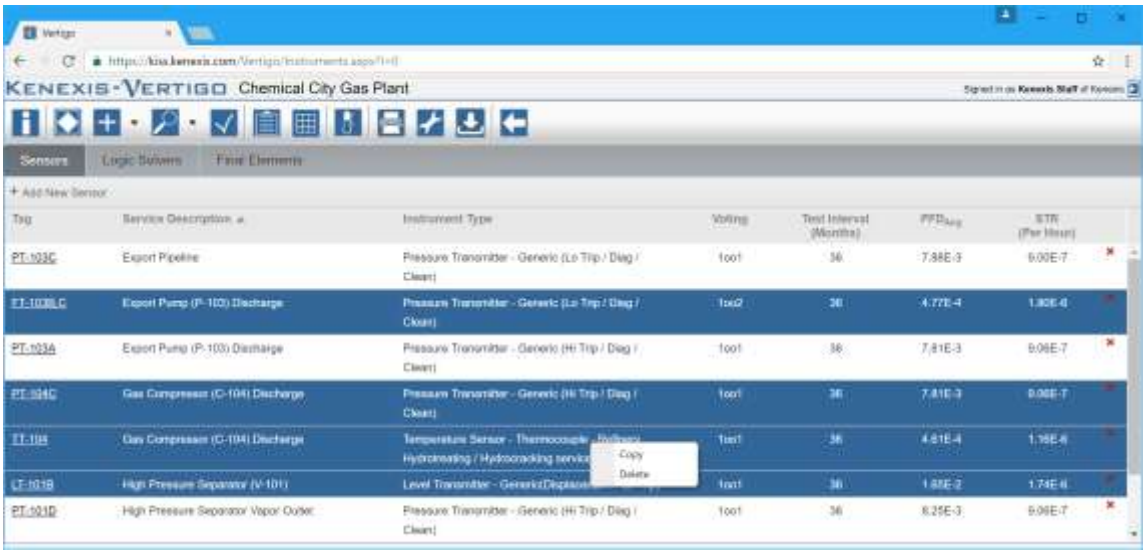
Grids can be sorted, grouped, and have their column display customized. Clicking on a column heading will change the sort from alphabetical, to reverse-alphabetical, to unsorted. Right-clicking on a column header will display the context menu that will allow you to select the desired sorting and group and allow the displayed columns to be changed.

Section 2 – Interface



2.4 Working with Grids – Context Menus

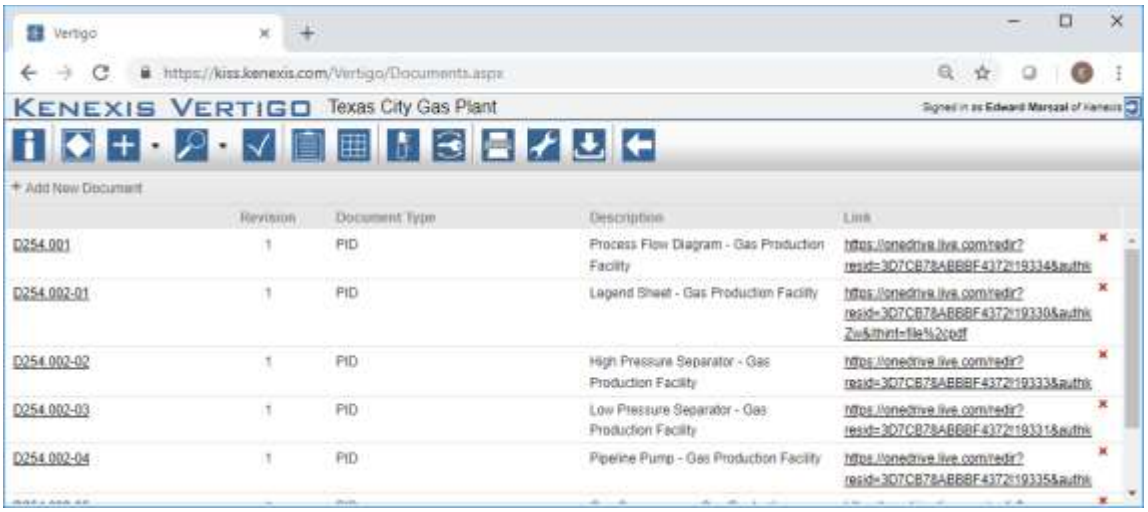
Many of the grids have context menus that allow you to perform specific actions to individual selected records or a group of selected records. The context menu is always accessed by right-clicking on the mouse after a selection of a record or records is made. All the context menus are different depending on the grid being displayed but copy and delete are common choices regardless of which grid is being displayed.



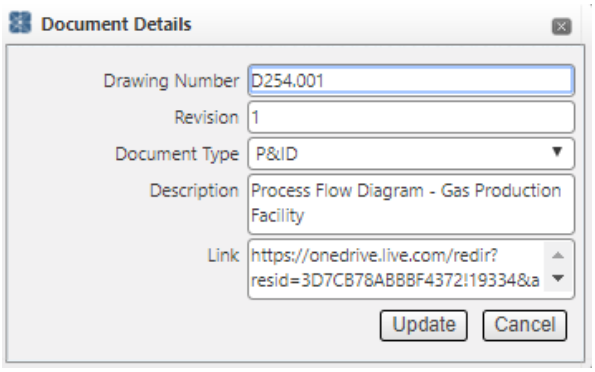
Section 2 – Interface

2.5 The Document List

Vertigo contains a document list that can include all the documents that a SIS design is based on. This can include the piping and instrumentation diagrams, process flow diagrams, specification sheets, safety manuals, risk analysis reports, and other various documents and specifications. The list includes information about the document and a hyper-link to allow easy access to the document from its storage location.



Individual documents are entered and edited in the Document Dialog Box.

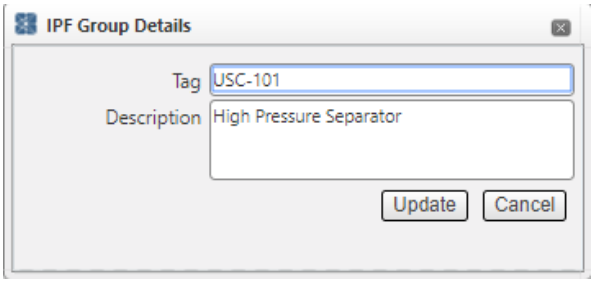


Section 2 – Interface

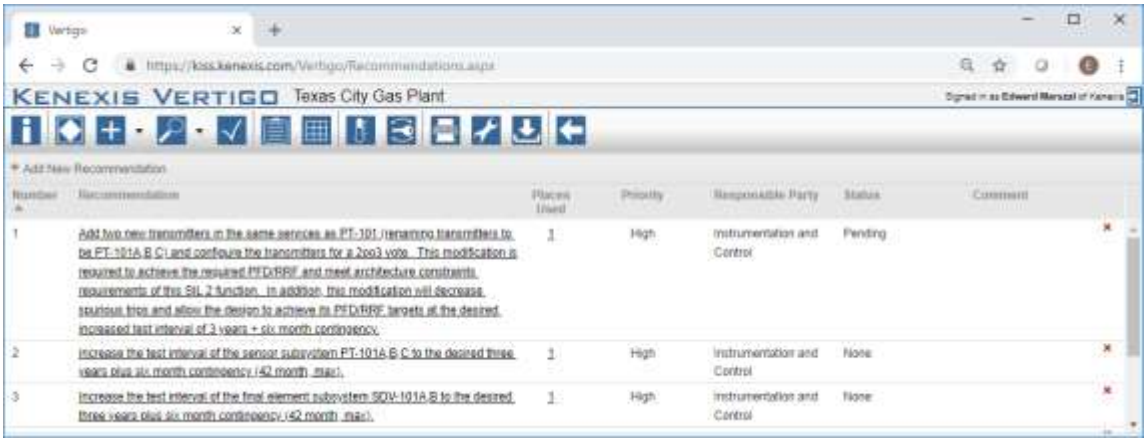
2.6 IPF Group List

SIS instrumentation are often grouped into larger collections than just a single SIF in order to facilitate documentation, maintenance, and testing. Often equipment is grouped by plant area or major pieces of equipment. In Vertigo these groupings are referred to as “IPF Groups”. IPF groups are created and edited on the IPF Groups page.

IPF groups are edited using the IPF Group Details dialog box.

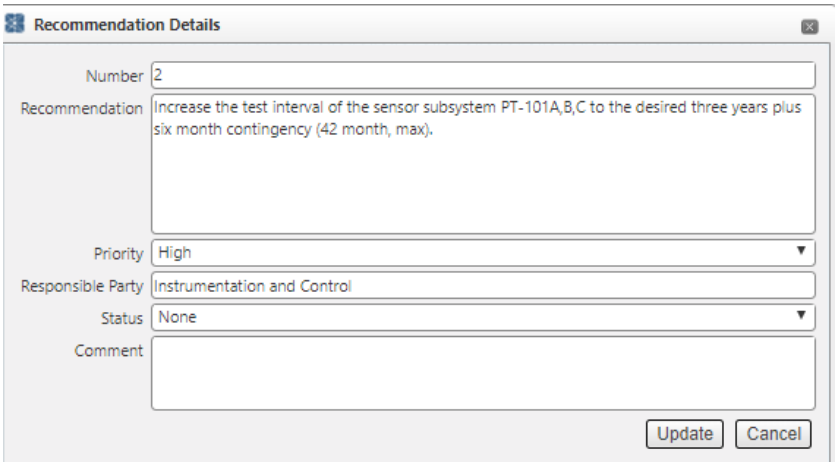


2.7 Recommendations List

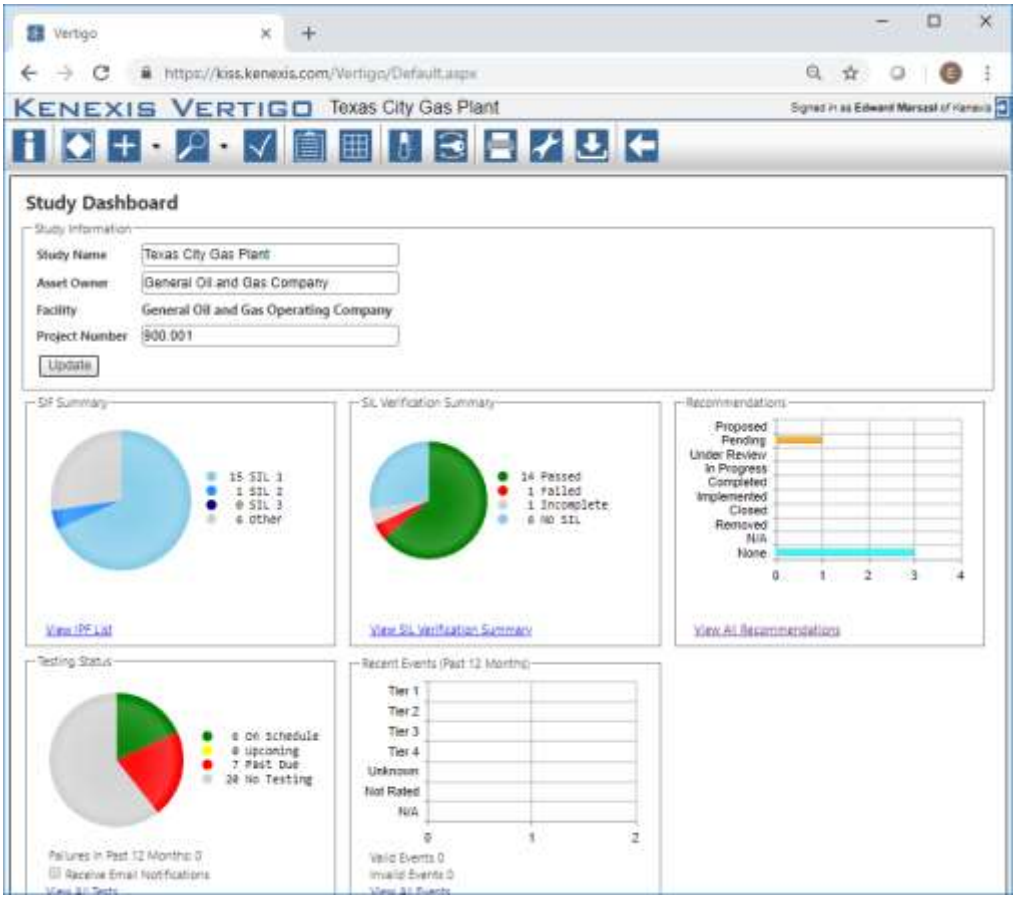


Section 2 – Interface

There are several places in Vertigo where recommendations can be generated and entered. The recommendations list provides a unified set of recommendations in one location. Recommendations can be edited using the recommendations details dialog box.



2.7 Overview – Dashboard



Section 2 – Interface

2.7 Exercise #2

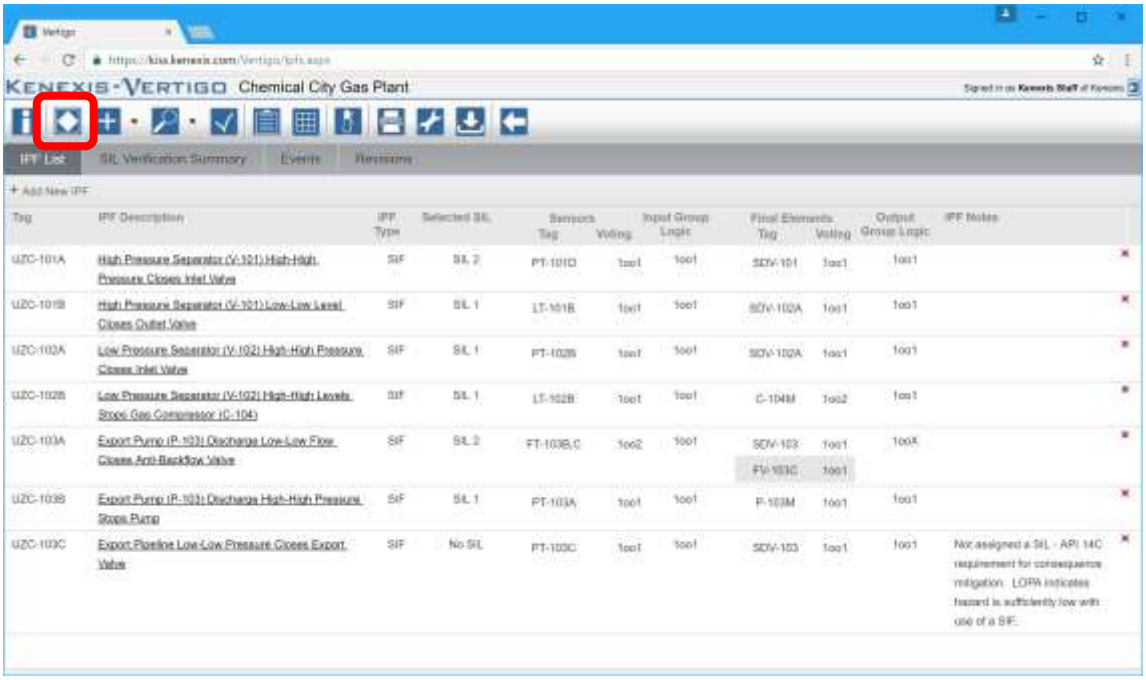
Create a document list and an IPF list for the General Oil and Gas Operating Company Chemical City Gas Plant. *Appendix A* contains a complete list of all the piping and instrumentation diagrams for the facility. The drawings include all the information that you need to complete to document details form other than a hyperlink to a document management system, which you can ignore for this exercise. *Appendix A* also includes a list of major equipment items in the process description section. Create an IPF Group for each equipment item and tag them sequentially starting with USC-101. There is no need to create a group for the support facilities.

Section 3 – SIL Verification

Section 3 – SIL Verification

This section will provide a detailed explanation of the portions of the Vertigo application that are used to perform, view, and edit SIL verification calculations. SIL verification is a core activity of the SIS safety lifecycle. It is the task where reliability engineering, probability, and statistics are combined to confirm that a proposed design can achieve its SIL target.

3.1 The IPF List

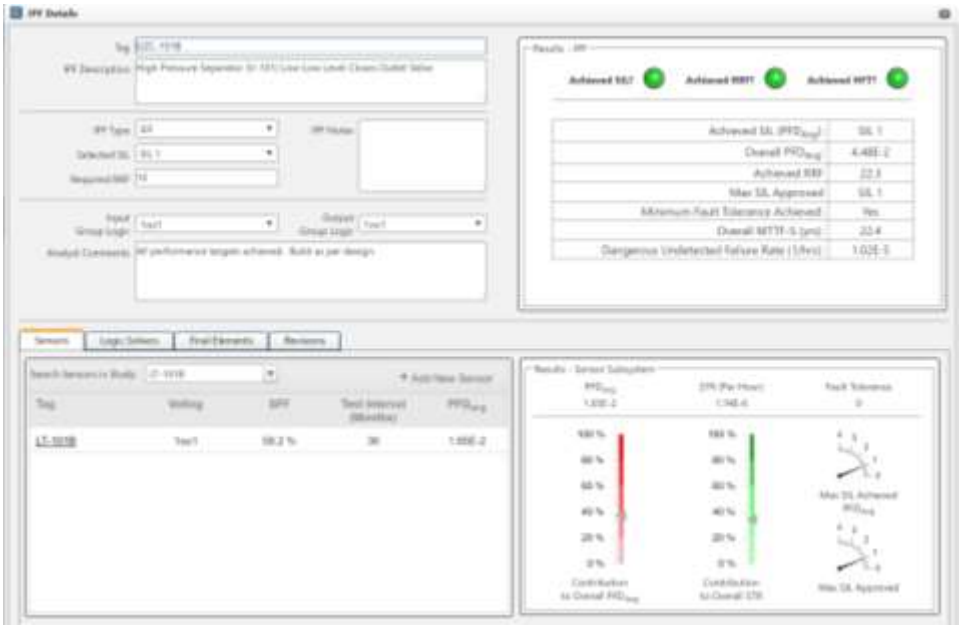


The IPF list is the primary interface for interacting with the SIF that are included in any study. This SIF list contains information on each SIF including, tagging description, inputs, outputs, group voting and notes.

3.2 The IPF Details Form

The IPF details form provides identification information for the SIF, a summary of the IPF calculation results, access to details on the equipment that comprises the SIF, and calculation results for individual subsystems of the SIF.

Section 3 – SIL Verification



3.3 Working with Instrument Types and Failure Rate Data

SIL Verification Calculations begin with data regarding the failure rate characteristics of the equipment that comprises the SIF. Since many instruments are of the same type, Vertigo begins the process by defining "types" of instruments that are included in a study. These equipment types fall into the following categories:

- Process Connections
- Sensor Interfaces
- Sensor Types
- Logic Solver Types
- Final Element Interfaces
- Final Element Types

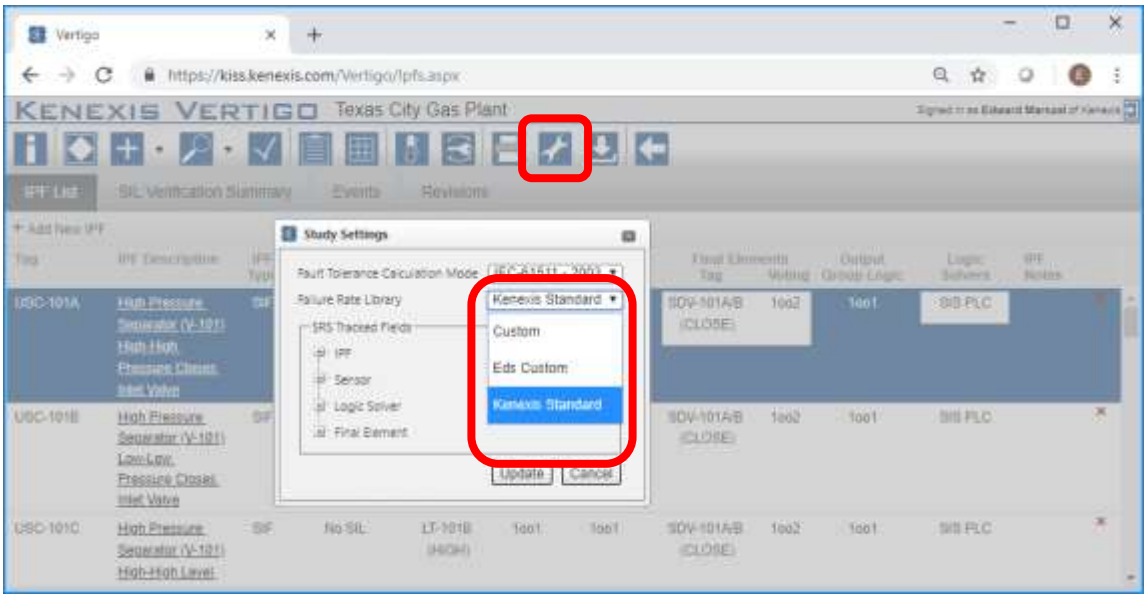
Sensor types are defined on a project level and can be defined in four ways:

- Pulled from a library
- Custom defined for a project
- Black Box Model Direct Input
- Black Box Model from Arbor Fault Tree

Section 3 – SIL Verification

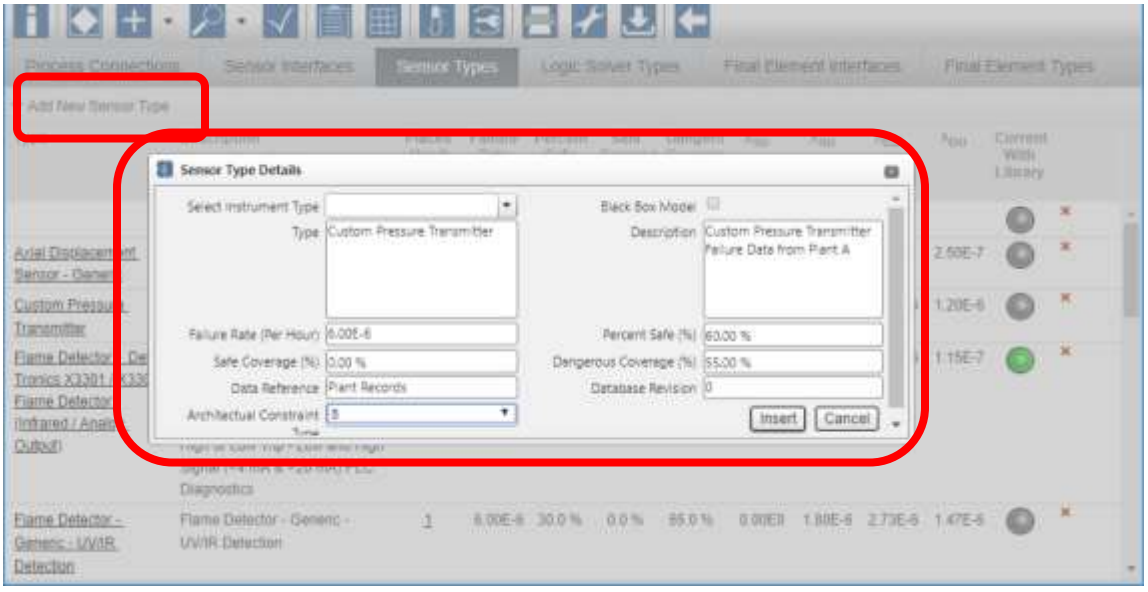
3.3.1 Selecting a Failure Rate Library

The most common way to assign failure characteristics to equipment types is to obtain those rates from a library. Kenexis Vertigo allow the user to select from the Kenexis standard library or custom libraries that are built by users or user organizations.



3.3.3 Create a Custom Instrument Type

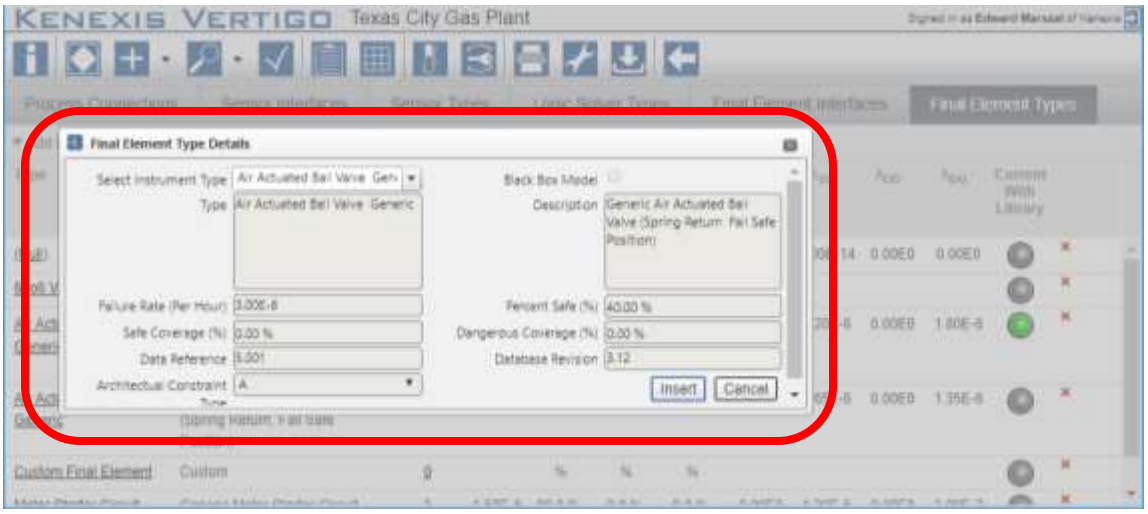
Custom instrument types are employed when a user desires to enter failure rate data for components in directly, and then have the Vertigo calculation engine calculate the PFD and STR of subsystems.



Section 3 – SIL Verification

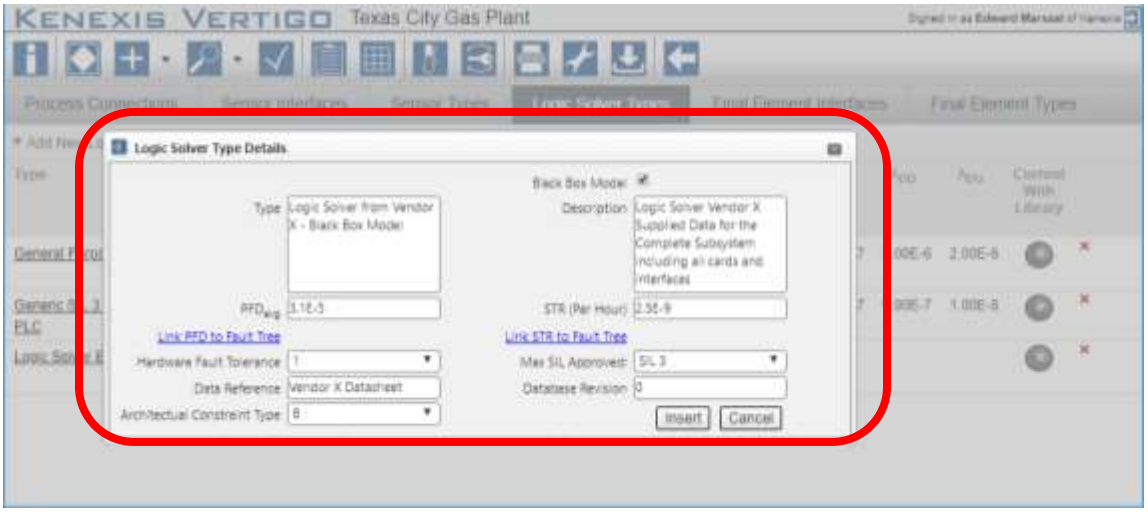
3.3.2 Create an Instrument Type from a Failure Rate Library

The most common way to create an instrument type is to pull the data from the library that has been selected in the settings dialog. Selecting the item from the drop down list will cause its information to be copied to the project. The "Current with Library" light tells the user whether the data in the project is consistent with the library and allows you to update.



3.3.4 Create a Block Box Model Instrument Type

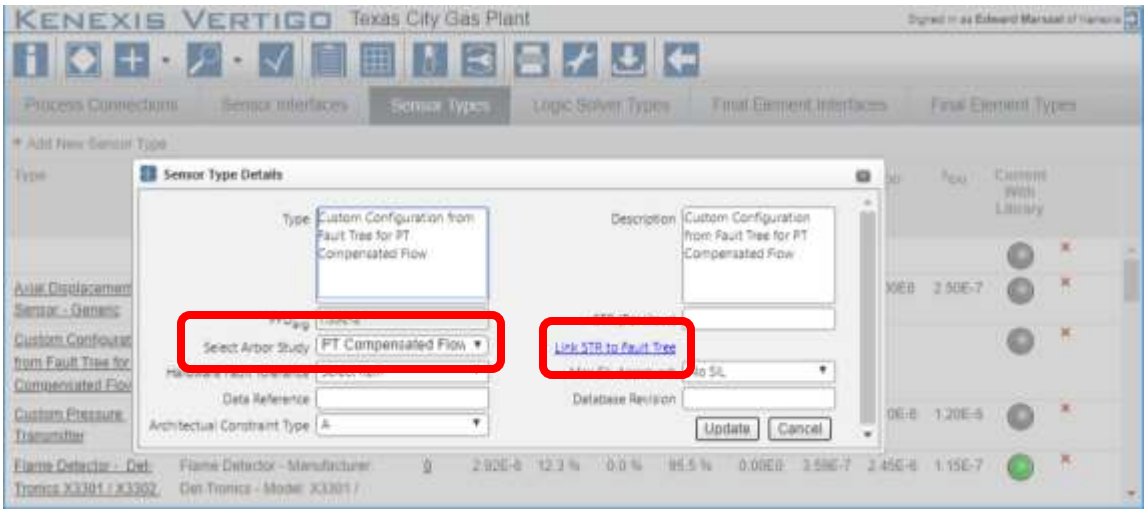
If a system is very complex, instead of entering in failure data and having Vertigo calculate PFD and STR for the subsystem, it can be entered directly. Simply check "Black Box Model" and enter the PFD and STR directly.



Section 3 – SIL Verification

3.3.4 Create a Block Box Model from Arbor Fault Tree

A common way to generate the PFD and STR for complex systems is by using a fault tree analysis. Vertigo allows you to directly connect a Vertigo study's instrument type data to an Arbor fault tree analysis study.



3.4 Working with SIF Components

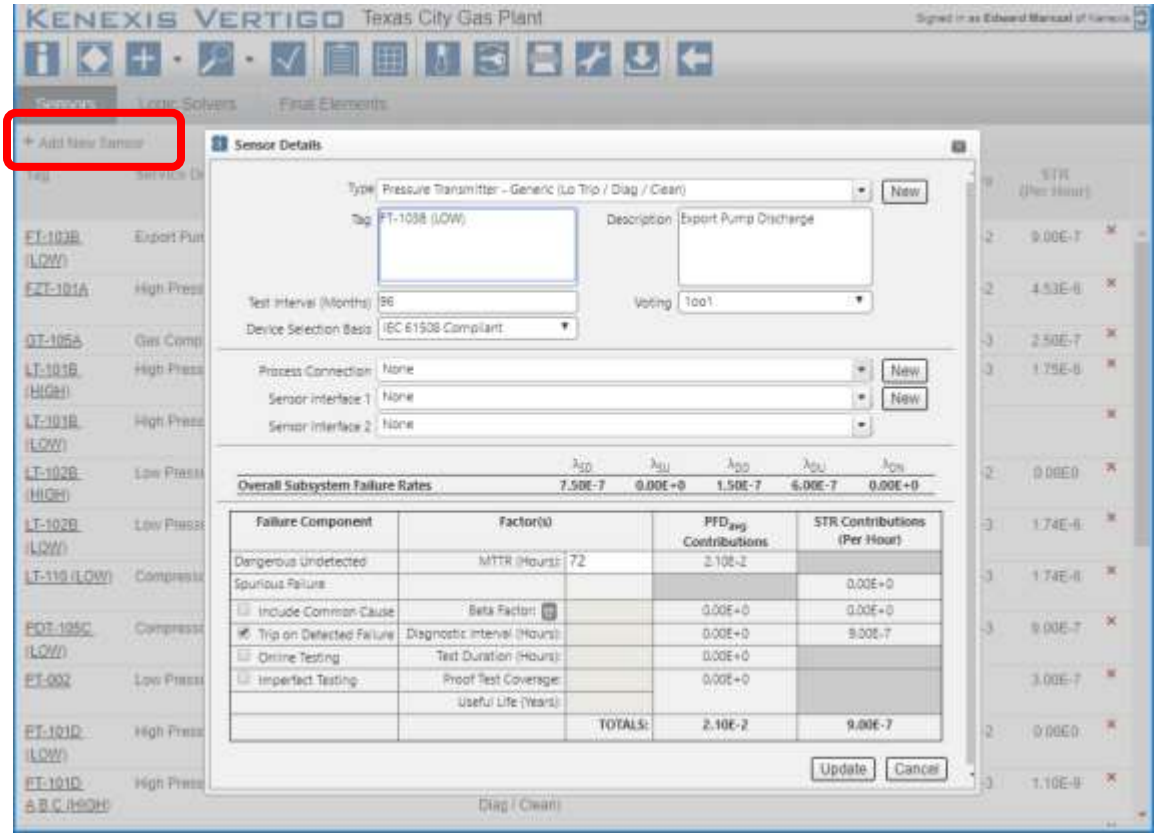
SIF are generally made up of a sensor subsystem, logic solver subsystem, and final elements subsystem. Each subsystem can be comprised of multiple instrument groups, but each instrument group is created individually on its component details page. The components that can be defined include.

- Sensor
- Logic Solver
- Final Element

Section 3 – SIL Verification

3.4.1 Component Details – Sensors

Sensors are created, defined, and edited on the sensor details page.



3.4.2 Component Details – Calculation Components

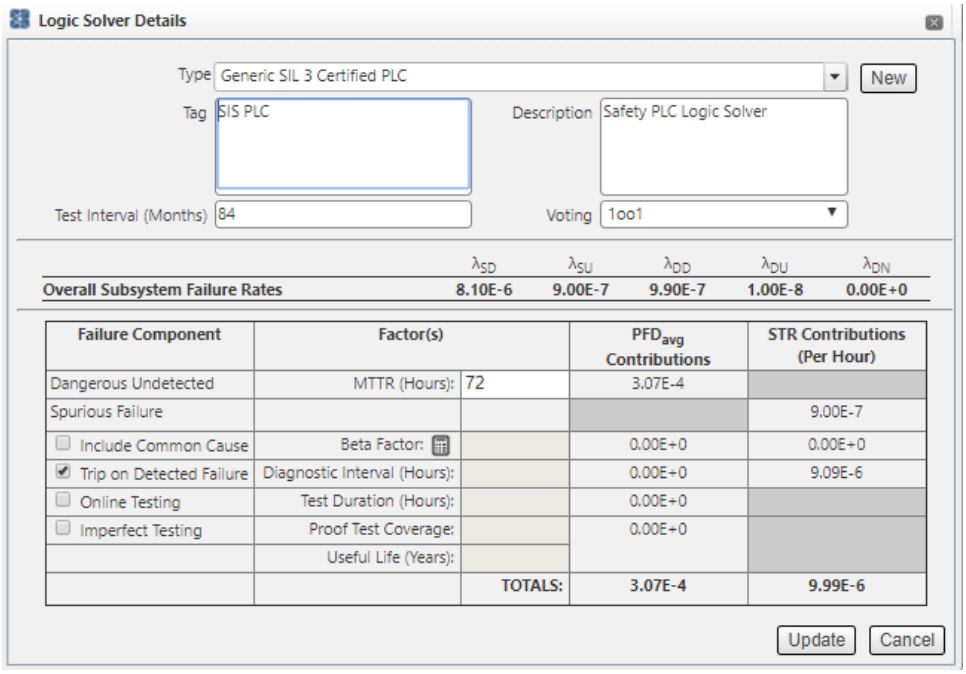
The component details page allows modification and shows results for the various items that contribute to the overall PFD and STR of a component, sub-system, and SIF.

Failure Component	Factor(s)		PFD_{avg} Contributions	STR Contributions (Per Hour)
Dangerous Undetected	MTTR (Hours):	72	1.79E-3	
Spurious Failure				9.72E-12
☑ Include Common Cause	Beta Factor:	0.005	1.13E-4	7.50E-10
☑ Trip on Detected Failure	Diagnostic Interval (Hours):		0.00E+0	3.45E-10
☑ Online Testing	Test Duration (Hours):	16	5.22E-4	
☑ Imperfect Testing	Proof Test Coverage:	0.99	9.32E-6	
	Useful Life (Years):	25		
		TOTALS:	2.43E-3	1.10E-9

Section 3 – SIL Verification

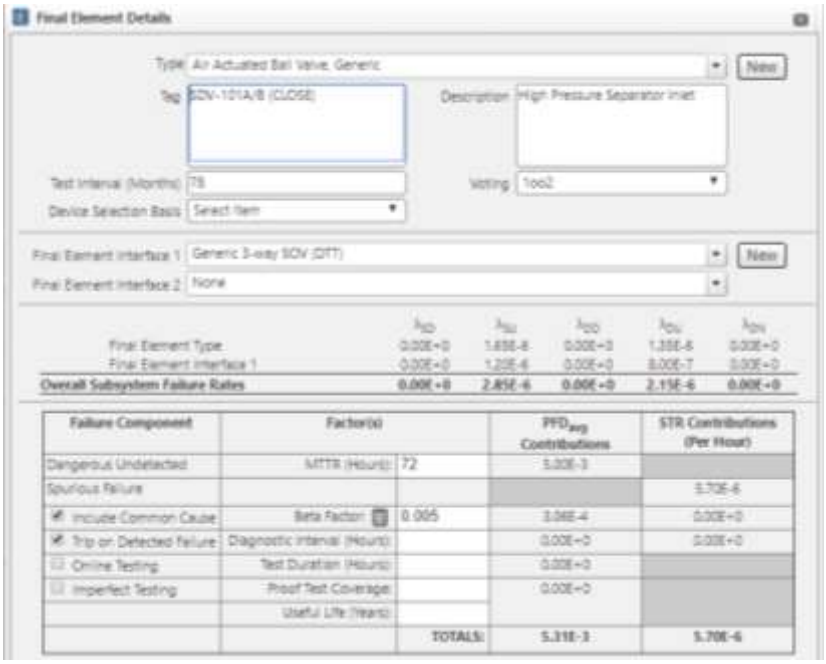
3.4.3 Component Details – Logic Solvers

Logic solver information is entered on the logic solver details page.



3.4.4 Component Details – Final Elements

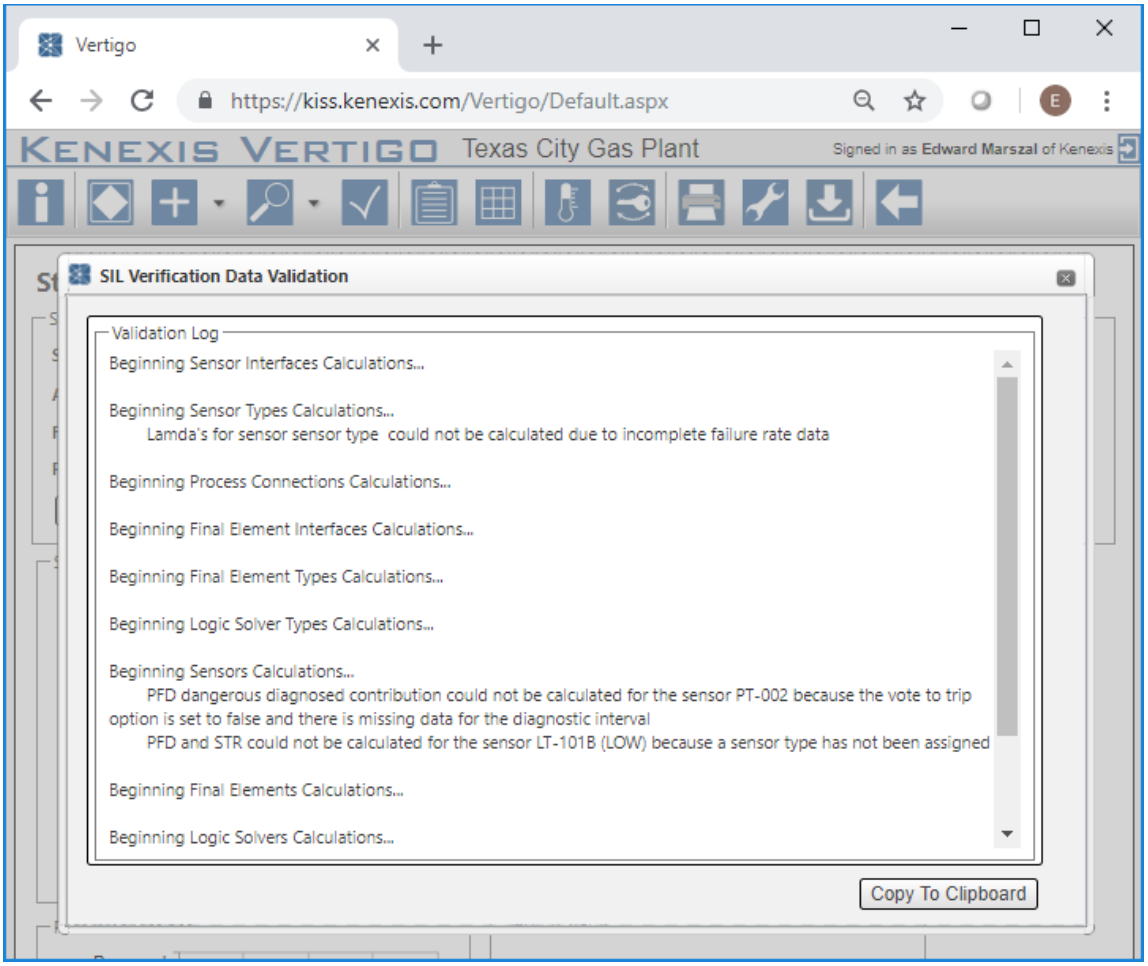
Final elements information is entered on the final elements details page.



Section 3 – SIL Verification

3.5 SIL Verification Data Validation Log

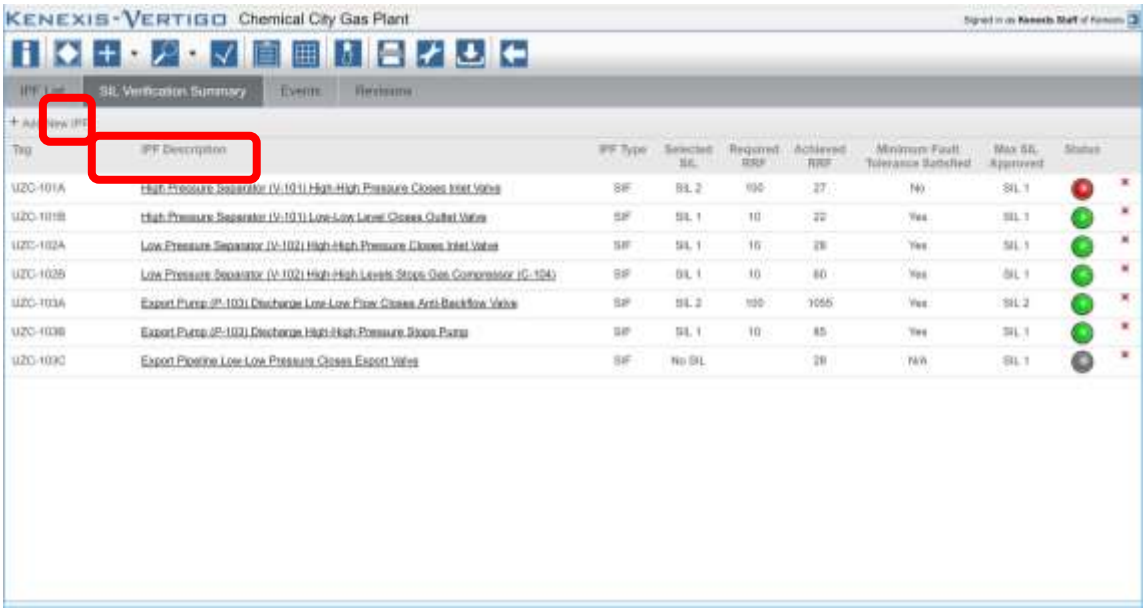
Vertigo provides a utility that allows the user to check the calculation status of all the components, subsystems, and SIF in a study. The utility will check each calculation to ensure that all the data required to perform the calculation is present. The data can also be copied and exported to other applications.



Section 3 – SIL Verification

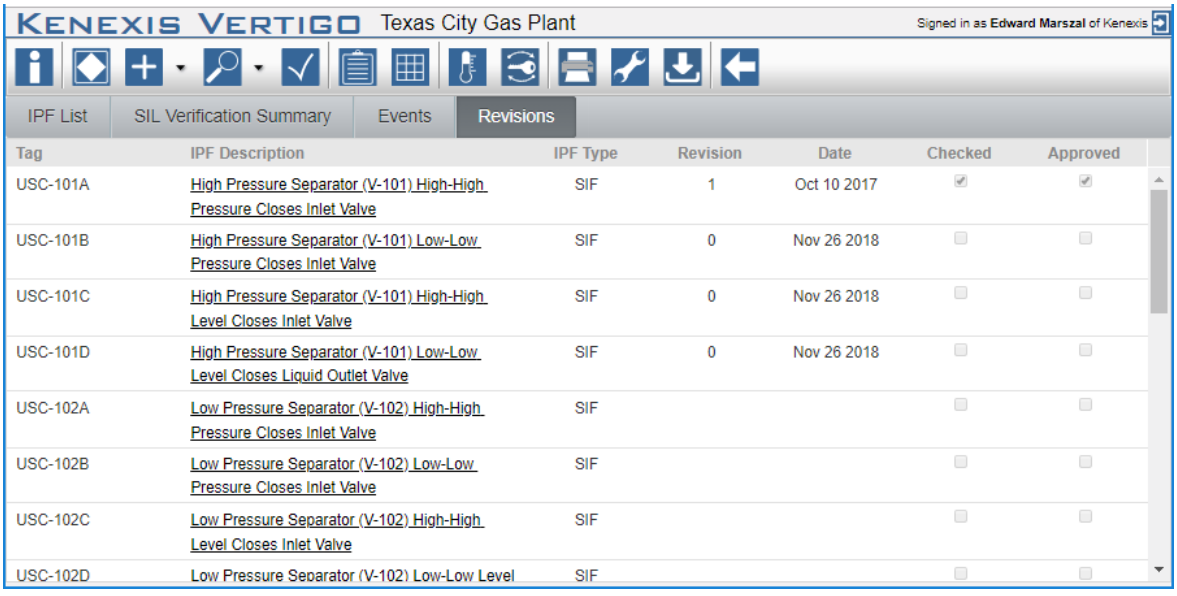
3.6 The SIL Verification Summary

The SIL Verification Summary page provides an overview of the results of all the SIF in study, but not the details of the calculations. This page is useful for determining, which, if any, SIF in a study have not achieved their targets.



3.7 SIL Verification Revisions Page

This page allows the user to view the revision level and approval status of all SIF in one location.



Section 3 – SIL Verification

3.8 Exercise #3

Create a SIF definition and perform SIL Verification Calculations for the High-Pressure Separator SIF of the General Oil and Gas Operating Company Chemical City Gas Plant. *Appendix A* contains a complete list of all the piping and instrumentation diagrams for the facility. The High-Pressure Separator is shown on Drawing D-254-002 Sheet 2 of 6.

There are two SIF associated with this vessel, both operating in low demand mode:

USC-101A – High Pressure Separator (V-101) High-High Pressure Closes Inlet Valve

- SIL 2 Target with Minimum Risk Reduction Factor of 150

USC-101B – High-Pressure Separator (V-101) High-High Level Closes Inlet Valve

- SIL 1 Target with Minimum Risk Reduction Factor of 35

The inputs and outputs to these functions can be seen on the drawing and are connected to the USC-101 function. Assume that the inlet shutoff valve type is a "Air Actuated Ball Valve, Generic", all level transmitters are "Level Transmitter – Generic (Displacement)", and all pressure transmitters are "Pressure Transmitter – Generic". For the inputs, assume that the process connection for the pressure transmitter is "typical" in clean service and that for the level transmitter the connection is "large" and in clean service. Also assume that there are no interface devices between the logic solver and the sensors. There is a single interface device for the shutoff valve which is a "Generic 3-way SOV (DTT)". The logic solver in this case is a "Generic SIL 3 certified PLC". The "Generic SIL 3 Certified PLC" data entry is an Equivalent 1oo1 type, so the voting should be 1oo1 regardless of the actual configuration. While the logic solver has been third party certified to be compliant with IEC 61508, the field devices have been selected based on prior use experience.

The major turnaround interval for this plant is 3 years, so assume a 36-month test interval, and also assume a Mean Time To Repair (MTTR) of 72 hours for all components. For the first pass of calculations, assume common cause is ignored, detected failures of all components result in a vote to trip (i.e., cause a shutdown), no online testing is performed, and manual proof testing is 100% effective.

1. Based on the above, determine Achieved SIL, Achieved RRF, and Overall MTTF-S for both SIF.

Section 3 – SIL Verification

2. Change the voting arrangement of the sensor subsystem for pressure measurement to 2oo3 voting with a common cause failure beta factor of 5%. For the high-pressure SIF – determine Achieved SIL, Achieved RRF, and Overall MTTF-S.
3. Change the response to detected failures for the pressure measurement subsystem to NOT trip on detected failures and include a diagnostic interval of one PLC scan (effectively 0). For the high-pressure SIF – determine Achieved SIL, Achieved RRF, and Overall MTTF-S.
4. Change the testing to "imperfect" for the pressure measurement subsystem and include a proof test coverage of 95% and a useful life of 25 years – determine Achieved SIL, Achieved RRF, and Overall MTTF-S.
5. Change the testing to include online testing for the pressure measurement subsystem and include two annual tests (after year 1 and after year 2), each having a duration of 2 hours (4 hours total over the mission) – determine Achieved SIL, Achieved RRF, and Overall MTTF-S.

Section 4 – SRS

Section 4 – Safety Requirements Specifications (SRS)

This section will provide a detailed explanation of the portions of the Vertigo application that are used to perform, view, and edit SIL verification calculations. SIL verification is a core activity of the SIS safety lifecycle. It is the task where reliability engineering, probability, and statistics are combined to confirm that a proposed design can achieve its SIL target.

4.1 SRS Overview

SRS data can be accessed from the Safety Requirements Specifications and Cause-and-Effect Diagrams pages. There are three types of SRS data:

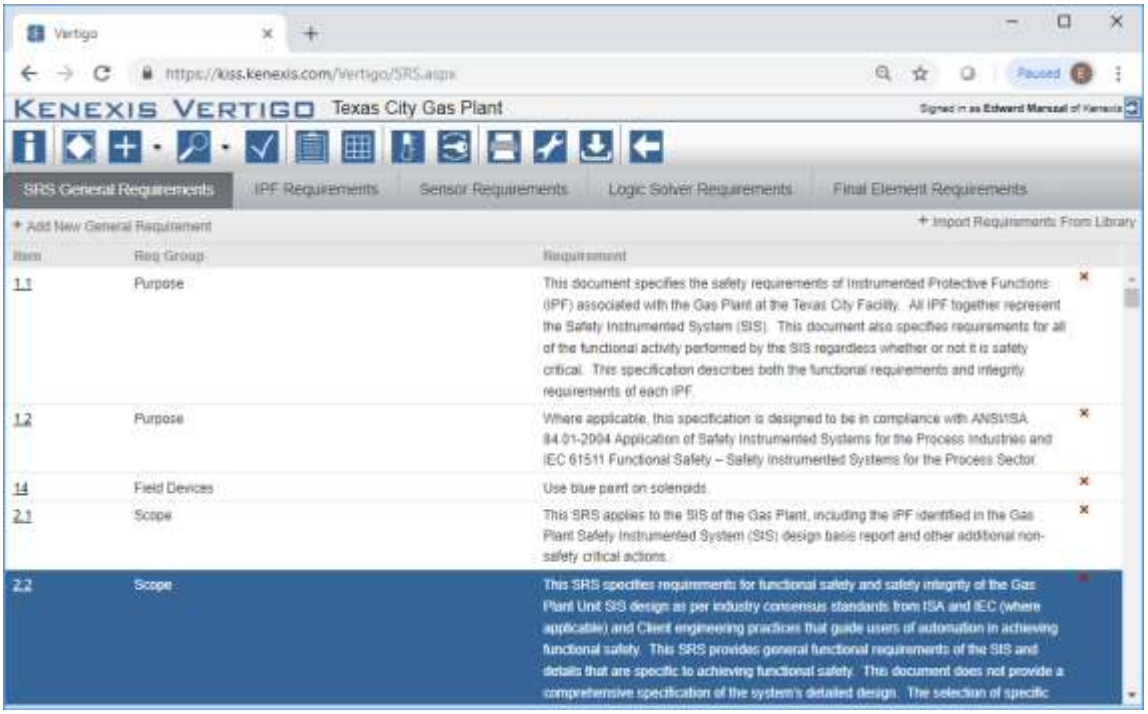
- General Requirements (and Specific Requirement Notes)
- Datasheets
- Logic Description (Cause-and-Effect Diagrams)

General requirements and datasheets for IPF, Sensors, Logic Solvers, and Final Elements are all accessed from the Safety Requirements Specification pages by using the tab strip at the top of the page. The set of cause-and-effect diagrams is available on the Cause-and-Effect diagram page by selecting which IPF Group's cause-and-effect diagram is to be displayed.

4.2 SRS General Requirements

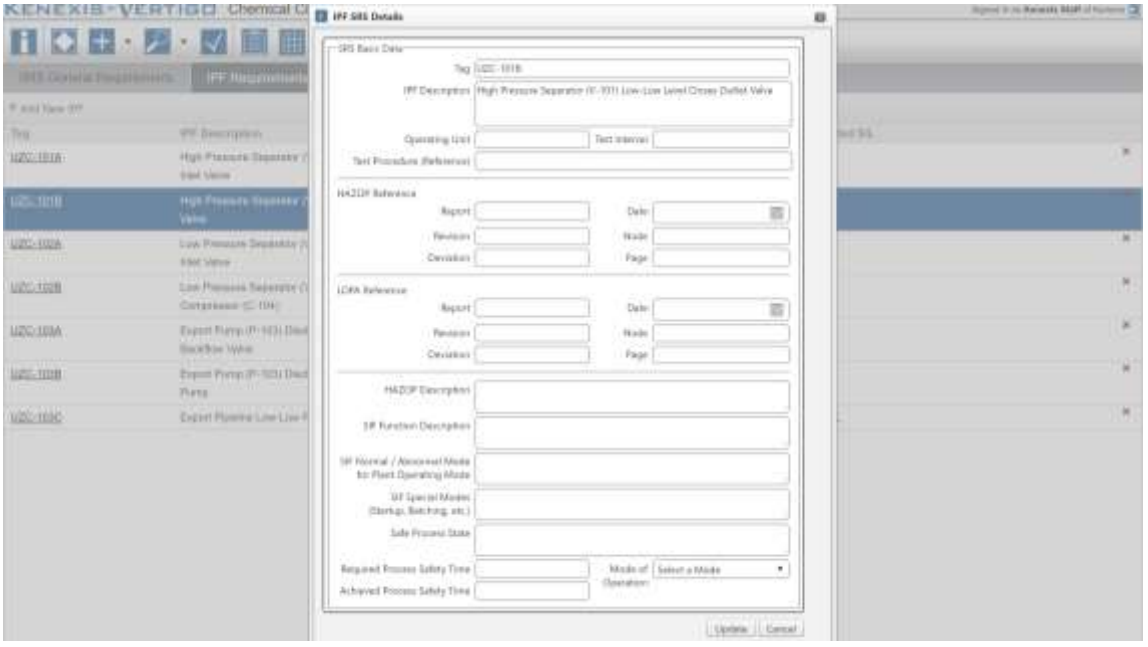
General requirements are a listing of textual specifications that apply to all instruments and IPF of a SIS. The general requirements are listed in a grid. Specific requirements or specific notes are also incorporated into the general requirements grid. Each requirement record contains a number, grouping labels (for sorting and classification purposes), and the text of the requirement itself. A large group of standardized general requirements can be imported from a library of individual requirements can be entered.

Section 4 – SRS



4.3 SRS Datasheets

Detailed information that is applicable to individual portions of an SRS are documented in datasheets. The content of the datasheet, in terms of available fields, is customizable from the Settings tab, allowing the user to only select the portion of the field superset that is appropriate for their organization.



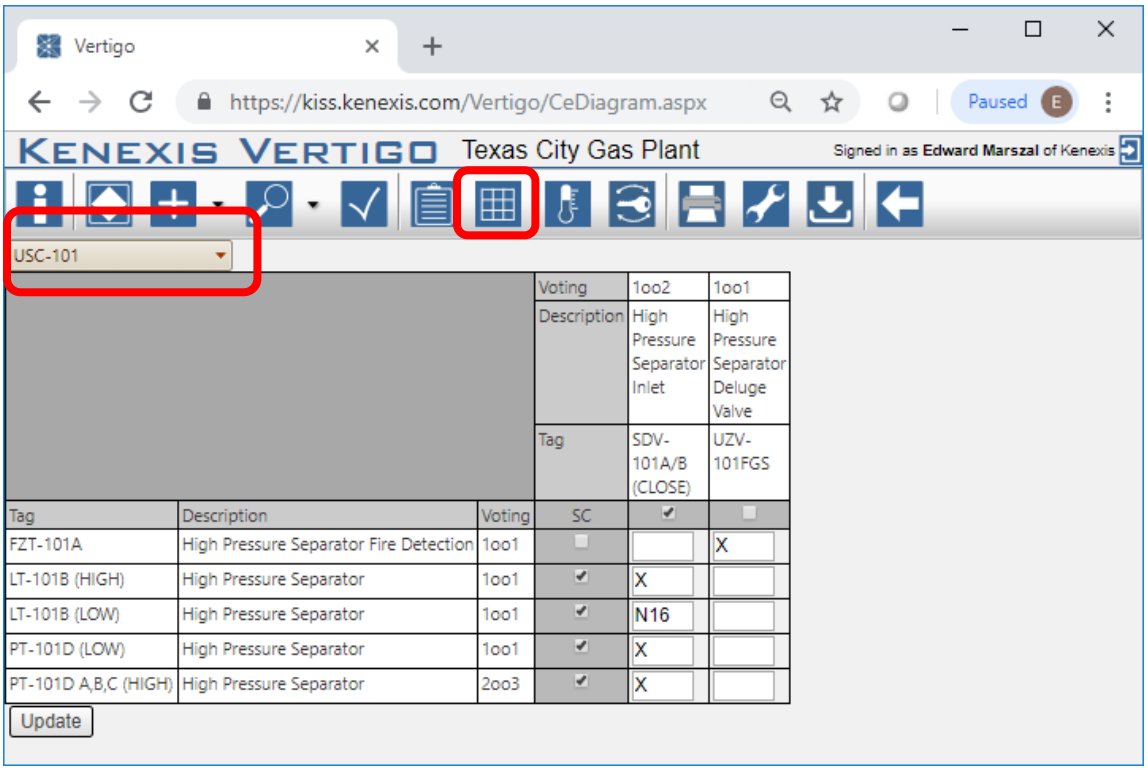
Section 4 – SRS

Datasheets are available for:

- IPF
- Sensors
- Logic Solvers
- Final Elements

4.4 Cause-and-Effect Diagrams

Vertigo documents SIS logic using cause and effect diagrams. The cause and effect diagram of each IPF Group can be viewed and edited by selecting the cause-and-effect diagram button from the navigation bar and then selecting the appropriate IPF Group from the IPF Group drop down box.



4.5 Exercise #4

Create some of the SRS information for the High-Pressure Separator SIF of the General Oil and Gas Operating Company Chemical City Gas Plant. Refer to *Appendix A* the

Section 4 – SRS

SRS

required plant information. The SRS information that should be incorporated for this exercise include the following.

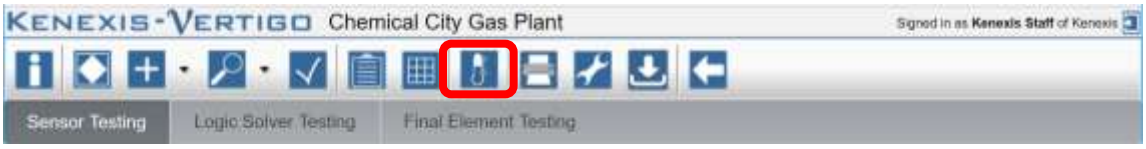
- Insert the set of general requirements from the Kenexis Standard Library
- Insert a new general requirement
    - Item Number 16
    - Group: Specific Notes
    - Requirement: Incorporate a 20 second time delay on closure of the high-pressure separator inlet vessel upon detection of a high level in the separator vessel.
- For the IPF tagged USC-101A add the following information:
    - IPF Group = USC-101
    - Equipment Number = V-101
- For the IPF tagged USC-101B add the following information:
    - IPF Group = USC-101
    - Equipment Number = V-101
- For the sensor tagged LT-101B
    - IPF Group = USC-101
    - Trip Type = HH
    - Data Reference = Sheet 2 of 6
    - Safety Critical = Checked
- For the sensor tagged PT-101D
    - IPF Group = USC-101
    - Trip Type = HH
    - Data Reference = Sheet 2 of 6
    - Safety Critical = Checked
- For the final element tagged SDV-101 (Close)
    - IPF Group = USC-101
    - SIF Action =Close
    - Data Reference = Sheet 2 of 6
    - Safety Critical = Checked
- Build out the cause-and-effect diagram intersections showing a reference to note 17 for the intersection with LT-101B

Section 5 – Test Tracking

Section 5 – Test Tracking

This section will provide a detailed explanation of the portions of the Vertigo application that are used to track and document the testing of SIS components.

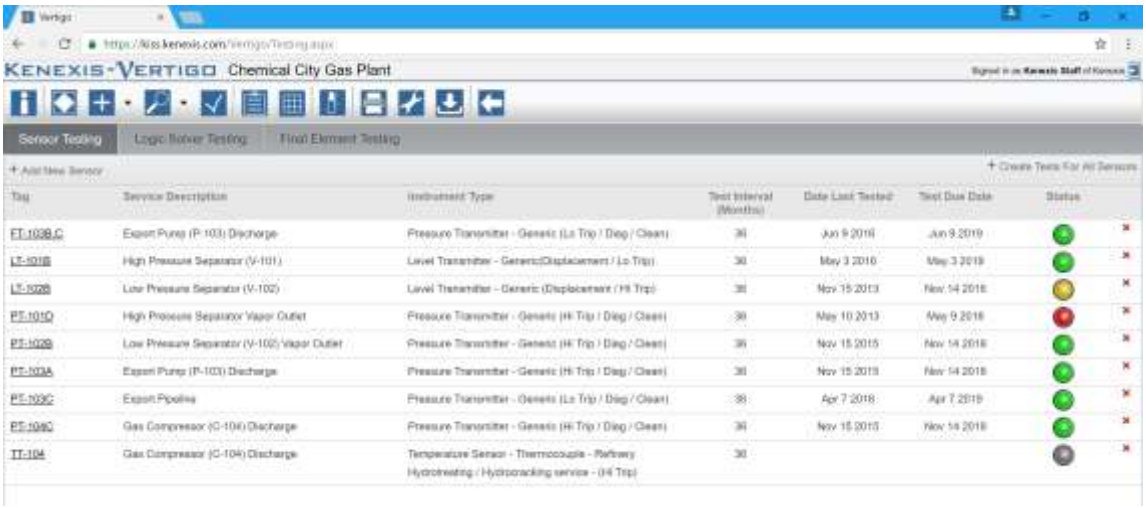
5.1 Test Tracking Overview



The test tracking and documentation section of Vertigo is accessed by selecting the Testing button on the navigation bar. This will bring you to the testing page which displays grids for all of the components of each type. There are grids for sensor, logic solvers, and final element.

5.2 Testing Summary Grid

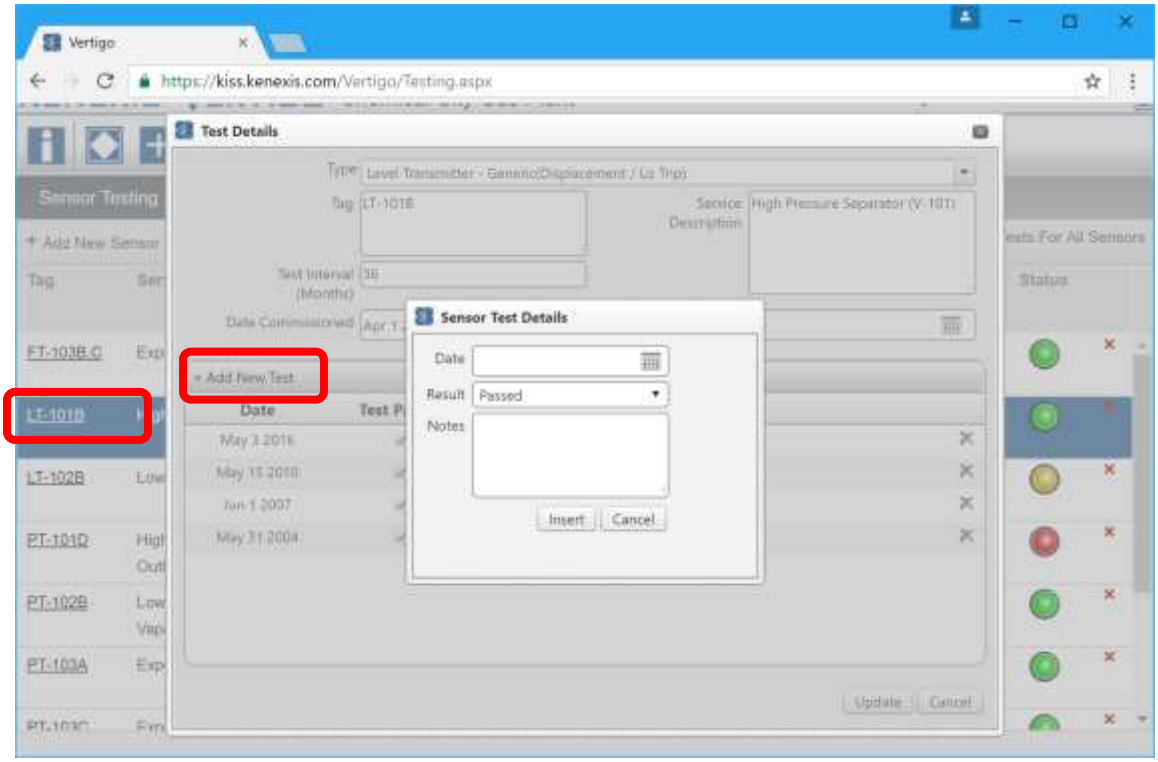
The testing grid for each SIS subsystem that lists the individual components of that type. The grid lists the current status of test for each component including test interval, date last tested, test due date, and a status light. From this form the user can view the historical test results for any component by clicking on its hyperlink. Also, the user can create a test record for all of the components into the database at one time by clicking on the link "+Create Tests for All Sensors", or logic solver, or final element.



Section 5 – Test Tracking

5.3 Testing Details

For each component, there is a testing details form that includes testing attributes of the component along with a list of all the tests that have historically been performed for that component. Each individual test can be viewed and edited by clicking on the individual test's hyperlink.



5.4 Exercise 5

Create some test tracking information for the High-Pressure Separator SIF of the General Oil and Gas Operating Company Chemical City Gas Plant. Refer to *Appendix A* the required plant information. The test tracking information that should be incorporated for this exercise include the following.

- For all four instruments that were created, insert a commissioning date of two years in the past
- For the LT, logic solver, and valve, insert a passed test with today's date
- For the PT insert a failed test (today's date) with a failure mode of Dangerous Detected, a description of Failed to Function, and failed component of "Sensor Type"

Section 6 – Event Tracking

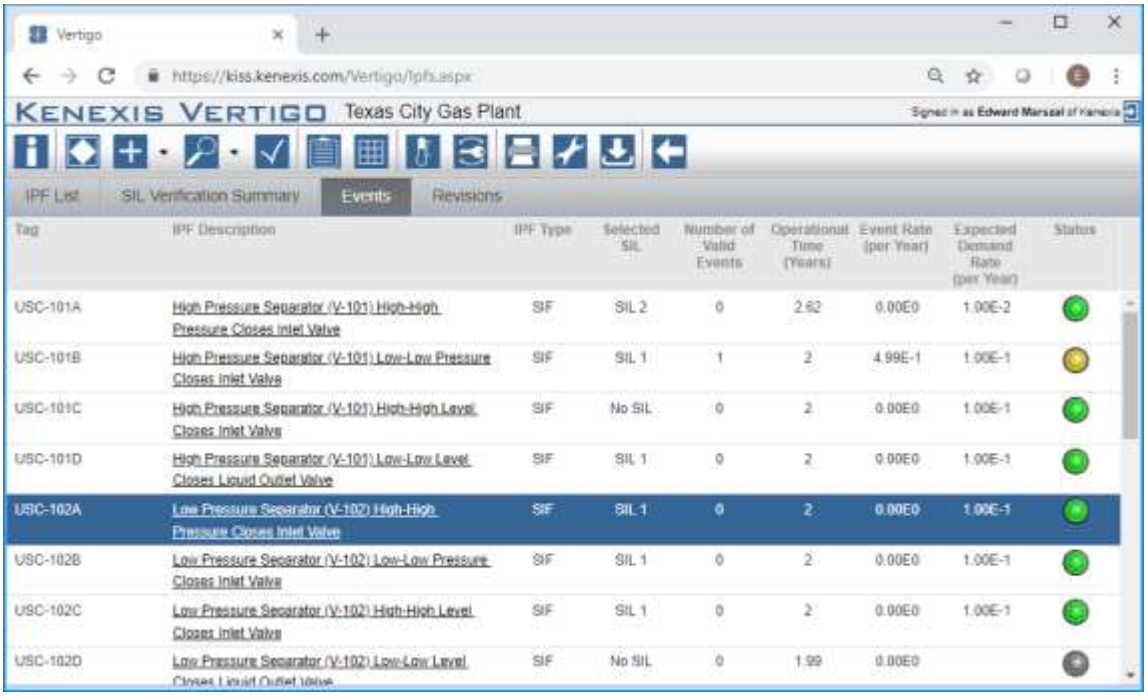
Section 6 – Event Tracking

This section will provide a detailed explanation of the portions of the Vertigo application that are used to track and document activation events of SIF or other protective functions managed using Vertigo.

6.1 Event Tracking Overview

The event tracking and documentation section of Vertigo is accessed by selecting the IPF List button on the navigation bar and then selecting “Events” from the . This will bring you to the testing page which displays grids for all of the components of each type. There are grids for sensor, logic solvers, and final element.

6.2 The Event Tracking Grid



The event tracking grid displays each IPF’s events, event rate, and status.

Section 6 – Event Tracking

6.3 The IPF Event Details Forms

Each individual IPF has a details form for input of commission/decommission dates and expected demand rate along with a list of events. The event input includes date and time, means of collection, validity, API 754 severity, and notes.

6.4 Exercise 6

Create some event tracking information for the High-Pressure Separator SIF of the General Oil and Gas Operating Company Chemical City Gas Plant. Refer to *Appendix A* the required plant information. The event tracking information that should be incorporated for this exercise include the following.

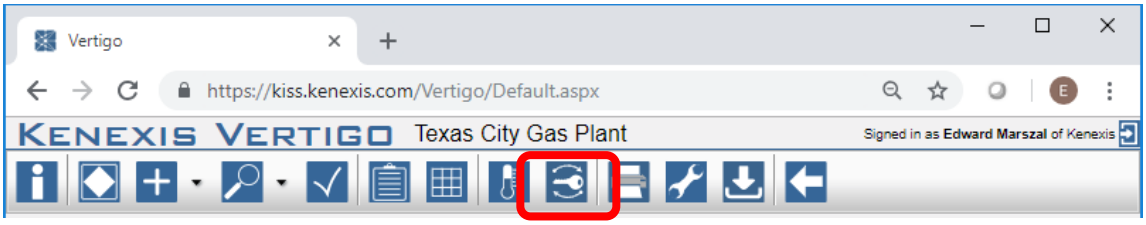
- For both IPF that were created, insert a commissioning date of two years in the past and an expected demand rate of 0.1 events per year.
- For IPF USC-101A, add an event that occurred today, has an API 754 severity of 3 and a note stating, “The high pressure separator V-101 high pressure shutdown activated due to excessive inlet pressure from the incoming pipeline.”

Section 7 – Bypass Tracking

Section 7 – Bypass Tracking

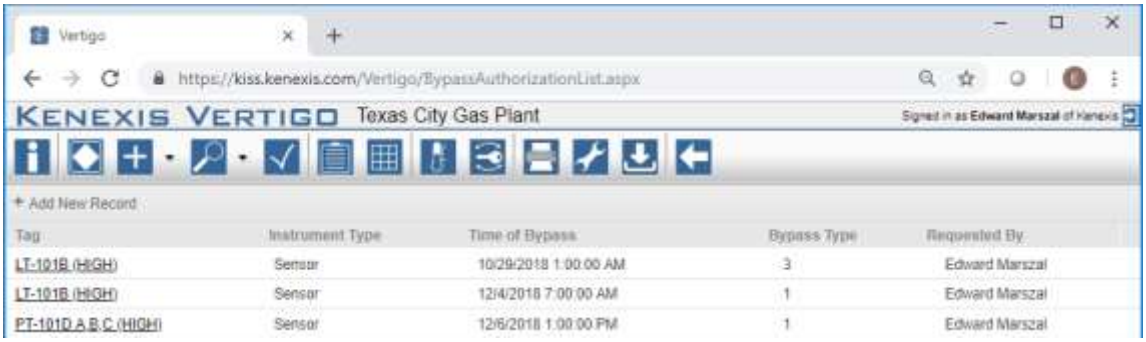
This section will provide a detailed explanation of the portions of the Vertigo application that are used to track and document IPF bypasses using Vertigo.

7.1 Bypass Tracking Overview



The bypass tracking section of the vertigo application is accessed by clicking on the Bypass button on the Navigation Bar. This will bring you to the Bypass Authorizations grid page.

7.2 Bypass Authorization Grid



The bypass authorization grid shows a list of all the bypass authorization records. The list contains identification information about the device that was bypassed along with bypass type, time, and requestor.

7.3 Bypass Authorization Form

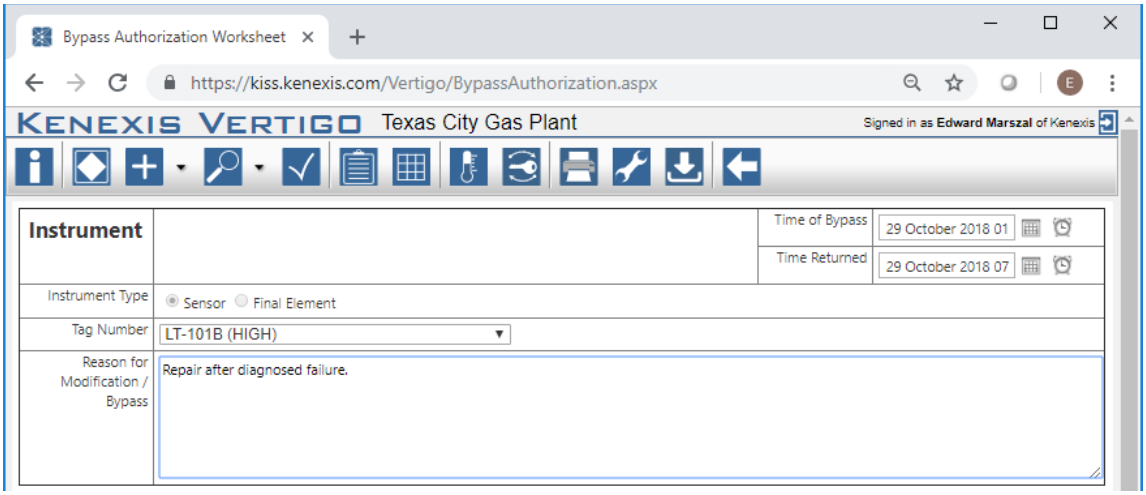
The bypass authorization form is a dynamic form that includes all data that might be required to properly document that assessment and authorization of a bypass, including the following sections.

- Bypass Identification
- Bypass Type Selection
- Alternate Protection Plan
- Bypass Risk Analysis

Section 7 – Bypass Tracking

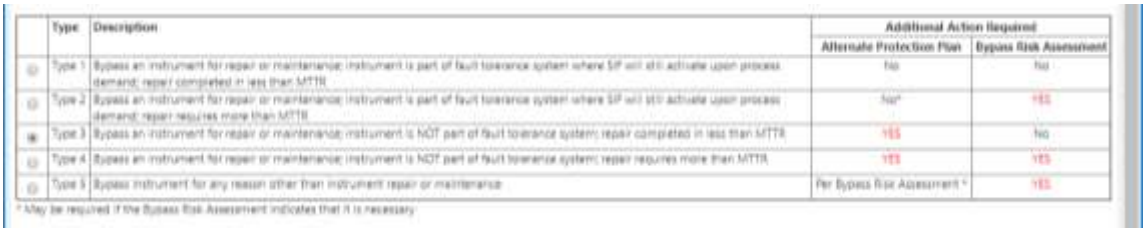
- Approvals

7.3.1 Bypass Authorization – Identification



The bypass authorization form identification section contains information related to what device was bypassed, when, and why.

7.3.2 Bypass Authorization – Type Selection



The bypass authorization type selection section allows the user to select what type of bypass is being performed, considering redundancy, ability to repair within MTTR, and reason for the bypass. This information is used to display other related sections.

7.3.3 Bypass Authorization – Alternate Protection Plan

If a bypass is to be implemented on a device where there is no redundancy to replace the device's functionality during the bypass, then an alternate protection plan must be documented using the following form.

Section 7 – Bypass Tracking

Alternate Protection Plan

Item	Value / Description
What process variable or variables must be monitored?	V-101 Sight Glass
What are the manual trigger points for the monitored variables?	70% full
Who is responsible for performing the process variable monitoring?	Outside Operator - Dedicated
Who is responsible for performing the manual shutdown action?	Board Operator
What specific actions must be taken to manually shutdown?	Close inlet control valve
Can a manual shutdown be performed within the process safety time?	Yes
Is there sufficient independence between the normal operating staff and the alternate protection?	Yes
A Bypass Risk Assessment has been performed and is acceptable (if required)	Not Required

7.3.4 Bypass Authorization – Bypass Risk Assessment

If a non-standard bypass is to be performed, specifically a bypass for reasons other than maintenance and repair one a bypass that will exceed the mean time to repair (MTTR) assumed in SIL verification calculations, then a bypass risk assessment form is displayed in order to assess and document the risk of the bypass.

Bypass Risk Assessment

Item	Value / Description
Reason for implementing the bypass	
Hazard that the bypassed instrument is intended to protect against	
Potential consequences if the alternate protection fails and the hazard is realized	
What are the potential causes of a situation that could place a demand on the bypassed function	
Is an alternate protection plan necessary, to mitigate the risk, and if so, can it be done effectively	
Is the risk associated with the bypass tolerable considering the Alternate Protection Plan	☐ Tolerable
Bypass Risk Assessment Team Members	

7.3.5 Bypass Authorization – Authorization

The authorization section includes the names of approvers of the bypass form.

Approvals

Requested By	Edward Marszal
Approved By	Edward Marszal
Approval Notes	

Section 7 – Bypass Tracking

7.4 Exercise 7

Create a bypass authorization for the high-level transmitter of the High-Pressure Separator SIF of the General Oil and Gas Operating Company Chemical City Gas Plant. Refer to *Appendix A* the required plant information. The event tracking information that should be incorporated for this exercise include the following.

- Assume that the bypass will be implemented today at 6 PM and is expected to remain in bypass for 2 hours.
- Review the information in Appendix A and your best judgment to document an alternate protection plan, if required.

Section 8 – Reporting

Section 8 – Reporting

This section will provide information on the reports that are available in Vertigo along with how to configure and customize them.

8.1 Reporting Overview

All reports are accessed from the same location, the reporting page. This page can be accessed by clicking the Reports button in the navigation bar.

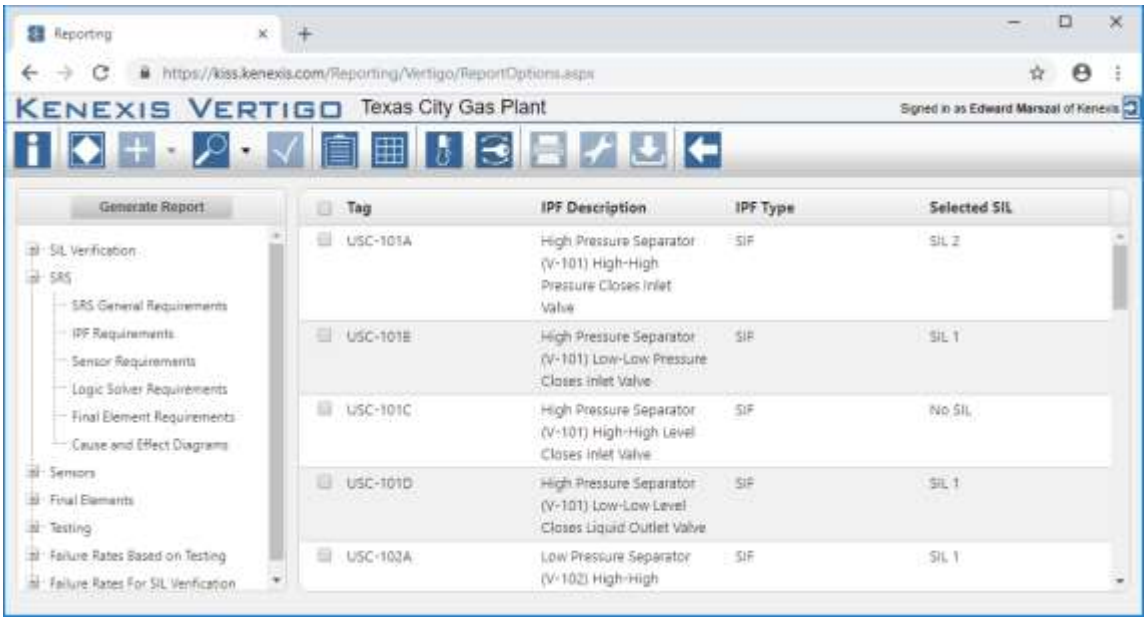
8.2 SIL Verification Reports

SIL Verification reports include:

- IPF List
- SIL Verification Summary
- SIL Verification Details
- Recommendations
- Documents

Section 8 – Reporting

8.3 Safety Requirements Specifications Reports



Safety Requirements Specifications reports include:

- SRS General Requirements
- IPF Requirements
- Sensor Requirements
- Logic Solver Requirements
- Final Element Requirements
- Cause and Effect Diagrams

Section 8 – Reporting

8.4 Sensor Reports

Sensor reports include:

- Setpoint List

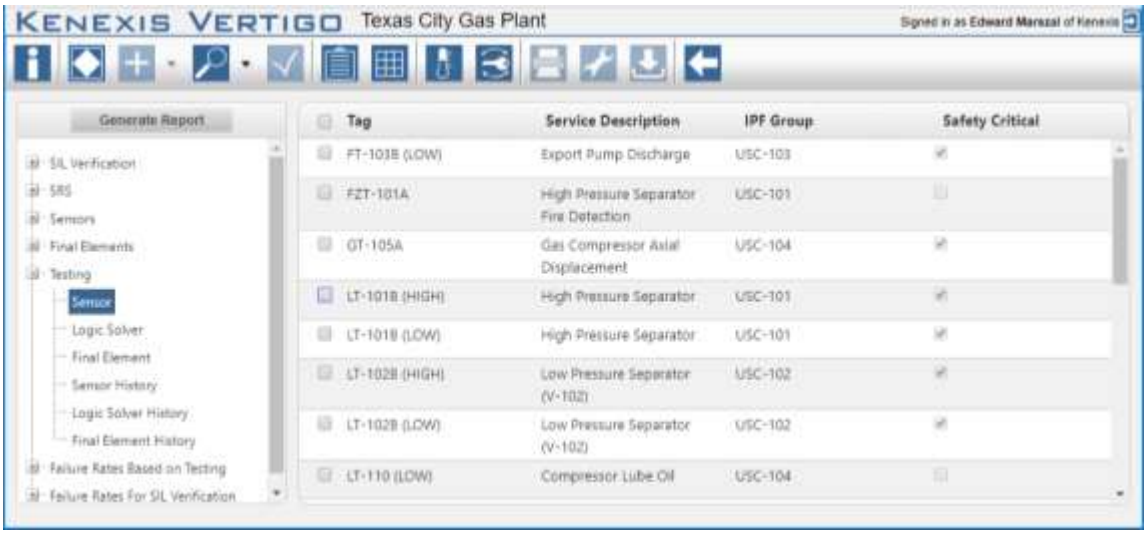
8.5 Final Element Reports

Final Element reports include:

- Activation Time List

Section 8 – Reporting

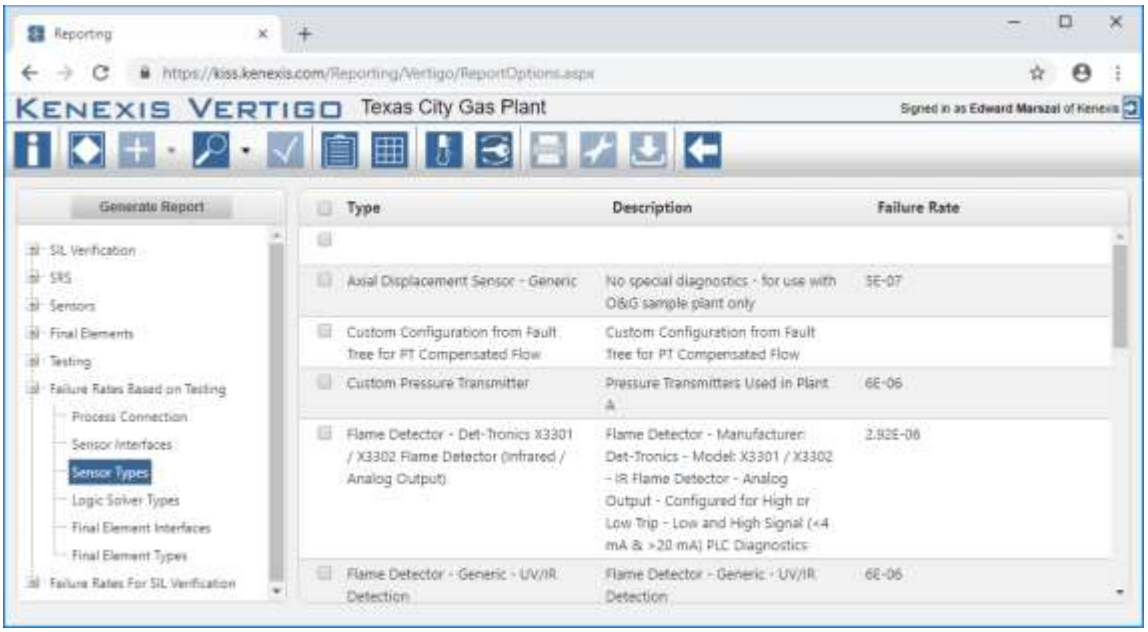
8.6 Testing Reports



Testing reports include:

- Sensor
- Logic Solver
- Final Element
- Sensor History
- Logic Solver History
- Final Element History

8.7 Failure Rate Based on Testing Reports

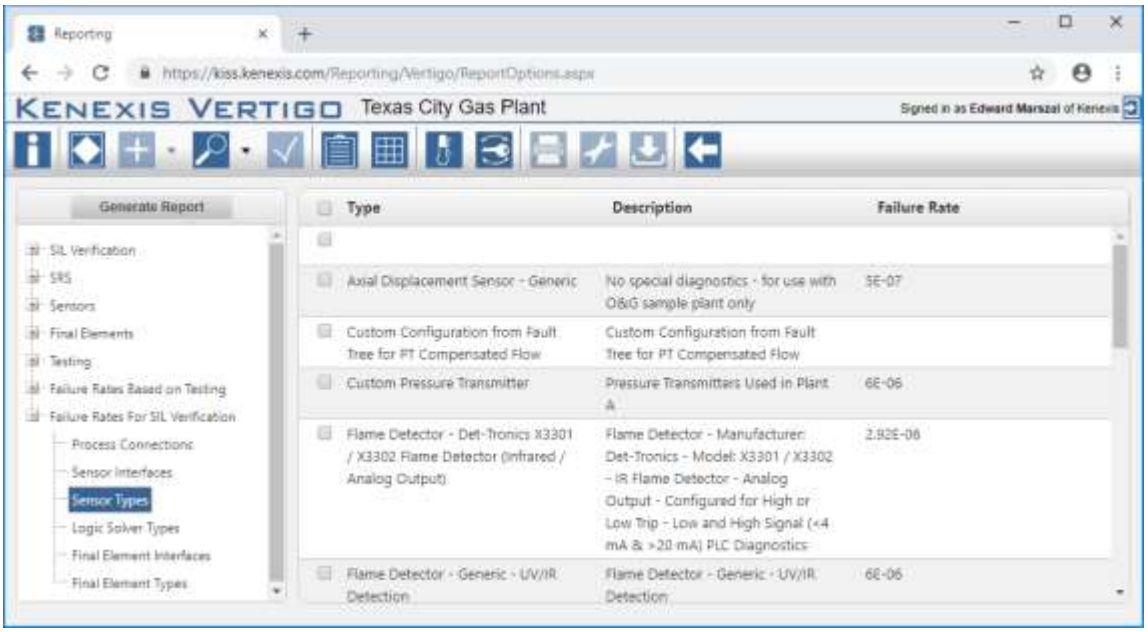


Section 8 – Reporting

Failure Rate Based on Testing Reports Include:

- Process Connections
- Sensor Interfaces
- Sensor Types
- Logic Solver Types
- Final Element Interfaces
- Final Element Types

8.8 Failure Rates for SIL Verification Reports



Failure Rate for SIL Verification reports Include:

- Process Connections
- Sensor Interfaces
- Sensor Types
- Logic Solver Types
- Final Element Interfaces
- Final Element Types

8.9 Exercise 8

Create some reports for the General Oil and Gas Operating Company Chemical City Gas Plant SIS. Refer to *Appendix A* the required plant information.

- Generate a SIL Verification Details report for the entire SIS along with an IPF List of the entire SIS

Section 8 – Reporting

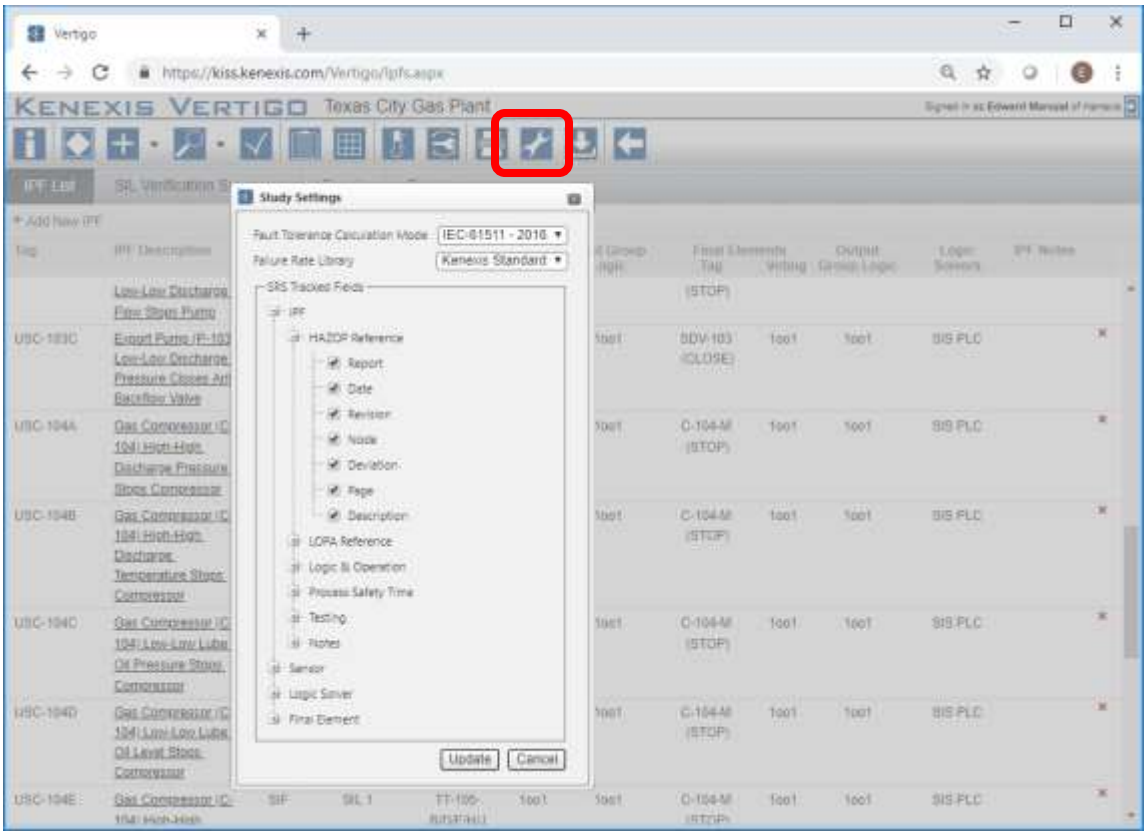
REPORTING

- Generate a cause-and-effect diagram
- Generate a failure rate based on testing report of the sensor type “Level Transmitter Generic”

Section 9 – Settings

Section 9 – Settings

In Vertigo, display, reporting, data base, and calculation methods can be customized based on user preferences. These preferences can be viewed and modified in the Study Settings form. The study settings form is accessed by clicking on the Setting Settings button in the navigation bar.



From the Study Settings window the user can modify:

- Which calculation mode is used for fault tolerance
- Which data library is used
- Which fields are shown in the detailed worksheets

Section 10 – Post Quiz

POST QUIZ

Post Instructional Quiz

1. What section of the Vertigo application is used to move between the different sections and pages?
   a. The grid control
   b. The overview page
   c. The project manager application
   d. The navigation bar
2. Many of the grids in the Vertigo application allow for sorting, filtering, and even editing multiple records at one time through a context menu. How is the connect menu displayed?
   a. By selecting context menu from the navigation bar
   b. By right-clicking on an item in a grid
   c. By hovering over a hyperlink in a grid
   d. By entering “context menu” into the command line
3. The document list makes it easy to view documents that are referenced by the SIS design basis by…
   a. Storing the name of the document to allow the user to look it up manually
   b. Storing the document in the Vertigo database for easy automatic access
   c. Storing a hyperlink to the location of the document in the user’s document management system
   d. Vertigo does not store information about reference documents
4. Collections of instruments that are all common or related to each other so that they can be grouped for purposes such as cause-and-effect diagram development are called what in Vertigo?
   a. Safety Instrumented Systems
   b. Safety Instrumented Functions
   c. IPF Groups
   d. Major equipment items
5. What is the Vertigo page that is the central point for SIL verification and includes an inventory of all the functions in the study, including the inputs and outputs instruments to the functions?
   a. SIL Verification Summary
   b. IPF List
   c. Revision Tab
   d. Study Settings Page

Section 10 – Post Quiz

POST QUIZ

6. How can data be entered into a Vertigo study with respect to failure rates of different types of Instruments?
   a. It can be pulled in from the Kenexis Standard database
   b. It can be pulled in from a custom database developed by users
   c. It can be entered directly into the project database
   d. All of the above
7. When a subsystem is too complex to be modeled as a standard voting arrangement the data for subsystem PFD and STR can be directly entered into the database instead of entering failure rates and requiring calculation, what type of entry is this referred to in Vertigo?
   a. Markov Model
   b. Complex System Assessment
   c. Black Box Model
   d. Distributed Computing Model
8. PFD and STR can be calculated in what other Kenexis software application and directly connected to a Vertigo database?
   a. Kenexis Open PHA HAZOP/LOPA Software
   b. Kenexis Open Audit Audit Tracking and Documentation Software
   c. Kenexis Effigy Fire and Gas Mapping Software
   d. Kenexis Arbor Fault Tree Analysis Software
9. How can you tell if an SIS component type, such as a level transmitter, has failure rate data that is no longer consistent with the library from which it was imported?
   a. The user needs to manually compare the databases
   b. On the Sensor Type page the “Current with Library” button will be red
   c. The calculation validation report will flag the data as old
   d. There is no way to verify that the project data is current with the library
10. Where in vertigo can you access the Beta Factor Estimation tool for estimating a common cause failure percentage for SIS component subsystems?
    a. Next to the Beta Factor Label on any details form (sensor, logic solver or final element)
    b. Select Beta Factor Tool from the Navigation Bar
    c. The Beta Factor tool is a separate application in the Kenexis Integrated Safety Suite
    d. Vertigo does not provide tools to assist in Beta Factor estimation, a literature search is required

Section 10 – Post Quiz

POST QUIZ

11. Which format of logic description is employed in the safety requirements specifications section of Vertigo?
    a. Text Narrative
    b. Cause-and-Effect Diagrams
    c. Sequential Function Charts
    d. Binary Logic Diagrams
12. If a result of a SIL verification calculation is being displayed as “NaN”, or not a number, an error exists in the data entered to perform the calculation. How can the user obtain a list of errors identified by Vertigo during calculation?
    a. Submit a request to support@kenexis.com
    b. Generate a SIL Verification Data Verification log by clicking on its icon in the Navigation Bar
    c. View the SIL Verification Summary Page
    d. Export the data file to Excel and check the error log
13. What test duration should be used for automatically performed diagnostics that are performed every device scan in devices like smart transmitters and logic solvers?
    a. 0 hours
    b. 1 Hour
    c. 8 hours
    d. 72 hours
14. Which term should be included into the SIL verification calculation (by clicking on its checkbox) when tests are not always performed while the plant is shutdown for turn-around, and require a bypass of the function because the plant is in operation?
    a. Include Common Cause
    b. Trip on Detected Failure
    c. Online Testing
    d. Imperfect Testing
15. Which of the following is not an SRS section in Vertigo?
    a. Operating Procedures
    b. General Requirements
    c. Data Sheets
    d. Cause-and-Effect Diagrams

Section 10 – Post Quiz

POST QUIZ

16. Where does the user go to add or remove items that are shown on SRS datasheets and their associated reports?
    a. Overview Page
    b. Study Settings
    c. Datasheet content cannot be modified
    d. Add or Remove data in exported reports using Word or Excel
17. What part of the bypass authorization form is displayed when the type of bypass requires a non-redundant instrument that the SIF is entirely dependent upon to be put into bypass?
    a. Identification Section
    b. Alternate Protection Plan Section
    c. Bypass Risk Analysis Section
    d. Authorization Section
18. Which standard from API defines the standard classifications or types of events that are tracked and report up through management?
    a. API 14C
    b. API 500
    c. API 754
    d. API 2500
19. When a Vertigo report is generated, all the data in the database in included in the report because filtering and selecting specific data is not possible?
    a. True
    b. False
20. Which report will show a failure rate of a type of SIS component based on the actual test data collected in Vertigo's test tracking functionality?
    a. SIL Verification Reports
    b. Safety Requirements Specification Reports
    c. Failure Rate Based on Testing Reports
    d. Failure Rates for SIL Verification Reports

Appendix 1 – Sample Process

Background Information

This section contains background information on a sample facility that is used as a basis for discussion for seminars and training classes. The sample facility is intended to present typical equipment utilized in the process industries in order to provide a realistic training environment, while keeping the process very small so that an entire facility can be analyzed during a single seminar or class.

The sample facility contains equipment that is similar to that which would be used for a natural gas production process and a high-head pumping system that would be similar to charge systems in some high-pressure refining units such as hydrotreaters and hydrocrackers.

It is important to note that this type of facility would not serve a real process purpose in isolation and is thus not entirely genuine. It is important for attendees at the training classes and seminars that use this sample plant to focus on the principles and techniques that are being discussed, and not to dwell on perceived inconsistencies or process engineering related issues related to the sample plant. This will ensure a beneficial training experience.

Process Description

Overview

The General Oil & Gas Operating Company's production facility located in Chemical City, TX processes hydrocarbon fluids coming out of natural gas wells located in production platforms. The wells discharge the production fluids into a main production header, which in turn supplies the facility with feedstock. In the first stage of the separation process (high pressure stage), the production fluids enter a high-pressure separator where the liquid and gas components are separated at a specific temperature and pressure. The gas leaving the high-pressure separator is predominantly composed of lighter hydrocarbons and does not need any additional treatment. The gas leaves the facility via the export gas pipeline to neighboring gas processing companies. In the second stage of the separation process (low pressure stage), the liquid from the first stage enters the low-pressure separator and flashes at a specific temperature and pressure. The gas stream from the low-pressure separator is compressed and the compressed gas combines with the gas leaving the high-pressure separator. The liquid from the low-pressure separator is considered to be stabilized for processing purposes and it is pumped into the high-pressure export liquid pipeline. The

major equipment used in this process, includes a High-Pressure Separator, Low-Pressure Separator, Export Pump and Gas Compressor are described in the following sections.

High-Pressure Separator (V-101)

Hydrocarbon fluids enter the high-pressure separator (V-101) through a pressure reducing valve (PV-101A) which reduces the pressure from approx. 700 psig (production header pressure) to 350 psig (first stage operating pressure). The pressure in the separator is maintained by the pressure control valve PV-101B. Flashing occurs in the vessel causing separation of gas and liquid components. Reduction in flow velocity causes the liquid droplets to drop out of the gas stream. The separator vessel provides the retention time needed for effective gas-liquid separation and provides a surge volume necessary to handle intermittent surges of liquid. The liquid level in the vessel is maintained by the level control valve LV-101A.

As the hydrocarbon fluids come into contact with the inlet diverter, most of the liquid falls into the liquid section and the gas flows over the inlet diverter. The gas stream continues to flow horizontally above the liquid section and small drops of liquid not separated by the inlet diverter are separated out by gravity. Drops of liquid that are too small to be separated by gravitational force are removed from the gas stream by a de-mister pad.

The gas leaves the high-pressure separator and enters the export gas pipeline to neighboring gas processing facilities. Over pressure protection of the high-pressure separator is provided by relief valve PSV-101.

Low Pressure Separator (V-102)

The liquid from the high-pressure separator enters the low-pressure separator through the level control valve LV-101A. The operating pressure in the low-pressure separator is maintained at 50 psig to flash off the lighter hydrocarbons into the gas phase and partially stabilize the liquid phase. The vapor and liquid disengage similar to V-101. The gas is sent to compressor C-104 and the partially stabilized liquid is pumped out using pump P-103. Over pressure protection of the low-pressure separator is provided by relief valve PSV-102.

Appendix 1 – Sample Process

Export Pump (P-103)

The partially stabilized hydrocarbon liquid from V-102 is pumped using high-pressure pump P-103 to the export liquid pipeline. P-103 is a multistage pump that discharges the liquid at a pressure of 2200 psig needed to transport the hydrocarbon liquid several miles before it can be further processed. The export pipeline is a common pipeline used by a number of production facilities that are all pushing liquid into the pipeline, as a result backflow from the pipeline back into the production facility is a concern. A pressure relief valve PSV-103 protects the pump from damage in case of a blocked flow in the export liquid pipeline.

Gas Compressor (C-104)

The gas stream leaving the low-pressure separator V-102 at a pressure of 50 psig enters compressor C-104 where its pressure is increased to 350 psig to match the gas pressure leaving the high-pressure separator. The pressure controller PIC-104A controls pressure from the compressor to the export gas pipeline. The pressure controller senses changes in separator pressure and sends a signal to either open or close the control valve PV-104A accordingly. Controller FIC-104 provides anti-surge control by "spilling back" enough material through FV-104 to the low-pressure separator and prevents surging. Over pressure protection of the suction and discharge sides of the compressor are provided by pressure relief valves PSV-104A and PSV-104B respectively.

Support Facilities

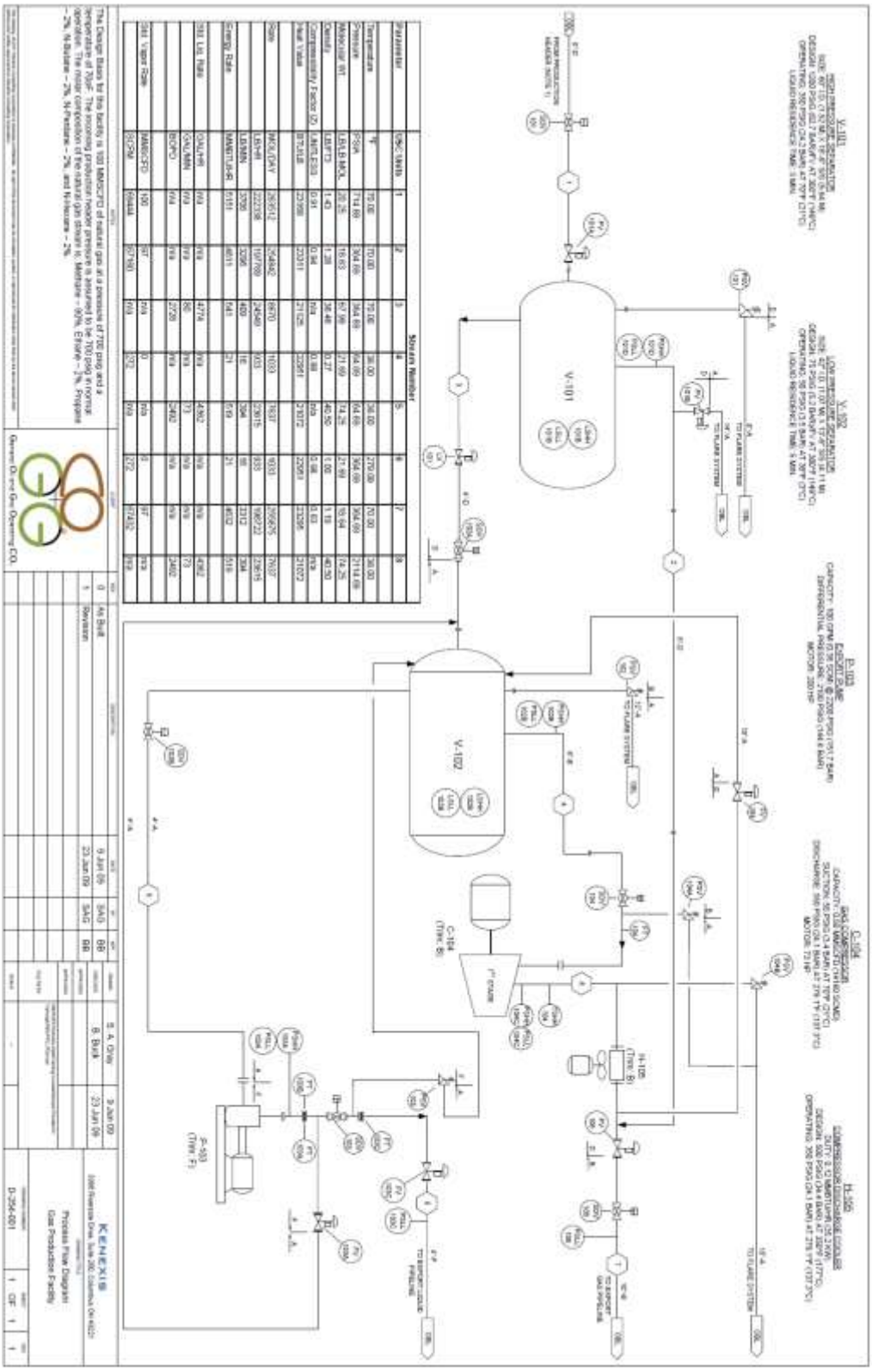
The support efforts include:

1. A site with roads
2. Security with perimeter chain link fencing a guard house and an entry gate
3. Utilities to enable the process to work: electricity; fuel oil or diesel; instrument air and water
4. Safety systems include fire water deluge, personnel protection, and escape
5. Vent systems which discharge to a flare header and flare

Appendix 1 – Sample Process

SAMPLE PROCESS

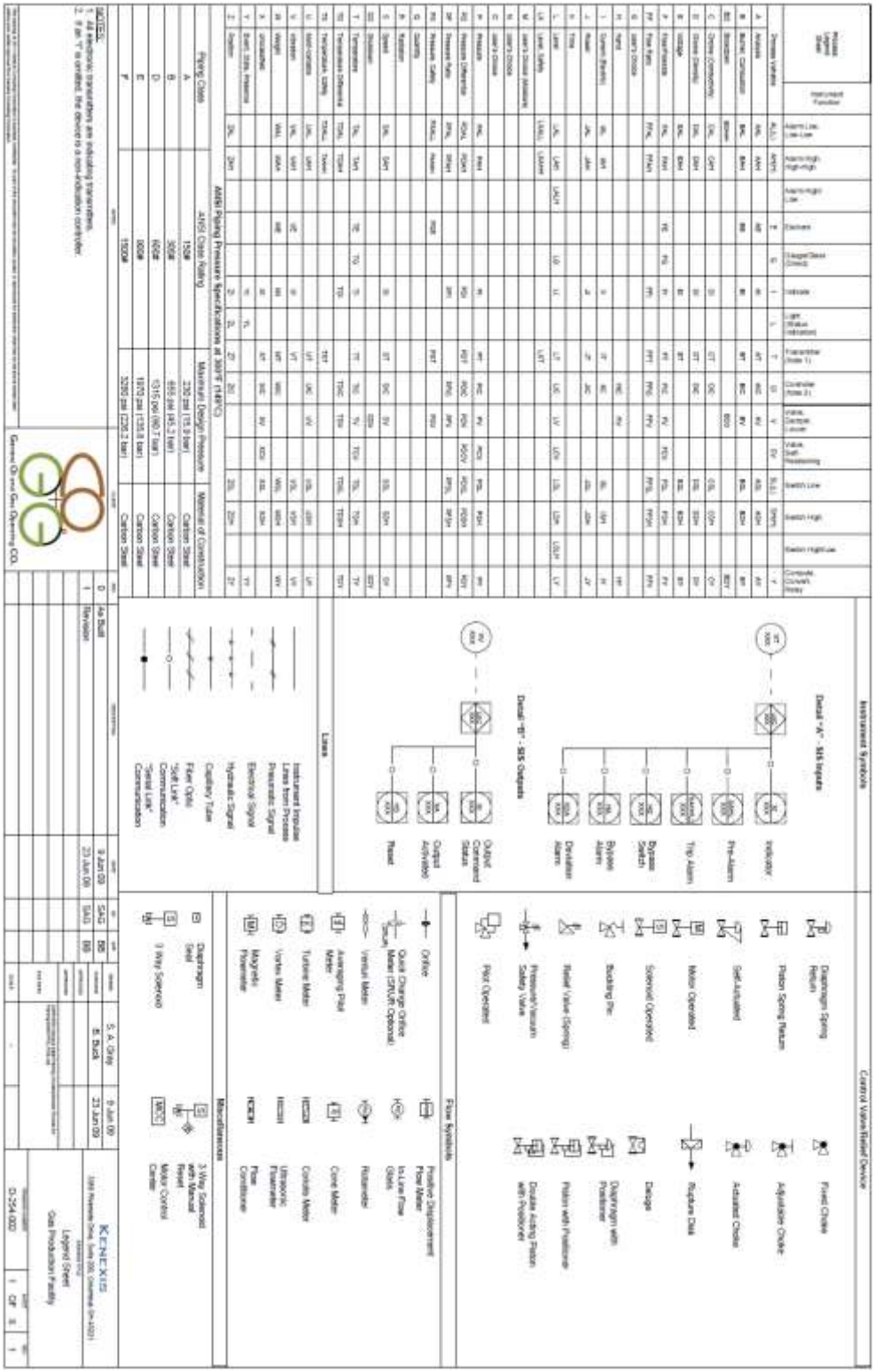
Process Flow Diagram



Appendix 1 – Sample Process

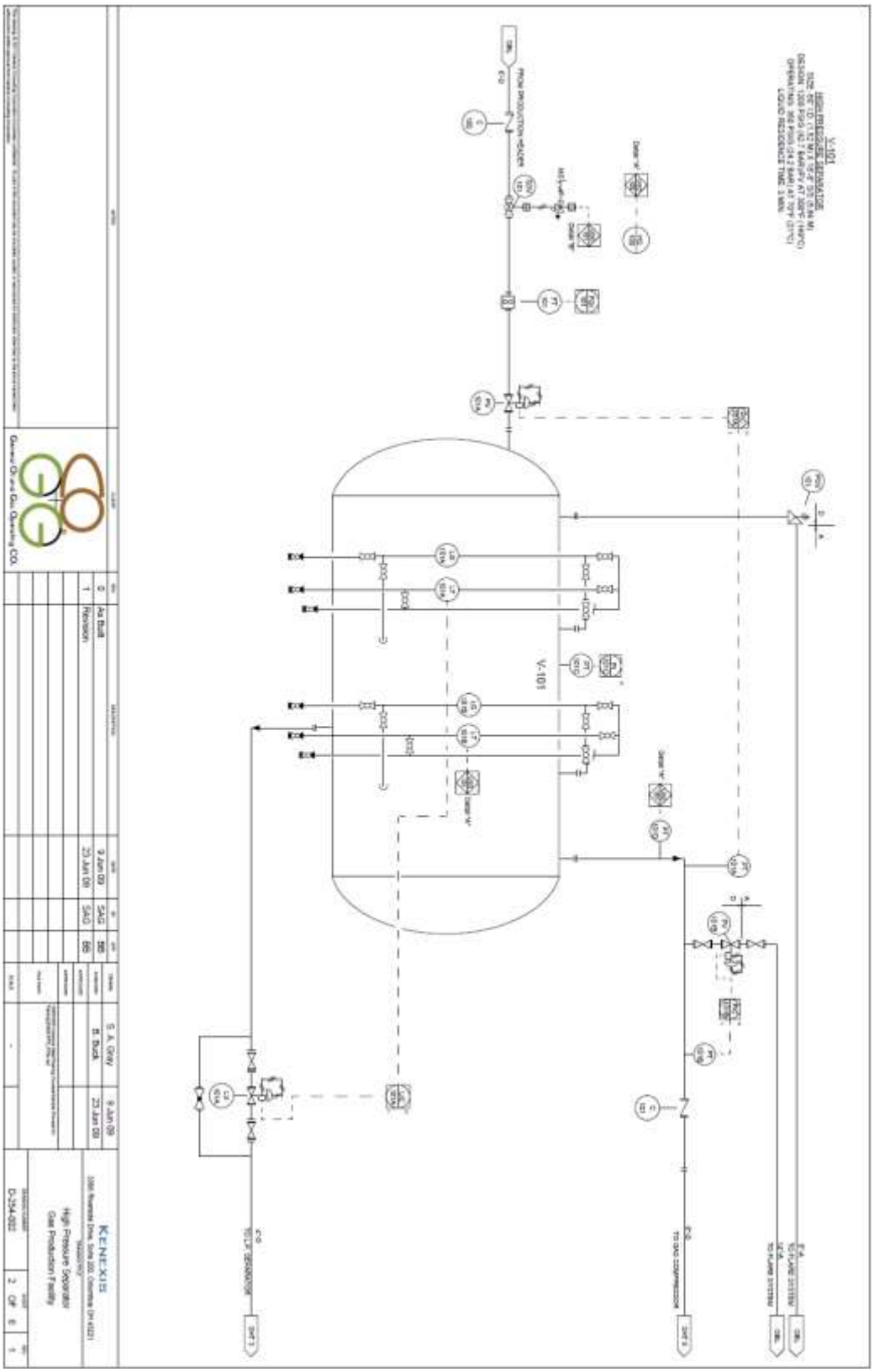
SAMPLE PROCESS

Piping and Instrumentation Diagrams



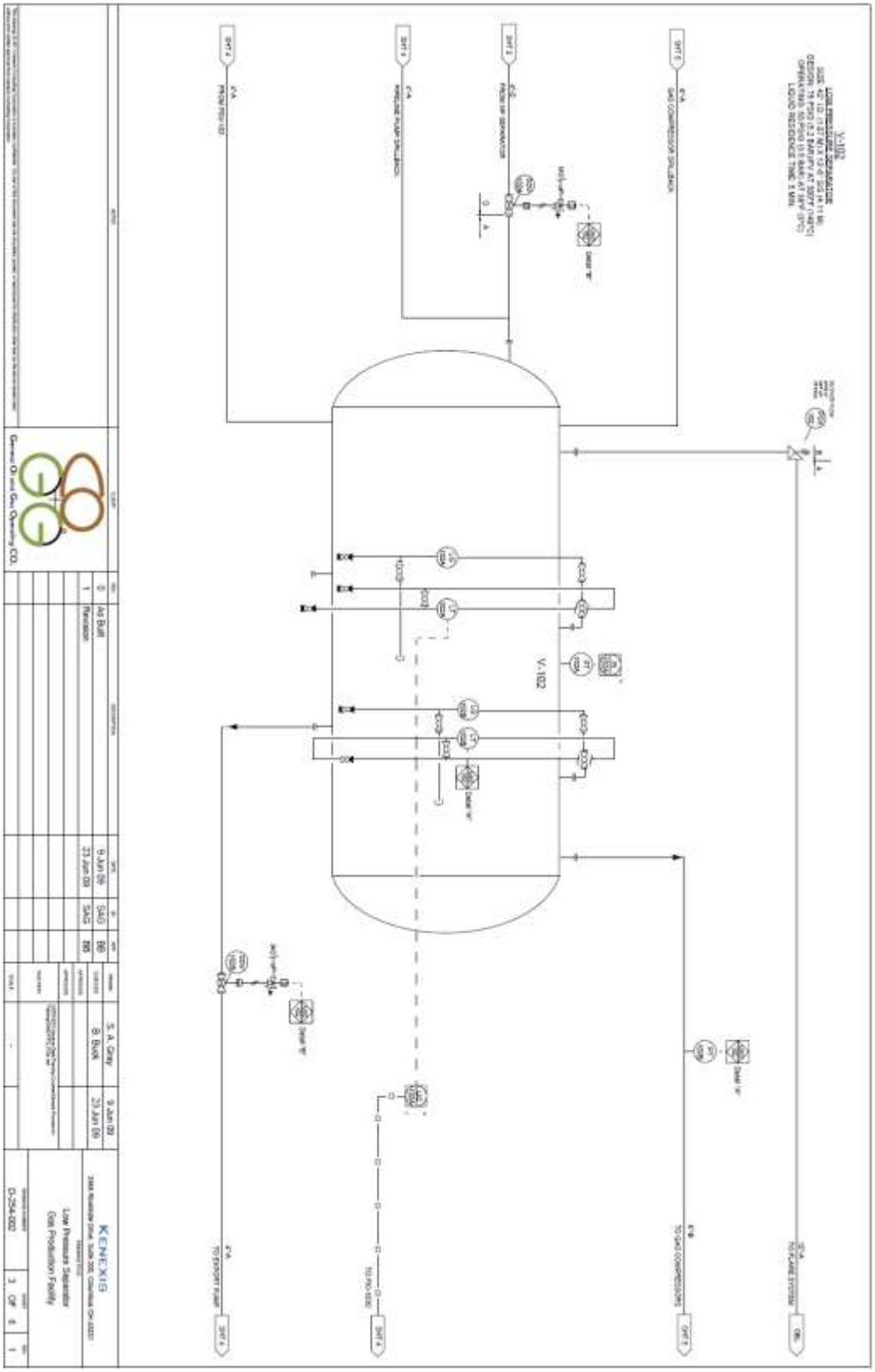
Appendix 1 – Sample Process

SAMPLE PROCESS



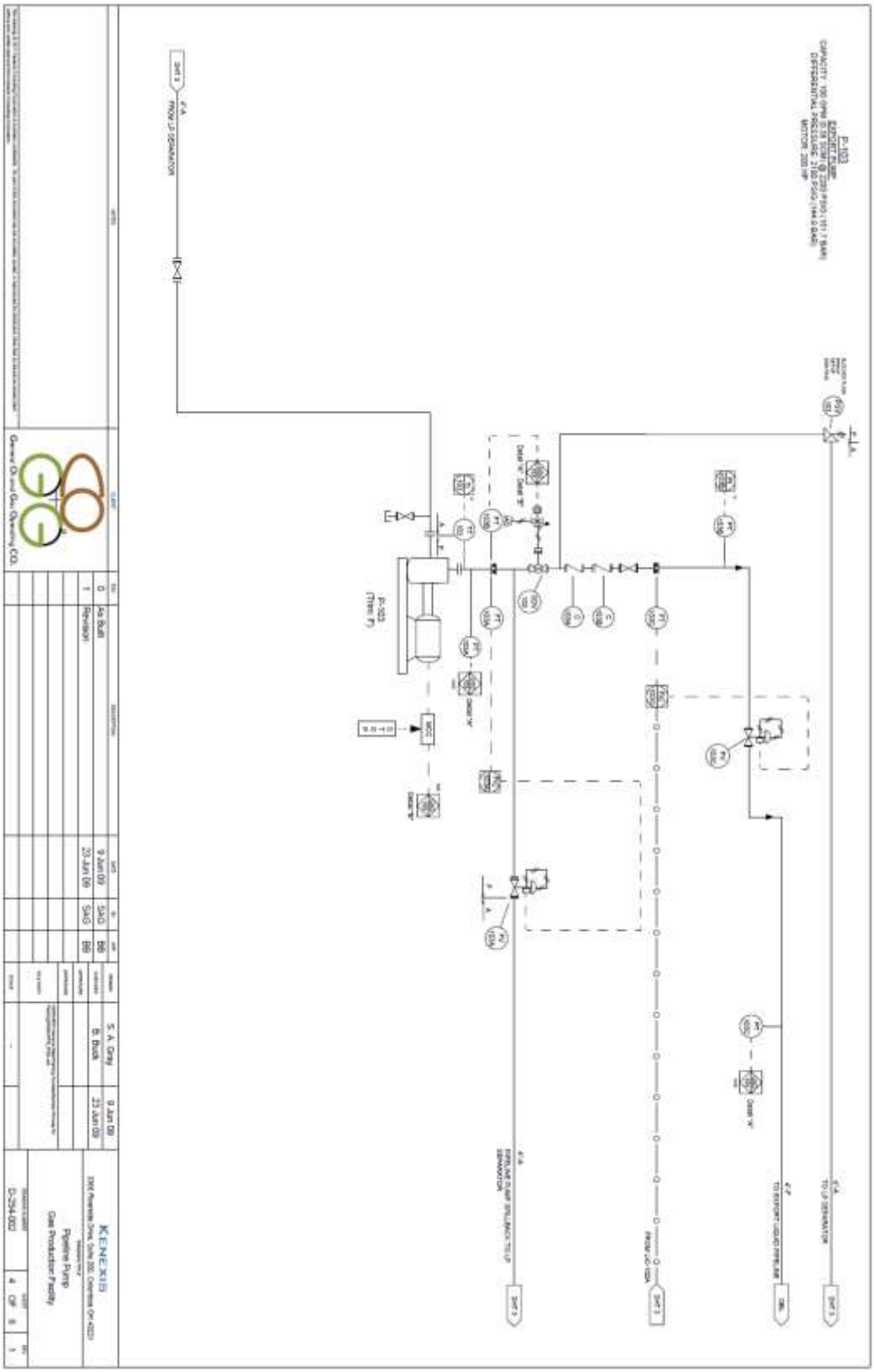
Appendix 1 – Sample Process

SAMPLE PROCESS



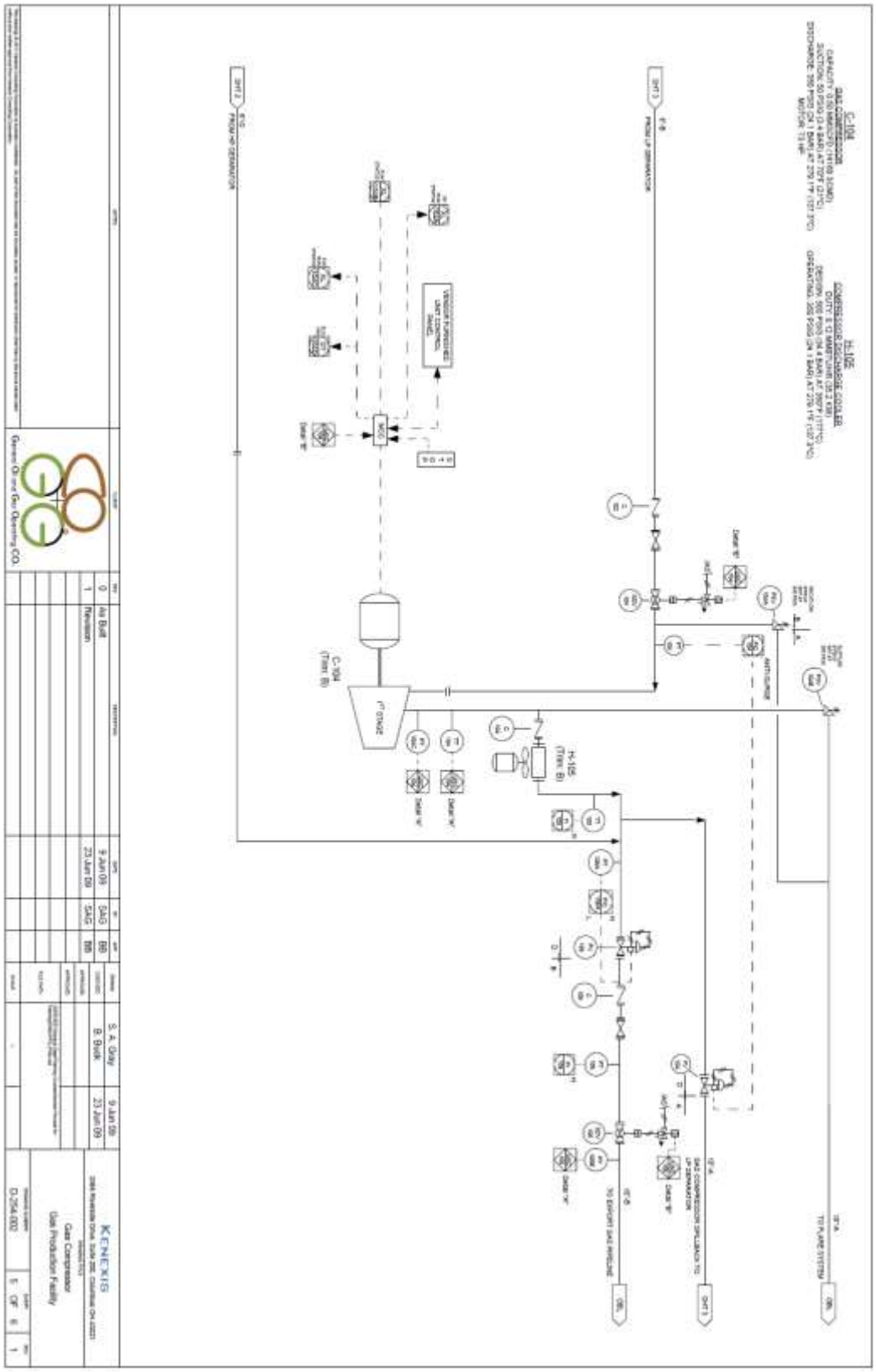
Appendix 1 – Sample Process

SAMPLE PROCESS



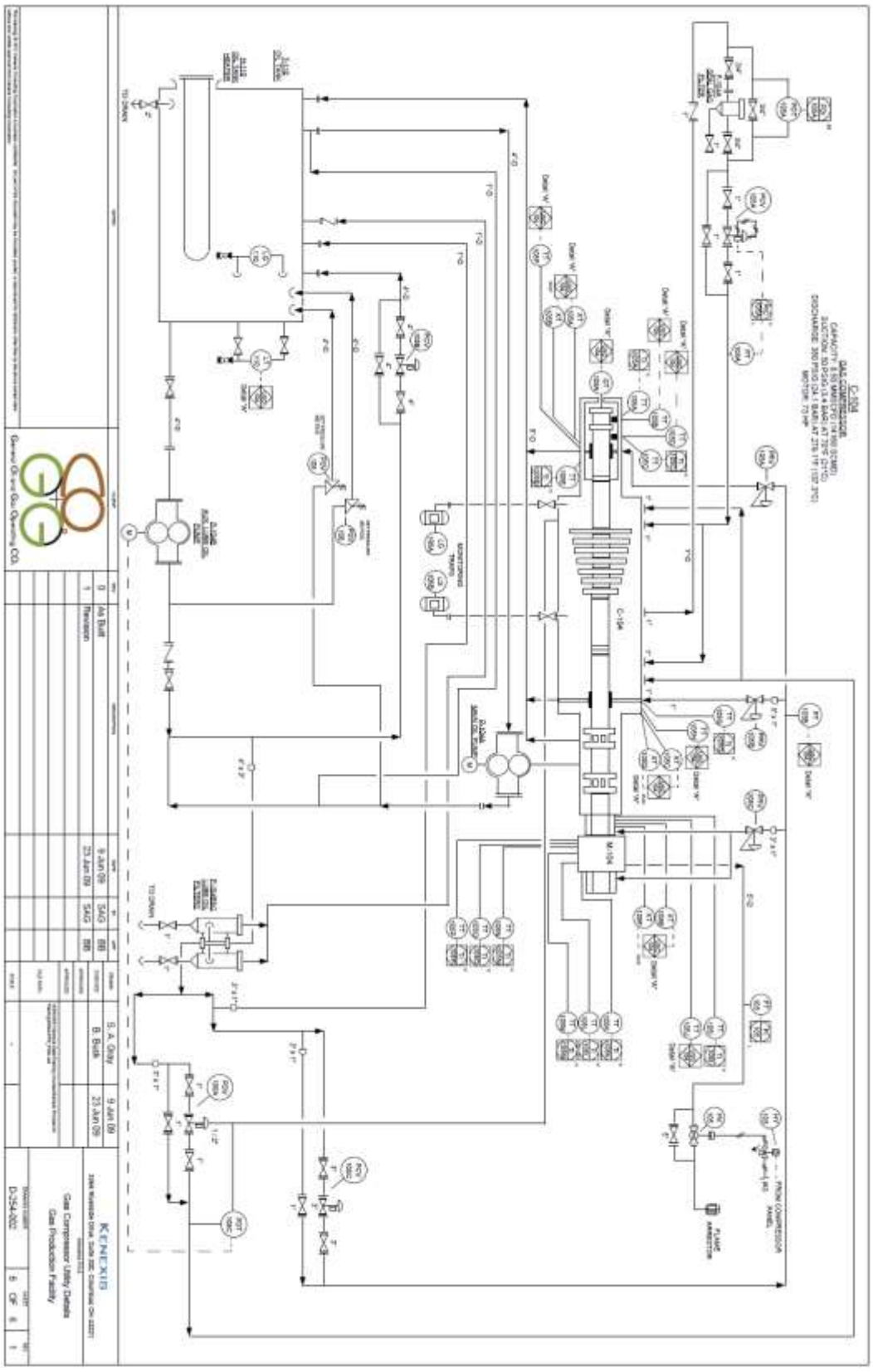
Appendix 1 – Sample Process

SAMPLE PROCESS



Appendix 1 – Sample Process

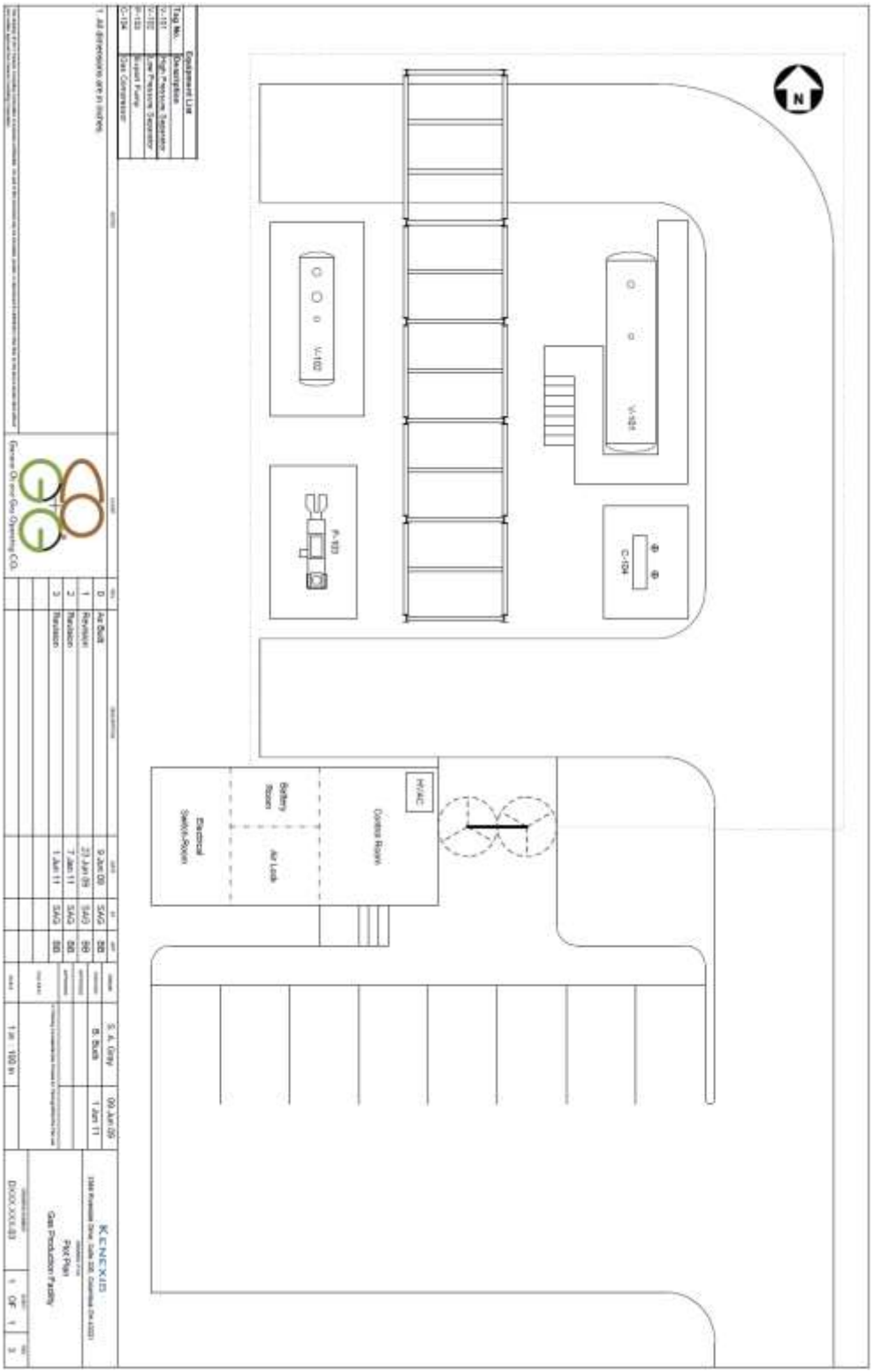
SAMPLE PROCESS



Appendix 1 – Sample Process

SAMPLE PROCESS

Plot Plan – Equipment Layout

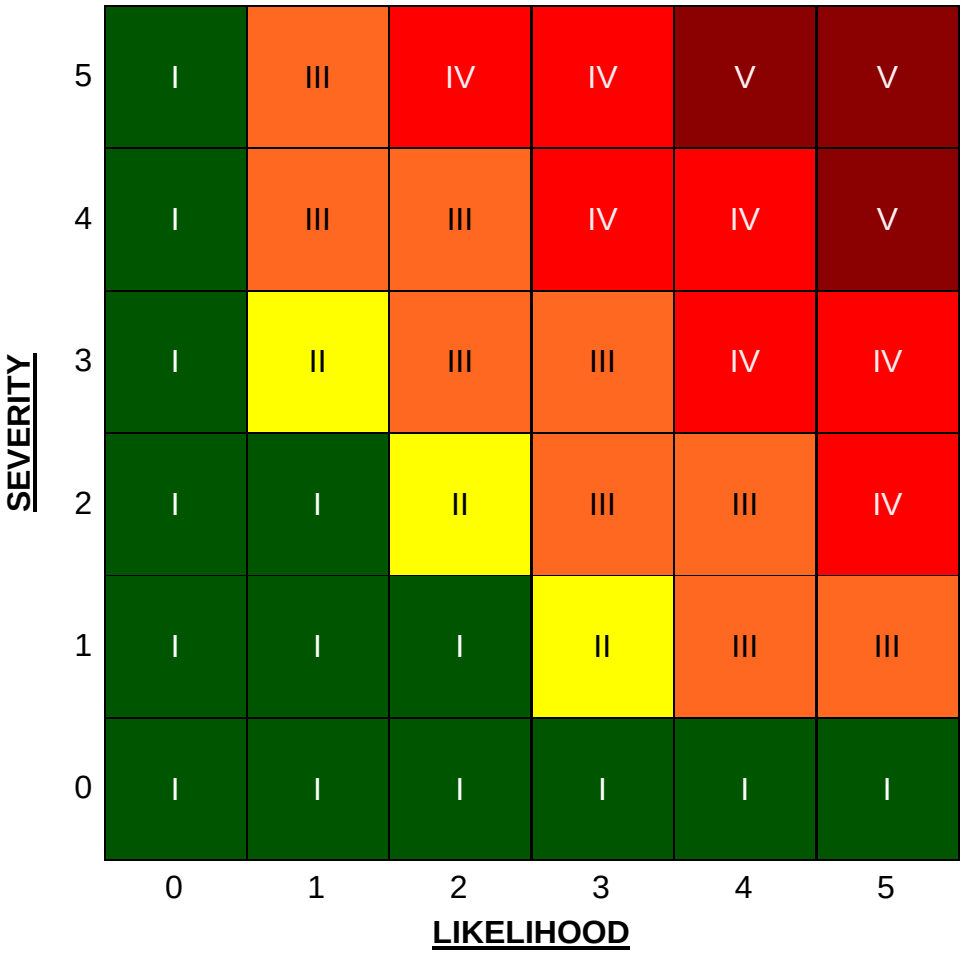


Appendix 1 – Sample Process

SAMPLE PROCESS

PHA Risk Ranking Matrix and Tables

Risk Matrix



Appendix 1 – Sample Process

SAMPLE PROCESS

Severity

S	Category	Safety Description	Environmental Description	Commercial Description
0	None	No significant safety consequence	None	None
1	Very Low	Minor injury - first aid	Small release with minimal clean up requirements	Less than $50,000
2	Low	Lost time injury not requiring extended hospitalization	Moderate release limited to onsite damage with moderate cleanup effort	$50,000 to $500,000
3	Moderate	Severe injury (extended hospitalization, dismemberment)	Large release with limited offsite impact, requires significant onsite clean up	$500,000 to $5,000,000
4	High	Single fatality	Large release offsite with extensive clean up and damage to sensitive areas	$5,000,000 to $50,000,000
5	Very High	Multiple fatalities	Very large release offsite with extensive clean up and permanent damage to several sensitive areas	Greater than $50,000,000

Likelihood

L	Category	Description	Recurrence
0	None	Not expected to occur	N/A
1	Very Low	Possible to occur, but not expected to occur in the lifetime of the plant, either at the plant or at a similar facility in industry	1,000 years
2	Low	Not expected to occur in the lifetime of the plant, but expected to occur within the lifetime of the plant at a similar facility in industry	100 years
3	Moderate	Expected to occur within the lifetime of the plant	10 years
4	High	Expected to occur about once per year	1 year
5	Very High	Expected to occur many times per year	0.1 years

Risk Ranking

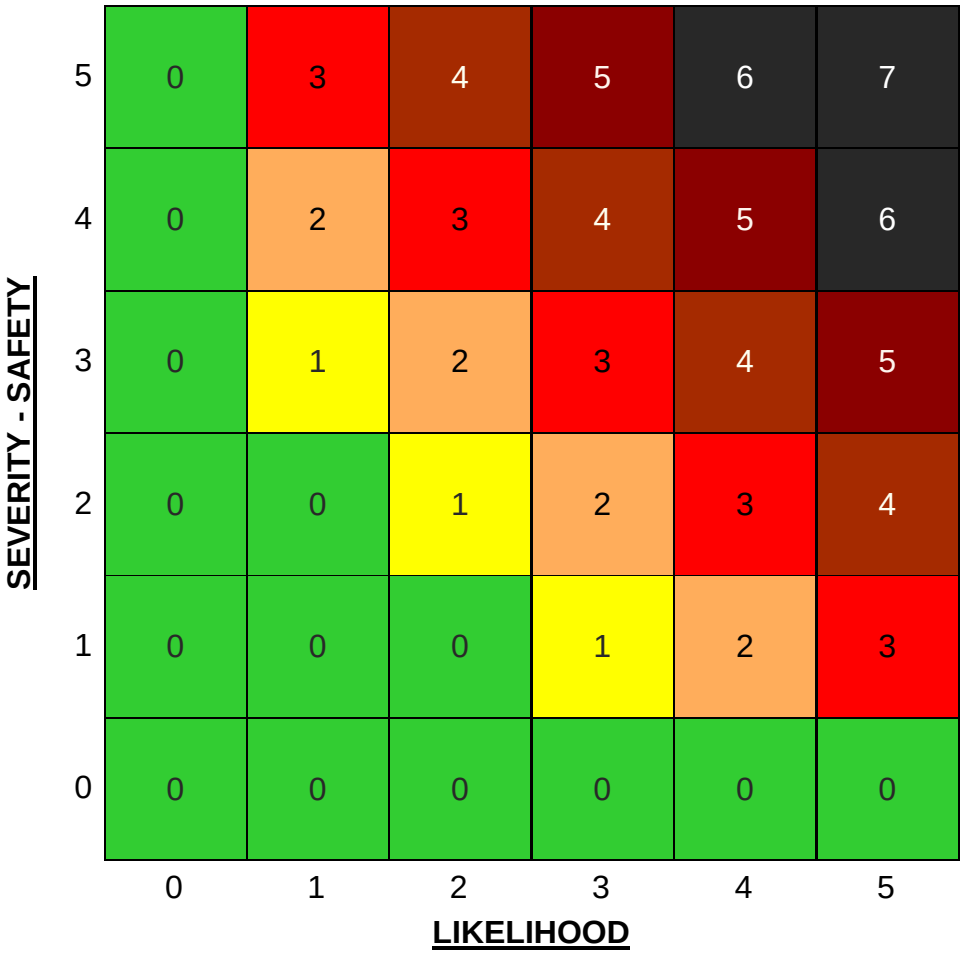
Risk Ranking	Category	Description
I	Low	Risk is low and/or sufficiently controlled - no additional risk reduction measures are required
II	Moderate	Risk is moderate - additional controls could be considered, but are not required
III	High	Risk is high and may not be sufficiently controlled - additional risk reduction measures should be considered
IV	Very High	Risk is high and is not be sufficiently controlled - additional risk reduction measures are required, and additional operations vigilance measures are required in order to operate the plant in the interim prior to implementing risk reduction measures
V	Intolerable	Risk is intolerably high - the facility cannot operate in this state. Additional risk reduction measures or process redesign to reduce risk shall be performed prior to allowing the plant to operate

Appendix 1 – Sample Process

SAMPLE PROCESS

SIL Selection Risk Ranking Matrix and Tables

Risk Matrix - Safety



Severity - Safety

Severity - S	Category	Description	TMEL-S
0	None	No significant safety consequence	
1	Very Low	Minor injury - First Aid	1E-02
2	Low	Lost time injury not requiring extended hospitalization	1E-03
3	Moderate	Severe injury (extended hospitalization, dismemberment)	1E-04
4	High	Single fatality	1E-05
5	Very High	Multiple fatalities	1E-06

Appendix 1 – Sample Process

SAMPLE PROCESS

Likelihood

Likelihood	Category	Description	Recurrence
0	None	Not expected to occur	N/A
1	Very Unlikely	Possible to occur, but not expected to occur in the lifetime of the plant, either at the plant or at a similar facility in industry	1,000 years
2	Unlikely	Not expected to occur in the lifetime of the plant, but expected to occur within the lifetime of the plant at a similar facility in industry	100 years
3	Occasional	Expected to occur within the lifetime of the plant	10 years
4	Frequent	Expected to occur about once per year	1 year
5	Very Frequent	Expected to occur many times per year	0.1 year

Risk Matrix - Environment

Severity - E	Category	Description	TMEL -E	Risk Matrix					
				Likelihood					
				0	1	2	3	4	5
				Risk Ranking	Risk Ranking	Risk Ranking	Risk Ranking	Risk Ranking	Risk Ranking
0	None	None	1E+00	0	0	0	0	0	0
1	Very Low	Small release with minimal clean up requirements	1E-02	0	0	0	1	2	3
2	Low	Moderate release limited to onsite damage with moderate clean-up effort	1E-03	0	0	1	2	3	4
3	Moderate	Large release with limited offsite impact requires significant onsite clean up	1E-04	0	1	2	3	4	5
4	High	Large release offsite with extensive clean up and damage to sensitive areas	1E-05	0	2	3	4	5	6
5	Very High	Very large release offsite with extensive clean up and permanent damage to several sensitive areas	1E-06	0	3	4	5	6	7

Appendix 1 – Sample Process

SAMPLE PROCESS

Risk Matrix - Commercial

Severity - C	Category	Description	TMEL-C	Risk Matrix					
				Likelihood					
				0	1	2	3	4	5
				Risk Ranking	Risk Ranking	Risk Ranking	Risk Ranking	Risk Ranking	Risk Ranking
0	None	None		0	0	0	0	0	0
1	Very Low	Less than $50,000	1E-02	0	0	0	1	2	3
2	Low	$50,000 to $500,000	1E-03	0	0	1	2	3	4
3	Moderate	$500,000 to $5,000,000	1E-04	0	1	2	3	4	5
4	High	$5,000,000 to $50,000,000	1E-05	0	2	3	4	5	6
5	Very High	More than $50,000,000	1E-06	0	3	4	5	6	7

Appendix 2 – Quiz Solutions

QUIZ SOLUTIONS

Post Instructional Quiz Solution

1. sections and pages?

   (d) The Navigation Bar

2. Many of the grids in the Vertigo application allow for sorting, filtering, and even editing multiple records at one time through a context menu. How is the connect menu displayed?

   (b) By right-clicking on an item in a grid

3. The document list makes it easy to view documents that are referenced by the SIS design basis by…

   (c) Storing a hyperlink to the location of the document in the user's document management system

4. Collections of instruments that are all common or related to each other so that they can be grouped for purposes such as cause-and-effect diagram development are called what in Vertigo?

   (c) IPF Groups

5. What is the Vertigo page that is the central point for SIL verification and includes an inventory of all the functions in the study, including the inputs and outputs instruments to the functions?

   (b) IPF List

6. How can data be entered into a Vertigo study with respect to failure rates of different types of Instruments?

   (d) All of the above

7. When a subsystem is too complex to be modeled as a standard voting arrangement the data for subsystem PFD and STR can be directly entered into

Appendix 2 – Quiz Solutions

QUIZ SOLUTIONS

the database instead of entering failure rates and requiring calculation, what type of entry is this referred to in Vertigo?

(c) Black Box Model

8. PFD and STR can be calculated in what other Kenexis software application and directly connected to a Vertigo database?

   (d) Kenexis Arbor Fault Tree Analysis Software

9. How can you tell if an SIS component type, such as a level transmitter, has failure rate data that is no longer consistent with the library from which it was imported?

   (b) On the Sensor Type page the “Current with Library” button will be red

10. Where in vertigo can you access the Beta Factor Estimation tool for estimating a common cause failure percentage for SIS component subsystems?

    (a) Next to the Beta Factor Label on any details form (sensor, logic solver or final element)

11. Which format of logic description is employed in the safety requirements specifications section of Vertigo?

    (b) Cause-and-Effect Diagrams

12. If a result of a SIL verification calculation is being displayed as “NaN”, or not a number, an error exists in the data entered to perform the calculation. How can the user obtain a list of errors identified by Vertigo during calculation?

    (b) The Navigation Bar

13. What test duration should be used for automatically performed diagnostics that are performed every device scan in devices like smart transmitters and logic solvers?

    (a) 0 hours

14. Which term should be included into the SIL verification calculation (by clicking on its checkbox) when tests are not always performed while the plant is

Appendix 2 – Quiz Solutions

QUIZ SOLUTIONS

shutdown for turn-around, and require a bypass of the function because the plant is in operation?

(c) Online Testing

15. Which of the following is not an SRS section in Vertigo?

    (a) Operating Procedures

16. Where does the user go to add or remove items that are shown on SRS datasheets and their associated reports?

    (b) Study Settings

17. What part of the bypass authorization form is displayed when the type of bypass requires a non-redundant instrument that the SIF is entirely dependent upon to be put into bypass?

    (b) Alternate Protection Plan Section

18. Which standard from API defines the standard classifications or types of events that are tracked and report up through management?

    (c) API 754

19. When a Vertigo report is generated, all the data in the database in included in the report because filtering and selecting specific data is not possible?

    (b) False

20. Which report will show a failure rate of a type of SIS component based on the actual test data collected in Vertigo's test tracking functionality?

    (c) Failure Rate Based on Testing Reports