FDC322013

Creating an Online, Interactive, 3D Piping Layout Application in Forge

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Learning Objectives

1. Discover why having Forge as a graphic-design tool is beneficial in current trends of web application development
2. Discover how gas-based fire-suppression systems work, and learn about the major factors that influence design and configuration
3. Learn about how important the role of managing data is at input, in processing, and for post processing
4. Learn how to design an agency-approved fire-suppression system configuration using Johnson Controls' web application: SDC

Description

Learn how Johnson Controls has used Forge to let its customers interactively design gaseous fire-suppression-system configurations on a webpage. The application enables dynamic section-by-section placement of piping network, and it automatically inserts appropriate fittings, warns the user of configuration mistakes, and automatically verifies the system design effectiveness. In this class, Johnson Controls team members will demonstrate their Forge-based application, design an agency-approved fire-suppression system, discuss the current development approach, and explain the benefits of the Forge-based solution.

Speaker(s)

Mayank Sharma:

Mayank Sharma is a Mechanical Engineering Analyst with Johnson Controls' Innovations & New Ventures team. He is the development lead for Suppression Design Center (SDC), and a subject matter expert. He obtained his bachelor's degree in Mechanical engineering from the Indian Institute of Technology, Bombay and master's degree in Turbomachinery and Aeromechanics from Duke University and Royal Institute of Technology, KTH.

Robert E. Smith:

Rob Smith is a Software Engineer/Analyst with Johnson Controls, specializing in Water-Based Fire Protection Systems. Rob began his fire protection career as a system designer in the Los Angeles area of California in 1980, and eventually moved into a software support role with the SprinkCAD group in 1996. Soon after, he moved to the Philadelphia, Pennsylvania region where he has been ever since. Rob has always enjoyed sprinkler system hydraulics and even performed hand-calculations of complex gridded systems early in his career. In his Support role, Rob has taught hundreds of classes and has helped countless designers better understand the intricacies of AutoCAD, sprinkler system design, sprinkler hydraulics, and SprinkCAD software. Married 36 years with 4 children (3 married) and 3 grandchildren, Rob loves to bowl, toss a Frisbee, Disc Golf, play Scrabble, and generally relax!

Chandra Kanth Injamuri:

Chandra Kanth is a Senior software engineer with Johnson Controls, Inc (Fire Suppression Products Innovation Team). He has a total of 15 years of experience in 3D programming, which includes 10 years of experience in AutoCAD and Revit APIs. He is currently the lead developer of the SprinkCAD for Revit. He has a master’s degree in Computer-Aided Design from Anna University. He is passionate about 3D programming and in his spare time he develops Android Apps.

Introduction

Performing the system design of a clean agent fire suppression system is a long and tedious process that involves a lot of time and hand calculation. Suppression Design Center (SDC) was developed to reduce the manual effort, save time and make the design process simpler. Complete SDC workflow can be described by the following steps:

1) Configuring a system
2) Entering pipe data
3) Performing a hydraulic calculation

Each of these steps is discussed in detail later in this document.

The second topic of focus in this handout is 3D design and the use of Autodesk Forge in SDC. Forge is a set of web services that allows creating custom workflows, it has multiple APIs to optimize the design process. JCI has used the Forge Viewer API to render a piping system and edit it and provide various information about the elements of this system.

The example selected for this handout is an L-Shaped room, which from the design perspective is a two-enclosure system. And, it will be protected using the Sapphire Plus 70 bar clean agent system.

*In this handout “we” refer to the audience and “JCI” refers to the team of developers.

Fire Suppression Industry terminology

Total Flooding System

In a total flooding system, the extinguishing agent is distributed into the 3D space as opposed to local application and after having reached the desired minimum concentration suppresses the fire.

Design Concentration

Minimum design concentration for a total flooding system is defined as the volume percent of agent required to suppress a fire in an enclosed environment.

Hazard

An area that is separate from other parts of a building requiring protection against fire. A hazard can be divided into multiple enclosures connected to each other requiring protection like floor void or ceiling associated with a server room.

Enclosure

A smaller space within a hazard separated virtually/physically from its other parts of the same hazard.

NOAEL

No observed adverse effect level indicates the highest design concentration at which there was no toxic reaction.

LOAEL

Low observed adverse effect level indicates the lowest design concentration at which there was an observed toxic reaction.

Reserve

A reserve system is where double the number of agent containers are installed in a single system for a quick replacement in case there was a discharge. Usually, AHJ requires systems to be up and running in less than 24 hours.

Transport approval

A transport approval is a special permit required by government in most of the countries for the transportation of hazardous material. In fire suppression industry this approval is required mostly for the transport of pressure vessels.

Hazard Description

The room that we are trying to protect in today's handout is an arbitrary example chosen meticulously for demonstration purposes so that multiple aspects of designing can be touched upon. Figure 1 shows the room (to which we will refer to as a hazard from now on).

The first thing we need to do in the design process is to collect data for the hazard. We must:

- Get dimensions, secure general arrangement drawings, identify all the exits and obtain volume reductions details if any.
- Gather hazard environment information and its normal operating range of temperatures. This data can be obtained either from ambient conditions or air handling system information.
- Find the elevation of hazard from sea-level - This is needed to add a correction factor to accommodate the effect of pressure changes.
- Identify the wall strength - It is important to know how much change of pressure the walls can withhold to design a safer workplace.
- Check if a leak test has been performed and whether room integrity has been proven.
- Identify used materials and what is stored in the room during general hours of operation. This helps in the determination of fire class and design concentration necessary to extinguish the fire.

Design Standard: ISO 14520 – Higher Hazard Class A Fire
Design Concentration = 5.6%
Minimum Hazard Temperature = $20° C$
Maximum Hazard Temperature = $40° C$
Altitude = Sea Level
Maximum positive pressure = 200 Pa
Maximum negative pressure = 300 Pa

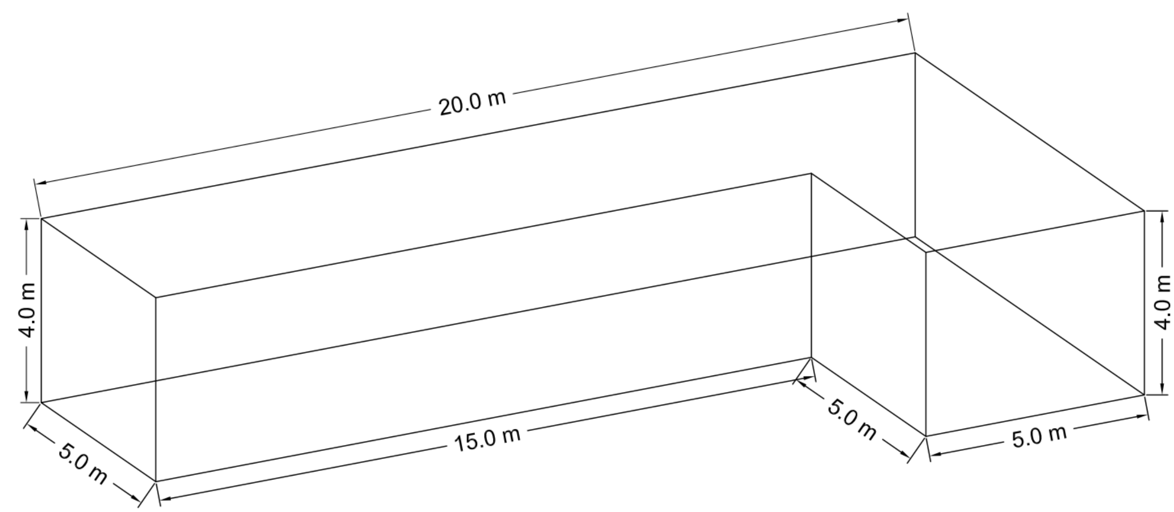


Figure 1: Room Dimension

Suppression Design Center

SDC is a web-based tool developed to help fire suppression engineers easily configure a gas-based fire suppression system. Technically speaking SDC is a WAMP (Windows Apache MySQL PHP) stack application, which uses Autodesk Forge to render objects in 3D. SDC was first developed as an estimator tool and 3D design was added later. Autodesk Forge is used like a 3D canvas to draw on. The Workflow of SDC:

1) System Definition and Estimate: Consists of 9 pages, which are used to capture user inputs and generate an estimated bill of material.
2) Hydraulic Run Manager: A little more dynamic in nature. For current example, the first four pages are for pre-configuring the system for 3D design. The next page is where Forge is embedded here, the system drawing is done. The next two pages are for reviewing data and showing results.

Web-based approach also opened a tremendous gateway for future expansion into the complete design, fabrication, and integration into JCI digital twin model system.

History

SDC started as an estimator tool that allowed distributors and designers to generate quick quotes. The idea behind SDC was to create a simple application to configure complicated engineered systems. Creating an easy to use application increases complexity of development. Same was true here, the two main challenges development team faced were;

1) Converting mechanical knowledge into logic*
2) Making application for a system which keep changing*

With tremendous amount of efforts from our subject matter experts and programmers SDC was made possible.

SDC – a web-based platform created an opportunity to expand app functionality from the simple estimator tool to an integrated system of on-line tools allowing addition of 3D design module and hydraulic engines. Incorporating Autodesk Forge technology was a critical step in development process it was only made possible with much-appreciated help from the Autodesk team (especially Michael Beal, Steven Preston, Ross Nishimura).

With an estimator, a 3D modeler and integrated calculation engines SDC became a one-stop-shop for designing a fire suppression system. The current version of SDC which will be expanding enables the design of the following systems:

1. Inert Gases (like Johnson Controls' iFLOW system)
2. Halocarbons (like new SAPPHIRE PLUS from Johnson Controls)

Autodesk Forge

As mentioned in introduction of the handout only the Forge Viewer API is used in SDC. The way it is used is not very conventional. Instead of rendering uploaded 3D models into the browser, in SDC the objects are drawn into the Forge environment. And, users draw using the command menu from JCI which is shown in Figure 24. To easily explain it we can say Forge is used as a canvas for 3D drawing. '3D Isometric Design Page' is the only place where Forge Viewer API is implemented in SDC. Please refer to the section for more details.

*Going into detailed solution is not in the scope of this handout

Data management

From information management perspective SDC is heavily reliant on data tables. Broadly speaking SDC database consists of,

1. Tables that drive logic: SDC is based on the principle of configuration where inputs are not independent of each other. A simple example will be the link between “System Type” and “System approval” options shown in figure 6. Systems approved to be used in the US doesn’t necessarily qualify it for use in Germany and vice versa. Hence, selection of “System Approval” is tied to “System Type”.
2. Tables that save current project information: Current project information constitutes of user inputs and results from background calculation. This data needs to be managed in a such way that it is readily available for use hence, it is put in a table from where it can be accessed easily.
3. Static tables: These are the tables from where all the results are pulled.

Interface

The interface is simple and starts with a home/management page, figure 2 which, allows us to interact with already existing projects or lets us create a new project. Each field in the project management page is searchable and some basic information about the project is displayed.

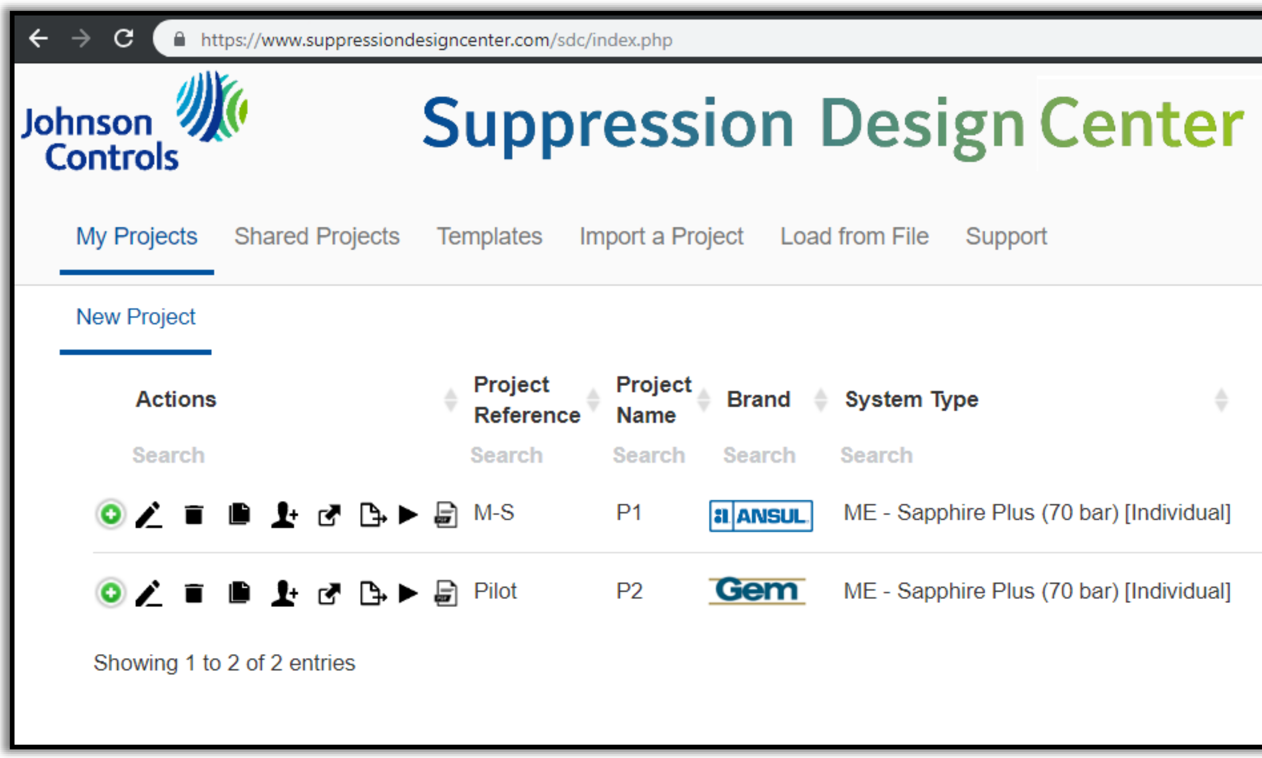


Figure 2: Home screen

Editing an existing project

A current project can be edited with the toolbar menu shown in figure 3. We can Edit, Delete, Duplicate, Share, Export and Save a project or look at the report (for finished projects) using this menu.

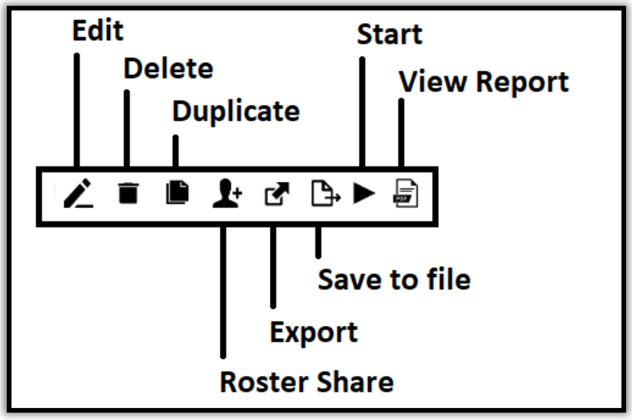


Figure 3: Action Buttons Project

Add a new project

Using the “New Project” command opens a window in which we enter essential project information: name, project description, system type, project units, apply a template if desired and provide additional information as necessary, figure 4.

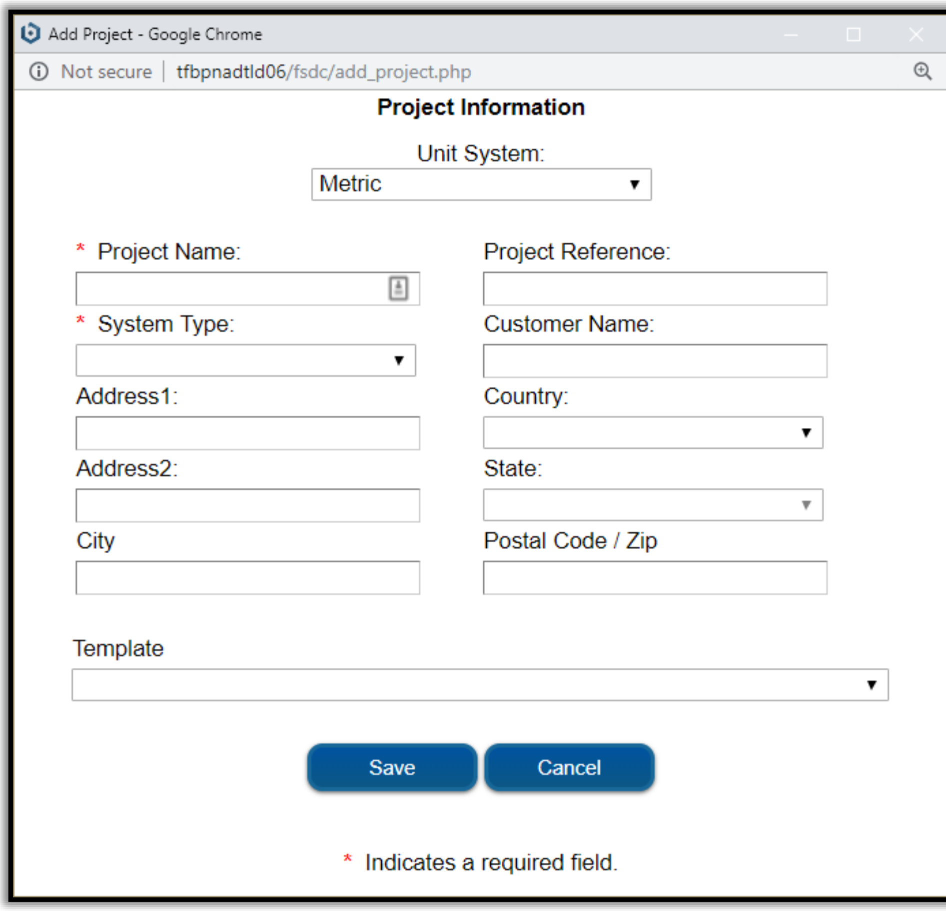


Figure 4: New Project Window

System Definition & Estimate

In this module, information regarding the system design is entered. Workflow in this section consists of 9 pages of which 5 are dedicated to collecting information, 3 are to review and modify configuration results and the last page is for reports.

Opening a project

To open a project in SDC we must click on the play button. This takes us to the last visited page. It is the first page for a new project. A logical (recommended) workflow is located on the left side of every page. This helps to navigate and track progress through color-coding: untouched page tabs are grey, completed page tabs are green, the current page tab is blue and any page tab that needs your attention is displayed as orange.

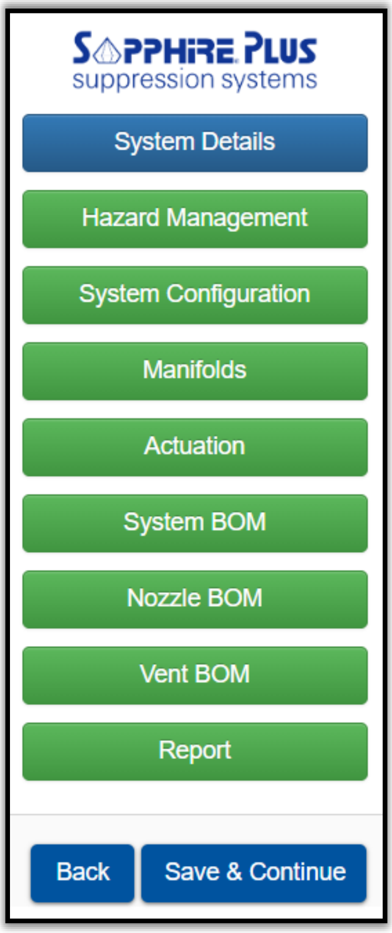


Figure 5: Left side menu tab - Full page view can be seen in appendix 1

System Details Page

The first step of starting a project in SDC is to add system details. The menu and options may slightly change based on the selected system type. There are four sections on this page.

General

Here we enter the basic information regarding agent type, design standard, fire class, and whether a reserve is required.

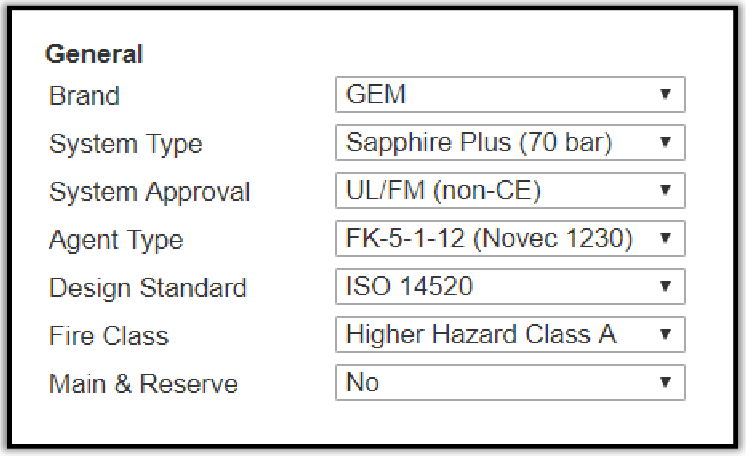


Figure 6: A snap showing general details section of System Details page

Hazard Environment Details

The second step is to provide hazard environment details which include wall strength, ambient temperatures, altitude, and leak proofing test results.

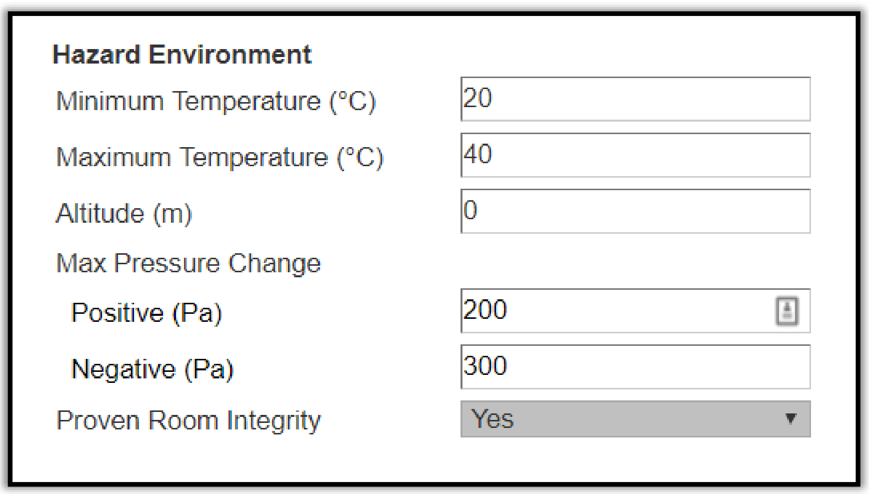


Figure 7: A snap of Hazard Environment details section in System Details page

System Options

In the next step, we choose from the available system options. Since SDC is used for generating quotes in most cases, these options make it easy to get a desired Bill of Material. The options are shown in figure 8.

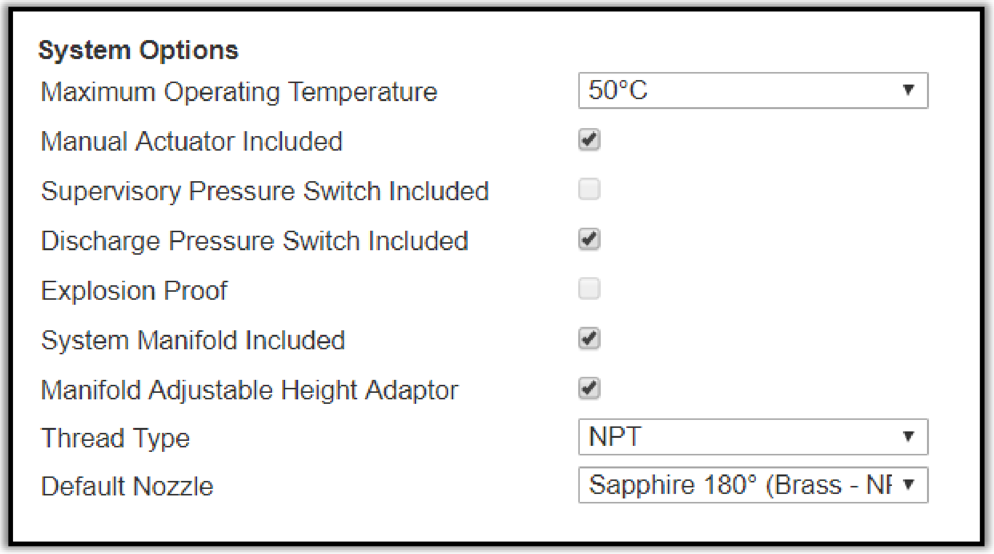


Figure 8: A snap of System Options from System Details page

Design

In the next group, we tweak the design parameters if needed. We must check through the default values shown in this section of the page and modify it if necessary. A little knowledge about the country's transport approvals, installation preference, and system design is required to make these choices.

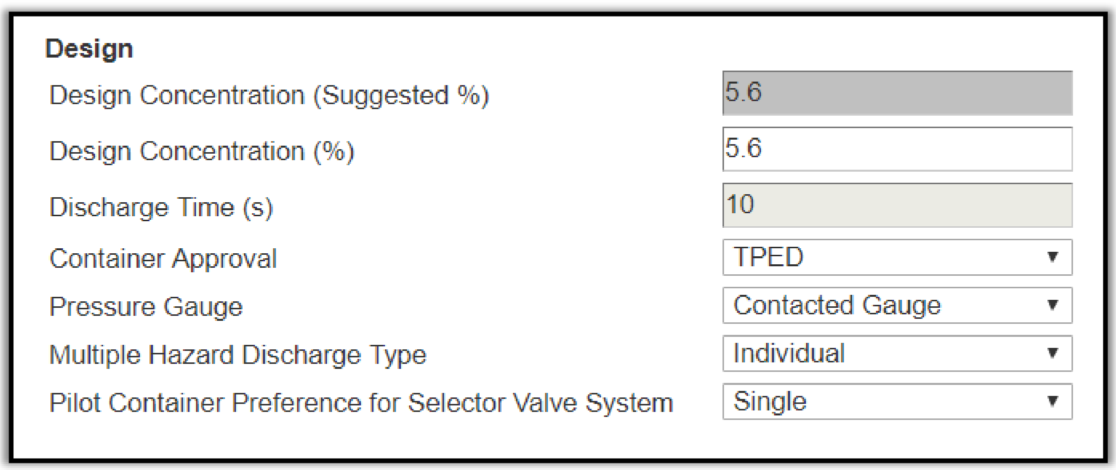


Figure 9: A snapshot of Design parameters from System Details page

Hazard Management Page

Now that we have entered all the relevant system information, we can enter the hazard parameters. A new hazard can be created using the 'Create Hazard' button which opens a window where the following information is entered: room dimensions, volume reduction, number of exits per room, floor area, etc. The current limit on the number of hazards is 6 and the number of enclosures per hazard is 3. If the global settings for nozzle type and/or wall strength do not apply to any particular hazard, these values can be changed in the pop-up window. Figure 10 shows a table summarizing details entered in the “Hazard Management” page.

Create Hazard

Actions	Hazard Name	Volume Name		Length (m)	Width (m)	Height (m)	Floor Area (m^2)	Volume Reduction (m^3)	Design Volume (m^3)	Design Concentration (%)
	Hazard 1	enclosure1	✕	20	5	4	0	0	400	5.6
		enclosure2	✕	5	5	4	0	0	100	
		enclosure3	✕	0	0	0	0	0	0	

Nozzle	Nozzle Size	Nozzle Qty	Discharge Time (s)	Maximum Pressure Change (Pa)	Exits
Sapphire 180° (Brass - NPT)	DN 50	Qty: 2	10	Positive: 200	
Sapphire 180° (Brass - NPT)	DN 32	Qty: 1		Negative: 300	
Sapphire 180° (Brass - NPT)					

Figure 10: Table showing fields from the Hazard Management page

System Configurations Page

This is where available configuration options are displayed based on the choices made earlier. There are two options for most cases; manifolded and modular.

- In a manifolded system, several containers are grouped together and forced to discharge through a single network of pipes. The advantage to that is longer pipe runs can be achieved and a larger area can be protected simultaneously.
- In a modular system, each cylinder has its own network of pipes. It is good for protecting smaller enclosures with complicated geometries and even bigger systems where the pipe sizes through the manifolded system become too big.

Manifolded systems are easy to maintain and build as all the equipment are located at a single place whereas modular system requires attention to details. Figures 11 and 12 below show the configuration sketches for manifolded and modular respectively and, figure 13 shows how information is displayed on the webpage.

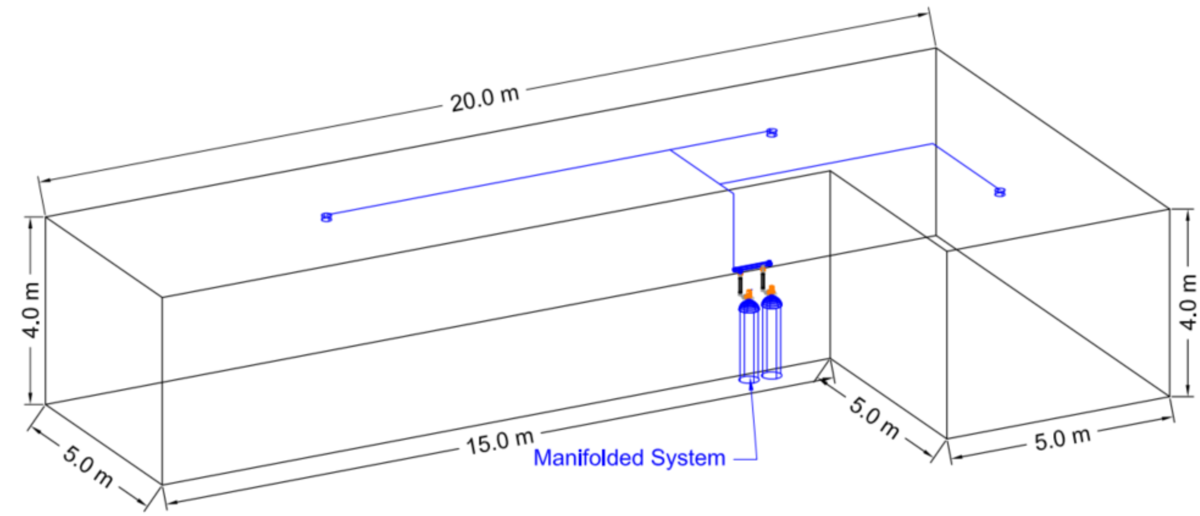


Figure 11: Manifolded configuration for current example

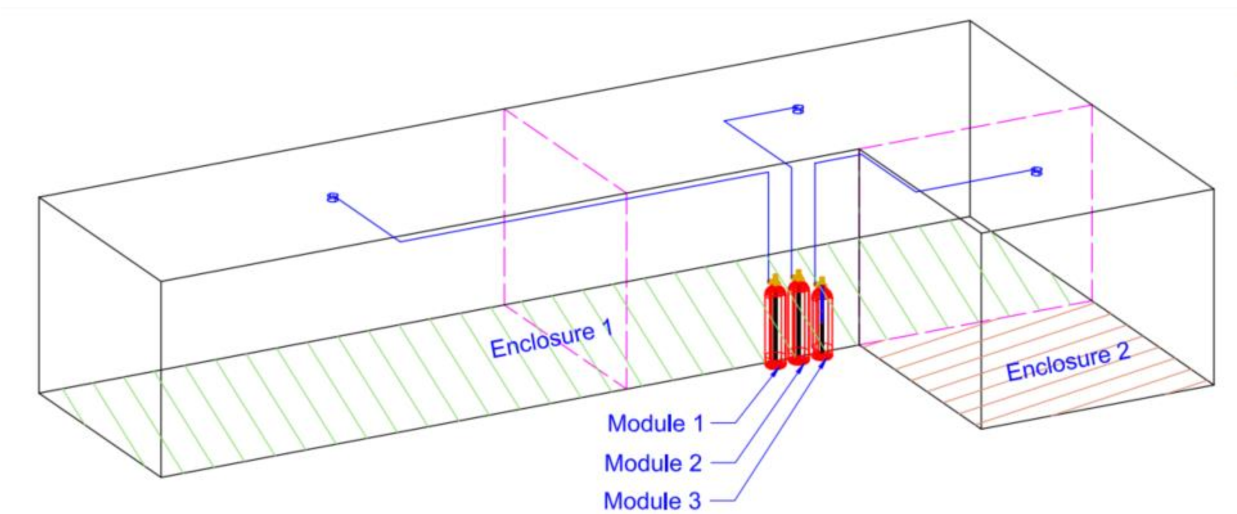


Figure 12: Modular configuration for current example

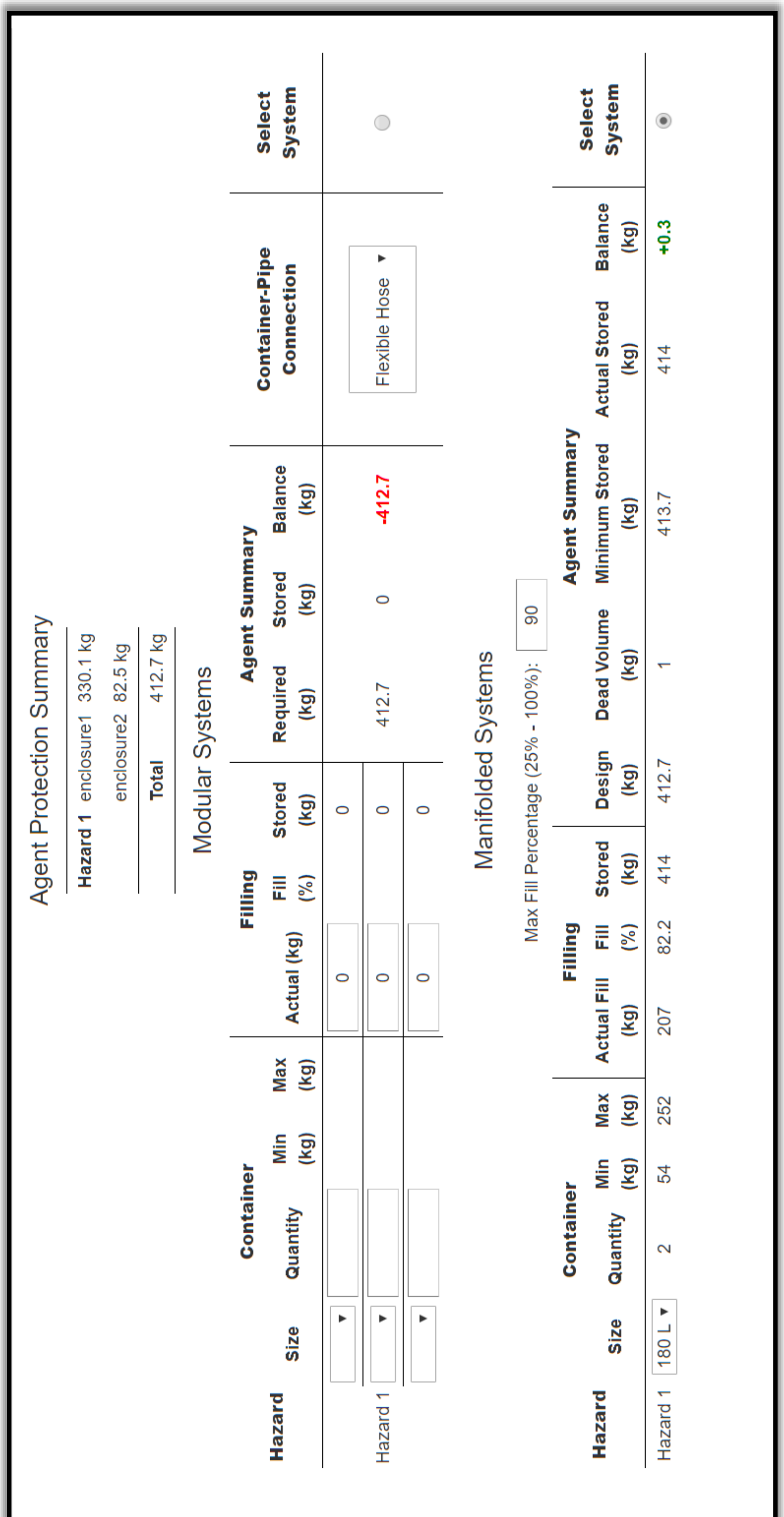


Figure 13: System Configuration page displaying available options to configure from

Manifold Configuration Page

Now, depending on whether we checked 'Include system manifold' option in the "System Details" page and chose manifolded option in the "System Configuration" page we will be directed here. The result defaults to an end-manifold but, depending on the available space as per the drawings, we can change to a different style of the manifold. The full list of choices is displayed in figure 14. During the custom selection of parts, we must ensure that the port count matches the number of cylinders, meaning the balance should be maintained at zero.

Port Summary: Hazard 1

Main	Reserve	Total	Balance
2	0	2	0

Manifold Size

DN 80 ▼

Manifold	Ports Provided	Quantity
307700004	2	1
307700005	3	0
307700006	4	0
307700007	5	0
307700008	6	0

Figure 14: Manifold Configuration page showing a summary of port count required against selected. It gives you a warning if balance is non-zero.

Actuation Page

Here, we configure by what action a container will initiate discharge. A system is almost always actuated using some type of electrical signal except for when a manual discharge is performed. The valves on the container can, however, be turned on using either an electrical signal or pneumatic action. There are limitations to both options.

Another choice to be made while configuring the system actuation is the line of connection between two cylinders. There are two options hard copper pipe and flexible hoses, one method may be preferred over the other. For example; in a manifolded configuration hose might be a better choice because of fixed spacing amongst cylinders whereas, for a modular system, a copper pipe would give better flexibility to spread the cylinders throughout the hazard.

To our advantage, this logic already exists in SDC which makes designing easier.

Manifolded System Actuation						
Hazard	Containers	Actuation Type	Master (Electric)	Subordinates (Pneumatic)	Actuation Line	Flexible Pilot Hoses
Hazard 1	2	Master-Subordinate ▼	1	1	Flex ▼	1

Figure 15: Configuration table displaying the actuation choice of Master-Subordinate with Flex pipe

System BoM Page

This page provides a preliminary estimate for parts based on the selections made in the previous five sections. Here the obtained Bill of Material can be modified and optional parts can be added by using the 'Add Parts' button if required.

Add Part | Edit | Delete | Select all | Deselect all

	Part Number	Estimated Quantity	Adjusted Quantity	Description
	Filter	Filter	Filter	Filter
☐	300.207.001	414	✎	Quantity of Novec 1230 (Metric = kg / US = lbs)
☐	302.209.005	2	✎	50 mm manifold check valve
☐	303700012	2	✎	180 litre container assembly (TPED) 50C CPG
☐	304.209.002	1	✎	Local manual actuator
☐	304.209.004	1	✎	Pneumatic actuator
☐	304.209.013	0	✎	Cable Pneumatic actuator
☐	304700001	1	✎	Electrical actuator - standard (bridge rectifier)c/w placement switch (TLX)
☐	304700003	0	✎	Manual Pneumatic actuator
☐	304700017	0	✎	13 L N2 100 bar pilot container TPED DIN477 (50C UL)

Figure 16: System BoM page showing estimated quantities for JCI parts (Proprietary). Grey and white are necessary to build an approved system and yellowed parts are optional

Nozzle BoM Page

Gives a summary of nozzles per enclosure per hazard. Details include quantity, size, pattern, and finish, any of these details can be modified to specific requirements.

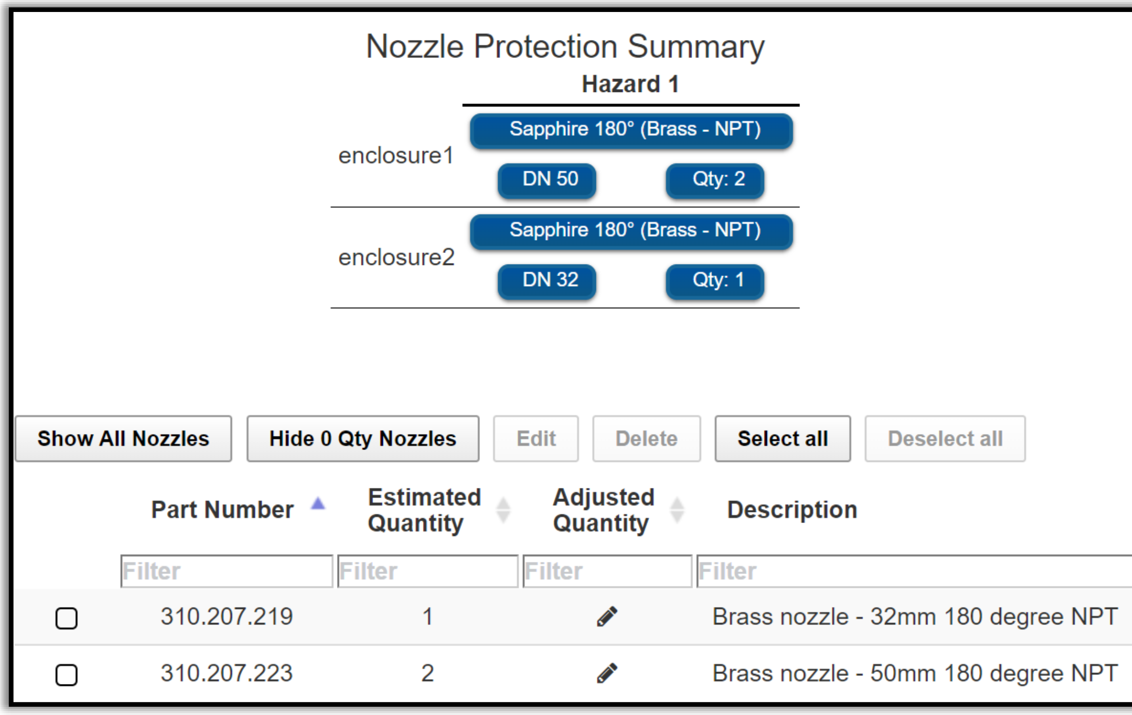


Figure 17: Nozzle configuration page showing nozzle protection summary and nozzle BoM

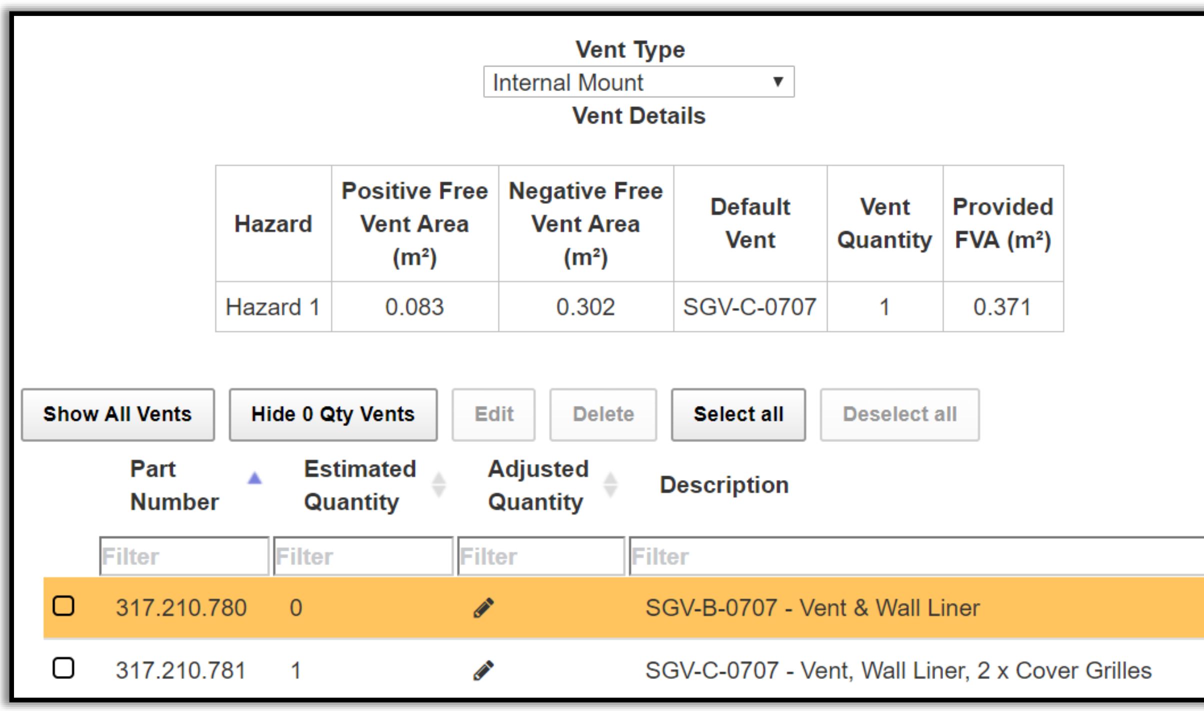


Figure 18: Vent BoM summary showing requirements for positive and negative free vent area and showing JCI parts for internal or external mounts based on selection

Vent BoM Page

Displays a summary of Free Vent Area generated based on wall strength data, agent requirement data, and proven room integrity test. The details can be reviewed by looking at the summary table and a change to the mount type can be made for suited installation internal or external, and a part list will be created automatically to match the selection.

Estimator Report

This page provides us the final estimate for the bill of material accounting for changes made in the previous three pages. At this point we can either print a pdf report highlighting all the input parameters, selections made and estimated part quantities, or we can export this data into excel format to keep it safe on the local machine. A full report for the current project is attached in appendix 2.

Hydraulics Run Manager

This is where we manage our hydraulic calculation runs. Just like the project management window here also we can look at the existing runs or create a new run for a project with an existing bill of material. The page layout changes slightly based on system type; individual manifolded, individual modular, selector valve and simultaneous as the designing philosophy is quite different in each case.

While in manifolded systems we layout the piping for the whole hazard at once, in the modular configuration we do it per cylinder/module. Not every design generates a working result hence, multiple runs are allowed per project.

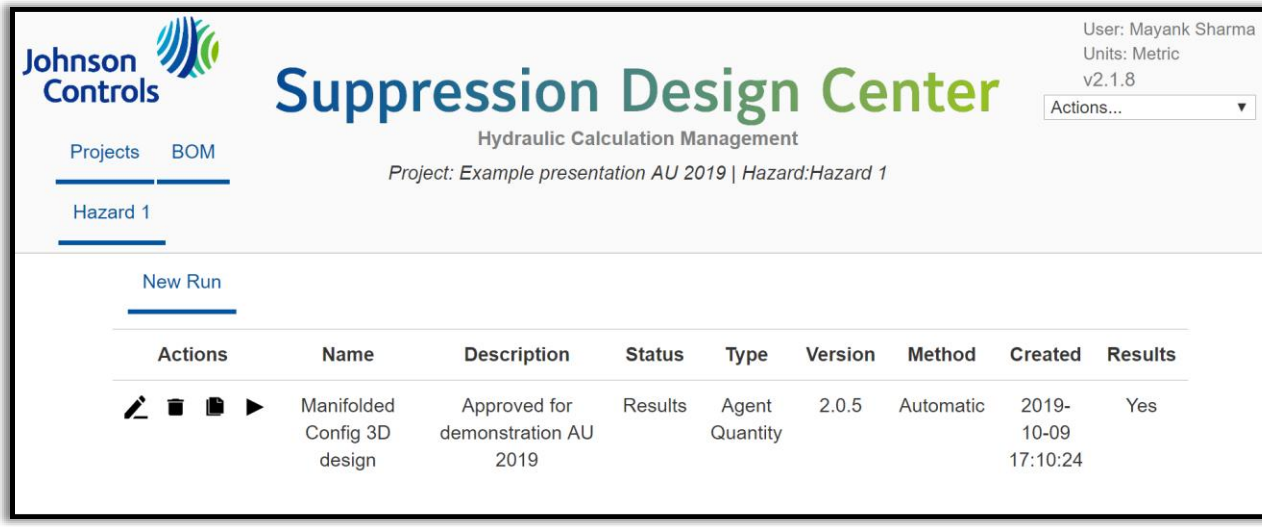


Figure 19: Hydraulic Run management page

Hydraulic Options Page

Our project settings are auto imported from the estimate, however, we can modify the imported values here. It happens often that a designer realizes that pipe run is too long, and an extra cylinder is needed to push the agent through or AHJ has more stringent/relaxed discharge time requirements, or any other similar scenario which doesn't fall in the normal category for these tricky cases ability to modify some of these parameters is necessary.

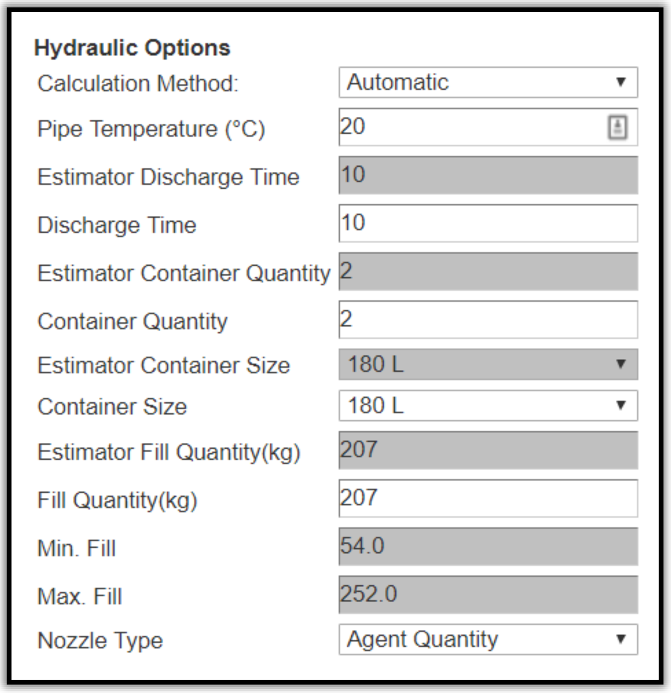


Figure 20: Hydraulic configuration options

Here, we can also make a selection for the run type. We either fix the discharge time or the agent quantity through a nozzle by fixing orifice size. Modifying calculation this way requires field knowledge and expertise, it should be left to default for most general cases.

Nozzle Configuration

In the structure of SDC, every nozzle is associated with an enclosure. Here we can select the percentage of volume protected by each nozzle. We can also, increase or decrease the number of nozzles and change the discharge pattern.

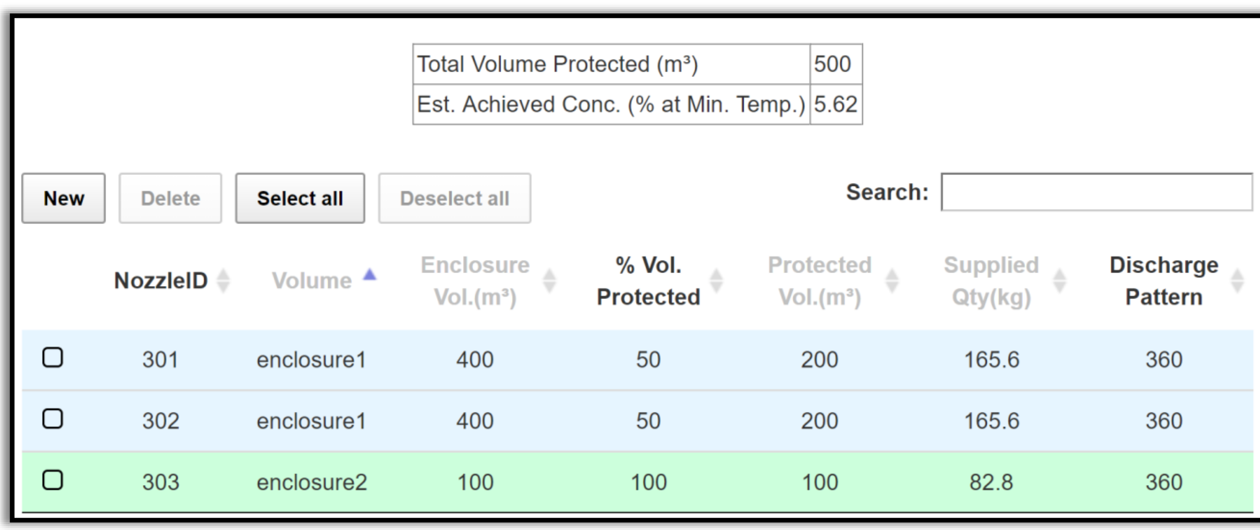


Figure 21: Nozzle protection summary, displaying the amount of volume protected by each nozzle and the agent that will be utilized to achieve the final concentration.

Container Bank Configurator

Generating an accurate container bank information is very important for hydraulic calculation. Here we can change manifold shape like from end to U or to center, pipe schedule, and size. Other important information is displayed based on which the pipe data and dead volume information are generated.

Container Size	180 L
Total Cylinders:	2
Manifold Shape:	End
Manifold Schedule:	80 THREADED
Manifold Size:	DN80
Reserve:	No
Height Adaptor:	Yes
Cylinder Connection:	Hose + CV

Figure 22:Container bank configuration properties, some of them can be modified and some cannot

Container Bank Edit

Let's say our project doesn't fit in any of the standard categories discussed above then we can manually enter pipe information here, using buttons on top.

New | Edit | Duplicate | Delete | Select all | Deselect all | Search:

Start	End	Length (m)	Elevation Change (m)	Pipe Size	Pipe Sched	Elbows	Side Tee	Thru Tee	Cplng/Union	Press. Tap	Containers
1	2	1.7	1.7	2	40 T	0	0	0	0	0	1
2	3	0.5	0	3	80 T	0	1	0	0	0	1
3	4	0.3	0	3	80 T	0	0	1	0	0	2

Figure 23: Table showing hose and pipe connection information for container bank

Forge Viewer API - 3D Isometric Design

In this section details regarding implementation of Forge Viewer API and 3D isometric design process are discussed. Figure 24 shows 3D design page with custom entities and generic Forge Viewer menus.

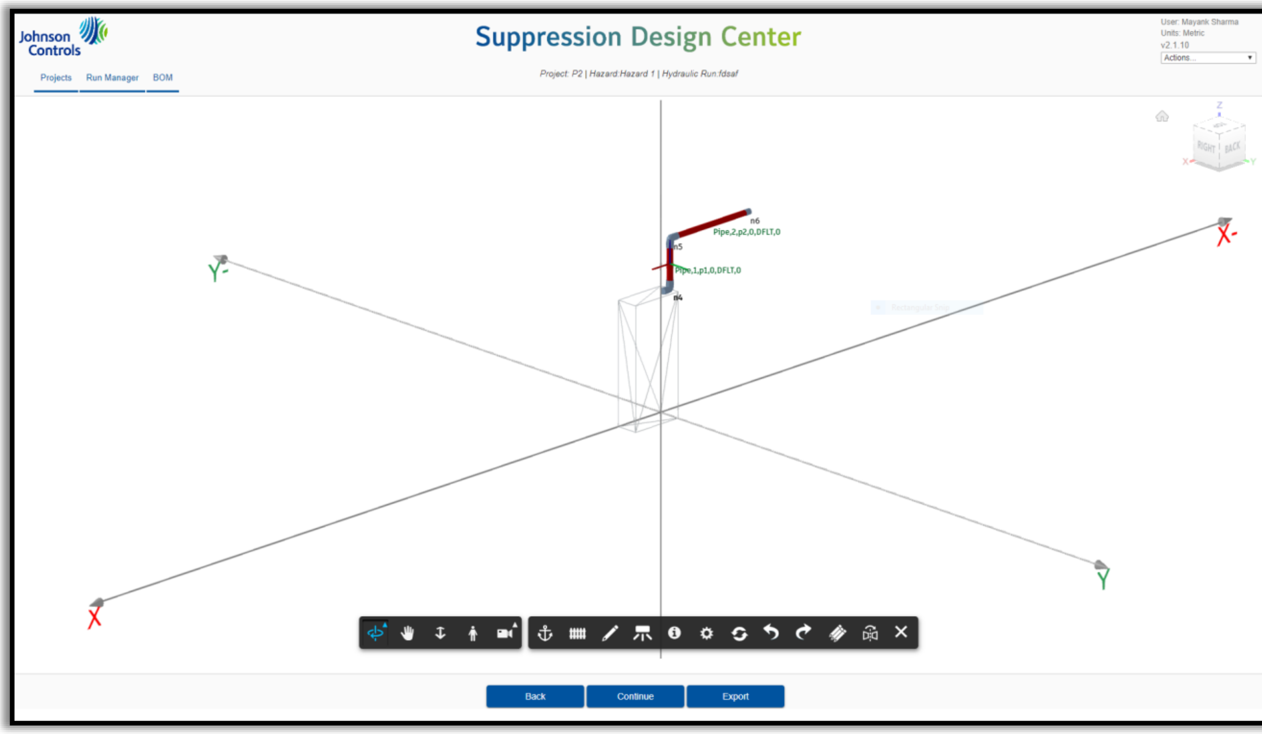


Figure 24: '3D Isometric design page'

In piping editor there are five main components/objects with which we design:

1) Pipe
2) Nozzle
3) Dirt Trap
4) Fitting
5) Container bank

Let us look at every component, its role in system design and its properties.

Pipe

Geometrically speaking a pipe can be defined as a cylindrical object with a length, a diameter, a starting point, and an ending point. It must also have a materialistic description which in SDC is given by its schedule. Any modification that adds hydraulic losses must also be considered hence, selection for pressure taps and selector valves have been made available in SDC. For graphical representation, a pipe has been assigned a display length (which can be different then original length), a color, a name, and a description.

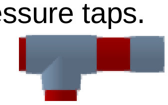
Hence, as a general concept, we should understand that the definition of an item requires a definition of its geometrical, mechanical, and graphical properties.

Nozzle

A nozzle is a complex geometrical object which requires many properties for its definition. Since the aim here is just to display the schematic we have assigned very few physical properties to it. A nozzle in SDC can be defined by its x, y, z location, nozzle ID (which signifies its association to an enclosure), discharge pattern, agent quantity, orifice diameter, and display color.

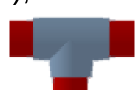
Dirt Trap

In SDC a dirt trap is an object which can only be used with a nozzle, its construction looks like a short pipe with an end cap. Its display properties are that of a pipe and a fitting. It has a name, schedule, a starting point, an ending point, length, diameter, display length, display color, section ID, description and count for pressure taps.



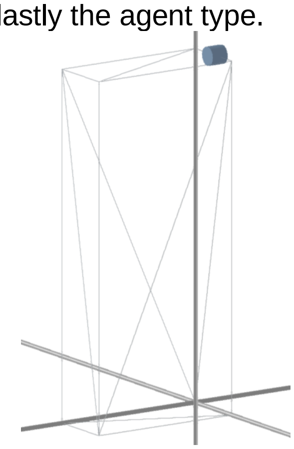
Fitting

There are 5 types of fittings that are UL/FM approved to be used in a gas-based fire suppression system. Elbow, coupling, Side Tee, Thru Tee and Bullhead Tee. The properties with which we define a fitting are its (x, y, z) location, its function, display color, display thickness (given by highest associated pipe thickness), schedule and flow direction.



Container Bank

Container bank is defined as a cubical box with an end pipe connection in SDC. Its properties include a length, a width, a height, a starting point for container bank, location of pipe outlet, manifold/outlet vector direction and lastly the agent type.



Commands

Following are the commands we can use in the 3D editor in SDC to perform an action:

1) Home button  in the top right corner resets the view to what we select as the home view or it defaults to 

. The home view can be set by clicking on three dots next to the isometric view window.

2) Menu following is a default from Forge which allows us to adjust the camera properties; rotate, zoom, change the focal length and change the view from first person to orthographic, etc.

3) 3D design menu for Forge viewer specific to SDC

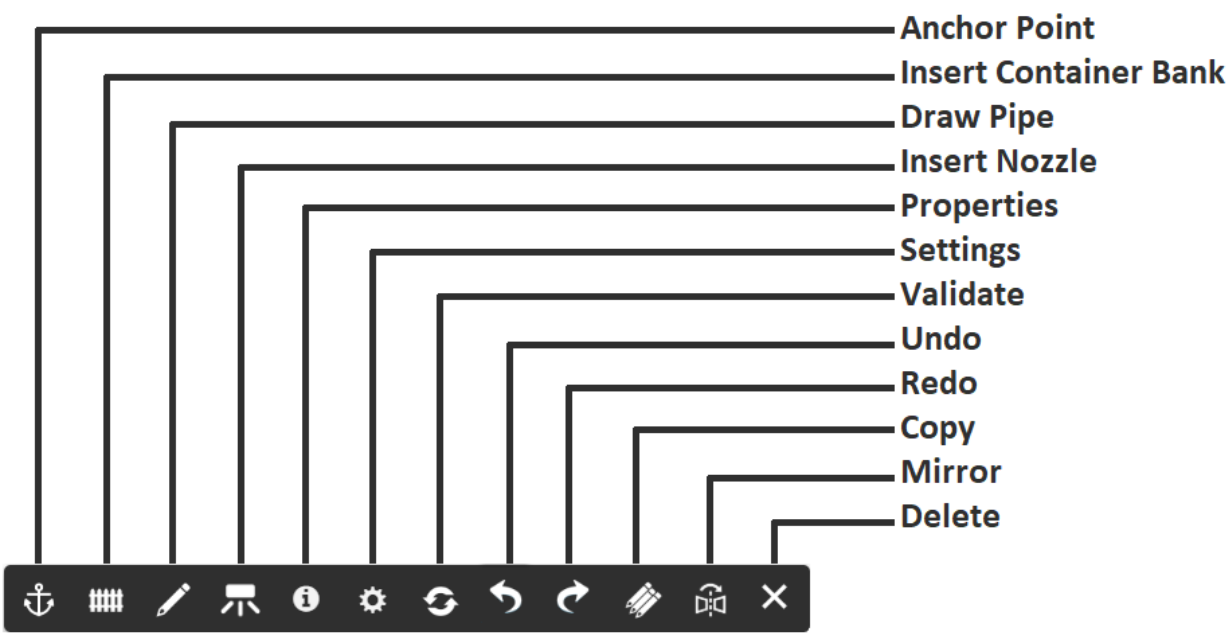
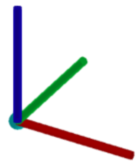


Figure 25: 3D piping menu labels SDC

a) Anchor Point: Selects the location for the next operation to occur. We can manually select any point in 3D or it will automatically detect a node point if in the vicinity to snap. Looks like .

b) Container Bank: Allows a container bank to be added if one doesn't already exist.

c) Draw Pipe: Clicking it opens a dialog box with which a pipe can be added in traditional x, y, z direction by selecting the radio button. You can choose to enter a pressure tap.

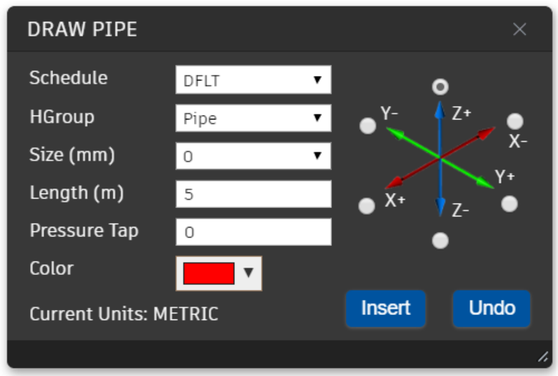


Figure 26: Draw pipe menu

d) Insert Nozzle: Opens a dialog box that lets us assign a nozzle to the end of the pipe network, we can also choose to enter a dirt trap if needed.

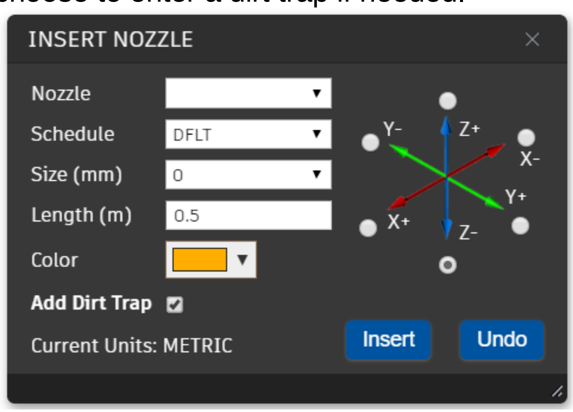


Figure 27: Add nozzle menu

e) Properties: Pops up a dialog box that displays properties of an object, allows some of these properties to be edited. Properties are discussed in detail in section **Error! Reference source not found.**.

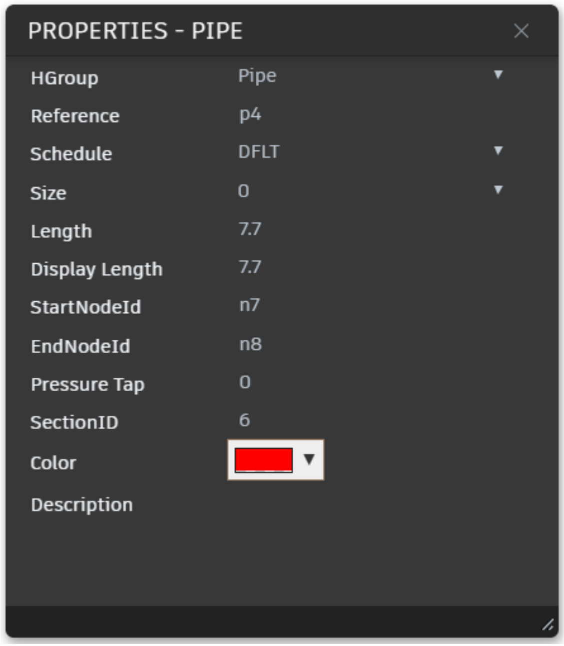
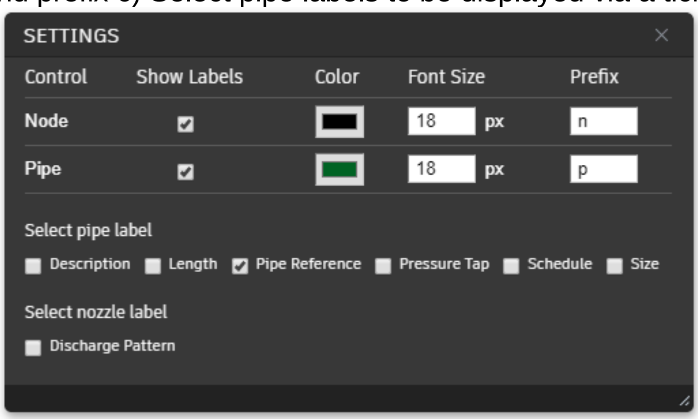


Figure 28: Properties menu

f) Settings: Shows the display menu a) Node labels, color, font size, and prefix b) Pipe labels, color, font size, and prefix c) Select pipe labels to be displayed via a tick box



g) Validate: Will verify if there is any discontinuity in the pipework and checks if the appropriate number of nozzles have been inserted.
h) Undo: Reverts last action performed.
i) Redo: Puts back the action performed.
j) Copy: Allows a pipe or branch of piping to be copy and pasted multiple times.
k) Mirror: Lets a branch or pipework to be mirrored with respect to the XY, YZ, ZX planes.
l) Delete: Let's you delete an item from pipework one at a time.

Figure 29: Settings menu

Modeling in Forge – Example Case

The first thing we must do to start a drawing in in SDC is to insert a container bank. As discussed in the previous section every container bank in our case is a cubical box with a pipe coming out of it.

As the second step we will draw pipes, a schematic drawing is shown in Figure 30. With help from a schematic drawing we can draw a similar system into SDC, a schematic could very well be hand-sketch, drawn while visiting the building. We can create the same drawing as shown in figure 30 into SDC by the using the following steps:

1) Insert a pipe of length 1.6m at node n4 in + 've' z-direction
2) Insert a pipe of length 0.6m at node n5 in + 've' y-direction
3) Insert a pipe of length 2.2m at node n6 in + 've' y-direction
4) Insert a pipe of length 7.7m at node n7 in - 've' x-direction
5) Insert a pipe of length 2.3m at node n8 in + 've' x-direction
6) Insert a pipe of length 4.8m at node n6 in + 've' x-direction
7) Insert a pipe of length 2.9m at node n10 in - 've' y-direction
8) Move the anchor point to n8
9) Insert nozzle with id 301 at node n8 in - 've' z-direction
10) Move the anchor point to n9
11) Insert nozzle with id 302 at node n9 in - 've' z-direction
12) Move the anchor point to n11
13) Insert nozzle with id 303 at node n11 in - 've' z-direction

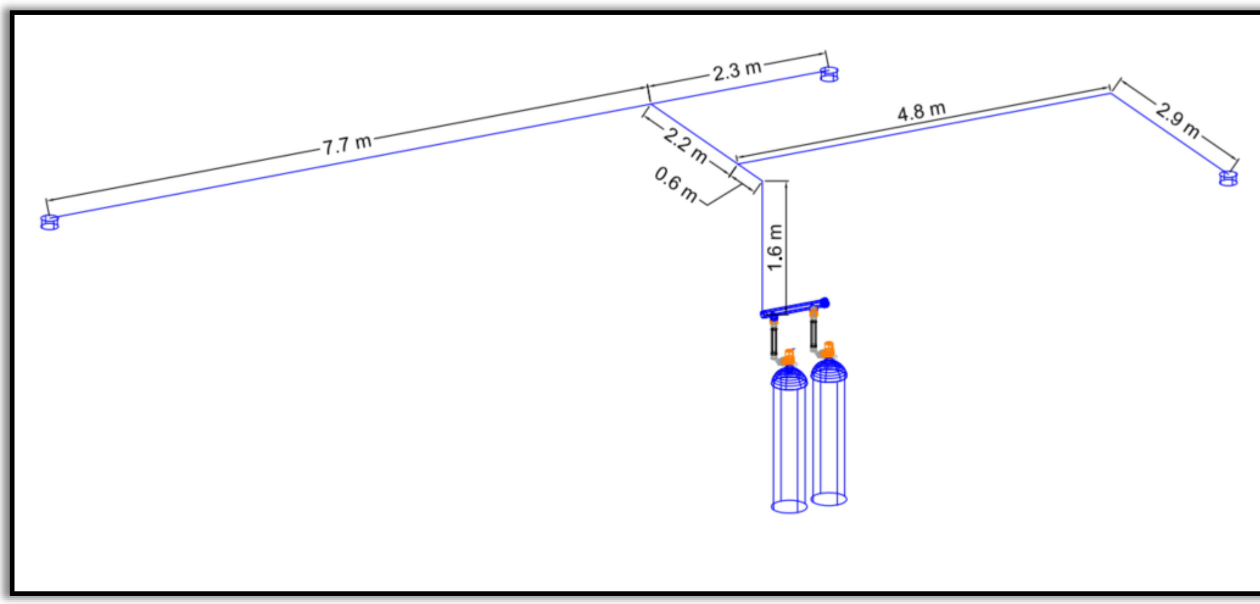


Figure 30: Schematic drawing obtained from Building engineer (Drawn in AutoCAD), real layout drawing could very well be a hand sketch

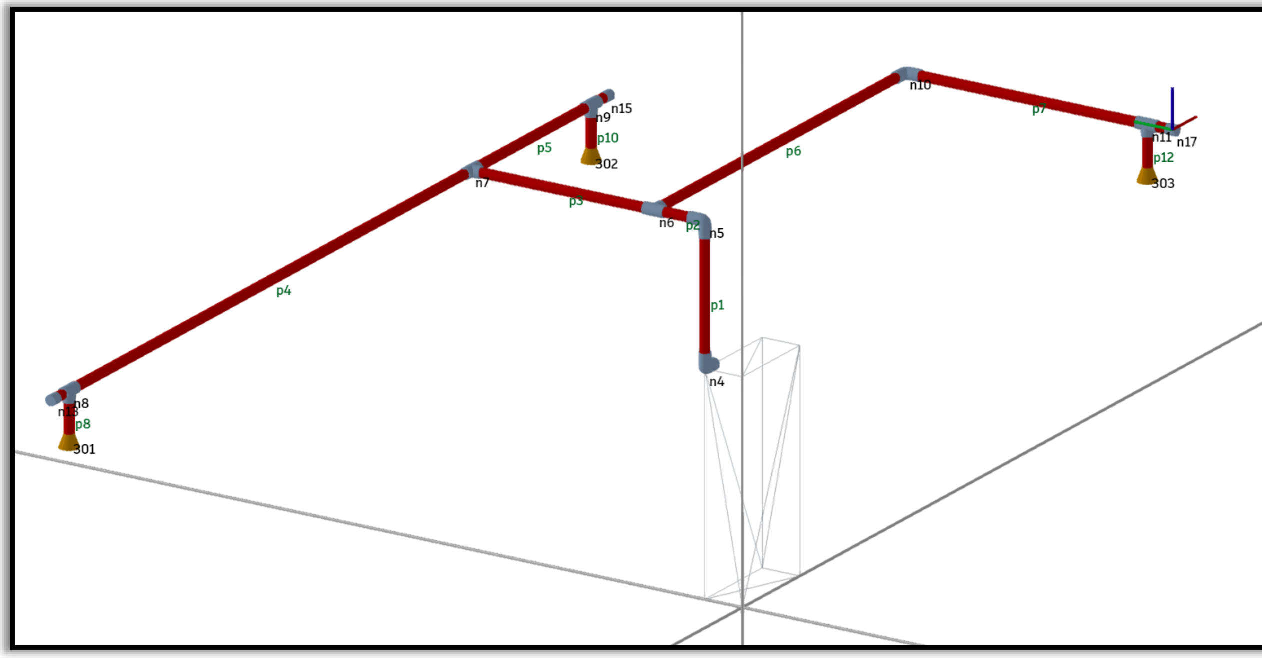


Figure 31: Piping layout for the example problem laid out in SDC

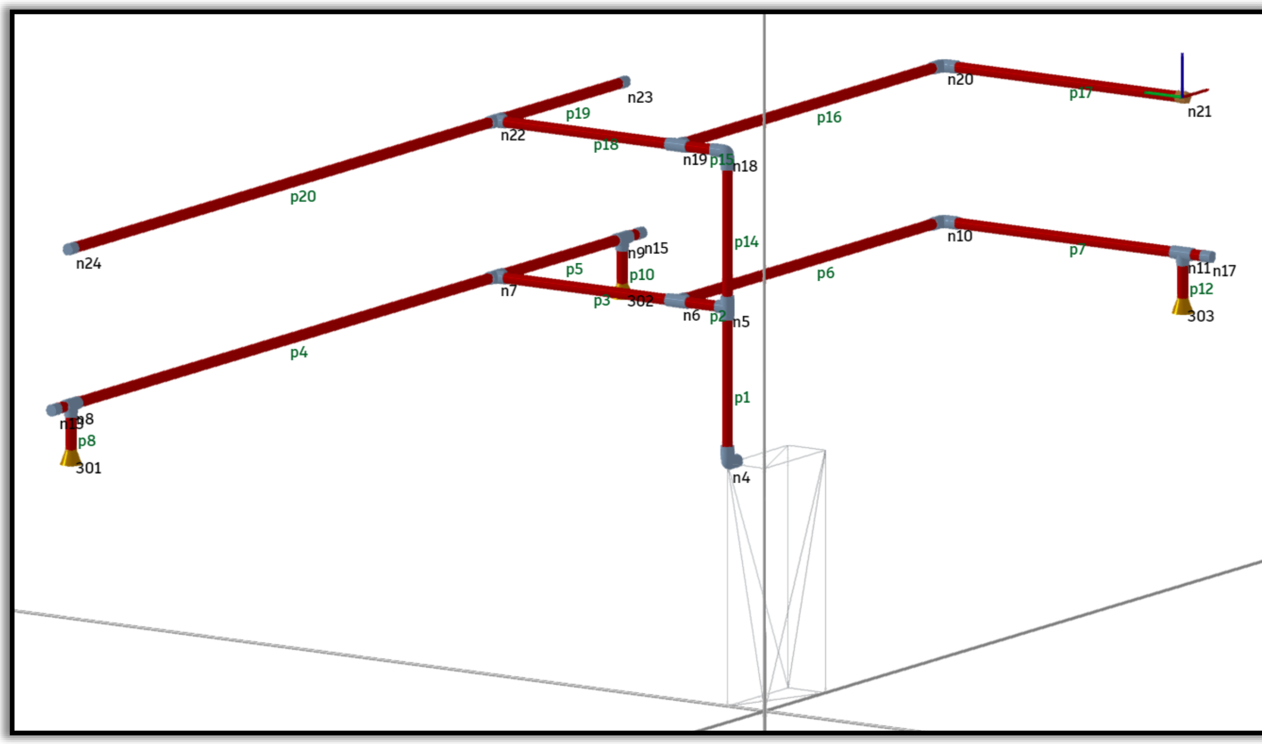


Figure 32: A screenshot showing copy command in action where pipes p7, p6, p4, p5, p3, p2 and p1 are copied.

Important Features:

Copy

Let’s say we had another floor with the same dimension and layout. We can use copy command by first selecting pipes p1, p2, p3, p4, p5, p6, and p7, then by selecting n4 as our base node and finally by selecting n5 as our destination node. Figure 32 shows the resulting isometric. Now, going to properties for pipe 14 we can adjust the height as necessary.

Mirror:

For many cases the piping layout is symmetrical hence, mirroring is a great way to speed up the process. Look at figure 33 for a large exhibit room, we can start drawing from node n6→n7→n9→n10 then we can mirror n9→n10 at n9 with respect to ZX plane and then by mirroring n7→n9→n10/n11 at n7 with respect to YZ plane.

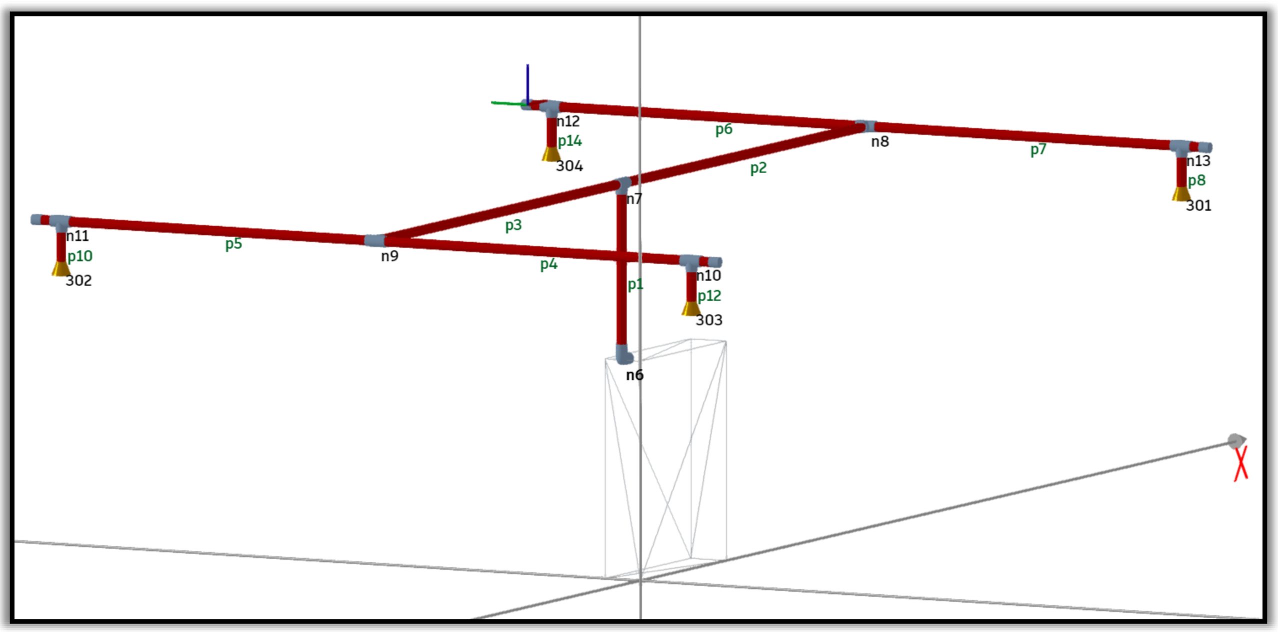


Figure 33: A drawing of a system created using mirror functionality at n9 and n7

Why is logic important in the 3D design process?

The whole concept of designing a fire suppression system is based on logic. We cannot have a nozzle without a pipe, dirt trap without a nozzle and pipes without a container bank. Having a governing sequence of operation is good both for development purposes (as it becomes more object-oriented) and from the user’s perspective (because of repeatability of operation).

Forge Implementation

For drawing and rendering objects into the Viewer API developers from JCI with help from Autodesk created an equivalent of a plug-in. This plug-in on the fly adds details like length, width, etc. to an object and displays it graphically. Each object in the background constitutes a few lines of code. The plug-in collects the component data combines it with the code for that primitive and renders it in the viewer. Primitive refer to the five objects from the previous section. All the information while drawing is saved just in the memory and when a user clicks either continue or back, data is sent to the server for future use.

Future:
Use of Forge Viewer creates a great opportunity to include detailed Revit / CAD drawings into the web platform. A sophisticated collision avoiding algorithm can be added or a digital twin model can be created for monitoring using internet of things, drawings presentable to AHJ can be auto exported, much more can be achieved.

Validation

There are two types of checks that are performed within 3D design process;

1) Client-side validation (done in Forge environment): Checks if all the nozzles are assigned, all the pipe networks are closed, connections are continuous and there are no collisions.
2) Processing engine (written in PHP): Performs two jobs broadly speaking
a) Administrative job – Queries the server for extracting data or saving information.
b) Analysis – Keeps track of flow direction, defines the type of a fitting and generates the section information for calculation module.

Wouldn't the loading time increase if the drawing gets bigger? Yes, it does, it is one of the drawbacks, however, the same would be true for any other application as well, the more the data the higher the processing time.

Pipe Data Page

This is where the piping data is presented to the user after being processed in our graphical engine. This page combines data from container bank, 3d design and nozzle configuration page and allows user to review the information before submitting to the calculation engine. Pressing continue sends data to the calculation module for generating hydraulic results. Figure 34 shows the pipe data table.

Hydraulic Calculation, Result, and Report

The results page provides us with a final summary from the calculation module. A full final report can be found in appendix 3. It is divided into five sections:

1) Concentration Results: Shows design quantity, supplied agent quantity, design concentration, and oxygen levels at provided ambient temperatures.
2) Pipe Section summary: Displays pipe sizes, inlet-outlet pressure, and flow rate data for each section. Fitting information is also generated and shown in the sections.
3) Nozzle performance summary: Provides details about end pipe connection, orifice diameter, amount of agent discharged and time.
4) FVA Results: Free vent area information with minimum positive and negative areas to allow for pressure surges is displayed.
5) Messages: This is where the status of calculation is shown, along with a couple of other general messages about pipe strength, amount of agent in a pipe, which listing the system refers to, the achieved discharge time, etc.

Search:

Start	End	Length (m)	Elevation Change (m)	Pipe Size	Pipe Sched	Elbows	Side Tee	Thru Tee	Cplng/Union	Dirt Trap	Press. Tap	Selector Valve	Nozzle Dischg Qty (kg)	Containers
1	2	1.7	1.7	2	40 T	0	0	0	0	0	0	No	0	1
2	3	0.5	0	3	80 T	0	1	0	0	0	0	No	0	1
3	4	0.3	0	3	80 T	0	0	1	0	0	0	No	0	2
4	6	2.2	1.6	0	DFLT	2	0	0	0	0	0	No	0	0
6	7	2.2	0	0	DFLT	0	0	1	0	0	0	No	0	0
6	303	8.2	-0.5	0	DFLT	2	1	0	0	1	0	No	82.8	0
7	301	8.2	-0.5	0	DFLT	1	1	0	0	1	0	No	165.6	0
7	302	2.8	-0.5	0	DFLT	1	1	0	0	1	0	No	165.6	0

Figure 34: Pipe data table displaying information to be submitted for hydraulic engine

Conclusions

Advantages of moving to web and the role of Forge

Two big advantages of having a web-application:
1) It reduces the development time. When developing a software for local machine operating system is a big concern. A single application needs to be developed for Windows, Linux, Mac OS, Android, IOS, etc. This is a big investment in terms of resources too.
2) An all rounded-packaged solution can be provided. Combining multiple modules is easier using internet.

How Forge can be helpful?
For companies that rely heavily on engineered systems and graphic models shifting to web-based services can be a challenge. Forge takes most popular design formats and render drawings directly into a browser, making it easier for companies to transition into era of internet and design.

Advantages of having 3D models on web
1) Good marketing: Having detailed visual representation of objects can be very good for business.
2) Easy bidding: Having detailed Revit models which can be interacted with within a browser window can increase the chance of winning a project.
3) AR / VR: AR / VR technology can be used in marketing, sales, digital twins, etc. and can create huge opportunities for companies.

Forge provides 8 more APIs and services, can be viewed at https://forge.autodesk.com/developer/documentation.

Drawbacks

- It could be a very costly affair in the beginning, with hard to provide business justifications at times.
- Resources with knowledge of Forge are scarce
- Heavy coordination with Forge team may be required to develop custom functionalities within Forge

Data Management in SDC

It is now clear to see that the backbone of SDC is data and logic. From page 1 itself, the data becomes important, it is acquired, processed and shown back in the form of result or action. A simple but, powerful example based on user input is, the check button in the “System Details” page called ‘include system manifold’ see figure 8. “Manifold configuration” can either be shown or skipped based on this input. This makes the workflow dynamic and as discussed above increases complexity of development.

SDC as mentioned earlier is a Windows Apache MySQL PHP (WAMP) stack application. It is designed using relational database. The tables in SDC are flushed out in a way to accommodate for engineering logic.

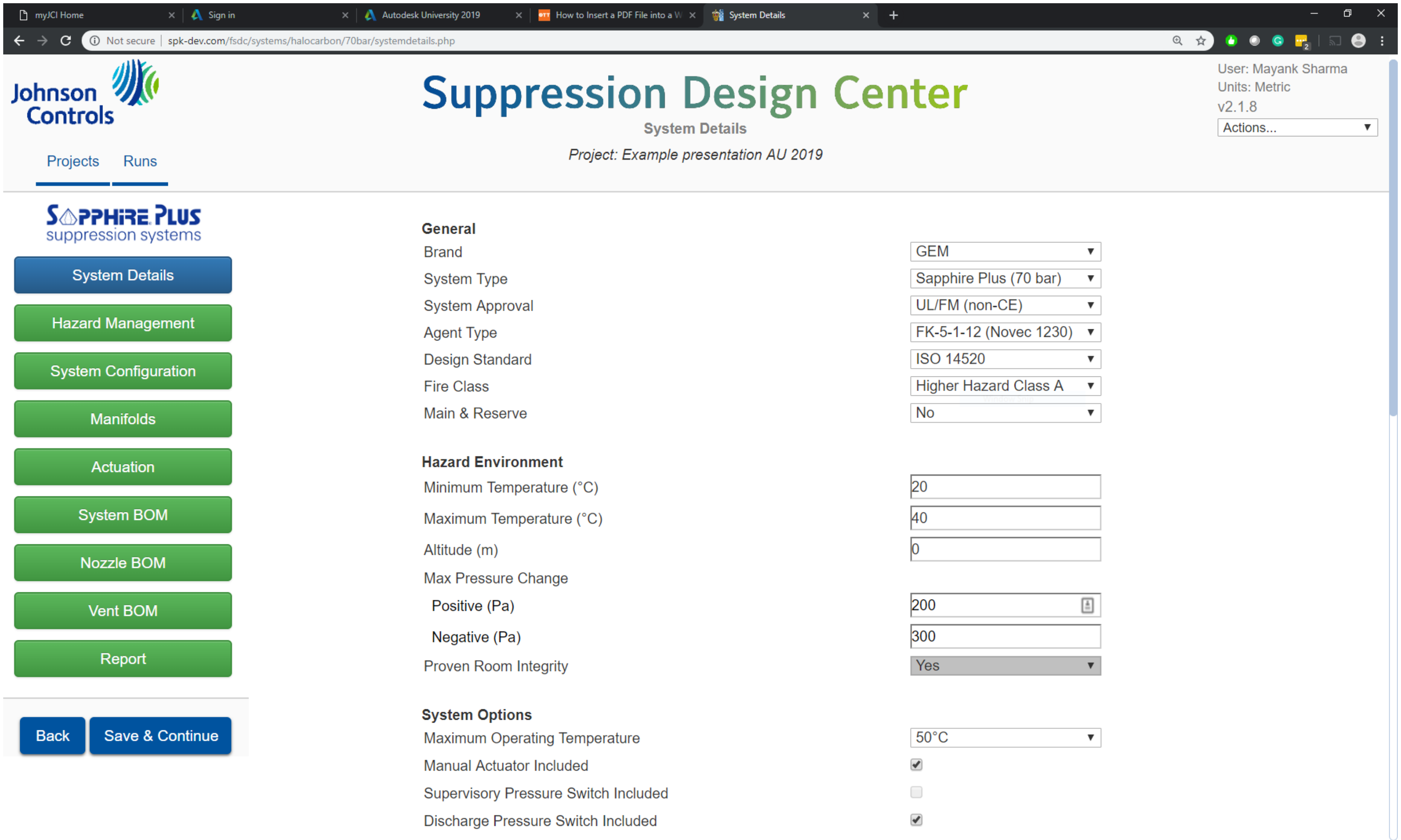
To obtain the bill of material we go through configuring multiple components of system as we pass through pages in System Estimate and Design. Each of these pages are driven by logic tables and choices made in each of these pages drive the result we obtain by querying the static tables.

In hydraulic run manager pages the processed data is taken as is from estimate-side. However, the changes made while creating hydraulic runs are not transferred back to the estimate. This one-way flow allows creation multiple runs for the same project.

One of the most important part of data management in SDC is the sequence in which it is gathered.

Appendix

Appendix 1: Full Page View



Appendix 2: Estimator Report

System Report (2424)
Project: Example presentation AU 2019

Project Details	
Project Name	Example presentation AU 2019 (Halocarbon)
Reference Number	Using Manifolded configuration to demonstrate 3D editor of SDC
Created By	Mayank Sharma
Customer	
Address	,

General	
System Brand	GEM
System Type	Sapphire Plus (70 bar)
System Approval	UL/FM (non-CE)
Agent Type	FK-5-1-12 (Novec 1230)
Design Standard	ISO 14520
Fire Class	Higher Hazard Class A
Detection & Control	No
Main & Reserve	No

Hazard Environment	
Minimum Temperature (°C)	20
Maximum Temperature (°C)	40
Altitude (m)	0
Maximum Pressure Change	
Positive (Pa)	200
Negative (Pa)	300
Proven Room Integrity	Yes

Design	
Design Concentration (%)	5.6
Discharge Time (s)	10
Container Approval	TPED
Pressure Gauge Type	Contacted Gauge
Multi Hazard Discharge Type	Individual
Pilot Container Preference for Selector Valve Syste,s	Single

System Options	
Max Operating Temp	50°C
Manual Actuator Included	Yes
Supervisory Pressure Switch Included	No
Discharge Pressure Switch Included	Yes
Explosion Proof	No
Thread Type	NPT
Default Nozzle	Sapphire 180° (Brass - NPT)
Actuation Line Preference	

Hazard Configuration

Hazard Name	Volume Type	Length (m)	Width (m)	Floor Area (m²)	Height (m)	Volume Reduction (m³)	Design Concentration (%)	Nozzle	Discharge Time (s)	Maximum Pressure Change (Pa)	Exits
Hazard 1	enclosure1	20	5	0	4	0	5.6	Sapphire 180° (Brass - NPT)	10	Positive: 200	
	enclosure2	5	5	0	4	0		Sapphire 180° (Brass - NPT)		Negative: 300	
	enclosure3	0	0	0	0	0		Sapphire 180° (Brass - NPT)			

Design Summary

Hazard	Volume Type	Design Volume (m³)	Design Concentration (%)	Agent Quantity (kg)	Nozzle Size	Nozzle Quantity
Hazard 1	enclosure1	400	5.6	330.1	DN 50	2
	enclosure2	100	5.6	82.5	DN 32	1
	enclosure3	0	5.6	0		

Manifolded Systems

Hazard	Container Size	Manifold Size	Dead Volume (L)	Container Quantity (Main Only)	Fill Quantity (kg)	Fill %	Provided Agent Quantity (kg)	Required Agent Quantity (kg)
Hazard 1	180 L	DN 80	0.6	2	207	82.2	414	412.7

Manifolded Actuation Configuration

Hazard	Container Quantity (Main Only)	Actuation Type	Master (Electric)	Subordinates (Pneumatic)	Actuation Line	Flexible Pilot Hoses
Hazard 1	2	Master-Subordinate	1	1	Flexible Hose	1

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Manifold Assignments

Hazard	Manifold Quantity	Manifold Part Number	Manifold Description
Hazard 1	1	307700004	80 mm manifold NPT - 2PT

Estimated Sizing - Summary

Hazard Name	Estimated Flow (kg/s)	Estimated Pipe Size
Hazard 1	41	DN 80

Vent Details

Vent Type	Hazard	Positive Free Vent Area (m²)	Negative Free Vent Area (m²)	Default Vent	Vent Quantity	Provided FVA (m²)
Internal Mount	Hazard 1	0.083	0.302	SGV-C-0707	1	0.371

NOTE: *BOM Report is to be utilized for system estimation and as a starting point for system design. Full system design, hydraulic calculation, and review of particular installation requirements are required ahead of finalizing complete system BOM. The complete system BOM for final quotation and ordering of components is the responsibility of the designer.*

Bill of Materials - System

Part Number	Quantity	Description	List Price	Discount (%)	Discount Price	Discounted Total
311700006	4	180 litre 406Ø container bracket	0.00	0%	0.00	0.00
306.205.003	2	DN1/4" PTFE flexible actuation hose x 710mm	0.00	0%	0.00	0.00
304.209.004	1	Pneumatic actuator	0.00	0%	0.00	0.00
302.209.005	2	50 mm manifold check valve	0.00	0%	0.00	0.00
310.207.219	1	Brass nozzle - 32mm 180 degree NPT	0.00	0%	0.00	0.00
304.209.002	1	Local manual actuator	0.00	0%	0.00	0.00
307700004	1	80 mm manifold NPT - 2PT	0.00	0%	0.00	0.00
314700001	2	Container label GEM (UL/FM)	0.00	0%	0.00	0.00
309.200.021	1	Male Tee (1/4" BSPP x 1/4" BSPP x 1/4" NPT)	0.00	0%	0.00	0.00
304700001	1	Electrical actuator - standard (bridge rectifier)c/w placement switch (TLX)	0.00	0%	0.00	0.00
300.207.001	414	Quantity of Novec 1230 (Metric = kg / US = lbs)	0.00	0%	0.00	0.00
303700012	2	180 litre container assembly (TPED) 50C CPG	0.00	0%	0.00	0.00
305.209.009	1	Discharge pressure switch - standard (UL FM version with adaptors)	0.00	0%	0.00	0.00
35009007	1	3" NPT Blind Cap	0.00	0%	0.00	0.00
306700004	2	DN50 adjustable adaptor	0.00	0%	0.00	0.00
306700002	2	50 mm discharge hose	0.00	0%	0.00	0.00
310.207.223	2	Brass nozzle - 50mm 180 degree NPT	0.00	0%	0.00	0.00
309.013.005	1	Male adaptor (1/4" BSPT x 1/4" BSPP)	0.00	0%	0.00	0.00
30888007	1	Union connector, 3" NPT x NPT, 140bar WP (with no drilled plate)	0.00	0%	0.00	0.00
					Total	**0.00**

Bill of Materials - Venting

Part Number	Quantity	Description	List Price	Discount (%)	Discount Price	Discounted Total
317.210.781	1	SGV-C-0707 - Vent, Wall Liner, 2 x Cover Grilles	0.00	0%	0.00	0.00
					Total	**0.00**

Appendix 3: Hydraulic Calculation Report

Hydraulic Report for Sapphire Plus (70 bar)
Project: Example presentation AU 2019
Software / Version: GSI 2.0.5
Date:14/10/2019

Project
- Project Name: Example presentation AU 2019
- Reference Number: Using Manifolded configuration to demonstrate 3D editor of SDC
- Created By: Mayank Sharma
- Customer:

General
- Protected Hazard: Hazard 1
- System type: Sapphire Plus (70 bar)
- System approval: UL/FM (non-CE)
- System pressure: 70 bar
- Container approval: TPED

Design
- Design standard: ISO 14520
- Fire Class: Higher Hazard Class A
- Minimum hazard temperature (°C): 20
- Maximum hazard temperature (°C): 40
- Altitude (m): 0
- Minimum design concentration (%): 5.6
- Discharge time (s): 10

Run Information

Name	Description	Type
Manifolded Config 3D design	Approved for demonstration AU 2019	Agent Qty

Run Options

Pipe Temperature (°C)	Discharge Time	Containers	Container Size	Container Fill Qty	Fized Nozzle	FVA Type
20	10	2	180 L	207	No	FIA

Nozzle Configuration - Input

Hazard	Volume	Nozzle ID	Agent Qty (kg)	Drill Diameter in Run (mm)
Hazard 1	enclosure1	301	165.6	
Hazard 1	enclosure1	302	165.6	
Hazard 1	enclosure2	303	82.8	

Pipe Configuration - Input

Start	End	Length (m)	Elevation Change (m)	Pipe Size	Pipe Sched	Elbows	Side Tee	Thru Tee	Cplng/Union	Selector Valve	Nozzle Dischg Qty (kg)	Containers
1	2	1.7	1.7	2"	40 THREADED	0	0	0	0	0	0	1
2	3	0.5	0	3	80 THREADED	0	1	0	0	0	0	1
3	4	0.3	0	3	80 THREADED	0	0	1	0	0	0	2
4	6	2.2	1.6	0	DFLT	2	0	0	0	0	0	0
6	7	2.2	0	0	DFLT	0	0	1	0	0	0	0
6	303	8.2	-0.5	0	DFLT	2	1	0	0	0	82.8	0
7	301	8.2	-0.5	0	DFLT	1	1	0	0	0	165.6	0
7	302	2.8	-0.5	0	DFLT	1	1	0	0	0	165.6	0

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Concentrations - Calculation Results

Area	Volume Name	Design Volume (m^3)	Design Agent (kg)	Supplied Agent (kg)	Max Concentration @ Max Temp	Minimum Concentration @ Min Temp	Requested Concentration @ Min Temp
Hazard 1	enclosure1	400	330.1	330.2	6 @ 40 °C	5.6 @ 20 °C	5.6 @ 20 °C
Hazard 1	enclosure2	100	82.5	83.8	6.09 @ 40 °C	5.68 @ 20 °C	5.6 @ 20 °C

Pipe Sections - Calculation Results

Start	End	Pipe Size	Pipe Schedule	Length (m)	EQL (m)	Elevation (m)	Fittings / Misc	Inlet Pressure (bar)	Outlet Pressure (bar)	Flow Rate (kg/s)	Nozzle Type	Orifice Drill Diameter (mm)	Nozzle Discharge (kg)	Liquid Time (s)
1	2	2	40 THREADED	1.7	19.65	1.7	1 cyl	27	22.8	27.3	0	0	0	0
2	3	3	80 THREADED	0.5	4.92	0	1 cyl	22.8	22.7	27.3	0	0	0	0
3	4	3	80 THREADED	0.3	1.77	0	2 cyl	22.7	22	54.6	0	0	0	0
4	6	3	40 THREADED	2.2	6.88	1.6	0	22	21.1	54.6	0	0	0	0
6	7	2 1/2	40 THREADED	2.2	3.45	0	Thru	21.1	20.2	43.6	0	0	0	0
6	303	1 1/4	40 THREADED	8.2	14.51	-0.5	Side	21.1	14.6	11	360/16	6.60	83.8	9.9
7	301	2	40 THREADED	8.2	16.08	-0.5	BHT	20.2	18.5	22	360/16	7.30	172	9.9
7	302	1 1/2	40 THREADED	2.8	8.93	-0.5	BHT	20.2	16.1	21.5	360/16	7.80	158.2	10.0

Nozzle Performance Summary - Calculation Results

Area	Volume Type	Nozzle	Pipe Size	Schedule	Nozzle Type	Calculated Drill Diameter (mm)	Agent Discharge (kg)	Liquid Time (s)
Hazard 1	enclosure1	301	2"	40 THREADED	360/16	7.30	172	9.9
Hazard 1	enclosure1	302	1 1/2"	40 THREADED	360/16	7.80	158.2	10.0
Hazard 1	enclosure2	303	1 1/4"	40 THREADED	360/16	6.60	83.8	9.9

FVA Results

Area	Volume Name	Positive Pressure Excursion (Pa)	Negative Pressure Excursion (Pa)	Minimum Positive FVA (m^2)	Minimum Negative FVA (m^2)
Hazard 1	enclosure1	200	300	0.1	0.5
Hazard 1	enclosure2	200	300	0	0.1
Hazard 1	Total	200	300	0.2	0.7

Messages

Hydraulic calculation successful
Hydraulic calculation was successful.
UL/FM Approved Calc Module Version 2.0.5 April 30, 2018 B5
Pipe Volume is 1.789748 cubic feet 50.6800270327339 L
Dead Volume is 0.6 Liters
Pipe System contains 18.9% agent in pipe.
Average liquid discharge time for all nozzles is 9.93 sec.
Pressure based on traditional reference pressure vs percent agent in pipe.
Calculation performed on 10/14/2019 2:02:25 PM

Displayed time of calculation occured in the Eastern Time Zone (ETZ).