



SP Technical Research Institute of Sweden

# FISPAT User Manual

Erik Hedin & Lars Strandén

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## Abstract

In 2002 an amendment was added to the International Convention for the Safety of Life at Sea (SOLAS)[1] which opened up for shipbuilders to replace steel with lightweight materials in the superstructures. However, SOLAS requires equal fire safety capability compared to ships with steel superstructures.

LASS-c is a cross-organizational project with the aim to find a method to build cruise ships with part of the superstructure made in lightweight materials. The purpose of this LASS-c sub-project has been to develop a software tool in Java (FISPAT) that helps identifying fire sensitive areas in cruise vessels structures. This report is the user manual to FISPAT and contains an introduction, explanation of the FISPAT Vessel Model, explanation of the GUI and a work process example.

In FISPAT the user can make a model of the vessel structure containing rooms, networks and devices. FISPAT then performs exhaustive simulation of fire spread and fault injections in the model and presents it to the user. The user analyzes the results to find fire and fault sensitive parts. By introducing additional networks and devices or altering the ones already existing, iterative exhaustive simulations lead to a better cruise vessel design. The goal is that the user should be able to translate its own vessel drawings into the application and perform simulations on it after reading this report.

Keywords: Fire spread, analysis, exhaustive, simulations, fault injection, network, sectioning device.

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## Preface

This is the user manual to FISPAT that is developed in the LASS-c project at SP Technical Research Institute of Sweden. This document concerns the operation of FISPAT but nothing on verification, validation, results etc. For this information, please see [2].

The manual has the following chapters:

1. Terminology: Explanatory dictionary.
2. FISPAT Model: How a real vessel is translated to be used in the program and policies used in the simulations.
3. Graphical User Interface: A thorough description of the GUI.
4. Analyzing Exhaustive Simulation Results: Guide for interpretation of the simulation results.
5. References: Sources used.

- Appendix 1. User Guide: Installation of the program and how to create input files.  
Appendix 2. Work Process Example: A brief guide how to use FISPAT. It is advised to look it through before using the program for the first time.

# 1 Terminology

Apparatus	Sub-group of Device. An apparatus maps dependencies between two or more networks of different kinds and is one of Pump, Electric Control Unit or Other. If a network depends on an apparatus and the apparatus gets non-functioning, so will the network (if there are no redundant apparatus of the same kind).
Control options	Options chosen by the user in each simulation that defines how fire and faults are spread. There are three control options (each explained in this Terminology): <i>Spread fire if no sprinkler</i> , <i>Water network non-functioning by fire</i> and <i>Ventilation spreads fire</i> .
Corridor	A subtype of room. Has identical properties as Room (see below) except its color in the Graphical Representation. The purpose of defining corridors is to make the Graphical Representation easier to comprehend.
Dependence	Defines how the functionality of networks and devices are affected by each other. Can be one-way (e.g. a water network depending on the electric network via a pump) or two-way (e.g. a computer depending on an electric network but also controls this).
Device	Maps dependence between two or more networks and need to depend on networks to function. For example a water pump that depends on an electrical network or a control device that controls a network while it depends on an electrical network. Device have two sub-groups; sectioning device and apparatus.
Exhaustive Simulation	All possible initial states of the Vessel Model are simulated without the need for the user to change setup manually. Before the exhaustive simulation is started the user sets the initial parameters: <ul style="list-style-type: none"> <li>• How many rooms that are initially on fire</li> <li>• How many networks that are initially non-functioning</li> <li>• How many devices that are initially non-functioning</li> </ul> FISPAT then simulates all possible initial states that fulfill the requirements above.
Fire	Indicates fire and smoke. Fire cannot be present without smoke.
Firewall	Graphical line FISPAT. Has no meaning for simulation or fire spread.
FISPAT	Fire Spread Analysis Tool.
GUI	Graphical User Interface.
LASS	Lightweight Construction Applications at Sea.
LASS-c	Sub-project to LASS focusing on cruise vessels.
Network	Allows a resource to be distributed within the vessel. A network can be one of the following types; electric power (E), water (W), ventilation (V), pneumatic (P), hydraulic (H), control network (C).

Prescriptive	According to SOLAS (normative).
Properly Connected Device	All networks a device depends on and affects have their end or start positions inside the device symbol (a proper definition can be found in section 2.1.3).
Redundancy	Dependence on more than one single resource. Networks can depend on redundant devices in which case one of the redundant devices can be non-functioning without affecting the functionality of the network. Devices can also depend on redundant networks in which case one of the redundant networks can be non-functioning without affecting the functionality of the device.
Room	Part of the Vessel Model that represents a room in the vessel.
Sectioning device	In real life separates the functionality of two or more sections of a network. However, in FISPAT the sections are instead considered as separate networks connected via the sectioning device. If one of the networks is non-functioning, the other(s) will not automatically be non-functioning if there is a functioning sectioning device between them. However, if the sectioning device is non-functioning, a fault in one network will spread to the other(s). If the Sectioning device is included in ventilation networks, its function is to prevent fire and smoke to spread between rooms containing the networks. If the sectioning device is non-functioning, fire and smoke will be able to spread.
Setup	The initial state of a simulation that is used with the Vessel Model to perform a simulation. Fire spreading neighbors, smoke spreading neighbors, initial status of the rooms, networks and devices are all specified in the setup. As is the control options.
Simulation	By using a particular setup with the Vessel Model a simulation can be performed. The initial state of the simulation is specified in the setup and the result state is the state of the Vessel Model after that the simulation has been performed.
SOLAS	International Convention for the Safety of Life at Sea.
SP	Technical Research Institute of Sweden.
Spread fire if no sprinkler	Control option that can either be true or false. If true, fire is spread between rooms that lack functioning water network. Both rooms need to lack functioning water network for the fire to be spread. If false, fire is only spread between sub-rooms and fire spreading neighbors defined by the user.
Status	For a room, the status is either fire, smoke or neither. For networks and devices the status is either functioning or non-functioning.

**Ventilation spreads fire**

Control option that can either be true or false. If true, fire is spread through ventilation and all rooms where the ventilation network is present will be set on fire. If false, fire will not be spread by ventilation.

**Vessel Model** The data structure representing a vessel. It contains rooms, networks and devices.

**Vinnova** Swedish government agency that provides research funding.

**Water network non-functioning by fire**

Control option that can either be true or false. If true, water networks turns non-functioning if present in a burning room. If false, their functionality are not affected by fire.

## 2 FISPAT Model

FISPAT uses a model representation of a vessel (Vessel Model) to perform simulations of the fire spread. The Vessel Model contains rooms, networks and devices. Firewalls are also part of the Vessel Model but have no relevance to the fire spread, they are merely a graphical component to simplify the interpretation after simulations are done. By changing simulation setups for the defined rooms, networks and devices, it is possible to find the most critical combinations that cause severe damage of the vessel. The initial state of a simulation is defined by the user in the simulation setup in the GUI. The Vessel Model is discussed in section 2.1 and the fire and smoke spreading models are discussed in section 2.2 and 2.3.

### 2.1 Vessel Model

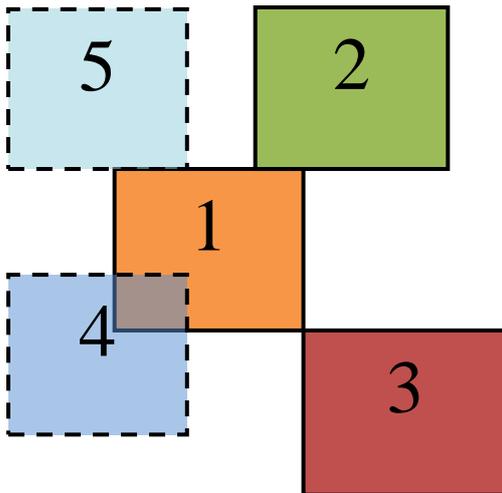
The FISPAT tool uses a model of the vessel called the Vessel Model to perform simulations. This Vessel Model is made up by three different parts; rooms, networks and devices.

#### 2.1.1 Rooms

All rooms are modeled as cubicles and each cubicle belongs to a deck. The corners of a cubicle are represented by positive integers in a three dimensional space ( $x, y, z$ ). The walls, ceiling and floor of a room need to be parallel to one axis of the coordinate system. This means that two adjacent corners only will have one coordinate that differs. The lowest  $z$ -coordinate indicates on which deck the room is present; hence this coordinate differs by one between two adjacent decks. The floor of one deck is the ceiling of the deck below and vice versa and a room can only be located on one deck. If a room stretches over several floors the room needs to be divided into several sub-rooms where each sub-room is located on one floor only. The  $x$  and  $y$  coordinates are also integers and their corresponding units can be chosen freely (but the same for all rooms).

Any other room shape than cubical is constructed by linking several cubicles (sub-rooms) together. This allows for a room to have a more complex structure. A room, or sub-room, cannot comprise another room, i.e. rooms cannot overlap another.

Neighboring rooms are identified by FISPAT. For two rooms to be neighbors they need to be either on the same deck or on adjacent decks. If on the same deck, one wall of each room needs to overlap one wall of the other (see Figure 1, object 1 and 2). If two rooms only have corners in common they are not considered neighbors (see Figure 1, object 1 and 3). If the rooms are located on adjacent decks, one room needs to have a corner within the other room as seen from above to be a neighbor (see Figure 1, object 1 and 4). It is not enough for the rooms to have edges in common (see Figure 1, object 1 and 5).



**Figure 1: 1, 2 and 3 are on the same deck while 4 and 5 are on an adjacent deck. 1 is neighbor to 2 and 4. 1 is not a neighbor to 3 and 5 since they have no overlapping surfaces.**

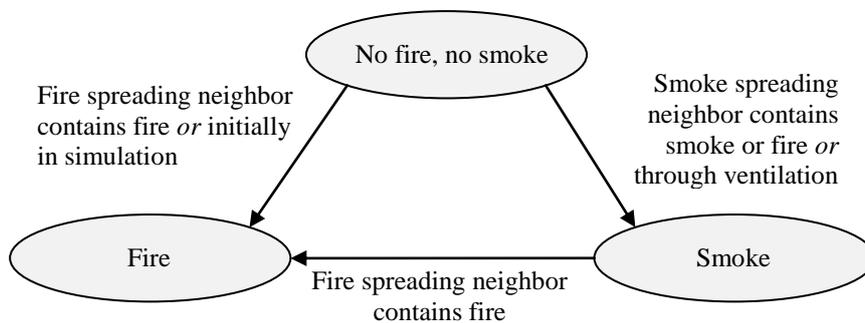
Each room has a unique ID which can be a string or a number, however all linked rooms have the same main ID and are separated by “-“ in the form “room ID-subroom ID”. These sub-rooms will automatically have the same fire and smoke status unless the user specifically sets them to be non-spreading neighbors. This is applicable when there are fire doors between rooms.

A room can be of the type corridor which is defined in the text file when setting up the room structure. The corridor type is just a graphical distinguishing to make it easier to visualize the Vessel Model for the FISPAT user.

The status of a room is one of

- Fire (indicating that smoke is also present)
- Smoke
- No fire and no smoke

The valid transitions between states are shown in Figure 2. Note that once fire or smoke is present there is no transition back to no fire and no smoke.



**Figure 2. The status of a room can be one of *No fire, no smoke*, *Smoke* and *Fire*. The transitions between states are shown.**

Apart from this the neighbors whom the room spreads fire to and whom it spreads smoke to can be defined in each simulation setup. The spreading neighbors are chosen by the user from the list of identified neighbors in the GUI. Note that fire can be spread between

rooms that are not explicitly set to be fire spreading neighbors if none of them have a functioning water network present and the control option *Fire is spread if no sprinkler* is chosen.

To summarize, a room is defined by its

- ID
- Corners
- Type
  - Room
  - Corridor
- Fire spreading neighbors
- Smoke spreading neighbors
- Status
  - No fire, no smoke
  - Smoke
  - Fire

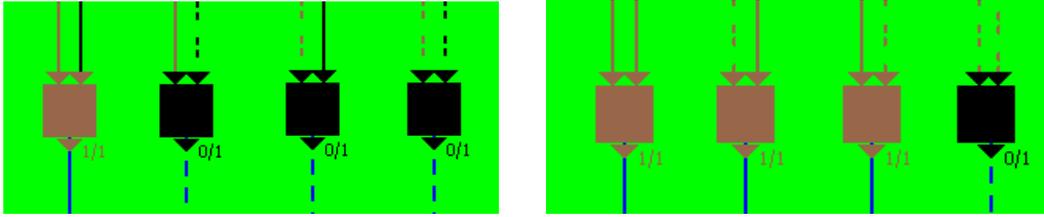
## 2.1.2 Networks

There are six types of networks represented in FISPAT:

- electric power
- water
- ventilation
- hydraulic
- pneumatic
- control (computerized or not)

All networks are defined by their type and their 3-d paths and are physically present in a set of rooms. The path of a network can only change in one direction at a time, meaning that the path is either in the x-, y- or z-direction. The placement of a network, *with respect to rooms*, is the same as in reality; however, the actual placement of networks within rooms does not need to be the same as in reality.

All networks can depend on apparatus (see section 2.1.3) to function or considered to be independent. The dependencies are specified in the apparatus except how many redundant apparatus the network needs to function which is specified in the network. If fewer than the defined redundant apparatus are functioning the network will also be non-functioning in the simulation. A network can be set to depend on two apparatus and have three redundant apparatus as input. In this case one of the apparatuses can become non-functioning and the network will still function. If more than one apparatus is non-functioning the network will however also be non-functioning. If a network depends on two different kinds of apparatus at least one of each type need to function for the network to function.



**Figure 3.** The brown boxes are functioning apparatus and the black boxes are non-functioning apparatus. The lines are functioning networks and the dotted lines are non-functioning networks. *Left:* Apparatus depends on different kinds of networks (arrows towards apparatus). Once one network is non-functioning so is the apparatus. *Right:* Apparatus depends on same kind of network and both networks need to be non-functioning for the apparatus to become non-functioning.

The status of a network is either functioning or non-functioning. A non-functioning network can never, during the simulation, be set as functioning again. There are three ways for a functioning network to become non-functioning:

- One of the rooms in which the network is present is set on fire (for water networks the control option *Water networks non-functioning by fire* needs to be chosen).
- Fewer than the required apparatuses on which it depends are functioning.
- The user sets the network to be non-functioning initially in a simulation.

Note that even though the network is present in a burning room it can be set functioning by the user at setup. This might be useful when testing the outcome of another type of network and/or material.

A ventilation network is set to have both an inlet and an outlet in all rooms it goes through as a consequence of the worst case scenario that is used throughout the simulation. In this way, all rooms where the ventilation network is present will be burning and/or contain smoke when the ventilation does. Individual rooms can however be excluded from spreading fire and smoke if specified by the user. The direction of air flow in a ventilation network is ignored i.e. the worst case scenario is used where fire and smoke is spread in both directions. Once fire or smoke is present in a room with a ventilation network, fire or smoke will spread (depending on Control Options) to all rooms where the ventilation network is present (unless a room is explicitly chosen not to spread).

Sinks and tanks are not part of the Vessel Model. If a water network relies on a water tank to function, the tank is omitted in the Vessel Model.

### 2.1.3 Devices

Devices are split up in two main categories: Apparatus and Sectioning devices. The status of a device is either functioning or non-functioning. A non-functioning device can never, during the simulation, be set as functioning again. If the device depends on several networks of the same kind, these are interpreted as being redundant and the device will function as long as one of the input networks of each type is functioning.

If a device depends on different kinds of networks, these network types are all interpreted as being needed for the functionality of the device. As long as one of the networks of each type is functioning, so is the device. This is to model redundant input networks. Any type of device can be set to depend or affect any type of network; there is no in-program check for the dependencies with respect to type of device and type of network.

There are three ways for a device to be non-functioning:

- The room in which the device is present is set on fire.
- One of the networks on which it depends is set non-functioning. This is not enough if there are redundant networks of the same type, in which case all of the redundant networks of one type need to be non-functioning.
- The user sets the device to be non-functioning initially in a simulation.

Devices are built graphically in FISPAT or can be specified by the user in a text-file. The networks on which the device depends or affects need to be built before the device can be built. This is because a device needs to depend and affect at least one network.

The positions of devices and networks in a room are not significant for the results of simulations in FISPAT. However in the Graphical Representation of the Vessel Model the user is forced to put networks that affect or depend on a device in contact<sup>1</sup> with the device. If a device has contact with all networks that it affects or depends on, it is properly connected. If not, it will get an error marking (yellow) in the GUI.

Devices are used to model dependencies between networks and can hence both affect and depend on networks. A device can depend on or affect the following types of networks (note that there is no in-program check for this):

Network	Device can depend on network	Device can affect network
Electricity	Yes	Yes
Water	No	Yes
Ventilation	No	Yes, but only via Sectioning device
Hydraulic	Yes	Yes
Pneumatic	Yes	Yes
Control	Yes	Yes

As mentioned above, there are two categories of devices; Apparatus and Sectioning devices.

#### Apparatus:

The type of the apparatus is defined by the user and can be one of:

- Pump
- Electric Control Unit
- Other

An apparatus is used to model a dependency between different networks. E.g. a water network can be dependent on an electrical network via an electric pump.

#### Sectioning devices:

Sectioning devices are used for making it possible to isolate two or more networks from each other. A functioning sectioning device prevents a fault in one network to spread to the other network. An example of a sectioning device is a valve on a water network which can prevent a wide spread loss of water pressure in case of a leak. The networks handled by the sectioning device must be of the same type.

<sup>1</sup> Contact is defined as  $D_{\text{Chebyshev}}(D, N_e) \leq L$  which is the area that's covered by the device symbol in the graphical representation.

$$L = \sqrt{\text{Average area of a room on the deck with highest amount of rooms}} / 14$$

D = Device position.

$N_e$  = Closest network endpoint

A sectioning device used in ventilation networks works in a slightly different way. A functioning sectioning device between two ventilation networks will prevent smoke (and fire if the user has set ventilation networks to spread fire using the control options) from spreading past the sectioning device including to the room where the sectioning device is present.

A sectioning device can itself be dependent on one or more input networks as in the case of a remotely controlled, electrical valve which is dependent on electricity and control networks. If electricity or control network connected to the sectioning device is faulty the sectioning device becomes faulty i.e. it cannot function as a sectioning device anymore; it becomes transparent. The effect of this will only be visible when one of the connected networks becomes non-functioning. In that case the other will be set as non-functioning as well. If the sectioning device depends on one of the networks that it sections, the other of the sectioned networks will depend on the first. Once the network that the sectioning device depends on is set non-functioning the other network will also be non-functioning.

### 2.1.4 Redundancy

Redundant networks and apparatus can be modeled in FISPAT. To model redundant networks, two or more networks need to be created. If a network has redundant inputs that it depends on, e.g. a water network that has two pumps, these pumps are created as two separate pumps that both affect the water network. Dependencies where a network needs more than one apparatus to function can also be modeled. In this case the network might need two functioning pumps to function and once there is less than two the network will also become non-functioning. There is no upper limit on how many redundant apparatus a network can depend on.

If a device depends on several networks of the same type, these networks are all redundant inputs to the device. As long as one of the redundant networks is functioning, so is the device. However, if all the redundant inputs are non-functioning, the device will be non-functioning. There is no upper limit on how many redundant networks a device can depend on.

## 2.2 Fire Spread Modeling

In general a conservative approach is taken in the simulations. A worst-case scenario is implemented where the following modeling aspects apply for rooms:

- A fire could start as a single fire centre or as multiple fire centers.
- A fire can exist simultaneously as faults.
- A fire does not affect mechanical strength of walls, floor and ceiling.
- A fire does not result in an explosion.
- Fire spread can occur horizontally, vertically (e.g. a fire in the funnel) or both at the same time.
- Fire can spread between rooms:
  - via Ventilation network.
  - if neighboring rooms lack functioning water networks.
  - if they are specified as fire-spreading neighbors.
  - via open doors (modelled as fire spreading neighbors).
- Once fire is present in a room, it will not be put out during the simulation.
- When fire is present, so is smoke. There cannot be fire without smoke; however smoke can be present in a room without fire.
- There can be multiple fire origins.

- Fire door is modeled by setting the rooms on both sides to be fire spreading neighbors (an open fire door) or by setting the rooms not to be fire spreading neighbors (a closed fire door).
- A conservative approach is used; if a room is burning the result is that all networks and devices present in that room will be non-functioning. However, water networks can be set as fire resistant by the user (the network will not be set as non-functioning because it is present in a room containing fire). The setting will apply to all water networks in the model, they cannot be individually set as fire resistant.
- A contained fire can be modeled by setting the room to not be able to spread fire to its neighbors.
- To analyze parts of a room, these parts can be modeled as virtual sub-rooms by dividing one room into several. Note that one room cannot comprise another room, i.e. rooms cannot overlap.
- If a fire can spread outside rooms e.g. at the outside of a vessel it can be modeled by adding an extra room representing the exterior of the vessel.

### Networks and devices

- A fire makes networks non-functioning. However water networks only get non-functioning if the control option *Water networks non-functioning by fire* is chosen.
- For water the only networks considered are those that are used for handling fire. For example, water networks for washing are not included.
- Fire and smoke are not spread via networks except ventilation.
- For ventilation networks, all rooms in which they are present are, by default, assumed to have both air inlet and outlet. This implies that once smoke is present in the ventilation network, all rooms will contain smoke (if not stopped by a functioning sectioning device). In the same way if ventilation networks are set to spread fire then once fire is present in a room with a ventilation network fire will spread to all rooms containing that network (if not stopped by a functioning sectioning device).
- Modeling of a room without air in-/outlet is done by excluding the room from the ventilation network. This only affects the selected room and allows the other rooms where the network is present to spread smoke/fire.
- For ventilation networks, the direction of air flow is ignored allowing fire and smoke to spread in both directions.
- A functioning sectioning device on a ventilation network will prevent smoke (and fire if the user has set ventilation networks to spread fire) from spreading past the sectioning device including to the room where the sectioning device is present.
- Manual control of devices is not modeled in FISPAT.
- For a network to exist it must be present in at least two rooms (a network completely located in a single room is not significant).

## 2.3 Smoke Spread Modeling

The following holds for the smoke spreading model:

- Smoke can spread between rooms:
  - Via ventilation networks
  - Between neighboring rooms if they are
    - Fire spreading neighbors (spreads fire too) *or*
    - Smoke spreading neighbors (spreads only smoke)
- Smoke can spread horizontally, vertically or both at the same time.

- Smoke is not a fault i.e. there could be a technical fault or a human error as well when smoke is present.
- Smoke may come from different places even if there is only one fire centre e.g. from different ventilation channels. Thus there is a very weak mapping between smoke location and location of fire centre.
- Since smoke is a secondary effect (from fire) it cannot be eliminated on its own.
- Smoke and toxic gases are assumed not to affect equipment such as networks and devices.

## 2.4 Limitations

The following aspects are not considered in simulations:

- Notion of time, only a *start* and an *end* state are relevant.
- The pace of the fire spread.
- Internal content of a room, i.e. all rooms will instantly be considered fully on fire once in contact with fire in accordance with the worst-case scenario approach.
- Probabilities of events.
- Recovery. Once an event has occurred it cannot be reversed.
- Resources to feed networks such as water, air pressure etc.
- Human interaction.
- Number of casualties.

The networks and devices in a room can be set functioning by the user even though the room is on fire. This might be useful to examine what would happen if a certain network wasn't affected by fire.

## 2.5 Fault Injection

Apart from simulating fire spread, FISPAT can be used to perform fault injection in the Vessel Model. In that case no room is set on fire; instead fault injection is done by setting one or several networks and/or devices as non-functioning. When the initial state is simulated, the spread of the fault can be analyzed in the resulting state. By performing exhaustive simulations with this kind of fault injection one can determine which networks and/or devices that are most critical. Redundant networks and devices can then be added to the Vessel Model to see if the construction can be made more robust and tolerable to faults.

## 2.6 Interfaces to other investigations

Room size and interior composition are not considered in the simulations which call for other investigations on how these parameters affect the fire spread. In FISPAT once fire is present in a room, the whole room is set on fire which is a simplification. For more knowledge on how the fire actually behaves, experiments may need to be undertaken. The simulations in FISPAT can serve as a starting point in choosing initial conditions for these experiments. The most critical rooms for fire spread can be found by simulations and experiments can then be performed on these.

Consequences and probabilities are not considered which opens up for separate analyses of number of people killed or injured in case of fire. This is not discussed in this report but FISPAT can be a good starting point for these analyses. By simulating different initial states and analyze which rooms will be on fire in the resulting state, the further consequences can be analyzed outside the program.

Spread speed (fire, smoke) is not considered and is also suitable for experiments. Once fire is present in the Vessel Model it will spread instantly to the rooms that meet the requirements for fire spreading. However in reality this can be analyzed in fire laboratories and more complex scenarios can be found and used for the overall consequence examination.

Performing iterative simulations in FISPAT with slightly different Vessel Models is a very efficient way to evaluate possible vessel drawings before a vessel is being built. Altering a network path to find the consequences of the overall fire spread is very easy. Once the worst outcome of an initial fire is found through simulations, means can be applied in order to reduce the consequences. Introducing redundant networks and devices can be efficient ways to reduce the effects of a fire.

## 3 Graphical User Interface

This chapter explains all parts of the GUI. Each sub-chapter starts with a short introduction followed by a screenshot and detailed information about the user interactions.

### 3.1 Menu

The menu at the top of the main window is used for basic program operations. This menu is the same for all tabs.

**Help:** Contains How to Use, user manual of FISPAT.

**About:** Information about the version number and the development of FISPAT.

**Exit FISPAT:** Exits the program. If networks or devices have been created and not saved, a warning message is displayed.

### 3.2 Vessel Model Setup Tab

This tab is shown once the program is started. It allows the user to load the files to the Vessel Model, i.e. room file, network file and device file. The format is described in Appendix 1.

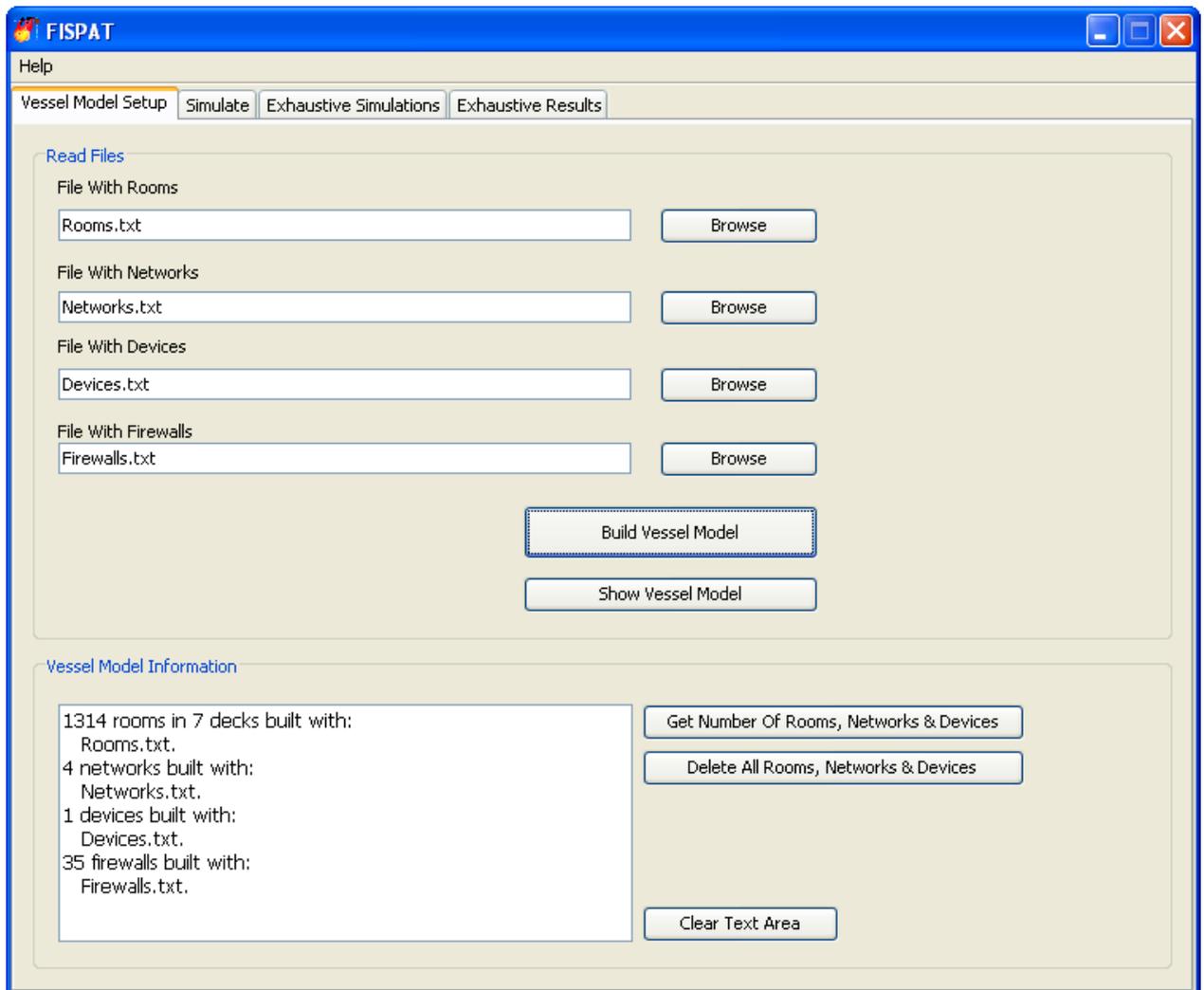


Figure 4: Vessel Model Setup tab.

**Read Files:**

**File With Rooms:** Press Browse to select the file containing the room information.

**File With Networks:** Press Browse to select the file containing the network information. If a network file is loaded but should not be used to build the Vessel Model, press the Delete All Rooms, Networks and Devices button to start over. If this text field is left blank, no networks will be loaded.

**File With Devices:** Press Browse to select the file containing the device information. If a device file is loaded but should not be used to build the Vessel Model, press the Delete All Rooms, Networks and Devices button to start over. If this text field is left blank, no devices will be loaded.

**File With Firewalls:** Press Browse to select the file containing the firewalls information. If a device file is loaded but should not be used to build the Vessel Model, press the Delete All Rooms, Networks and Devices button to start over. If this text field is left blank, no firewalls will be loaded.

**Build Vessel Model**

Builds a Vessel Model with the room, network, device and firewall files specified. If any of the files is corrupt (incorrect syntax, references to networks

or rooms not defined etc) an error message is shown in the information text area. If networks and devices have been loaded once but should not be present in a new loaded Vessel Model, the button Delete All Rooms, Networks and Devices can be pressed and the new files can be loaded.

#### **Show Vessel Model**

Opens a “pop-up” with a visual representation of the Vessel Model with the rooms, networks and devices loaded by the user (see section 3.3).

#### **Vessel Model Information:**

##### **Get Number of Rooms, Networks and Devices**

Displays the number of rooms, networks and devices in the present Vessel Model.

##### **Delete All Rooms, Networks and Devices**

Deletes everything built so the user can build a new Vessel Model. This does not need to be done to build a new Vessel Model, but it resets the file selection fields if the user wants to create a Vessel Model without devices or networks and devices.

##### **Clear Text Area**

Clears the text area with information about the Vessel Model.

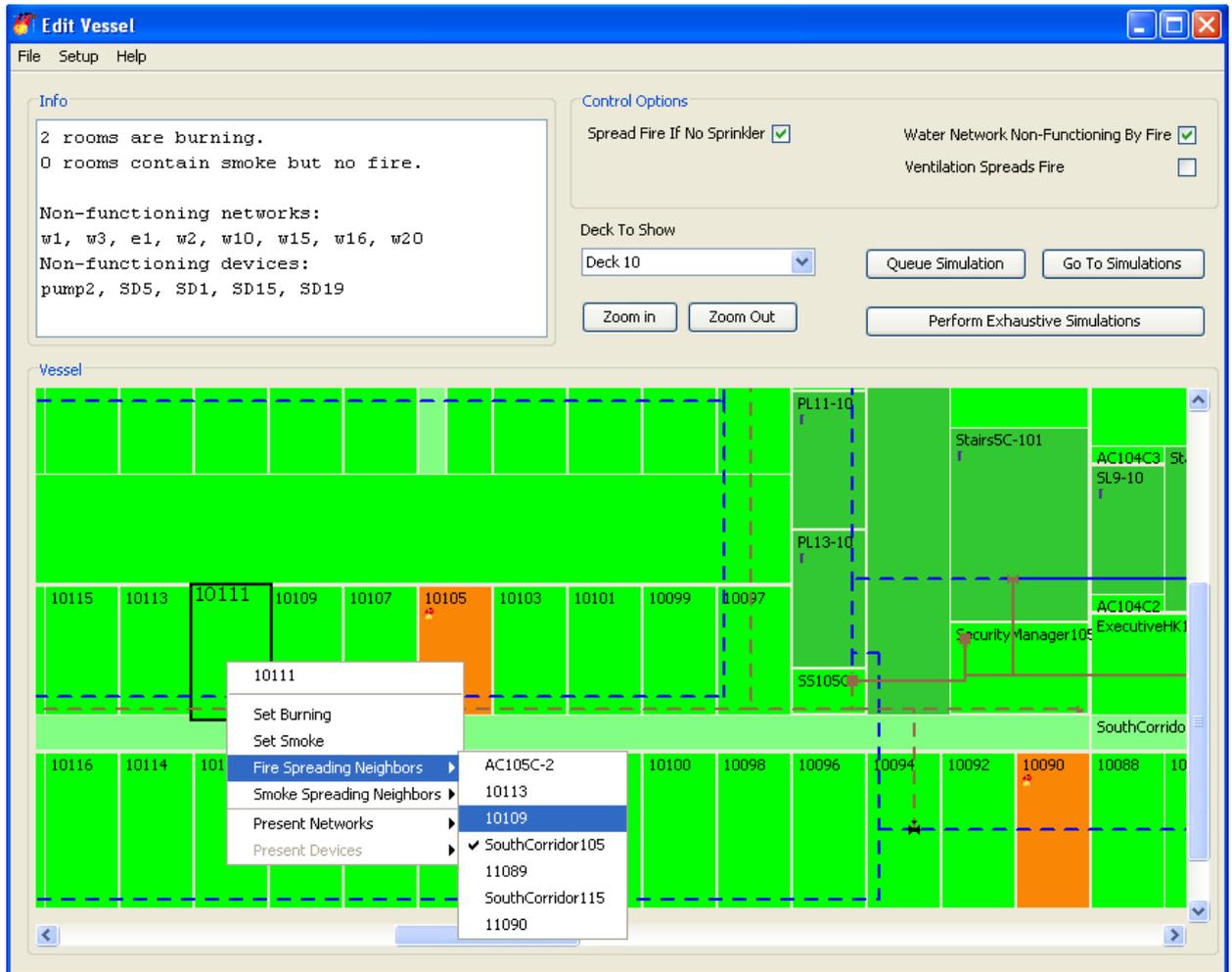
## **3.3 Graphical Representation**

The Graphical Representation is used to set the initial state of a new simulation, but also to get a graphical view of the initial and end states of a finished simulation.

This frame can be invoked in different ways and shows a graphical representation of the Vessel Model. It can be one of three types:

- Edit Vessel: invoked by “Show Vessel Model” in Vessel Model Setup tab or “Edit Item” in the Simulate tab.
- Initial Vessel: invoked by ”Show Initial Vessel” in the Simulate tab or Exhaustive Results tab.
- Resulting Vessel: invoked by “Show Resulting Vessel” in the Simulate tab or the Exhaustive Results tab or by double-clicking one of the results in the Exhaustive Results list.

If the frame is an “Edit Vessel” the user can create simulations by setting up the initial state and then queue the simulation. Only one Edit Vessel frame can be open at a time. If the frame is an Initial or Resulting Vessel interaction in the frame is limited to actions that show information. Multiple frames of these kinds can be open at the same time, allowing the user to compare different initial and resulting states. An extra feature when viewing an exhaustive simulation Resulting Vessel is the possibility to highlight all burning rooms that share the same fire origin (see chapter 4).



pop-up browser. The saved Vessel Model setup file is editable if it is saved here and can hence be modified later by loading the setup file.

**Load Setup:** Loads txt file with a Vessel Setup previously saved. The user must make sure to choose a file with corresponding rooms, network and devices or this action might corrupt the results. The file to load is chosen by the user in a pop-up browser. If the setup file is editable it will be loaded into the current Vessel Model in the Graphical Representation. If the loaded setup is a resulting Vessel Model setup it will be opened in a new window where the result can be examined.

### Help

**Graphical Explanation:** Shows a scheme of the colors and symbols used in the Graphical Representation.

**Help Documentation:** Displays the help files.

## 3.3.2 Text Area and Buttons

**Info Text Area:** Contains information about the Vessel Model that is currently displayed. It contains information about how many rooms that are burning and how many that contains smoke, which networks and devices that are non-functioning along with information from and to which files Vessel Model setups are loaded and saved.

**Deck to Show:** Allows the user to select which deck to show.

**Zoom In/Out:** Zooms the displayed Vessel Model.

**Queue Simulation:** Saves the current setup as an initial simulation state in the list in the Simulate tab (see section 3.8). If there are badly connected devices, an error message is displayed and no simulation is queued.

**Go To Simulations:** Brings the Simulate tab into focus.

**Perform Exhaustive Simulations:** Brings the Exhaustive Simulations tab into focus where the user can perform exhaustive simulations on the Vessel Model in the Graphical Representation. If there are badly connected devices, an error message is displayed and these errors need to be resolved before exhaustive simulations can be undertaken.

### Control Options

**Spread Fire If No Sprinkler:** Fire will be spread if there are no functioning water networks present in adjacent rooms.

**Water Network Non-Functioning by Fire:** Fire will make water networks non-functioning if this box is ticked.

**Ventilation Spreads Fire:** Ventilation will spread fire if this is selected. If this box is deselected, only smoke will be spread through the ventilation.

### 3.3.3 Mouse Interaction

- **Wheel scrolled:** Zooms in and out. Disabled if the shift or ctrl key is pressed.
- **Left button:** Pans the Vessel model while pressed and dragged.
- **Right button:** Invokes a pop-up menu where the setup of the clicked room can be altered. The room can be set as burning or containing smoke and it can be set to spread fire or smoke between its neighbors. Sub-rooms are automatically identified as fire spreading neighbors. The functionality of the present networks and devices can also be set and their dependencies are shown. The “Go To” option will appear when a network depends on a device. When clicked, the chosen device will be in focus of the image. Note that the device might not be in the middle of the image if it is located close to an edge of the Vessel Model. When interacting with a room containing a ventilation network the exclude room option is available under /present networks/ the ventilation network. If this option is selected, the ventilation network will not spread smoke or fire to the room and vice versa.
- **Ctrl + left button pressed and dragged:** Draws a network. When the mouse button is released, a pop-up menu appears with the options “New Network”, “Extend Network” and “Branch Network”. Choosing a network option will invoke the Network Creator frame (see section 3.4) which allows the drawn network to be created.
- **Ctrl + left clicked:** Invokes a menu with the option “New Device”. Choosing “New Device” will invoke the Device Creator frame (see section 3.6) which allows creation of a device where the mouse button was pressed.
- **Shift + left button clicked:** If on a device will invoke Device Creator and the dependencies of the device can be altered. If in a room with a network endpoint, this network coordinate can be deleted as well as the whole network. If there are many endpoints in the room, the endpoint closest to the mouse can be edited.
- **Shift + left button pressed and dragged:** If on a device lets the user move the device around. If in a room with a network endpoint, this endpoint can be moved to a new position or deleted. When the mouse button is released, an option menu that asks “Save” or “Cancel” will show. Apart from above options, the endpoint or the whole network can be deleted if these options are chosen in the pop-up menu.

### 3.3.4 Graphical Explanation

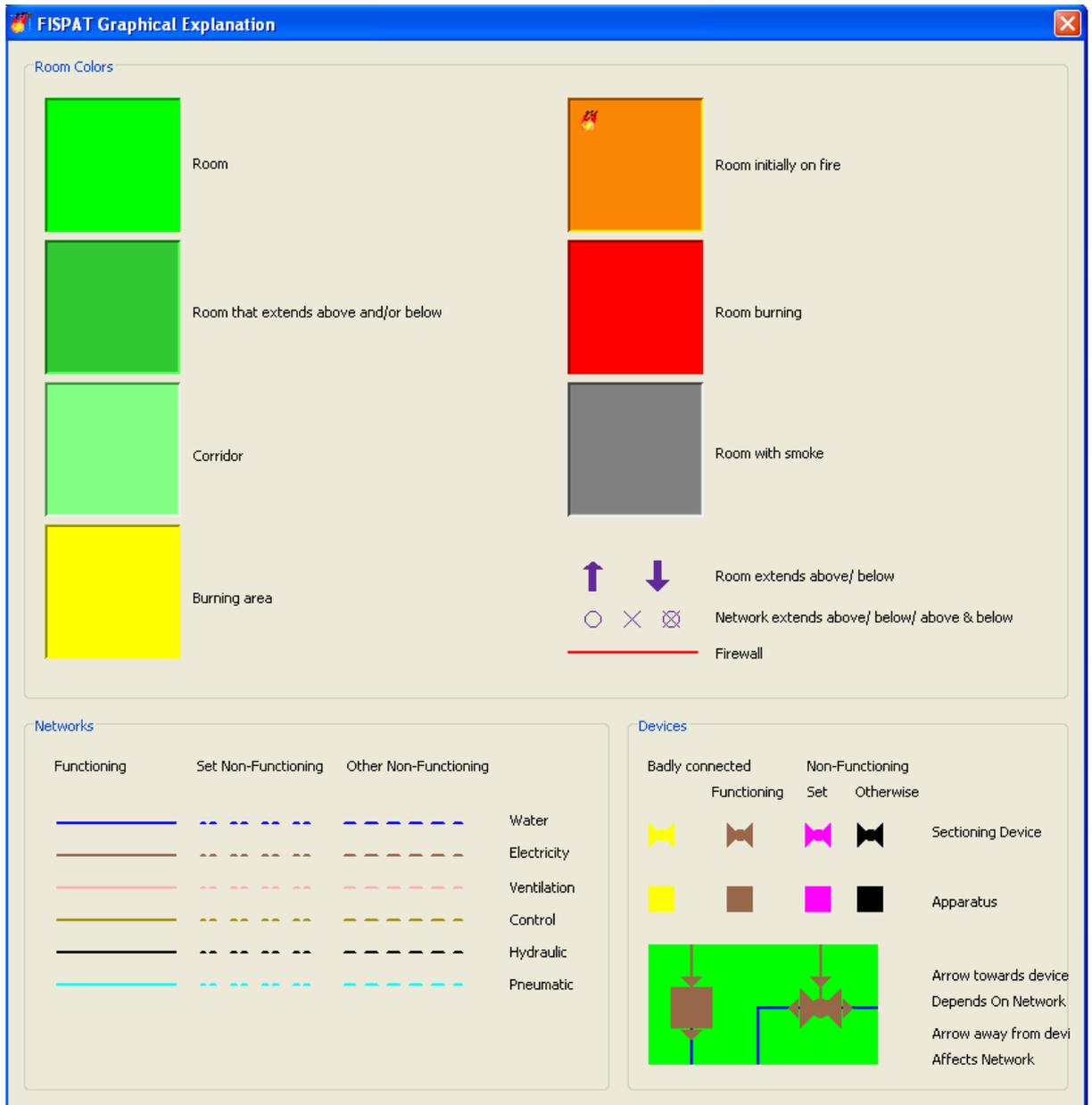


Figure 6. Graphical Explanation of the colors and symbols used in FISPAT.

#### Rooms:

- Green: Indicates that there is no fire or smoke in the room.
- Dark Green: Indicates that there is no fire or smoke and that the room extends through several decks.
- Light Green: Indicates that there is no fire or smoke and that the room is defined as a corridor by the user in the input file.
- Orange + Fire Icon: Indicates that the room was initially set on fire by the user.
- Red: Indicates that fire was spread to the room during a simulation.
- Gray: Indicates that there is smoke but no fire in a room.
- Yellow: Only shows when viewing an exhaustive simulation result. When the mouse pointer is on a burning room all rooms sharing the same fire origin is turned yellow.

- Blue Arrows: The room extends to deck above (↑ up arrow) or below (↓ down arrow).
- Circle: Network continues on the deck above.
- Cross: Network continues on the deck below.
- Circle and cross: Network continues above and below.
- Red line: Firewall between rooms.

#### **Networks:**

- Color: Indicates the type of network.
- Double dashed: Network initially set non-functioning by the user at setup or initially in a simulation.
- Single dashed: Network non-functioning as a consequence of presence in a burning room or dependency on non-functioning devices.

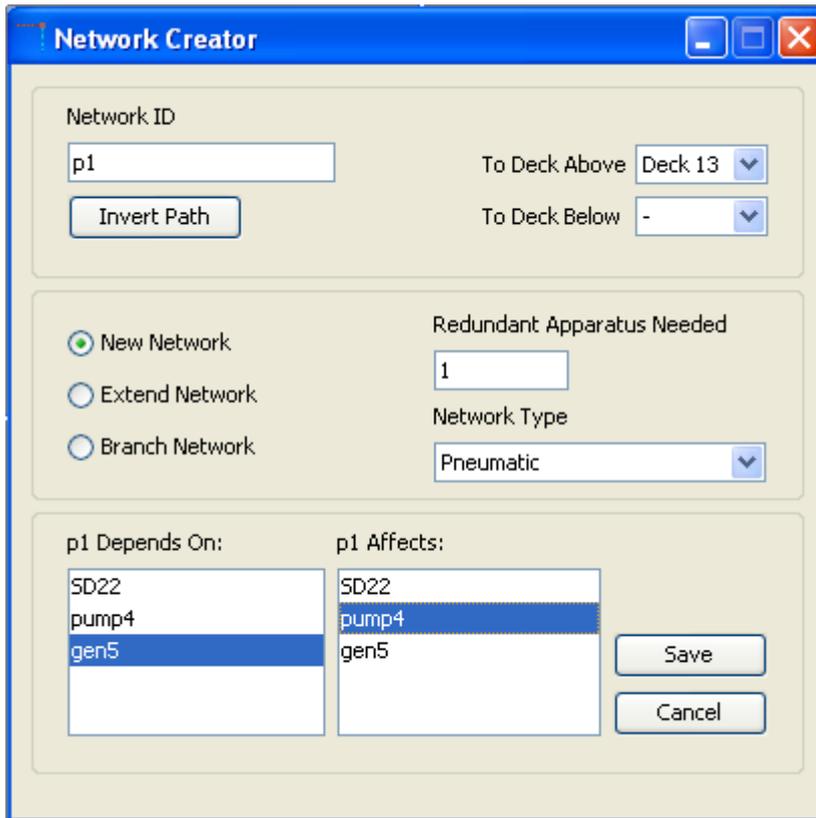
#### **Devices:**

- Bow-tie: Sectioning device.
- Square: Apparatus.
- Yellow: Badly connected. The device is not properly connected or lacks network that it depends on or affects. Sectioning devices must affect at least two networks and all need to be of the same type. The yellow color has precedence over the other colors so any other color indicates that the device is properly connected.
- Brown: Functioning device.
- Magenta: Device initially set as non-functioning at setup.
- Black: Device set non-functioning as a consequence of dependence on non-functioning networks or presence in a burning room.
- Arrow towards a device: the device depends on the network.
- Arrow away from device: the device affects the network.

## **3.4 Network Creator**

The Network Creator is used to build new networks and to extend and branch existing ones. This window is invoked in the Graphical Representation by holding down ctrl while dragging the mouse with the left button pressed. The action draws a network parallel to the x- and y-axis between two coordinates (i.e. L-shaped) in the Graphical Representation of the Vessel Model. When the user is satisfied with the drawn network, the left mouse button is released and the user selects whether the new path should extend or branch an existing networks or be a new network.

For a network to have a path built up by more than two lines it can be extended several times which allows for more complex paths than a single L-shape.



**Figure 7.** The Network Creator is used to build new networks and to extend or branch existing ones.

**Network ID:** Depending on the network type chosen, the program will suggest an ID that is the first possible of the chosen type according to the following convention:

- w -water
- e -electric
- v -ventilation
- h -hydraulic
- p -pneumatic
- c -control

The type of the new network is determined in the Network Type combo box (see Network type below). The number following the letter is the lowest available ID of that network type. If electrical networks with ID:s “e1” and “e2” exist, the ID “e3” will be suggested. However, the ID can be chosen by the user to be any combination of A-Z and 0-9, e.g. to comply with a blueprint. A warning will show if the ID is already occupied by another network. When a network is saved, the ID can only be changed by editing the text file (if networks are saved). However, editing the network ID in the text file might corrupt the device file if that is not edited accordingly.

If Extend Network or Branch Network is chosen, the Network ID will be the same as the network chosen in the scrollbar and cannot be changed.

**Invert Path:** Changes the direction of the network path drawn in the Graphical Representation. If the network is painted in the x-direction at the top, this button will paint it the other way around (┌ will become └). If any part of the network will be outside the vessel, a message is displayed and the operation is not undertaken.

**To Deck Above/Below:** Extends the end of the new network to the deck/decks selected.

**New Network:** Creates a new network with the path drawn by the user in the Graphical Representation when the window was invoked. The type of network can be chosen in the type scrollbar and the network ID can be edited in Network ID.

The possible geometries of new networks are limited by the drawing function in the Graphical Representation. Some limitation can be bypassed by the branch and extend functions, this is done by once again holding down ctrl while dragging the mouse with the left mouse button pressed. When the mouse button is released, this window is invoked and the network can be extended or branched.

**Extend Network:** Can only be used if the room where the new network starts contains an endpoint of an existing network. The existing networks that have an endpoint in that room will show in the scrollbar. If a network that spreads over several floors should be extended in one of the intermediate floors, Extend Network must be used.

**Branch Network:** Is used to branch an existing network. The existing network must be located in the room where the drawn network starts, i.e. the user needs to start the drawing of the new network part in a room where the existing network to branch is located. All the networks in the room will show in the scrollbar and the network to branch can be selected. The new branch will start from the closest part of the existing network that is perpendicular to the new part. Even though the user did not start the new network path exactly on the network to branch, the program will make sure it does.

**Redundant Apparatus Needed:** How many apparatus of the same kind that the network needs to function. If the network needs two pumps to function, two is printed in this field. Once fewer than two redundant pumps are functioning, the network will also become non-functioning.

**Network Type Scrollbar:** Depending on if the added network is new, extended or branched, the scrollbar will show different alternatives. If Extend or Branch Network is chosen, the headline will be changed to “Network To Extend/Branch”. If New Network is chosen, the type of network to build is chosen in the scrollbar. If Extend Network is chosen, networks with an end- or start-coordinate in the present room can be chosen here. The network that should be extended is chosen. If Branch Network is chosen, all the networks present in the room will show and the desired network to branch can be chosen.

**Depends On:** The devices that the network is to depend on are selected in this list. When branching or extending a network the user can not edit this list, this must be done when editing the involved devices (see section 3.6). When creating a new network, the devices that the network depends on are selected in this list. Only devices that are present in the room where the network is are displayed. To select more than one device or to deselect, hold down Ctrl while clicking the left mouse button. To create a double dependence the network is selected to depend on and affect the same device. In this way, the functionality of the network and the selected device will depend on each other.

**Affects:** Similar to Depends On. Here the devices that depend on the network are selected. When branching or extending a network the user can not edit this list, this must be done when editing the involved devices.

When creating a new network the devices the network affects can be edited in this list. Only devices that are present in the room where the network is present are displayed. To select more than one device or to deselect, hold down Ctrl while clicking the left mouse button.

**Save:** Saves the network to the present Vessel Model. See section 3.3.1 on how to save the networks to file.

**Cancel:** Cancels the network creation and returns to the Graphical Representation.

### 3.5 Network Delete

If a network is created by mistake, hold down shift and click the left mouse button close to a network endpoint. Choose “Delete Network” in the pop-up menu.

### 3.6 Device Creator

The Device Creator frame is used to create new devices and to change dependencies of present devices. This frame can be invoked in two ways:

- By holding down ctrl and then clicking the left mouse button where the new device should be located in the Graphical Representation.
- By holding down shift while clicking the left mouse button on an existing device in the Graphical Representation. This allows for editing an existing device.

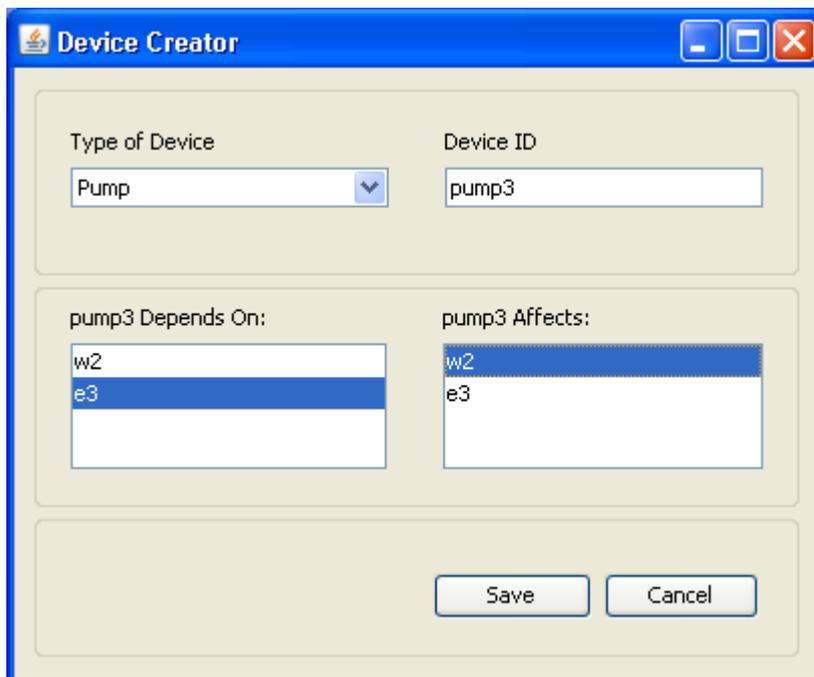


Figure 8. The Device Creator is used to build new devices and to edit existing ones.

**Type of Device:** The type of the device to build is chosen in the scrollbar. If device type Other is chosen this will be saved as other.

**Device ID:** Depending on the device type chosen, the program will suggest an ID that is the first possible of the chosen type. If Pumps with ID:s “pump1” and “pump2” exist the ID “pump3” will be suggested. However the ID can be chosen by the user to be any combination of A-Z and 0-9, e.g. to comply with a blueprint. A warning will show if the ID is already occupied by another device.

**Depends On:** The networks that the device depends on are selected in this list. To select more than one network or to deselect, hold down Ctrl while clicking the left mouse button. Networks present in the same room as the device are listed together with the networks that the device depends on even though these are not in the same room as the device. If different types of networks are chosen, all those network types need to function for the device to function.

**Affects:** The networks that the device affects are selected in this list. To select more than one network or to deselect, hold down Ctrl while clicking the left mouse button. Networks present in the same room as the device are listed together with networks that are previously selected to be affected by the device. For sectioning devices, the networks whose functionalities are sectioned are selected and at least two networks need to be chosen as affected by the sectioning device. These networks need to be of the same type.

**Save:** Saves the device to the present Vessel Model. See section 3.3.1 on how to save devices to file.

**Cancel:** Cancels the device creation and returns to the Graphical Representation.

### 3.7 Device Delete

If a device is created by mistake it can be deleted by holding down shift while clicking the device with the left mouse button. Choose “Delete Device” in the pop-up menu.

### 3.8 Simulate Tab

The second tab in the main frame is called Simulate. Here single simulations can be executed and the initial and resulting states can be viewed. The initial state can also be edited further. It is also possible to retrieve and view the end and initial state of all finished simulations.

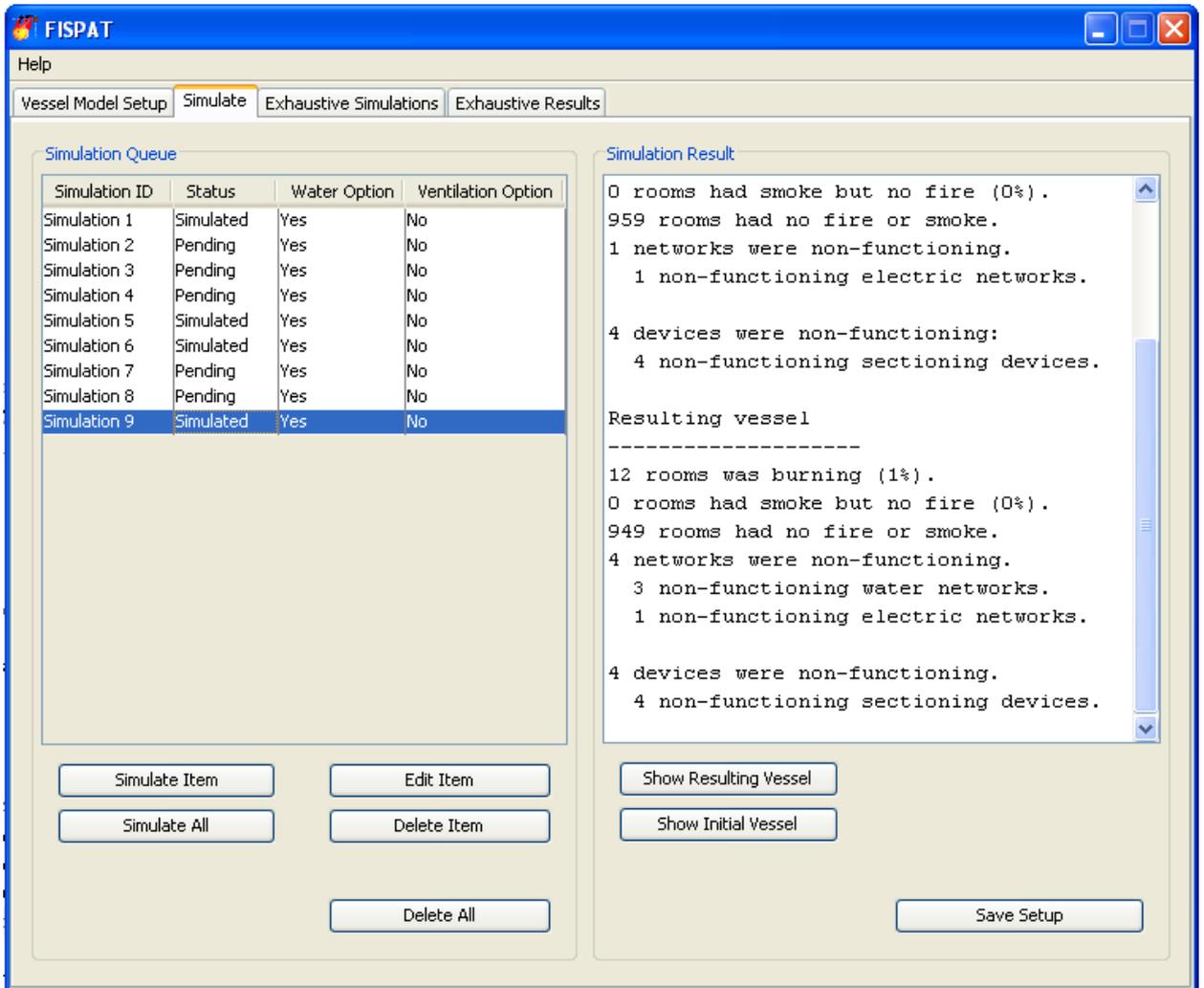


Figure 9: Simulate tab in FISPAT where single simulations can be run and examined.

**Simulation Queue:** A list of all simulations that have been queued in the Graphical Representation.

**Simulation ID:** An ID to keep track of the simulations; the number indicates the order in which the simulation was added to the list.

**Status:** Pending/Simulated, indicates if the simulation has been simulated or is pending.

**Water Option:** Yes/No. Indicates if water networks are damaged by fire (a control option).

**Ventilation Option:** Yes/No. Indicates if ventilation networks spread fire (a control option).

**Simulate Item:** Runs the selected simulation in the list. When the simulation is done, the status will change to “Simulated”.

**Edit Item:** Loads the initial state of the simulation to the Graphical Representation, allowing the user to further manipulate it and queue new simulations. Note that the initial state of the chosen simulation will not change; the state will only be used to queue new simulations originating from this.

**Simulate All:** Simulates all pending simulations in the list. When the simulations are done, their status will change one by one from “Pending” to “Simulated”.

**Delete Item:** Deletes the selected simulation. No files are saved from this simulation; the simulation is deleted.

**Delete All:** Deletes all the queued simulations from the Simulation Queue list.

**Simulation Result:**

**Text Area:** Contains information about the selected simulation. If the simulation is done, the text area presents information about the initial and resulting Vessel Model states. If the simulation is not yet run it only presents information about the initial state.

**Show Resulting Vessel:** Shows a Graphical Representation of the resulting state of the selected simulation.

**Show Initial Vessel:** Shows a Graphical Representation of the initial state of the selected simulation.

**Clear Text Area.**

Clears the Simulation Result text area with information about the highlighted simulation.

**Save Setup:** Shows a browser where the user can specify a file and save the initial state. The file names used to build the Vessel Model are included in the file header, as is the result statistics from the Simulation result text area for the specific simulation. This setup can later be loaded from the menu in the Graphical Representation.

## 3.9 Exhaustive Simulations Tab

In the third tab in the main frame exhaustive simulations are set up. Here the user can run large numbers of simulations and identify the most interesting initial states. This tab uses the Vessel Model displayed in the editable Graphical Representation (if no editable Graphical Representation is displayed the model that was initially loaded in Vessel Model Setup is used). The rooms that are set as initially burning in the Graphical Representation will be set as burning in all simulations performed within the exhaustive simulations. Similarly, all networks and devices set as non-functioning in the Graphical Representation will be kept as non-functioning throughout all simulations in the exhaustive run. When all criteria in this tab are set, the program run all simulations that match the setup criteria and save all the initial states that meet the save criteria. Initial parameters are set for limiting the amount of simulations for efficiency reasons and limiting the amount of results displayed in the exhaustive results tab (see section 3.10).

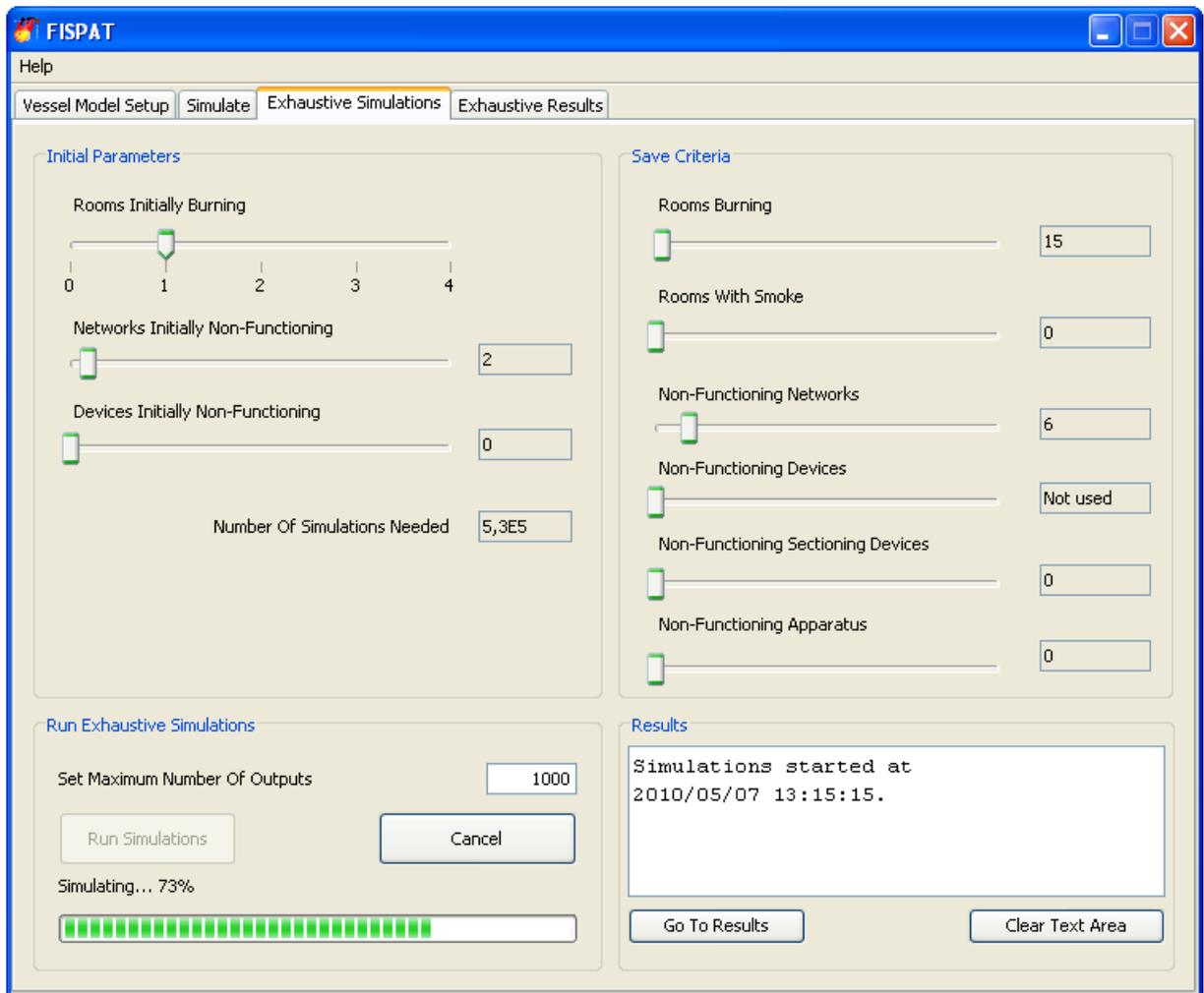


Figure 10. Exhaustive Simulations Tab in FISPAT.

### **Initial Parameters:**

The initial parameters determine the amount of initially burning rooms and initially non-functioning networks and devices. The initially burning rooms slider represents the sum of all rooms being on fire in each simulation, including those set manually by the user in the Graphical Representation. The same holds for networks and devices initially non-functioning. The sliders are automatically updated when rooms, networks and devices are set as burning or non-functioning in the Graphical Representation.

**Rooms Initially Burning:** The total number of initially burning rooms is set. Rooms set as initially on fire in the Graphical Representation will be set as initially burning in all simulations.

**Networks Initially Non-Functioning :** Total amount of initially non-functioning networks in the simulations. Networks set as non-functioning in the graphical interface will be non-functioning in all simulations.

**Devices Initially Non-Functioning :** Same function as the network slider but for devices. It determines the amount of initially non-functioning devices. As the network slider it also includes the devices set as non-functioning in the graphical interface and is updated automatically.

**Number of Simulations Needed:** Gives an approximation of the number of simulations needed for covering all possible setups corresponding to the Initial Parameters given. The number of simulations is:

where:

$$\begin{array}{lll} n_1 = R - R_b & n_2 = N - N_f & n_3 = D - D_f \\ k_1 = R_s - R_b & k_2 = N_s - N_f & k_3 = D_s - D_f \end{array}$$

R = Number of rooms in the Vessel Model

R<sub>b</sub> = Number of rooms set as initially burning in the Graphical Representation

R<sub>s</sub> = Rooms Initially Burning value

N = Number of networks in the Vessel Model

N<sub>f</sub> = Number of networks set as initially non-functioning

N<sub>s</sub> = Networks Initially Non-Functioning value

D = Number of devices in the Vessel Model

D<sub>f</sub> = Number of devices set as initially non-functioning

D<sub>s</sub> = Devices Initially Non-Functioning value

The time for finishing an exhaustive simulation is approximately proportional to the number of simulations. This is useful if the user wants to approximate the time for an exhaustive simulation. The number turns red when it exceeds 10<sup>9</sup> (written as 1E9 in the text field) indicating that the number of simulations probably is too high for completion in a reasonable amount of time on a personal computer.

The required number of simulations can be significantly smaller than the stated if many rooms are fire spreading neighbors. In this case only one of them are set to be initially on fire and none of the other initial states are simulated.

### **Save Criteria:**

The criteria for a simulation to be saved are specified here. A simulation needs to meet all the criteria otherwise it will not be saved. When a simulation meets these criteria it is saved and can be viewed in the exhaustive results tab.

The criteria are:

- Number of burning rooms
- Number of rooms with only smoke
- Number of non-functioning networks
- Number of non-functioning devices
- Number of non-functioning sectioning devices
- Number of non-functioning apparatus

If the number of non-functioning devices criterion is specified, the non-functioning sectioning devices and non-functioning apparatus criteria are disabled and vice versa. Thus the device criterion and sectioning device/ apparatus criteria are mutually exclusive.

If all corresponding numbers in the resulting vessel of a simulation are equal or greater than the criteria the simulation is saved in a list in the Exhaustive Results tab.

**Rooms Burning:** The number of burning rooms the simulation result needs to have for it to be saved.

**Rooms With Smoke:** The number of rooms with only smoke the simulation result needs to have for it to be saved.

**Non-Functioning Networks:** The number of non-functioning networks the simulation result needs to have for the simulation to be saved.

**Non-Functioning Devices:** The number of non-functioning devices the simulation result needs to have for the simulation to be saved. If this slider is used, Non-Functioning Sectioning Devices slider and Non-Functioning Apparatus slider will be set as not used.

**Non-Functioning Sectioning Devices:** The number of non-functioning sectioning devices the simulation result needs to have for the simulation to be saved. If this slider is used, so is the Non-Functioning Apparatus, while the Non-Functioning Devices slider will be set as not used.

**Non-Functioning Apparatus :**The number of non-functioning devices the simulation result needs to have for the simulation to be saved. If this slider is used, so is the Non-Functioning Sectioning Devices, while the Non-Functioning Devices slider will be set as not used.

#### **Run Exhaustive Simulations:**

**Set Maximum Number Of Outputs:** Maximum number of results to be saved from the exhaustive simulations. If there are more simulations that meet the criteria, the exhaustive simulations are stopped and a message is shown in the Results text field. Note that there can be more severe setups than the ones represented in the results as a consequence of that not all simulations are executed. To run all simulations, increase the save criteria and/or the maximum number of outputs.

**Run Simulations:** Executes the exhaustive simulation. Makes an automatic check of all devices to see that they are properly connected. If any device is not properly connected the user receives a warning about these devices and the simulation is not started.

**Cancel:** Cancels the running exhaustive simulation even though not all simulations are performed. However, all results up until the cancellation are presented in the exhaustive results tab and can be trusted.

**Progress Bar:** Updates when another one percent of the simulations is done. If the mouse is held over this bar it says how many percent of the simulations are done. The text above the bar is updated when the exhaustive simulation is started, finished or cancelled.

#### **Results:**

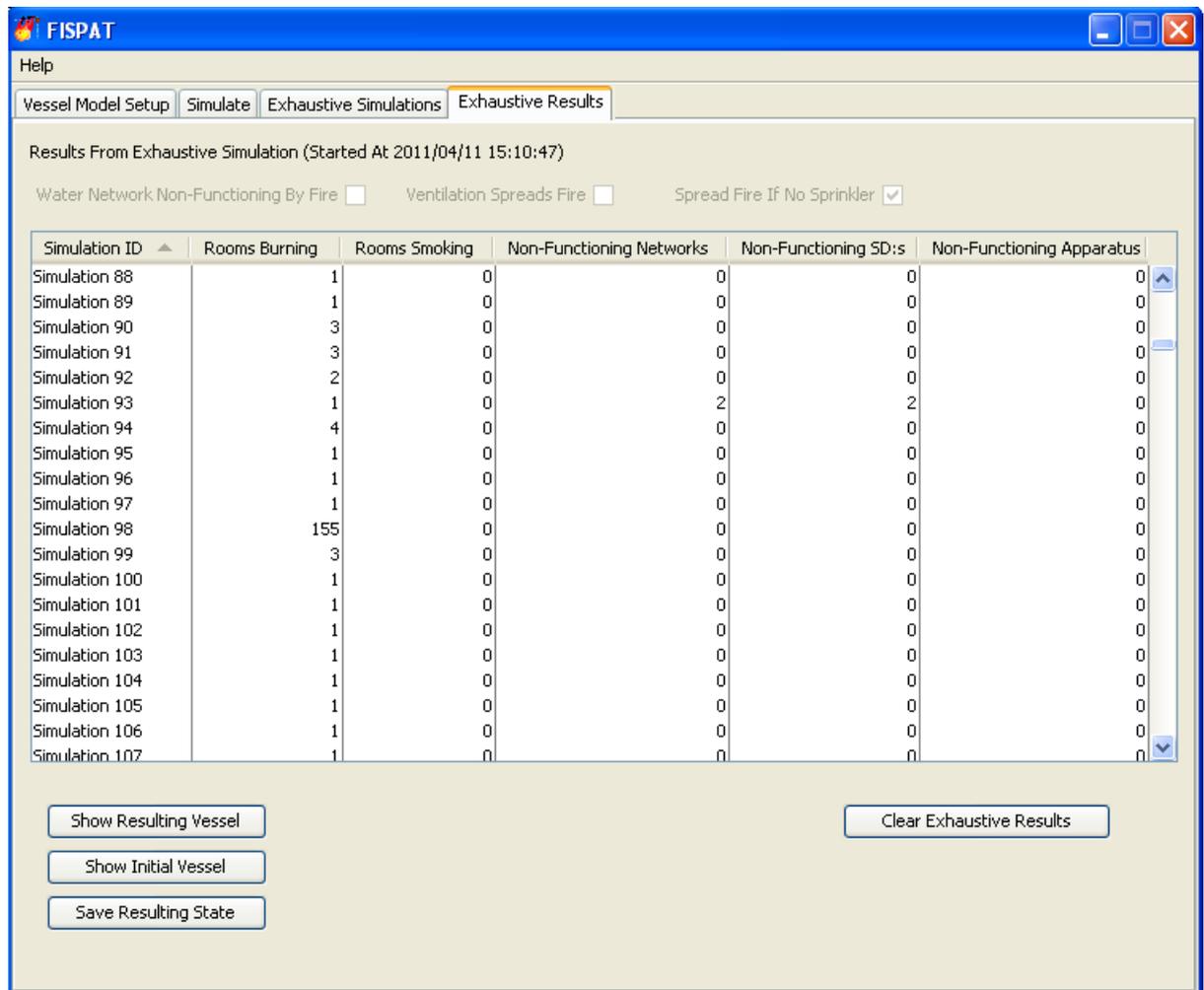
**Text Area:** Information about the running exhaustive simulation is displayed.

**Go To Results:** The Result tab is set in focus.

**Clear Text Area:** Clears the text area.

### 3.10 Exhaustive Results Tab

The fourth tab in the main frame is called Exhaustive Results. In this tab the results from an exhaustive simulation are viewed. Here it is possible to retrieve and view the initial and resulting states of all finished simulations from an exhaustive simulation.



**Figure 11. Exhaustive Results tab where the results from exhaustive simulations can be viewed and saved.**

**Show Resulting Vessel:** Shows a Graphical Representation of the resulting state of the highlighted simulation.

**Show Initial Vessel:** Shows a Graphical Representation of the initial state of the highlighted simulation. This is just one of possibly many initial states that have the same outcome. The other initial states are not simulated since FISPAT knows they result in the same resulting state.

**Save Resulting State:** Invokes a browser that lets the user save the resulting Vessel Model state. The resulting state can be loaded in the Graphical Representation using load setup.

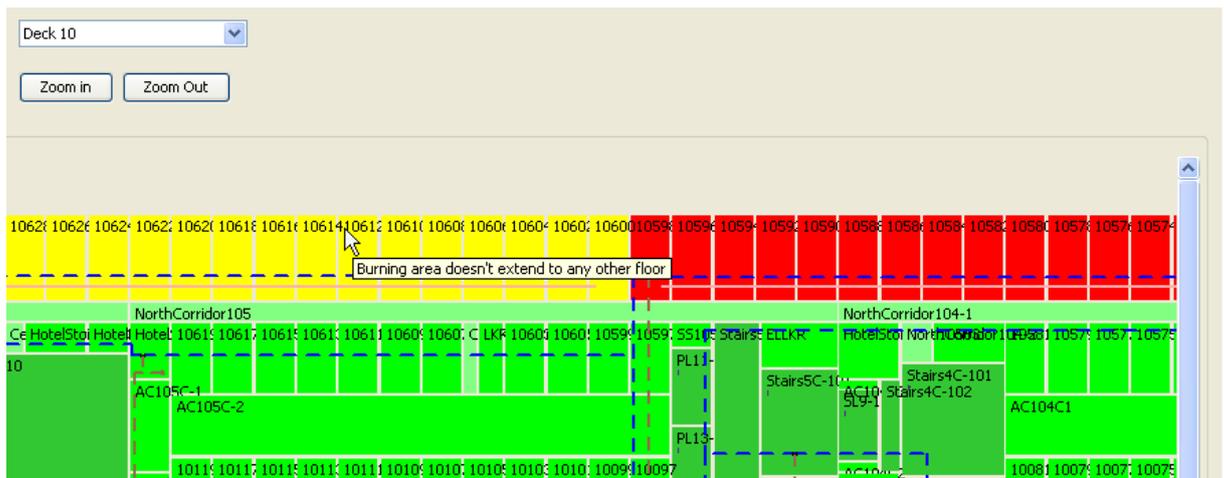
**Clear Exhaustive Results:** Clears the results table.

## 4 Analyzing Exhaustive Simulation Results

When performing exhaustive simulations, FISPAT reduces the simulations that would produce the same results. This is done for two reasons; reduce total simulation time and reduce the number of results that need to be analyzed by the user.

When viewing the exhaustive simulation results the user is potentially viewing the results of several different initial setups. Because fire spread between rooms are commutative and deterministic it doesn't matter in which room, of the burning rooms in the end state, the fire started in. Thus, if the fire started in any of the rooms ending up burning, the end state would be the same, and this end state is saved only once. If there are multiple initial fires in separate parts (i.e. different groups of rooms) of the Vessel Model, any combination of one initial fire in each of the separate parts would produce the same result. This fact is used by FISPAT to reduce the number of simulations.

When viewing the Graphical Representation of a result this fact is shown by making all burning rooms with the same fire origin as yellow when the mouse pointer is on a burning room (see Figure 12). When the mouse pointer leaves the rooms that are burning then the color is turned back to red.



**Figure 12: The Graphical Representation of an exhaustive simulations result. The yellow rooms are burning and have the same origin of fire. The red rooms are also burning but have a different origin of fire.**

All combinations of an initial fire in a yellow room and an initial fire in a red room would produce the results shown in Figure 12. If all possible ways to produce the results would be presented one by one this would generate an amount of results that would not be significant. By presenting it this way the user only has to analyze one Graphical Representation where all results are presented. To reproduce the end state with a single initial setup the user needs to set one or more initial fires in each separate burning area and set the same devices and networks that were initially non-functioning as non-functioning in the new single simulation.

## 5 References

- [1] *The International Convention for the Safety of Life at Sea (SOLAS), 4<sup>th</sup> ed.*. IMO publications. International Maritime Organization. London 2004.
- [2] **Hedin, Erik & Strandén, Lars.** *Evaluation of FISPAT Fire Spread Analysis Tool*. SP Technical Notes 2011:37. SP Technical Research Institute of Sweden. ISBN 978-91-86622-67-1. Borås 2011.
- [3] **Hedin, Erik & Lundsten, Johannes.** *Java Application for Analysis of Lightweight Constructions in Cruise Vessels*. SP Technical Notes 2010:5. SP Technical Research Institute of Sweden. Borås 2010.

## Appendix 1 User Guide

### a. Installation

FISPAT requires Java Runtime Environment<sup>2</sup>. The FISPAT tool has been tested for Java Version 6 update 20 and might not function well with previous Java versions. The tool has only been tested on Windows XP SP3 and might not function correctly on other operating systems such as Mac OS X.

These files are distributed with FISPAT and are needed for the program to work properly:

```
\Fire Spread Analysis Tool.jar
/Images\Fireicon.png
/Images\Fispaticon.png
/Images\Networkicon.png
/Images\Dependency.png
\Help Files\Simulate.txt
\Help Files\Version.txt
\Help Files\Input Files.txt
\Help Files\Simulation Setup.txt
\Help Files\Vessel Representation.txt
\Help Files\Copyright.txt
```

### b. Input Files

White space can be used in all input files between type, ID, coordinates etc. to make the files more easy to read. However white space cannot be used in an ID. The // notation can be used in the beginning of a line to insert comments. That line is only used by the user to insert comments and will not be read by FISPAT to load information. Line feeds can be used between rooms, networks and devices to make the files easier to read. However, line feeds cannot be used in the middle of a line of information.

For practical and safe handling of input files the following rules should be followed:

- Create and modify Room File by editing
- Create and modify Network File and Device File graphically. Comments could be added manually by editing.
- Handle Setup File via Graphical User Interface. Comments could be added manually by editing.

#### i. Room File

To build a set of rooms in a Vessel Model, browse a txt-file with the room information in the Vessel Model Setup tab (see section 3.2). When the desired rooms, networks and devices files are loaded the Vessel Model is built by pressing the Build Vessel Model button. The rooms text file syntax is:

```
RoomID;(x1,y1,z1)(x2,y2,z2)
```

For FISPAT to separate rooms and corridors in the Graphical Representation, corridors can be specified in the text file. A corridor will get a different color than a room but is the same in all other senses. Its format is:

```
Corridor;RoomID;(x1,y1,z1)(x2,y2,z2)
```

---

<sup>2</sup> Java Runtime Environment can be found at [java.com](http://java.com)

**RoomID:** The room ID must be unique for all rooms and include A-Z and 0-9 without white-space or other characters. The room is identified as a corridor if “Corridor;” is specified before its ID. If a room ID already exists, an error message is displayed when the Vessel Model is built. If the room is one of several sub-rooms, "roomID-subroomID" can be used to link together the sub-rooms. These sub-rooms are automatically set to be fire spreading neighbors.

**Coordinates:**  $(x_1, y_1, z_1)(x_2, y_2, z_2)$  are the coordinates of two opposite corners of the room; the lower south west and the upper north east corners. North is pointing in the positive y direction, east is the positive x direction and up is in the positive z direction. The z-coordinate of the first corner is the deck to which the room belongs; hence the z-coordinate differs by one between two adjacent decks. The coordinates need to be positive, e.g.:

Room1;(0,0,0)(3,3,1)	Note that:
Room2-1;(3,0,0)(6,3,1)	$0 \leq x_1 < x_2$
Room2-2;(6,0,0)(8,7,1)	$0 \leq y_1 < y_2$
Corridor;SouthCorridor;(0,3,0)(9,4,1)	$0 \leq z_1 < z_2$

All rooms are rectangular cuboids. Any other shape needs to be constructed by linking several rooms. The algorithm identifies neighboring rooms by their coordinates.

Comments can be inserted in the file by putting // in the beginning of a line.

## ii. Network File

To load and build a set of networks from file, browse networks information file in the Vessel Model Setup tab (see section 3.2). When the desired rooms, networks and devices files are loaded the Vessel Model is built by pressing the Build Vessel Model button. Note that networks and devices files can be left blank if no networks or devices are to be built. The Vessel Model has to contain rooms before networks can be built. The networks text file syntax is:

Type; NetworkID;  $(x_{11}, y_{11}, z_{11})(x_{12}, y_{12}, z_{12}) \dots (x_{1n}, y_{1n}, z_{1n}) | (x_{21}, y_{21}, z_{21})(x_{22}, y_{22}, z_{22}) \dots (x_{2n}, y_{2n}, z_{2n})$

**Type:** Specifies the type of network with a string. Supported network types are:

- Water
- Electric
- Ventilation
- Control
- Hydraulic
- Pneumatic

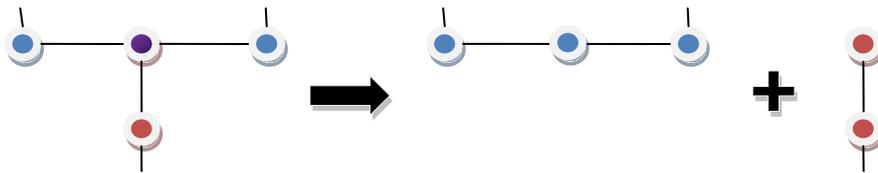
Any other string as type will generate an error.

**NetworkID:** The unique ID of the network. Can include A-Z and 0-9 without white-space or other characters. If a network ID already exists, an error message is displayed when the Vessel Model is built.

**Coordinates:**  $(x_{11}, y_{11}, z_{11})(x_{12}, y_{12}, z_{12}) \dots (x_{1n}, y_{1n}, z_{1n})$  are the coordinates of the network path.

$(x_{11}, y_{11}, z_{11})$  is the start position,  $(x_{12}, y_{12}, z_{12}) \dots (x_{1(n-1)}, y_{1(n-1)}, z_{1(n-1)})$  are the coordinates of every corner while  $(x_{1n}, y_{1n}, z_{1n})$  is the end-coordinate. The z-coordinate is the deck to which the network coordinate belongs. The coordinates can only change in one direction at a time meaning the paths are either in the x-, y- or z-direction. If the path changes in more than one direction between two following coordinates, an error message is shown when the Vessel Model is built. That is also the case if a coordinate is on a deck where there is no room.

**Branch:** The “|” denotes a network branch. A branch needs to be defined when the network has three or more paths from a given point. When creating a network that branch, the network needs to be divided into several stretches see Figure 13.



**Figure 13:** Creating the network to the left is done by creating two stretches.

When creating a part of network that branch, the main stretch (blue dots in Figure 13) of the network is defined as described above. When creating the branch of the network (red dots) the coordinate sequence has to start with the branching coordinate (upper red dot) which is the same as the middle coordinate of the blue stretch. The entire network is created by writing all stretches coordinate sequences on a single line delimited by “|”.

### iii. Device File

To load and build a set of devices from file, browse the device file in the Vessel Model Setup tab (see section 3.2). When the desired rooms, networks and devices files are loaded the Vessel Model is built by pressing the Build Vessel Model button. Note that networks and devices files can be left blank if no networks or devices are to be built. Both rooms and networks files need to be loaded if a device file is to be loaded. The device text file syntax is:

Type; DeviceID;  $(x_1, y_1, z_1); (AN_1, AN_2, \dots, AN_n) | (DN_1, DN_2, \dots, DN_n)$

**Type:** The type of the device can be one of following

- “Sectioning Device”
- “Apparatus”
  - “Pump”
  - “Electric Control Unit”
  - “Other”

If the text type equals anything else, the device will be built as “other”.

**DeviceID:** The unique ID of the device. Can include A-Z and 0-9 without white-space or other characters. If a device ID already exists, an error message is displayed when the Vessel Model is built.

**Coordinates:**  $(x_1, y_1, z_1)$  is the coordinate of the device. The z-coordinate is the deck to which the device belongs. If the coordinate is not present in a room, an error message is displayed when the Vessel Model is built.

**Affects Networks:** ( $AN_1, AN_2, \dots, AN_n$ ) are the ID:s of the  $n$  number of networks whose functionalities depend on the device. To define redundancy, the same network depends on two or more devices of the same type. For sectioning devices, the networks whose functionalities are separated are specified here.

**Depends On Networks:** ( $DN_1, DN_2, \dots, DN_m$ ) are the ID:s of the  $m$  number of networks that the device depends on to function.

#### iv. Firewall File

Firewalls are loaded in the Vessel Model tab and are added to the Vessel Model once the Build Vessel Model button is pushed. Note that the Vessel Model doesn't need firewalls, they merely helps the user to map them between the real drawings and the Vessel Model in FISPAT. The firewall text file syntax is:

$$(x_{11}, y_{11}, z_{11})(x_{12}, y_{12}, z_{12}) \dots (x_{1n}, y_{1n}, z_{1n})$$

Where each pair of parentheses is one coordinate of the firewall. One firewall can consist of many coordinates. Multiple firewalls are specified on separate lines.

#### v. Setup File

The setup file is used to load the status of the Vessel Model. It also contains the control options that were used when the file was saved. This file contents cannot be manually edit but its contents is explained here. However, comments can be inserted at editing by // notation in the beginning of the commented line.

First there is a comment area with date and type of Vessel Model used for the saved setup file. Information about how many rooms that were burning or smoking, number of non-functioning networks and devices are also shown. Also the names of the files used to build the Vessel Model are saved. This information is for the user but is not used by FISPAT to load setup information.

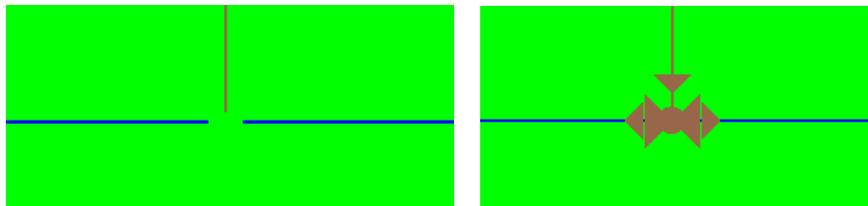
The setup loaded into FISPAT is the control options, the status of the rooms, networks and devices and the fire and smoke spreading neighbors. Note that currently set fire and smoke spreading neighbors in the Vessel Model will still be present. The loaded fire and smoke spreading neighbors will be added to those already existing.

## Appendix 2 Work Process Example

This is an example of the work process using FISPAT. It is advised that you look it through before using the program for the first time. Steps might be skipped once you are familiar with FISPAT.

### Setting Up the Vessel Model

1. Define the room structure in a text file.
2. Load the file in the Vessel Model Setup tab under “File With Rooms”. Press Build Vessel Model.
3. Look at the Graphical Representation of the room structure by clicking the Show Vessel Model button in the Vessel Model Setup tab. Make sure the room structure is correct and that all floors can be viewed. Check that the neighbors are correct for some rooms.
4. Create the firewalls in a new file and load it into FISPAT. The coordinates can be found in the graphical representation of the rooms by holding down Ctrl while moving the cursor over the vessel. In this way the coordinates are shown and can be written into a text file.
5. Create the networks either in a text file (not recommended) or in the Graphical Representation of the Vessel Model (save them as a text file if they are to be used in a later session).
6. Make sure the networks go through the correct rooms and that they are of the correct type. Put the start/end point of a network close to the start/ end point of another network if they are to affect or depend on the same device (see Figure 14). In this way, the device can be put above the network end points and be correctly connected upon creation.



**Figure 14: a) Networks before the sectioning device is added and b) when the sectioning device has been added. The dependency arrows are added automatically when the sectioning device is chosen to affect and depend on networks in the Device Creator.**

7. Create the devices either in a text file (not recommended) or in the Graphical Representation of the Vessel Model (save them as a text file if they are to be used in a later session).
8. Make sure the devices are in the correct rooms and that they are of the correct type. Also make sure the devices depend on and affect the correct networks. This can be done by checking the dependency arrows (see Figure 14) or by holding down shift while clicking the device with the left mouse button. Click Edit Device in the pop-up menu.
9. Set up fire and smoke spreading neighbors in the Graphical Representation.

### Perform Single Simulations

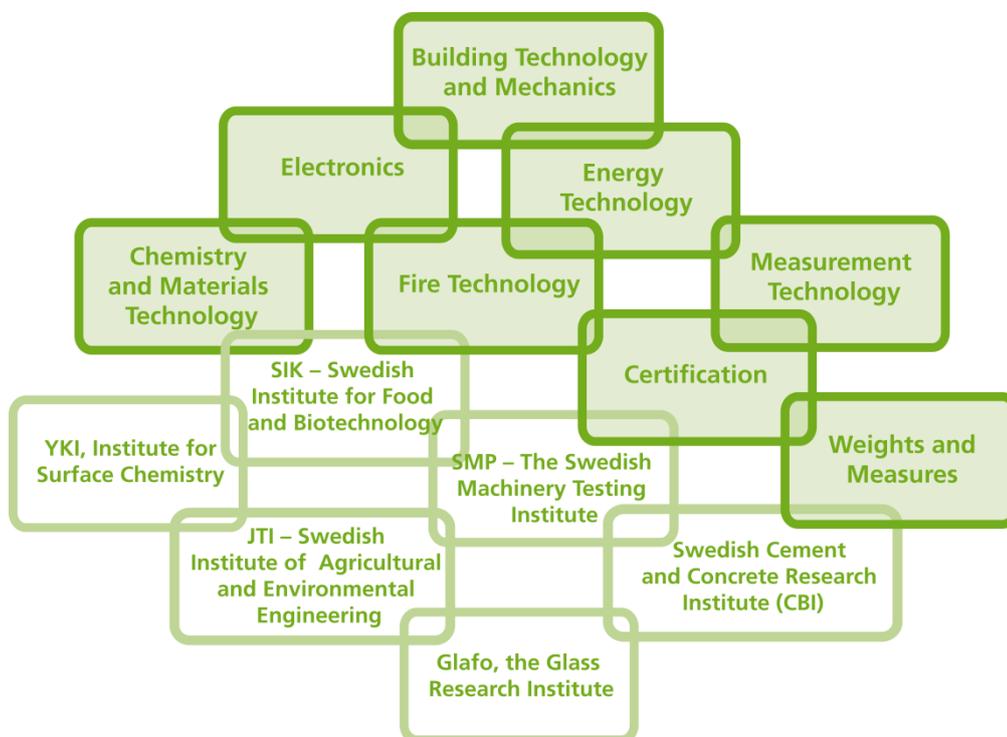
10. Perform single simulations by setting one or several rooms on fire as well as networks and devices non-functioning. Click the Queue Simulation button. Queue a couple of simulations and press Go To Simulations.
11. Select a simulation and press Simulate Item. Press Show Resulting Vessel and make sure the resulting Vessel Model is satisfying. Do this with all queued simulations.

**Perform Exhaustive Simulations**

12. When the single simulations are performed, go to the Graphical Representation of the Vessel Model and set up the initial state that should be used in the exhaustive simulations.
13. Press Perform Exhaustive Simulations to go to the Exhaustive Simulations tab and specify the initial parameters and the save criteria. Run simulations and make sure you get results. If there are no, or too many, results change the save criteria and try again.
14. Go to results and sort them by different categories by clicking the top of the table.
15. Identify the parameters that cause the worst result by looking at the resulting Graphical Representation.

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