Point85

Overall Equipment Effectiveness (OEE) Applications User Guide

Version 2.4.0

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June 10, 2019

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OVERVIEW

The Point85 Overall Equipment Effectiveness (OEE) applications enable:

- collection of equipment data from multiple sources to support OEE calculations or general purpose data acquisition
- resolution of a collected data value into an availability reason or produced material quantity to provide input to the performance, availability and quality components of OEE
- calculation of the OEE key performance indicator (KPI) for the equipment using an optional work schedule for defining the scheduled production time
- monitoring of equipment availability, performance and quality events

Sources of equipment availability, performance and quality event data include:

- *Manual*: web browser-based data entry
- *OPC DA*: classic OLE for Process Control (OPC) Data Acquisition (DA)
- *OPC UA*: OLE for Process Control Unified Architecture (UA)
- *HTTP*: invocation of a web service via an HTTP request
- *RMQ Messaging*: an equipment event message received via a RabbitMQ message broker
- *JMS Messaging*: an equipment event message received via a JMS message broker
- *MQTT Messaging*: an equipment event message received via an MQTT message server
- *Database Interface Table*: a pre-defined table for inserting OEE events
- *File Share*: a server hosting OEE event files
- Modbus: a Modbus master communicating with its slaves.

The Point85 applications supporting OEE are:

- *Designer*: a GUI application for defining the plant equipment, data sources, event resolution scripts, manufacturing work schedule, availability reasons, produced materials and units of measure for data collectors. The designer also includes a dashboard and trending capabilities.
- *Collector*: a headless Windows service or Unix deamon to collect the equipment event data and store it in a relational database
- *Monitor*: a GUI application with a dashboard to view the current equipment OEE and status
- *Operator*: a GUI application for manual entry of equipment events

- *Operator* Web: a web-application for manual entry of equipment events

In addition, two GUI test applications assist in the development of an OEE solution:

- *Tester*: HTTP requester and a message publisher
- *Test Collector*: UI front end for a data collector

Please send comments and suggestions to point85.llc@gmail.com.

OEE CALCULATIONS

OEE is the product of equipment availability, performance and quality each expressed as a percentage. The time-loss model is used to accumulate time in loss categories (or "no loss" if the equipment is running normally). See *[Kennedy]* for details. A data source provides an input value to a data collector's resolver JavaScript function that maps that input value to an output value (reason or production count).

For availability and performance, the output value is a reason that is assigned to one of the following loss categories:

- *Value Adding:* the "no loss" or "running OK" category.
- *Not Scheduled:* this is non-working time. Non-working periods (e.g. holidays) typically are planned in the work schedule that is assigned to equipment.
- *Unscheduled*: working time when the equipment is not scheduled for normal production (e.g. an R&D or laboratory test run).
- *Planned Downtime*: working time when the equipment is not scheduled for normal production but the activity is intended to support production (e.g. planned preventive maintenance).
- *Unplanned Downtime*: working time when the equipment is not available due to an unexpected fault (e.g. motor failure or jam).
- *Setup*: working time when the equipment is being changed over in order to run new material.
- *Stoppages*: minor or short periods of time when the equipment is not producing as expected (such as a blocked or starved condition).
- *Reduced Speed*: the equipment is producing, but not at its design speed or ideal run rate.

For quality or yield, the data source provides a production count in the good, reject/rework or startup & yield categories in the defined units of measure for the material being produced.

ARCHITECTURE

The OEE applications can be grouped into design-time and run-time. The design-time Designer application is used to define the plant equipment, data sources, event resolution scripts, manufacturing work schedule, availability reasons, produced materials and units of measure for data collectors. The designer also includes a dashboard and trending capabilities.

A run-time data collector service receives an input value from a data source and executes a JavaScript resolver on this input to calculate an output value. The output value is a reason (mapped to an OEE loss category) for an availability event, a new production count (good, reject/rework or startup) for performance and quality events or a material/job change event (a job is also known as an order, lot or batch). For the case of a custom event, the output value is ignored. The event data is stored in a relational database where it is available for OEE calculations. Microsoft SQL Server, Oracle 12c/18c Express Edition, MySQL, PostgresQL and HSQLDB are currently supported.

A manual web-based data collector and desktop collector record the OEE events based on information entered by an operator. Similar to the in-process collector, this data is also stored in the relational database.

If the system is configured for RMQ messaging, the event data is also sent to a RabbitMQ message broker to which a run-time monitor application can subscribe. A monitor displays a dashboard for viewing equipment OEE events. It also displays collector notifications and status information as messages are received.

TECHNOLOGIES

Technologies used for the OEE applications are:

- Java 8 programing language and JavaFX for the GUIs
- JavaScript for resolving an input value into an output value based on an OEE event. The Nashorn script engine included in the Java 8 JVM is used.
- Vaadin and Tomcat for the web application
- j-Interop and OpenSCADA utgard for the OPC DA client
- Eclipse Milo for the OPC UA client
- Hibernate with a Hikari connection pool and JPA interface for persisting data to a relational database
- NanoHTTPD for the embedded HTTP server
- RabbitMQ and Erlang for the messaging middle-ware
- ActiveMQ client for JMS
- Eclipse Paho client for MQTT
- Google Gson for message and HTTP request serialization into a JSON string and deserialization
- Java Service Wrapper (JSW) for Windows process and Unix collector daemon
- j2mod for Modbus

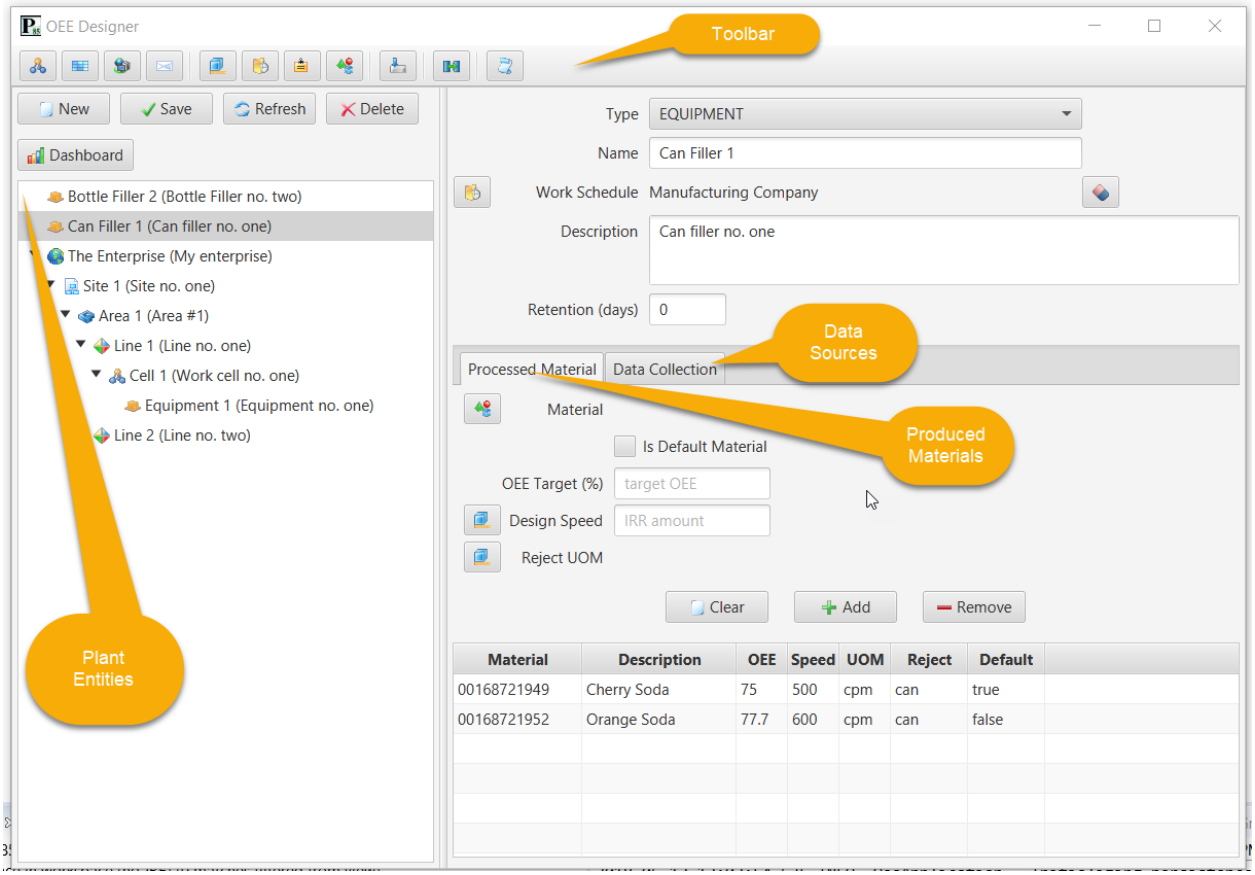
Please see the *Contributing Technologies* section below for additional details.

DESIGNER APPLICATION

The Designer application is used to define all aspects of an OEE solution. It is launched from a shell script. A splash screen is first displayed during the time the database connection is being established and plant entity objects are being created.

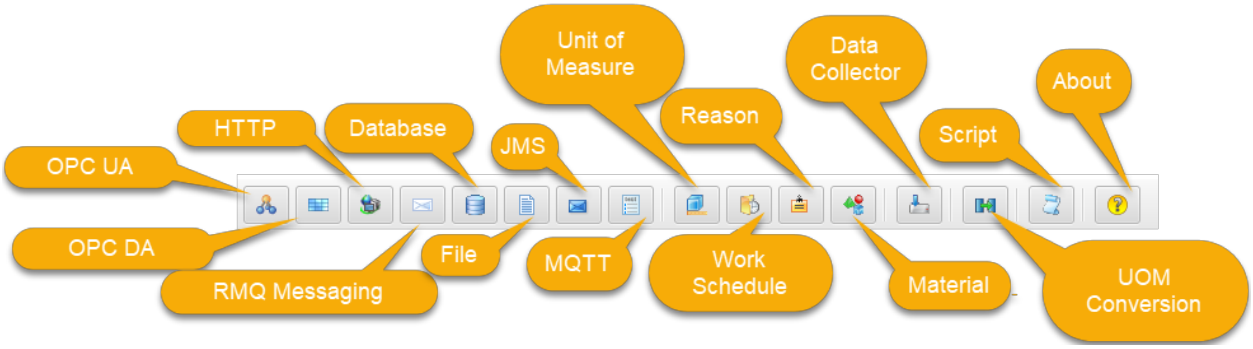
PLANT ENTITY EDITOR

Upon launch of the Designer, the plant entity editor is displayed, for example:

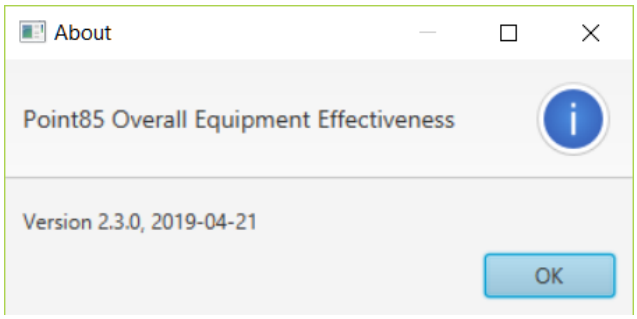


Toolbar

The toolbar buttons that launch other editors or applications (as discussed below) are:



The About button shows an informational dialog:



Entity Hierarchy

To begin, the plant entity physical model on the left side of the editor would typically be defined first. This is the ISA-95 organizational hierarchy of Enterprise -> Site -> Area -> Production Line -> Work Cell -> Equipment and is closely related to the process industry's ISA 88 unit/machine model. Only equipment can have OEE calculations, but higher level entities can have an associated work schedule and data retention period that apply to equipment contained below them. It is not necessary to define all levels, only equipment objects are required for OEE calculations, and any object can be a top-level object.

The physical model editor buttons are:

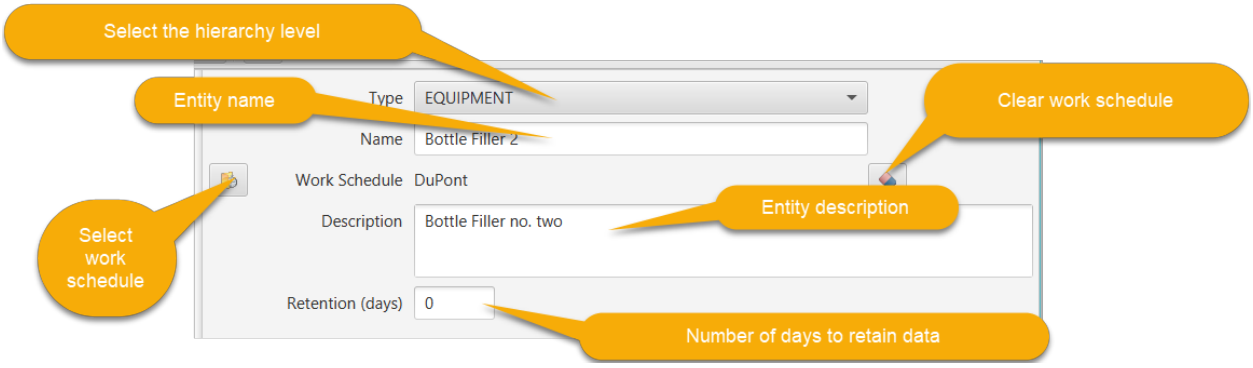
- *New*: clear the editor to begin defining a new entity
- *Save*: save the selected entity to the database. The parent entity (if any) must be selected first. If a parent is selected, the child must be created of the proper type (e.g. Equipment if the parent is a Work Cell).
- *Refresh*: refresh the selected entity from the database to synchronize the editor with the entity's saved state
- *Delete*: delete the selected entity and any children from the database

The Dashboard button displays the OEE dashboard for the selected equipment entity. The dashboard is discussed below.

The physical model has a context menu accessed by right-clicking in the left-hand pane. The menu items are:

- *Save All Entities*: save all entities in the hierarchy to the database
- *Refresh All Entities*: restore all entities in the hierarchy from their state in the database
- *Clear Selected Entity*: de-select the entity so that no entity is selected

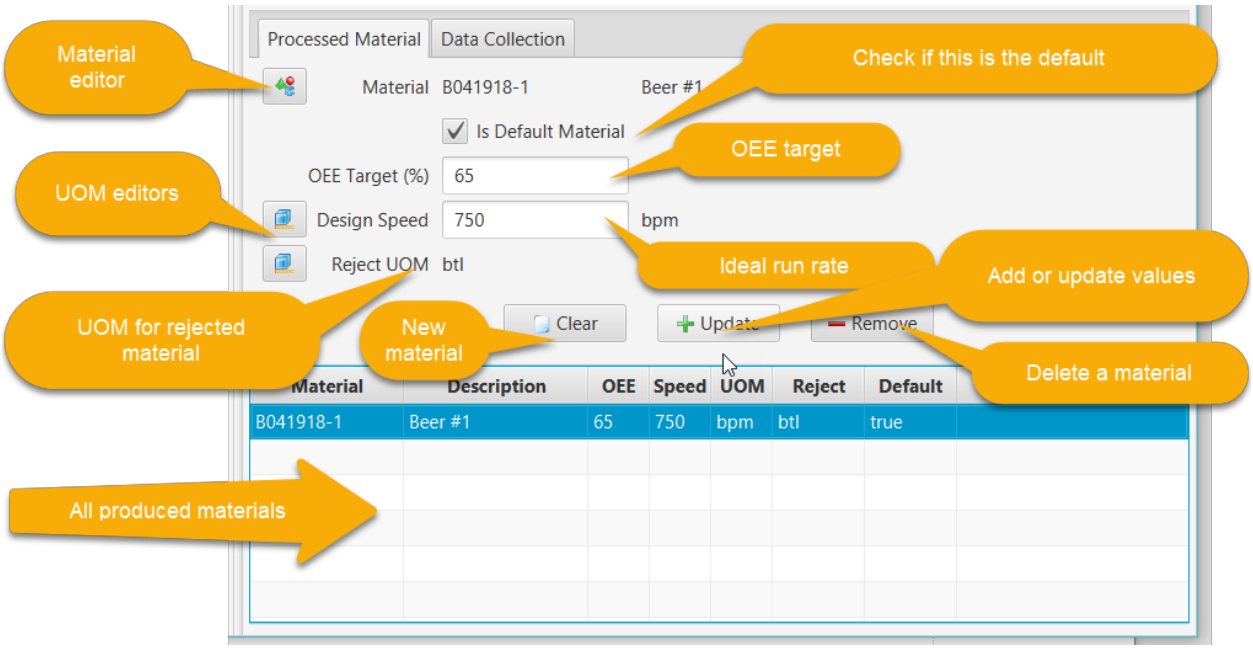
The entity's attributes are displayed and edited in the upper right-hand corner of the editor:



The work schedule and data retention days apply to that entity and to all children below it. For example, a work schedule could be defined for each Site or Area within a plant and have it apply to the contained equipment. A retention of 90 days means that any event records older than 90 days for that equipment will be deleted from the database when a new availability event is recorded.

Equipment Processed Materials

Equipment can produce many different materials. This one-to-many relationship is defined in the Processed Material tab:



The editor actions are:

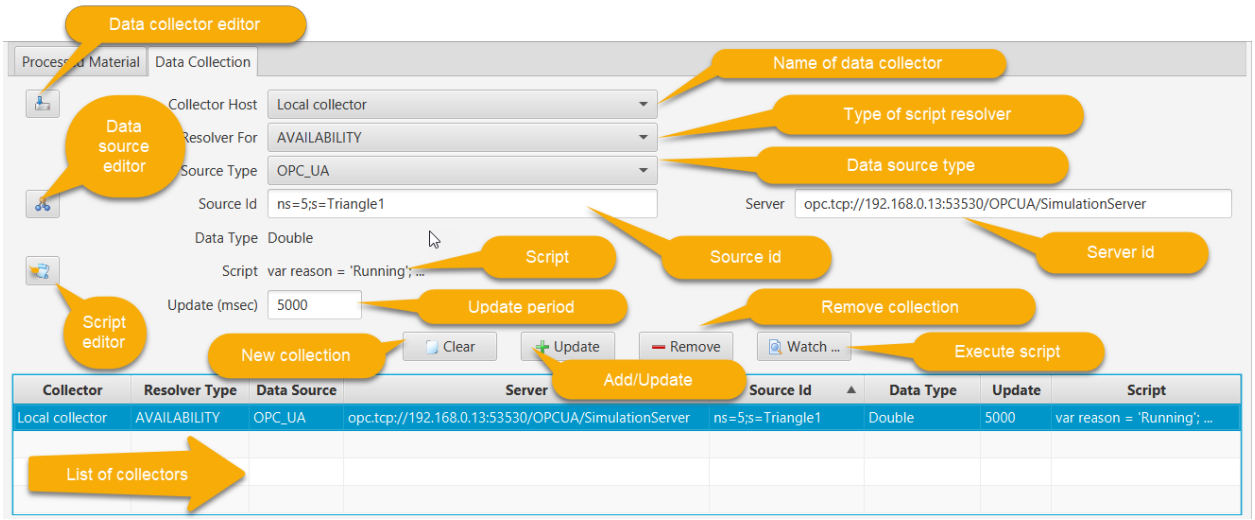
- *Clear*: clear the editor controls in order to define a new processed material. The Add/Update button text will change to “Add”.
- *Add*: After defining the properties of a new material, clicking this button will add it to the list of materials
- *Update*: after selecting an existing processed material, the current values will be moved into the editing controls. Make the necessary edits, then click this button to apply the changes to the list.
- *Remove*: after selecting an existing processed material, click this button to remove it from the list.

Note that after making changes to the list of processed materials, the plant entity must be saved to the database by clicking the Save button. An unsaved entity will be marked as such.

The material editor is accessed by clicking on the material button in this tab. The produced material is then selected in the editor and the dialog closed. The unit of measure editor for the design speed and rejects is accessed in a similar fashion.

Equipment Data Collection Events

Equipment can have many different sources of availability and production events. This one-to-many relationship is defined in the Data Collection tab:



The editor actions are:

- *Clear*: clear the editor controls in order to define a new resolver. The Add/Update button text will change to “Add”.
- *Add*: After defining the properties of the resolver, clicking this button will add it to the list
- *Update*: after selecting an existing resolver, the current values will be moved into the editing controls. Make the necessary edits, then click this button to apply the changes to the list.
- *Remove*: after selecting an existing resolver, click this button to remove it from the list.

- *Watch*: after selecting a resolver, click this button to launch a dialog to observe execution of the resolver script when a new input value arrives or one is manually entered. The output resolution is not saved to the database. The dialogs are discussed below under the individual data source editors.

Note that after making changes to the list of event resolvers, the plant entity can be saved to the database by clicking the Save button.

A data collector host is a Windows process or Unix daemon that interfaces to one or more data sources to collect data for OEE calculations. A previously defined data collector for this event can be selected in the dropdown, or the editor can be launched by clicking the editor button. This editor is discussed below.

The event type is selected in the next dropdown:

- AVAILABILITY - availability
- PROD_GOOD - good production
- PROD_REJECT - reject/rework production
- PROD_STARTUP - setup & yield production
- MATL_CHANGE - material change
- JOB_CHANGE - job/order change
- CUSTOM - application defined according to the JavaScript being executed

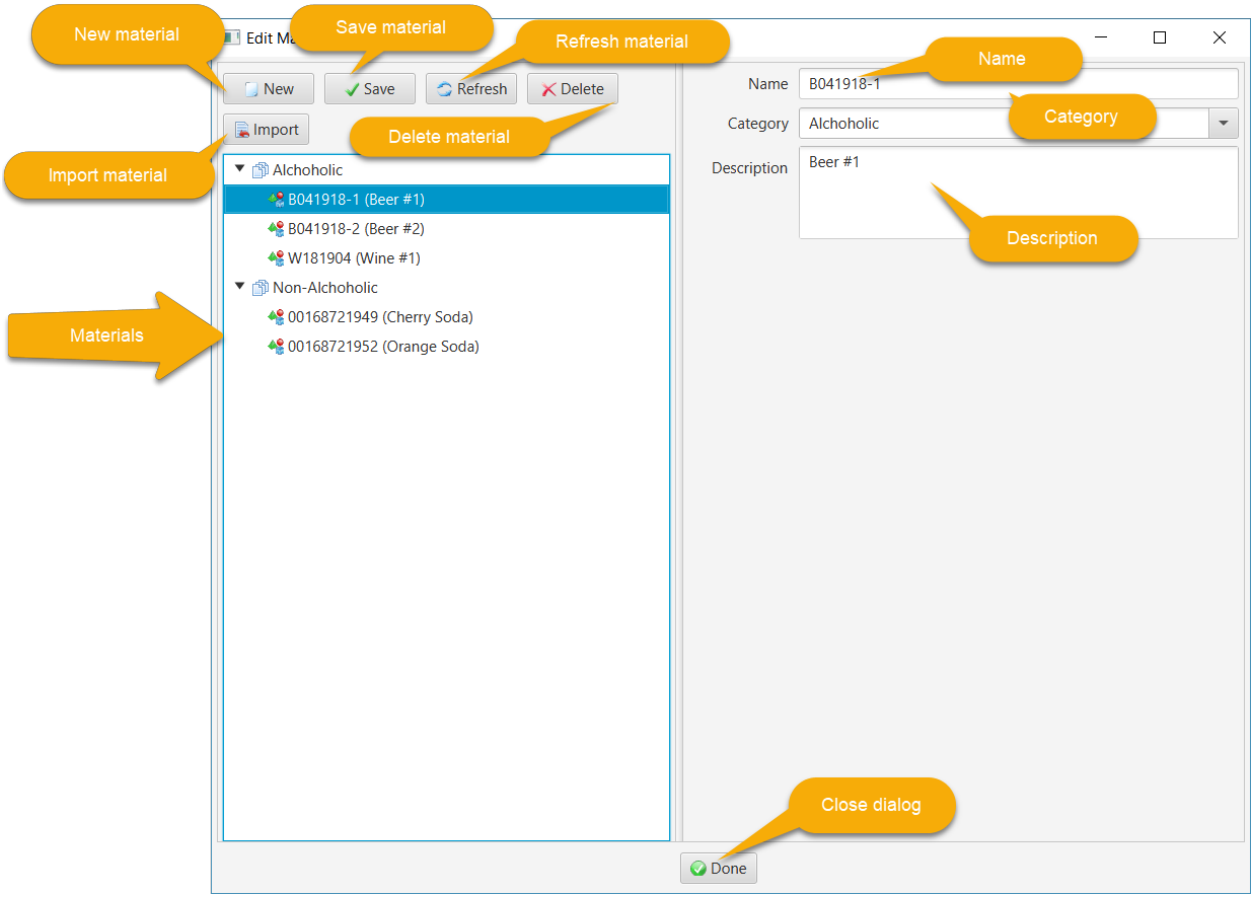
Note that a reason can be associated with a production quantity. If manually inputting the data, enter a production quantity followed by a comma followed by the reason name, e.g. “10, 101” for a quantity of 10 produced with reason named “100”. If set by JavaScript, the value is set into the event resolver (see below).

The data source type (OPC DA, OPC UA, HTTP, RMQ messaging, JMS, MQTT, Modbus, file or database table) is selected in the next dropdown.

The data source editor is launched by clicking on the button next to the source id field. For an OPC DA source, a tag is selected in the browser. For OPC UA a node is selected. For HTTP, the HTTP data collector’s embedded server is selected. For an RMQ messaging source, the RabbitMQ broker is selected. Similarly, for a JMS source, the JMS broker is selected and for an MQTT source, the MQTT server. For the HTTP, RMQ, JMS, MQTT, file and database table sources, a default source id will be automatically created, but can be changed as long as it is unique system-wide. For OPC DA the source id is a tag identifier and for OPC UA a node identifier. For Modbus the source id is an endpoint and cannot be changed.

MATERIAL EDITOR

Materials produced by equipment are defined in this editor. For example:



The material editor buttons are:

- *New*: clear the editor to begin defining a new material
- *Save*: save the selected material to the database.
- *Refresh*: refresh the selected material from the database to synchronize the editor with the material's saved state
- *Delete*: delete the selected material from the database
- *Import*: Import materials from a comma-separated value (CSV) file

The material editor has a context menu accessed by right-clicking in the left-hand pane. The menu items are:

- *Save All Material*: save all materials to the database
- *Refresh All Material*: restore all materials from their state in the database

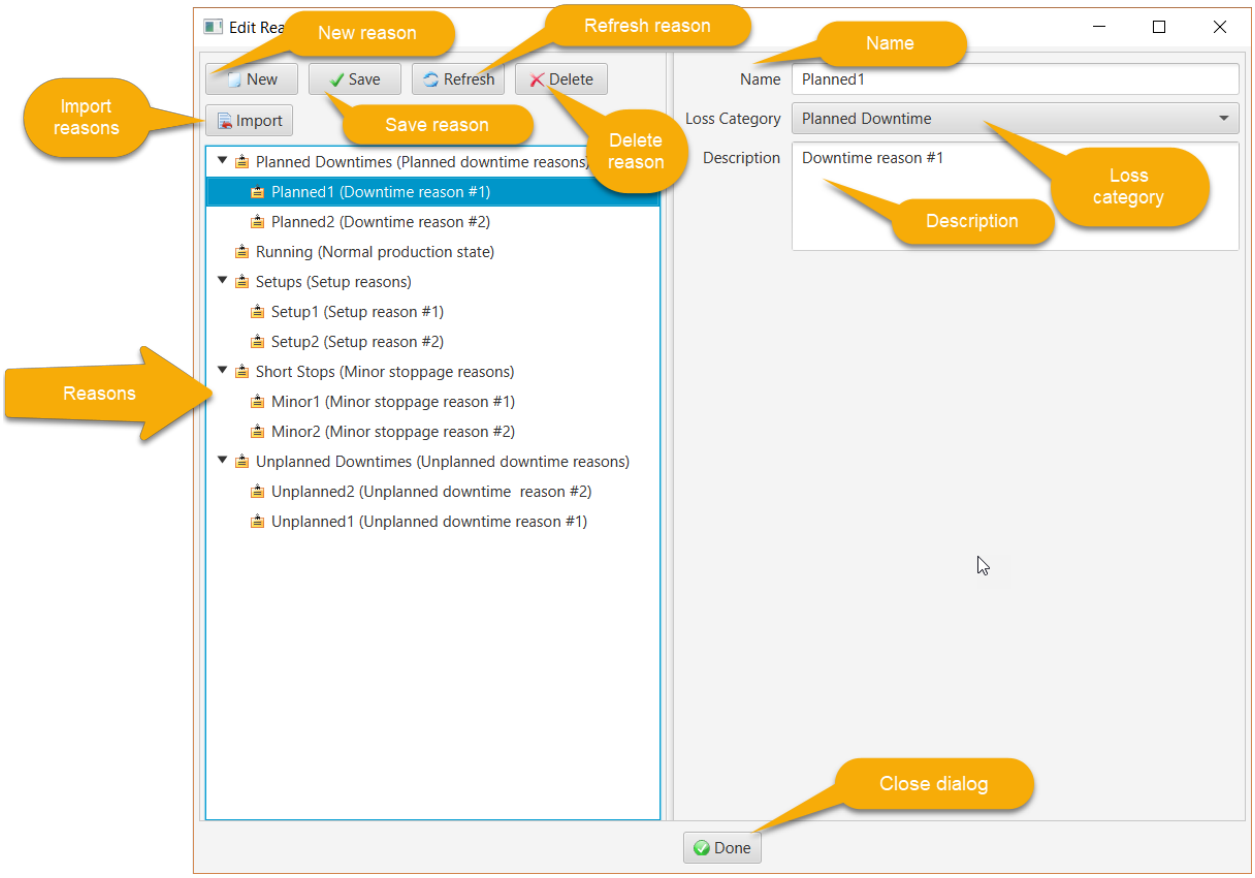
The material category provides a convenient way to organize different material.

Clicking the Import button launches a dialog to choose a text file with a comma-separated lines for each material. The format is “name, description, category”. The “materials.csv” file is included in the project as a example. For example:

```
B041918-1, Beer #1, Alcoholic

B041918-2, Beer #2, Alcoholic

W181904, Wine #1, Alcoholic

00168721952, Orange Soda, Non-Alcoholic

00168721949, Cherry Soda, Non-Alcoholic
```

Reason Editor

Availability and performance reasons are defined in this editor. For example:



The reason editor buttons are:

- *New*: clear the editor to begin defining a new reason
- *Save*: save the selected reason to the database.
- *Refresh*: refresh the selected reason from the database to synchronize the editor with the reason’s saved state

- *Delete*: delete the selected reason from the database
- *Import*: Import reasons from a file

When saving a reason, if a parent reason is selected after creating the new reason, you will be asked to confirm that the new reason is a child of this parent. This hierarchy provides a way to organize the reasons. If a reason is used to determine an availability or performance event, it must have a loss category. Any reason with a loss category can be used in an OEE availability event.

The reason editor has a context menu accessed by right-clicking in the left-hand pane. The menu items are:

- *Save All Reasons*: save all reasons to the database
- *Refresh All Reasons*: restore all reasons from their state in the database
- *Clear Selected Reason*: unselect the selected reason so that no reason is selected

Clicking the Import button launches a dialog to choose a text file with comma-separated lines for each reason. The "reasons.csv" file is included in the project as a example. The format is "name, description, loss category, parent reason". For example:

```
Running, Normal production state, NO_LOSS
Setups, Setup reasons, ,
Setup1, Setup reason #1, SETUP, Setups
Setup2, Setup reason #2, SETUP, Setups
Planned Downtimes, Planned downtime reasons, ,
Planned1, Downtime reason #1, PLANNED_DOWNTIME, Planned Downtimes
Planned2, Downtime reason #2, PLANNED_DOWNTIME, Planned Downtimes
Unplanned Downtimes, Unplanned downtime reasons, ,
Unplanned1, Unplanned downtime reason #1, UNPLANNED_DOWNTIME, Unplanned Downtimes
Unplanned2, Unplanned downtime  reason #2, UNPLANNED_DOWNTIME, Unplanned Downtimes
Short Stops, Minor stoppage reasons, ,
Minor1, Minor stoppage reason #1, MINOR_STOPPAGES, Short Stops
Minor2, Minor stoppage reason #2, MINOR_STOPPAGES, Short Stops
```

The loss category name must match the TimeLoss.java enum name:

- `NO_LOSS`
- `NOT_SCHEDULED`
- `UNSCHEDULED`
- `PLANNED_DOWNTIME`
- `SETUP`
- `UNPLANNED_DOWNTIME`
- `MINOR_STOPPAGES`

- REDUCED_SPEED
- REJECT_REWORK
- STARTUP_YIELD

UNIT OF MEASURE (UOM)

Description
Good, reject/rework and setup/yield production quantities must have a unit of measure. The equipment's design speed (a.k.a. ideal run rate) must be a quotient UOM, i.e. rate. The reject/rework units must also be specified. These units of measure are used in OEE calculations when the input and output UOMs differ. For example, a case packer might accept "can" as the input and reject UOM, but output a "case" of 12 cans.

A measurement system is a collection of units of measure where each pair has a linear relationship, i.e. y = ax + b where 'x' is the abscissa unit to be converted, 'y' (the ordinate) is the converted unit, 'a' is the scaling factor and 'b' is the offset. In the absence of a defined conversion, a unit will always have a conversion to itself where a = 1 and b = 0. A bridge unit conversion is defined to convert between the fundamental SI and International customary units of mass (i.e. kilogram to pound mass), length (i.e. metre to foot) and temperature (i.e. Kelvin to Rankine). These three bridge conversions permit unit of measure conversions between the two systems. A custom unit can define any bridge conversion such as a bottle to US fluid ounces or litres if needed.

A simple unit, for example a metre, is defined as a scalar UOM. A special scalar unit of measure is unity or dimensionless "1".

A unit of measure that is the product of two other units is defined as a product UOM. An example is a Joule which is a Newton·metre.

A unit of measure that is the quotient of two other units is defined as a quotient UOM. An example is a velocity, e.g. metre/second.

A unit of measure that has an exponent on a base unit is defined as a power UOM. An example is area in metre^2. Note that an exponent of 0 is unity, and an exponent of 1 is the base (root) unit itself. An exponent of 2 is a product unit where the multiplier and multiplicand are the base unit. A power of -1 is a quotient unit of measure where the dividend is 1 and the divisor is the base unit.

Units are classified by type, e.g. length, mass, time and temperature. Only units of the same type can be converted to one another. System pre-defined units of measure are also enumerated, e.g. kilogram, Newton, metre, etc. Custom units (e.g. a 1 litre bottle) do not have a pre-defined type or enumeration and are referred to by a unique base symbol.

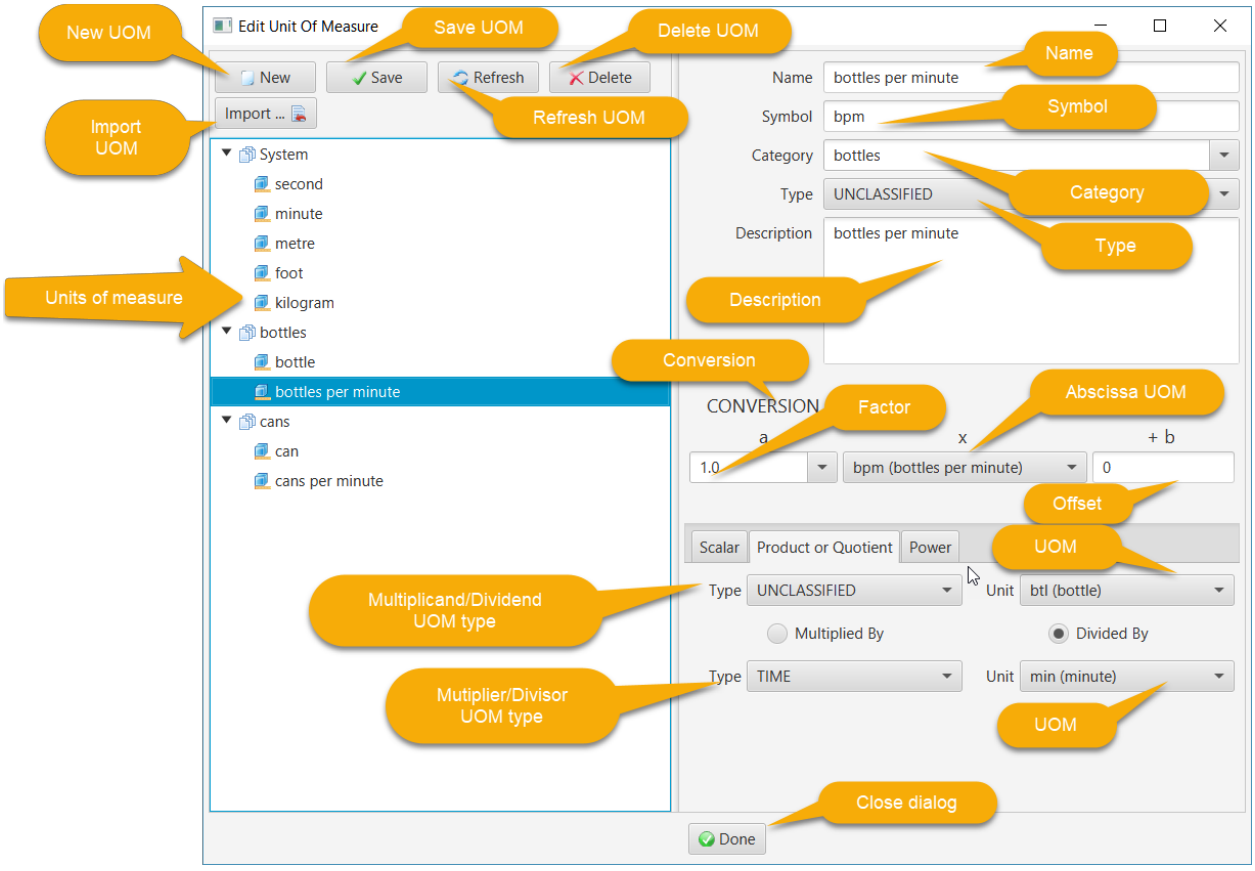
All units have a base symbol that is the most reduced form of the unit. For example, a Newton is kilogram·metre/second^2. The base symbol is used in the measurement system to register each unit and to discern the result of arithmetic operations on quantities. For example, dividing a quantity of Newton·metres by a quantity of metres results in a quantity of Newtons.

A quantity is an decimal amount together with a unit of measure. When arithmetic operations are performed on quantities, the original units can be transformed. For example, multiplying a length quantity in metres by a force quantity in Newtons results in a quantity of energy in Joules (or Newton-metres).

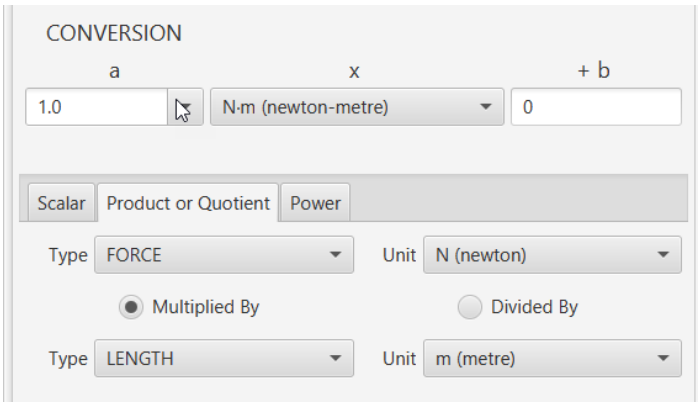
The unit of measure code is available as a standalone Java project at https://github.com/point85/Caliper and as a C# project at https://github.com/point85/CaliperSharp. More information about unit of measure capabilities along with examples can be found at the Caliper web sites.

Editor

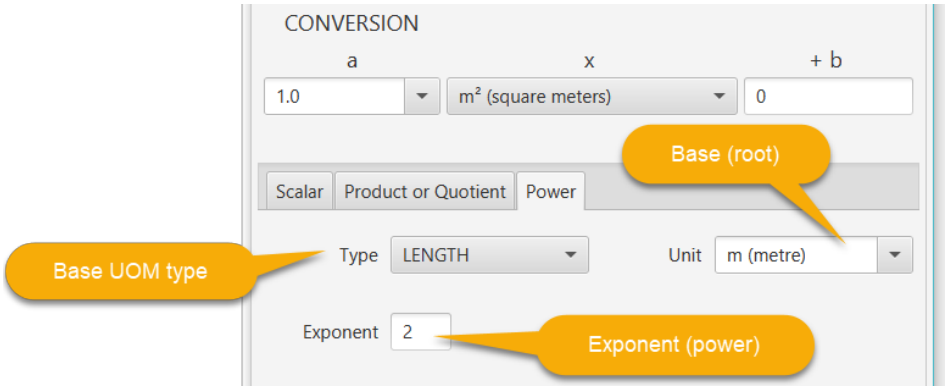
Units of measure are defined in the editor shown below. In this example, a quotient (rate) UOM "bottles per minute" has been created. The dividend is a scalar unit of "bottle" that was previously created. The divisor is a system time unit of "minute".



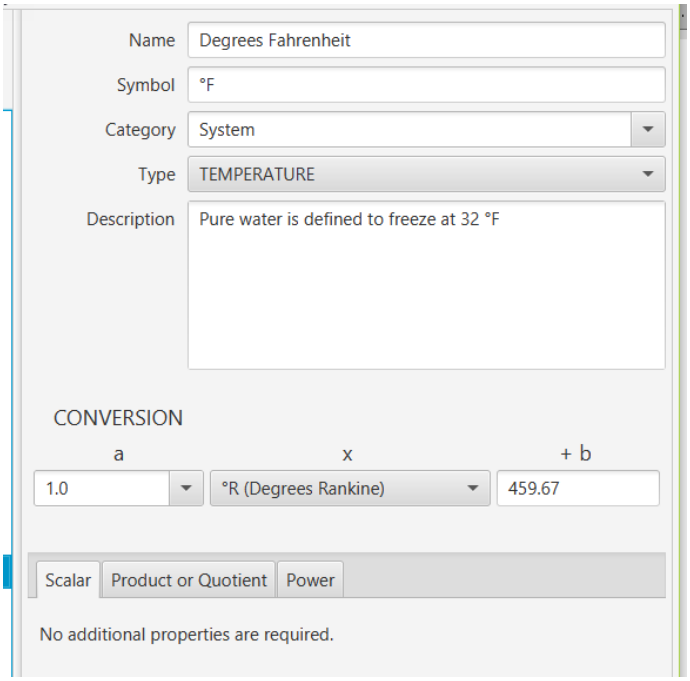
The UOM of measure editor is a general purpose editor and thus supports creation of quotient, product and power units as well as scalar ones (e.g. bottle, can, minute). For example, a Newton-metre is a system-defined product UOM created by importing it (as described below):



As a second example, square metres is a power UOM, again created by importing it:



Temperature in Fahrenheit is an example where the unit has a defined offset from Rankine units:



The UOM editor buttons are:

- *New*: clear the editor to begin defining a new UOM
- *Save*: save the selected UOM to the database.
- *Refresh*: refresh the selected UOM from the database to synchronize the editor with the UOM's saved state
- *Delete*: delete the selected UOM from the database
- *Import*: Import a system UOM from pre-defined choices

When creating a UOM, a category needs to be specified. The category provides a way to group related units. The "System" category is reserved for the pre-defined UOMs such as metre.

A UOM must also have a type. All units with the same type can be converted between each other. For packaging units like "can" or "bottle" the UNCLASSIFIED type should be chosen. Whether or not a conversion between units in this category makes sense is determined by application logic, since there is no physical basis for such units.

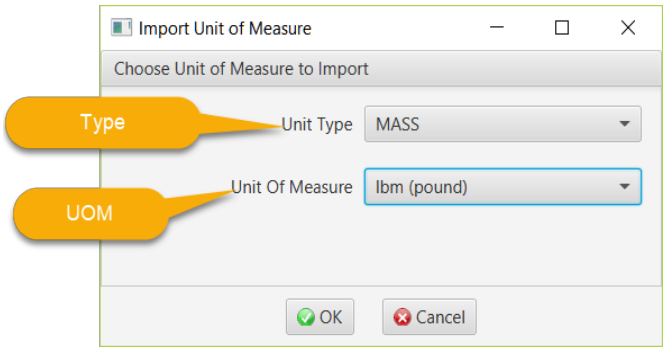
A large number of system-defined types and the corresponding UOMs are included:

- *dimension-less "1"*: UNITY
- *fundamental physical*: LENGTH, MASS, TIME, ELECTRIC_CURRENT, TEMPERATURE, SUBSTANCE_AMOUNT, LUMINOSITY
- *other physical*: AREA, VOLUME, DENSITY, VELOCITY, VOLUMETRIC_FLOW, MASS_FLOW, FREQUENCY, ACCELERATION, FORCE, PRESSURE, ENERGY, POWER, ELECTRIC_CHARGE, ELECTROMOTIVE_FORCE, ELECTRIC_RESISTANCE, ELECTRIC_CAPACITANCE, ELECTRIC_PERMITTIVITY, ELECTRIC_FIELD_STRENGTH, MAGNETIC_FLUX, MAGNETIC_FLUX_DENSITY, ELECTRIC_INDUCTANCE, ELECTRIC_CONDUCTANCE, LUMINOUS_FLUX, ILLUMINANCE, RADIATION_DOSE_ABSORBED, RADIATION_DOSE_EFFECTIVE, RADIATION_DOSE_RATE, RADIOACTIVITY, CATALYTIC_ACTIVITY, DYNAMIC_VISCOSITY, KINEMATIC_VISCOSITY, RECIPROCAL_LENGTH, PLANE_ANGLE, SOLID_ANGLE, INTENSITY, TIME_SQUARED, MOLAR_CONCENTRATION, IRRADIANCE
- *computer science*
- *currency*

The UOM editor has a context menu accessed by right-clicking in the left-hand pane. The menu items are:

- *Save All Units of Measure*: save all UOMs to the database
- *Refresh All Units of Measure*: restore all UOMs from their state in the database

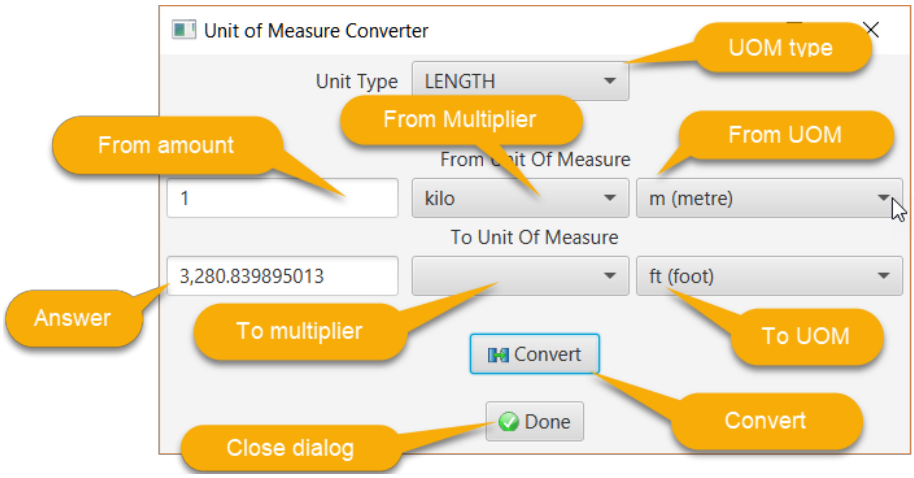
Clicking the Import button launches a dialog to choose the system-defined type and then the UOM of interest. For example to import the customary UOM of pound-mass:



Click "OK" to import the unit or "Cancel" to cancel out. Note that importing a UOM will import that UOM and all referenced units.

Converter

This utility is launched from the toolbar. It is used to convert from one UOM to another UOM of the same type (e.g. length to length). For example, 1 kilometre (1000 metre) is 3,280.8 feet:



First, choose the unit type (e.g. LENGTH), the enter the "from" amount (1), "from" factor if desired (kilo) and "from" unit (metre). Then, select the "to" factor (if any) and "to" unit (foot). Click the Convert button to display the answer of 3,280.8 feet.

Work Schedule

Description

The time equipment is scheduled for production is defined by a work schedule. The work schedule is attached to the equipment itself or to any node in the hierarchy above it. The search starts at the equipment with the availability event and moves up the hierarchy until a schedule is found. Therefore a work schedule could be defined for area or site and apply to all equipment below it.

A work schedule consists of one or more teams who rotate through a sequence of shift and off-shift periods of time. Breaks during shifts can be defined as well as non-working periods of time (e.g. holidays and scheduled maintenance periods) that are applicable to the entire work schedule.

A work schedule is defined with a name and description. Zero or more non-working periods can be defined. A non-working period has a defined starting date and time of day and duration. For example, the New Year's Day holiday starting at midnight for 24 hours, or three consecutive days for preventive maintenance of manufacturing equipment starting at the end of the night shift.

A shift is defined with a name, description, starting time of day and duration. An off-shift period is associated with a shift. Shifts can be overlapped (typically when a hand-off of duties is important). A rotation is a sequence of shifts and off-shift days. An instance of a shift has a starting date and time of day and has an associated shift definition.

A team/crew is defined with a name and description. It has a rotation with a starting date. The starting date shift will have an instance with that date and a starting time of day as defined by the shift. The same rotation can be shared between more than one team, but with different starting times.

A rotation is a sequence of working periods (segments). Each segment starts with a shift and specifies the number of days on-shift and off-shift. A work schedule can have more than one rotation.

A non-working period is a duration of time where no production teams are working. For example, a holiday or a period of time when a plant is shutdown for preventative maintenance. A non-working period starts at a defined day and time of day and continues for the specified duration of time.

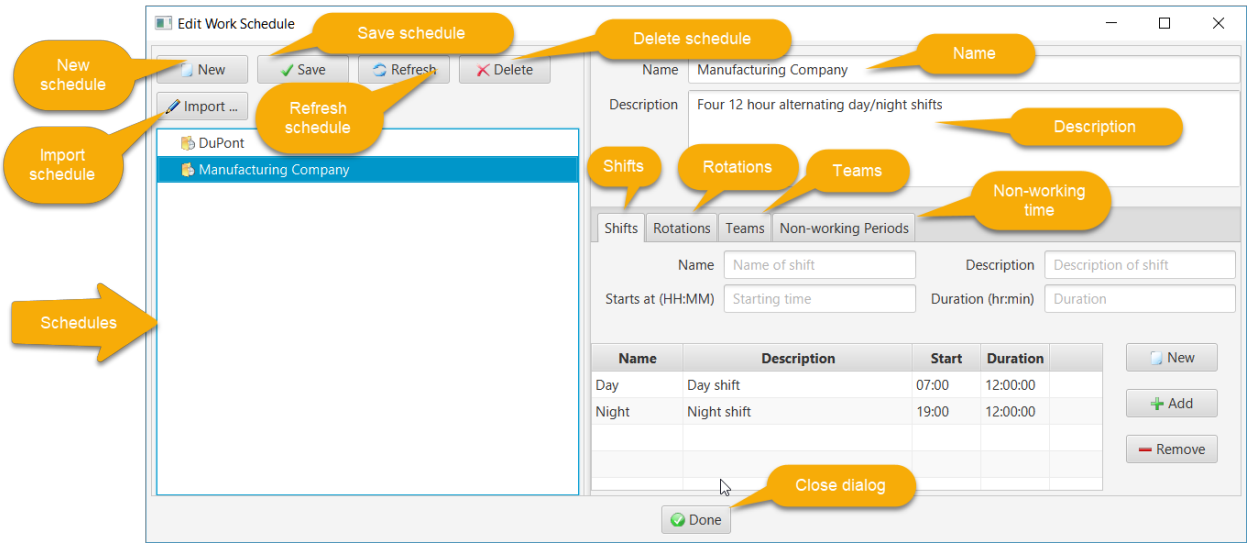
A shift instance is the duration of time from a specified date and time of day and continues for the duration of the associated shift. A team works this shift instance.

After a work schedule is defined, the working time for all shifts can be computed for a defined time interval. This duration of time is the maximum available productive time and is the input to the calculation of Overall Equipment Effectiveness (OEE). Time accumulated in the various loss categories subtracts from this total time to finally arrive at the value adding time. The shift when an OEE event occurs will be also recorded in the database.

The work schedule code is available as a standalone Java project at https://github.com/point85/Shift and as a C# project at https://github.com/point85/ShiftSharp. More information about work schedule capabilities along with examples can be found at the Shift web sites.

Editor

For the work schedule editor shown below, the Manufacturing Company schedule has been selected:



The work schedule editor buttons are:

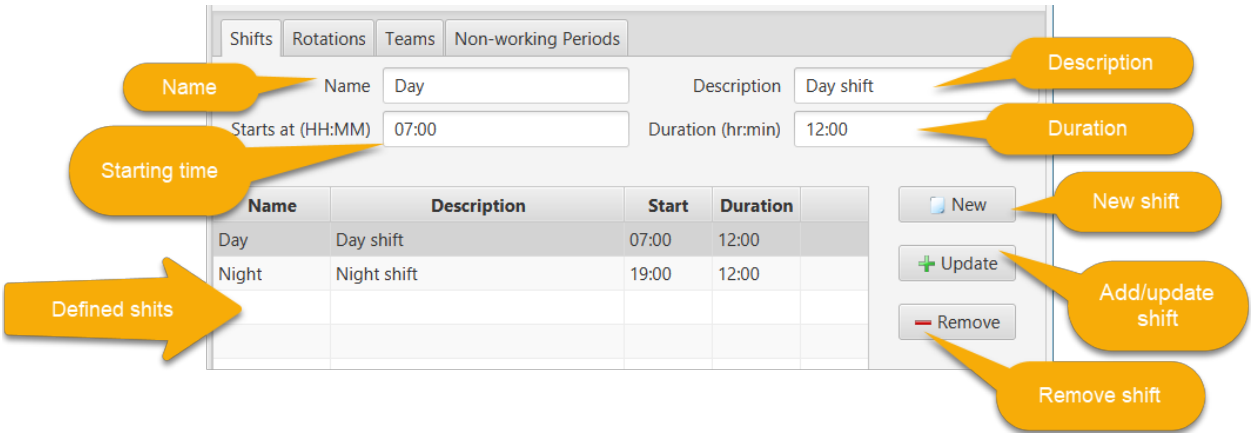
- *New*: clear the editor to begin defining a new schedule
- *Save*: save the selected schedule to the database.
- *Refresh*: refresh the selected schedule from the database to synchronize the editor with the schedule's saved state
- *Delete*: delete the selected schedule from the database
- *Shifts*: display a dialog to show the shift instances for a specfied period of time
- *Import*: import a schedule from pre-defined templates

The work schedule editor has a context menu accessed by right-clicking in the left-hand pane. The menu items are:

- *Save All Schedules*: save all schedules to the database
- *Refresh All Schedules*: restore all schedules from their state in the database

Shifts

The "Shifts" tab is used to define shifts:



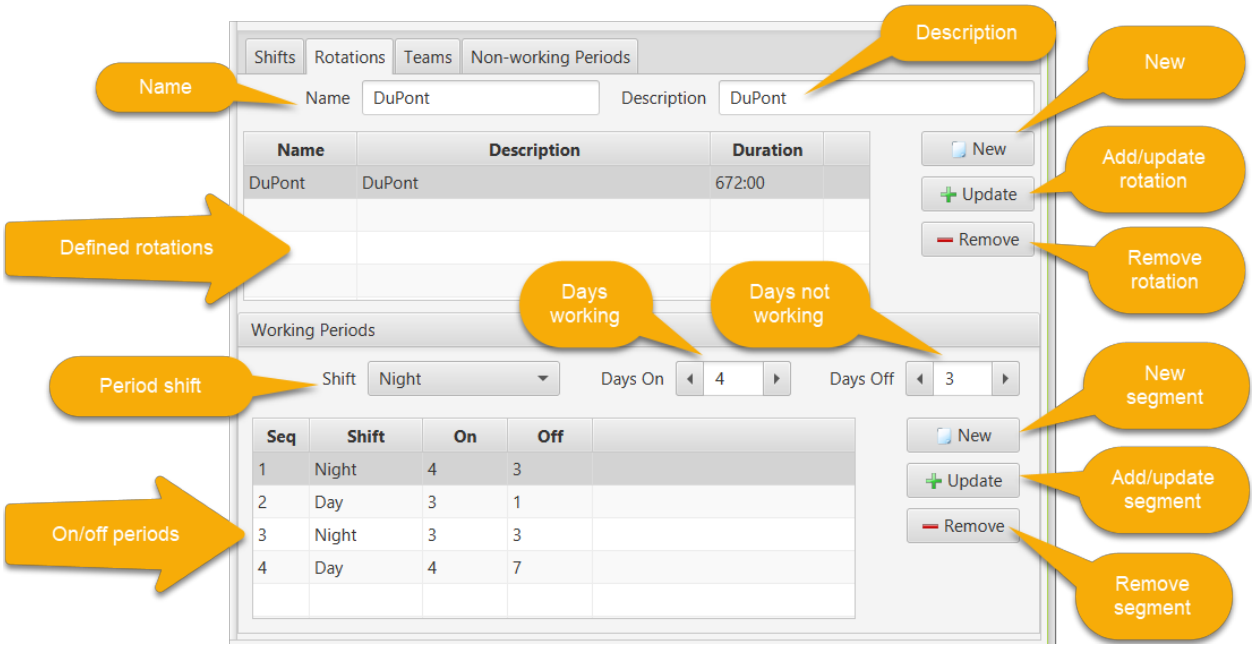
The editor actions are:

- *New*: clear the editor controls in order to define a new shift. The Add/Update button text will change to "Add".
- *Add*: After defining the properties of a new shift, clicking this button will add it to the list of shifts
- *Update*: after selecting an existing shift, the current values will be moved into the editing controls. Make the necessary edits, then click this button to apply the changes to the list.
- *Remove*: after selecting an existing shift, click this button to remove it from the list.

The starting time of day is entered in 24-hour format (hours:minutes from 00:00 to 23:59). The shift duration is entered as hours:minutes between 00:00 and 24:00. Note that after making changes to the list of shifts, the work schedule must be saved to the database by clicking the Save button.

Rotations

The "Rotations" tab is used to define rotations:



In this example, the DuPont 12-hour rotating shift schedule uses 4 teams (crews) and 2 twelve-hour shifts to provide 24/7 coverage. It consists of a 4-week cycle where each team works 4 consecutive night shifts, followed by 3 days off duty, works 3 consecutive day shifts, followed by 1 day off duty, works 3 consecutive night shifts, followed by 3 days off duty, work 4 consecutive day shift, then have 7 consecutive days off duty. Personnel works an average 42 hours per week.

This DuPont example has one long rotation of 672 hours (28 days or 4 weeks) consisting of 4 segments in this sequence:

1. Night shift, 4 days on followed by 3 days off
2. Day shift, 3 days on followed by 1 day off
3. Night shift, 3 days on followed by 3 days off
4. Day shift, 4 days on followed by 7 days off

The editor actions for rotations are:

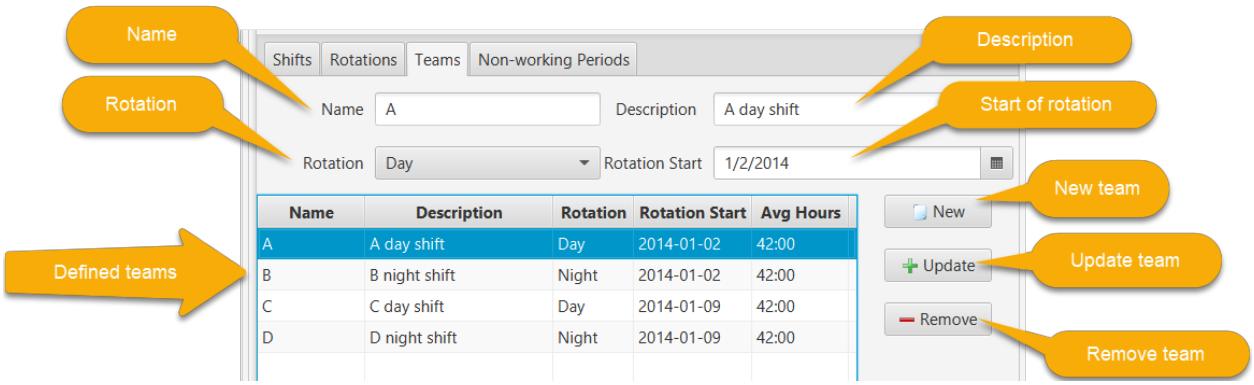
- *New*: clear the editor controls in order to define a new rotation. The Add/Update button text will change to “Add”.
- *Add*: After defining the properties of a new rotation, clicking this button will add it to the list of rotations
- *Update*: after selecting an existing rotation, the current values will be moved into the editing controls. Make the necessary edits, then click this button to apply the changes to the list.
- *Remove*: after selecting an existing rotation, click this button to remove it from the list.

The editor actions for rotation segments are:

- *New*: clear the editor controls in order to define a new rotation segment. The Add/Update button text will change to "Add".
- *Add*: After defining the properties of a new rotation segment, clicking this button will add it to the list of rotation segments
- *Update*: after selecting an existing rotation segment, the current values will be moved into the editing controls. Make the necessary edits, then click this button to apply the changes to the list.
- *Remove*: after selecting an existing rotation segment, click this button to remove it from the list.

Teams

The "Teams" tab is used to define teams (crews):

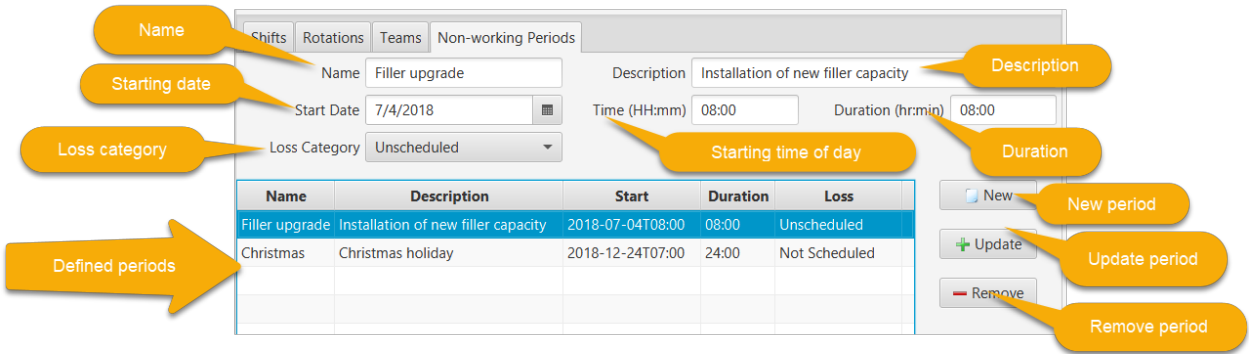


The editor actions for teams are:

- *New*: clear the editor controls in order to define a new team. The Add/Update button text will change to "Add".
- *Add*: After defining the properties of a new team, clicking this button will add it to the list of teams. The average working hours will be displayed in the last column, e.g. 42 hours and 0 minutes in this example.
- *Update*: after selecting an existing team, the current values will be moved into the editing controls. Make the necessary edits, then click this button to apply the changes to the list.
- *Remove*: after selecting an existing team, click this button to remove it from the list.

Non-working Periods

The "Non-working Periods" tab is used to define intervals of time on an exception basis where no production will take place, for example holidays and planned maintenance outages:

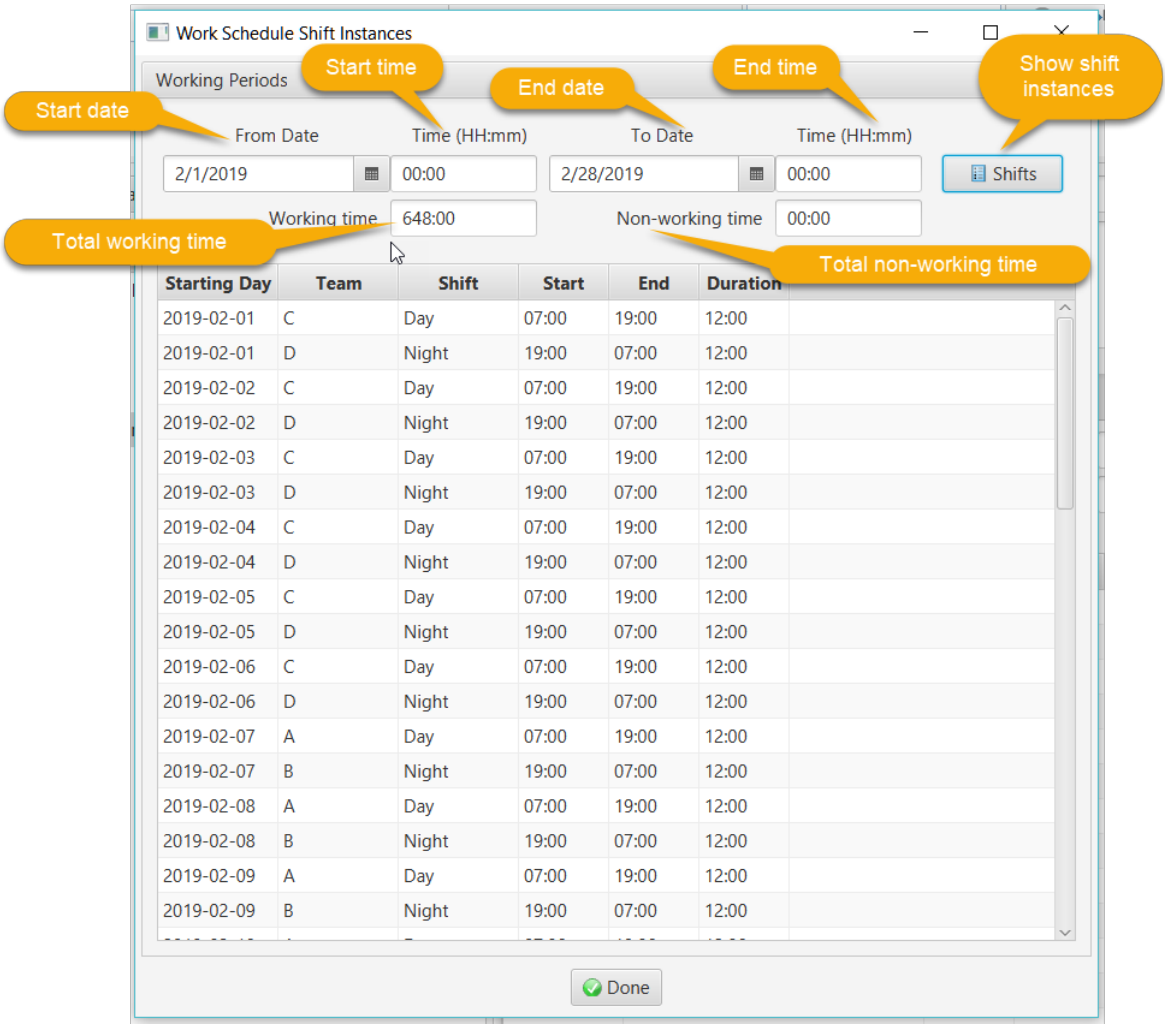


The editor actions for teams are:

- *New*: clear the editor controls in order to define a new non-working period. The Add/Update button text will change to "Add".
- *Add*: After defining the properties of a new non-working period, clicking this button will add it to the list of periods. The loss category is one of two choices (1) Not Scheduled (e.g. holiday), or (2) Unscheduled (special event).
- *Update*: after selecting an existing non-working period, the current values will be moved into the editing controls. Make the necessary edits, then click this button to apply the changes to the list.
- *Remove*: after selecting an existing non-working period, click this button to remove it from the list.

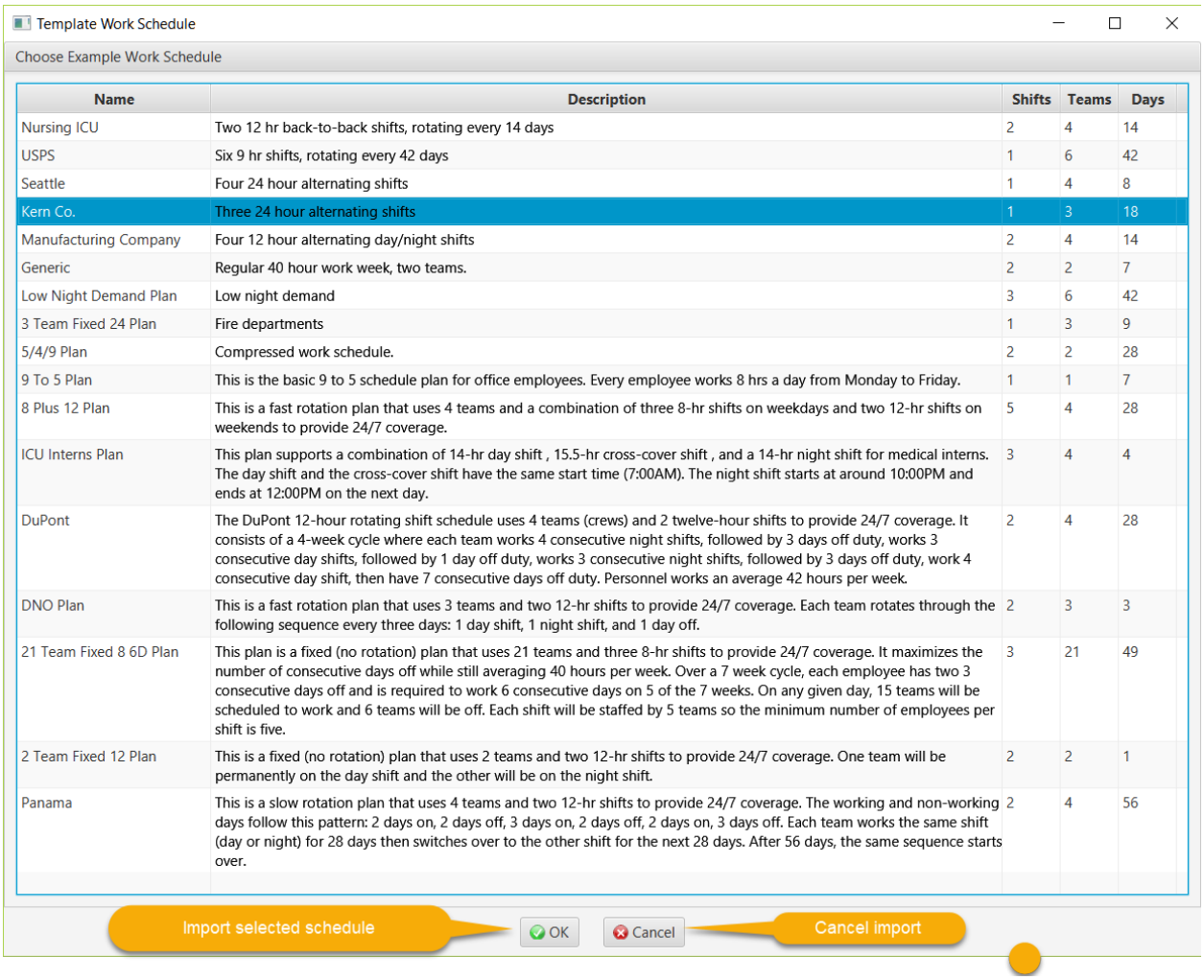
Show Shift Instances

Click the Shifts buttin to launch a dialog to view shift instances for the selected work schedule. For example, the dialog below shows shift instances for the month of February for the Manufacturing Company work schedule:



Import Schedule

Click the Import button to launch a dialog to choose a pre-defined work schedule (similar to a desired one) and then save it to the database for further editing:



SCRIPTING

Description

A JavaScript function must defined for each equipment resolver. This script is executed by the Java 8 Nashorn script engine. It accepts an input value from a data source event and returns a value matching the type of the resolver (e.g. availability, production count, material or job change). For the case of a CUSTOM event, the output value (if any) is used only for display in the trend chart. The script editor is used to write and test the body of this function. The script can call any OEE method accessible through the OeeContext object or any java code in external jar files.

An availability script outputs the name of a Reason (which is associated with an OEE loss category). A good, reject or startup production script outputs a count in the unit of measure defined for that equipment. A good production amount has the dividend UOM of the design speed, whereas a reject or startup production amount has the defined reject UOM. A material change script outputs the name of a defined material. A job change script outputs the name of a job/order. In order to perform OEE calculations, the material must be defined as the first event before the time period of interest.

The script has three input arguments:

1. OeeContext *context*: an instance of the OeeContext class containing information about the script execution environment (see below for details)
2. Object *value*: the input value. The data in this input depends on the event source and data type. For OPC DA and UA the value can be a scalar or array.
3. EventResolver *resolver*: the event resolver. The resolver's last value can be used in rollover calculations for production counts. The equipment for the executing script is also available as a resolver attribute.

The OeeContext class has these primary public "getter" methods (note that domain javadocs are available in the "docs" folder in the domain_docs.zip file):

- *getLogger()*: Get an instance of an org.slf4j.Logger. The logging output(s) is configured in the log4j.properties file
- *getMaterial(Equipment equipment)*: Get the material currently being processed on this equipment. The equipment object is obtained from resolver.getEquipment()
- *getJob(Equipment equipment)*: Get the job currently being run on this equipment. The equipment object is obtained from resolver.getEquipment()
- *getOpcDaClients()*: Get the collection of DaOpcClient objects. A client object can then be used for reading and writing tags, e.g. readSynch()/writeSynch()
- *getOpcUaClients()*: Get the collection of UaOpcClient objects. A client object can then be used for reading and writing nodes, e.g. readSynch()/writeSynch()
- *getMessagingClient()*s: Get the collection of MessagingClient objects. A client object can then be used to send a message to the "Point85" exchange on a RabbitMQ broker, e.g. publish()
- *getJMSClient()*s: Get the collection of JMSClient objects. A client object can then be used to send a message to the JMS broker
- *getMQTTClient()*s: Get the collection of MQTTClient objects. A client object can then be used to send a message to the MQTT server
- *getHttpServer()*s: Get the collection of HTTP servers.
- *getDatabaseEventClient()*s: Get the collection of DatabaseEventClients.
- *getFileEventClient()*s: Get the collection of FileEventClients.
- getModbusMasters(): Get the collection of ModbusMasters.

The JavaScript below in the Custom Scripting section shows examples of calling these methods.

The default script for availability, material and job is to simply return the input value (passthrough):

```
return value;
```

However, the default script for a production count provides for a rollover of the counting sensor:

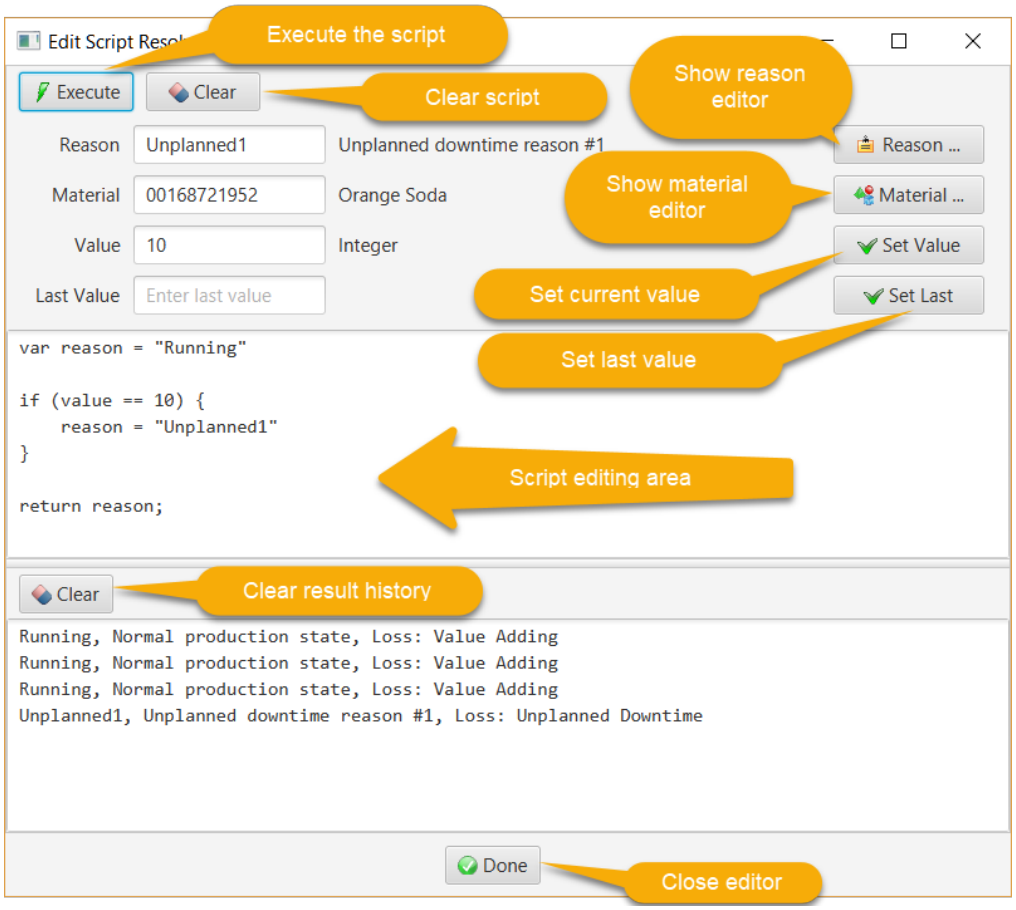
```
var ROLLOVER = 0;

var lastValue = resolver.getLastValue();

var delta = value - lastValue;

if (value < lastValue) {

    delta += ROLLOVER;

}

return delta;
```

The variable “ROLLOVER” must be defined for the sensor. If the last value of the count is greater than the current value, then the counter must have rolled over at the ROLLOVER value to zero in this example.

Editor

The script editor dialog is launched either by (1) selecting an equipment resolver in the list in the “Data Collection” tab of the equipment entity and then clicking the editor button or (2) clicking a button on the toolbar. If the editor is launched from the toolbar, functionality will be limited since the resolver input argument to the script will be null.

The editor looks like:



The editor actions are:

- *Execute*: execute the script. The returned object's toString() method will be called and the result displayed in the execution history in the bottom pane.
- *Clear*: clear the script editor or history
- *Reason*...: Display the reason editor to create or update a reason and choose an existing reason. The name is displayed in the text field where it is available for cutting and pasting into the script.
- *Material*...: Display the material editor to create or update a material and choose an existing material. The name is displayed in the text field where it is available for cutting and pasting into the script.
- *Set Value*: Set the value in the text field as the input value to the script before it is executed.
- *Set Last*: Set the value in the text field as the previous input value to the script before it is executed.

Depending upon the type of resolver, the script area initially will be populated by a default script. Availability, material change and job change scripts pass the input value through to the output:

```
return value;
```

whereas a production count script provides a variable called "ROLLOVER" as a place-holder to take into account the case where a counter can output a lower value than a previous value:

```
var ROLLOVER = 0;
var lastValue = resolver.getLastValue();
var delta = value - lastValue;
if (value < lastValue) {
    delta += ROLLOVER;
}
return delta;
```

Custom Scripting

A resolver script can be used for general purpose (non-OEE) data collection by choosing the "CUSTOM" type. In this case, the input value to the script is used in the script logic as required by a custom application. The output value (if any) is displayed in the trend chart.

Example 1 - Logging

This example show how to log to the Point85.log file.

```
// logger
var logger = context.getLogger()
// equipment
var eq = resolver.getEquipment()

// log info
logger.info("Material: " + context.getMaterial(eq))
logger.info("Job: " + context.getJob(eq))
logger.info("Source id: " + resolver.getSourceId())
logger.info("Last value: " + resolver.getLastValue())
logger.info("Last timestamp: " + resolver.getLastTimestamp())
logger.info(context.toString())
```

Example 2 - Database

For this example, suppose that a custom database table (TEST_CUSTOM) has been created with three columns (string, integer and float values). When the input string (value) is received, a record is inserted into this table by making use of the PersistenceService singleton's executeUpdate() method:

```
var PersistenceService = Java.type('org.point85.domain.persistence.PersistenceService');
var sql = "insert into dbo.TEST_CUSTOM (A_STRING, AN_INT, A_FLOAT) values ('" + value + "', 1,
0.0)";
var result = PersistenceService.instance().executeUpdate(sql);
```

The executeQuery() method of PersistenceService returns a JSON list of all records in this table:

```
var PersistenceService = Java.type('org.point85.domain.persistence.PersistenceService');
```

```
var sql = "select * from dbo.TEST_CUSTOM";

var json = PersistenceService.instance().executeQuery(sql);

print(json);
```

Example 3 - Publish Message

```
// send RMQ message for a configured messaging data source

var CollectorNotificationMessage =
Java.type("org.point85.domain.messaging.CollectorNotificationMessage")

var routingKey = Java.type("org.point85.domain.messaging.RoutingKey").NOTIFICATION_MESSAGE

var severity = Java.type("org.point85.domain.messaging.NotificationSeverity").INFO

var msg = new CollectorNotificationMessage("localhost", "192.168.0.8")

msg.setText("This is a notification")

msg.setSeverity(severity)

context.getMessagingClient().publish(msg, routingKey, 30)
```

Example 4 - Send Alarm Notification

```
// send RMQ message to the collector's notification server.  This alarm will be displayed in the
monitor's "Collector Notifications" tab

var MessagingClient = Java.type("org.point85.domain.messaging.MessagingClient")

var client = new MessagingClient()

var collector = resolver.getCollector()

var host = collector.getBrokerHost()

var port = collector.getBrokerPort()

var user = collector.getBrokerUserName()

var pwd = collector.getBrokerUserPassword()

var HIGH = 20000

var LOW = 10000

if (value > HIGH) {

    var severity = Java.type("org.point85.domain.messaging.NotificationSeverity").ERROR

    var text = "Alarm high level of " + HIGH + " exceeded.  Value is " + value

    client.connect(host, port, user, pwd)

    client.sendNotification(text, severity)

    client.disconnect()

}  else if (value < LOW) {

    var severity = Java.type("org.point85.domain.messaging.NotificationSeverity").WARNING

    var text = "Alarm low level of " + LOW + " exceeded.  Value is " + value

    client.connect(host, port, user, pwd)

    client.sendNotification(text, severity)

    client.disconnect()
```

```
}
```

Example 5 - Read/Write Values with OPC DA

```
// OPC DA read integer value

var logger = context.getLogger()

var variant = context.getOpcDaClient().readSynch("Random.Int4")

logger.info("Value: " +  variant.getValueAsNumber())


// OPC DA write integer value

var OpcDaVariant = Java.type("org.point85.domain.opc.da.OpcDaVariant")

var variant = new OpcDaVariant(100)

context.getOpcDaClient().writeSynch("Data Type Examples.16 Bit Device.K Registers.Short1",
variant)
```

Example 6 - Read/Write Values with OPC UA

```
// OPC UA read current server time

var logger = context.getLogger()

var NodeId = Java.type("org.eclipse.milo.opcua.stack.core.types.builtin.NodeId")

var nodeId = new NodeId(0, 2258)

var dataValue = context.getOpcUaClient().readSynch(nodeId)

logger.info(dataValue.getValue().getValue())


// OPC UA write integer value

var logger = context.getLogger()

var NodeId = Java.type("org.eclipse.milo.opcua.stack.core.types.builtin.NodeId")

var Variant = Java.type("org.eclipse.milo.opcua.stack.core.types.builtin.Variant")

var nodeId = new NodeId(3, "Int32DataItem")

var value = new Variant(100)

code = context.getOpcUaClient().writeSynch(nodeId, value)

if (code.isBad()) {

        logger.error("Write failed, code = " + code.getValue())

}
```

Example 7 - Database Event Table Query

```
// database query

var logger = context.getLogger()

var service = Java.type("org.point85.domain.persistence.PersistenceService").instance()

var sql = "Select top 10 EVENT_TYPE, JOB from OEE_EVENT order by START_TIME desc"

var rows = service.getEntityManager().createNativeQuery(sql).getResultList()
```

```
for (i = 0; i < rows.size(); i++) {
        var row = rows.get(i)
        logger.info("Type: " + row[0] + ", Job: " + row[1])
}
```

Example 8 - Set a Reject and Rework Reason

```
// set a reject and rework reason named "002" for this production event
resolver.setReason("002");
return value;
```

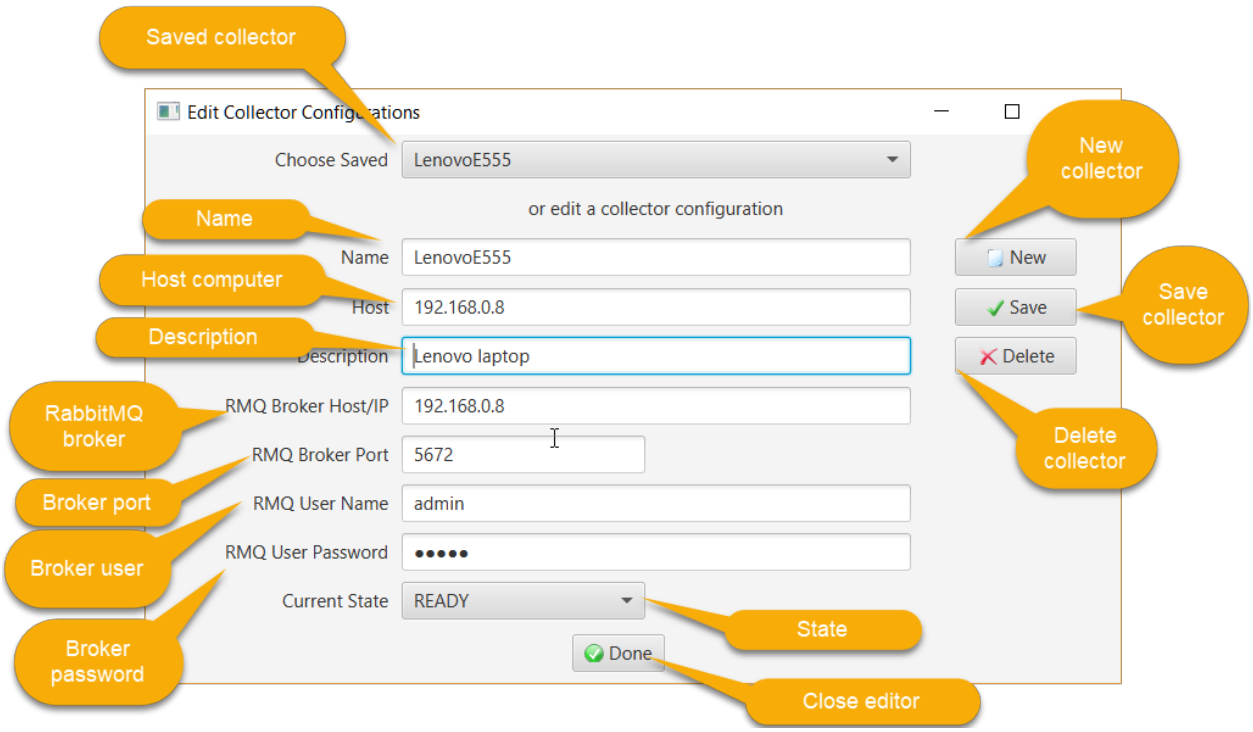
Example 9 - Read/Write Modbus Data Values

```
// 1.  In the resolver script, the value is a List<ModbusVariant> containing an Integer
return value.get(0).getNumber();


// 2.  Write a boolean to a coil at address 0
var master = context.getModbusMaster();
master.writeCoil(255, 0, false);


// 3.  Write a signed 16-bit short integer value to a holding register
var ModbusVariant = Java.type("org.point85.domain.modbus.ModbusVariant");
var ModbusDataType = Java.type("org.point85.domain.modbus.ModbusDataType");
var ModbusEndpoint = Java.type("org.point85.domain.modbus.ModbusEndpoint");
var Short = Java.type("java.lang.Short");


var variant = new ModbusVariant(ModbusDataType.INT16, new Short(1234));
var endpoint = new ModbusEndpoint();
endpoint.setUnitId(255);
endpoint.setRegisterAddress(0);
endpoint.setReverseEndianess(true);
context.getModbusMaster().writeHoldingRegister(endpoint, variant);
// 4.  Read a single value (in a list) for a reason (availability) code.  Only save an event
record if the value has changed.
var newValue = value.get(0).toString();
var returnValue = newValue;
if (resolver.getLastValue() != null) {
    lastValue = resolver.getLastValue().get(0).toString();
    if (newValue.equals(lastValue)) {
        returnValue = null;
```

```
    }
}
return returnValue;
// 5.  Read a single value (in a list) for a production amount. Only save an event record if the
amount is positive.
var variant = value.get(0);
var returnValue = null;
if (variant.isPositiveNumber()) {
    returnValue = variant.getNumber();
}
return returnValue;
```

DATA COLLECTOR EDITOR

The collector for receiving data from data sources and resolving them to OEE events is defined in this editor. For example:



The state is one of DEV (under development and cannot be used), READY (released for use) or RUNNING (in use). All ready or running collectors will be started to collect data.

If collector status and notification messaging is desired, then the RMQ broker host IP address, port, user name and password are defined in this editor.

The data collector editor buttons are:

- *New*: clear the editor to begin defining a new collector
- *Save*: save the selected collector to the database.
- *Delete*: delete the selected collector from the database
- *Test*: delete the RMQ connection

DATA SOURCE EDITORS

The data source editors define where a non-manual input value to a resolver script can come from. The supported sources are:

- OPC DA: classic OLE for Process Control (OPC) Data Acquisition
- OPC UA: OLE for Process Control Unified Architecture (UA)
- HTTP: invocation of an HTTP POST request with the data in the request body
- Messaging: an event message received via a RabbitMQ message broker with the data as the message payload
- JMS: an event message received via an JMS message broker with the data as the message payload
- MQTT: an event message received via an MQTT message server with the data as the message payload
- Database: an event record(s) inserted into the DB_EVENT table. The JavaScript resolver's input value is a list of DatabaseEvent objects.
- File: a text file written into the ready folder. The JavaScript resolver's input value is content of this file.
- Modbus: A standard for reading and writing to a controller such as a PLC. The JavaScript resolver's input value is a list of data values read from a slave register(s).

OPC UA Data Source

Browser

The OPC UA data source browser dialog is launched from the toolbar or from the Data Collection tab after an equipment object with an OPC UA source has been selected in the physical model. It is used to browse to the node providing the input value. This dialog looks like:

In this example, the browser is anonymously connected to the Prosys demo server running on a host at 192.168.0.13 IP address on port 53530 with a server name/path of OPCUA/SimulationServer.

If a secure connection is desired for a server, under the Security Settings tab, the Security Policy can be chosen from None, Basic128Rsa15, Basic256, Basic256Sha256, Aes128_Sha256_RsaOaep or Aes256_Sha256_RsaPss. The Message Security Mode can be chosen from None, Sign or Sign & Encrypt. Under the Authentication Settings tab, the Java keystore file name can be specified in the Keystore text field and its password in the Password text field. The keystore file must be placed in the config/security folder. The user name and user password text fields can be used to specify the user name and password for user authentication. The button to the right of the keystore file name clears out these security settings.

The actions for an OPC UA data source are:

- *New*: clear the editing controls to define a new data source

- *Save*: save the data source to the database
- *Delete*: delete the data source from the database

The actions for establishing a connection are:

- *Connect*: connect to the data source
- *Disconnect*: disconnect from the data source
- *Cancel*: cancel an unsuccessful connection attempt

After a connection is established, the server namespace can be browsed. Selection of a node will display the current value and information about it below the tree view. In this example, the node namespace is 5 with a string id of "Triangle1".

Clicking the Done button will assign the selected node as the script resolver's input source.

Trending

Suppose that an OPC UA event resolver executes an availability script for a Unified Automation OPC UA demo server. An availability script must output a reason. For this node (triangle trend for a double value), the publishing interval is every 5 seconds. The script outputs a reason based on the input value:

```
var reason = 'Running';
if (value < 0.0)
{
    reason = 'Unplanned1';
}
return reason;
```

By clicking the Watch button for this resolver, the execution of the script can be observed:

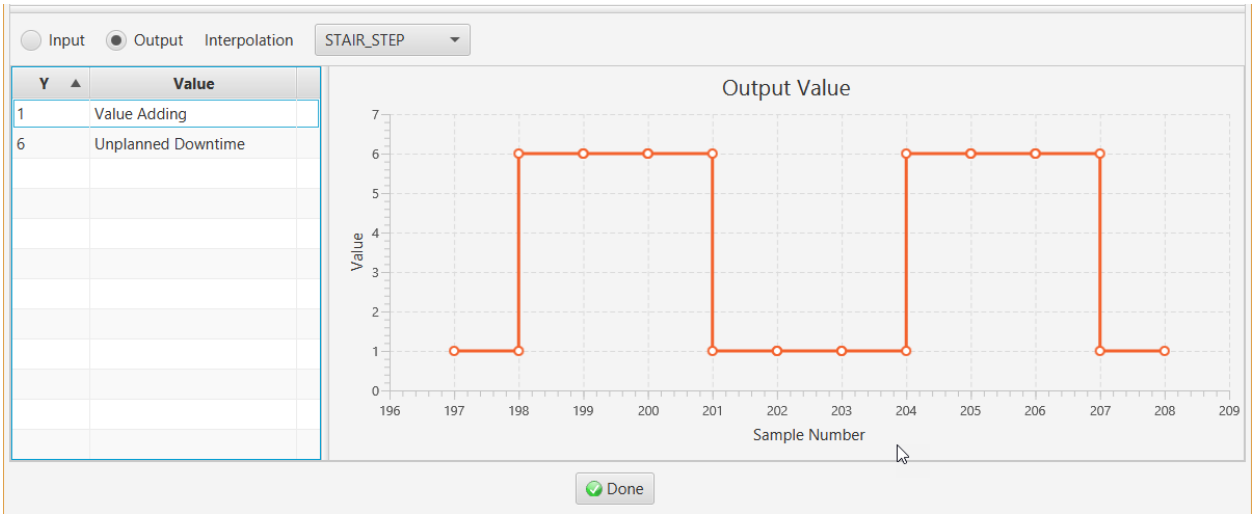
The actions are:

- *Connect*: connect to the OPC UA data source. After a successful connection, the server id and node ids are displayed along with the server status (Running in this case).
- *Disconnect*: disconnect from the data source
- *Cancel*: abort an unsuccessful connection attempt
- *Stop/Start*: The trending can be paused by clicking this button. The text will change to Start. The trend can be restarted by clicking it again.
- *Reset*: Restart trending after changing either the update period or number of points to display.

The table shows the item id, input value, timestamp and output value. If the output is an availability reason, the time loss category is displayed (Unplanned Downtime in this case).

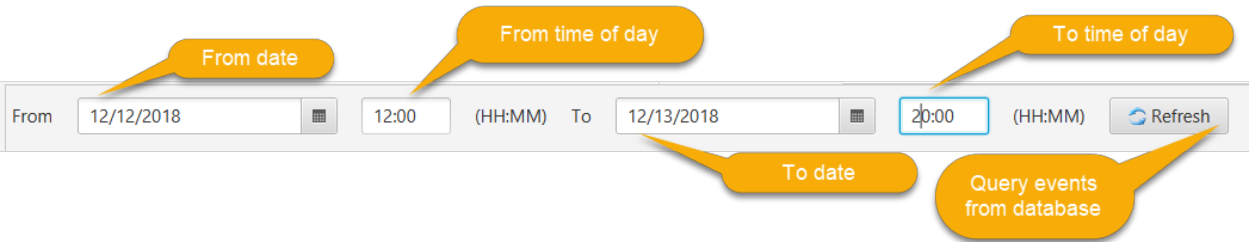
The current update period and number of data points to display on the X axis is displayed. These values can be changed when the trend is stopped and take effect after it is reset and restarted.

If Output is selected for the trend, the chart looks like:



Since the output is a reason, the values are discrete and thus a stair step interpolation is desired (the screen capture above displays a linear interpolation). The table on the left shows an integral value for the Y axis and the corresponding discrete value. Linear interpolation applies to continuous values such as integer or floating point data.

Previous event records can be fetched from the database and displayed in the table and in the trend chart.

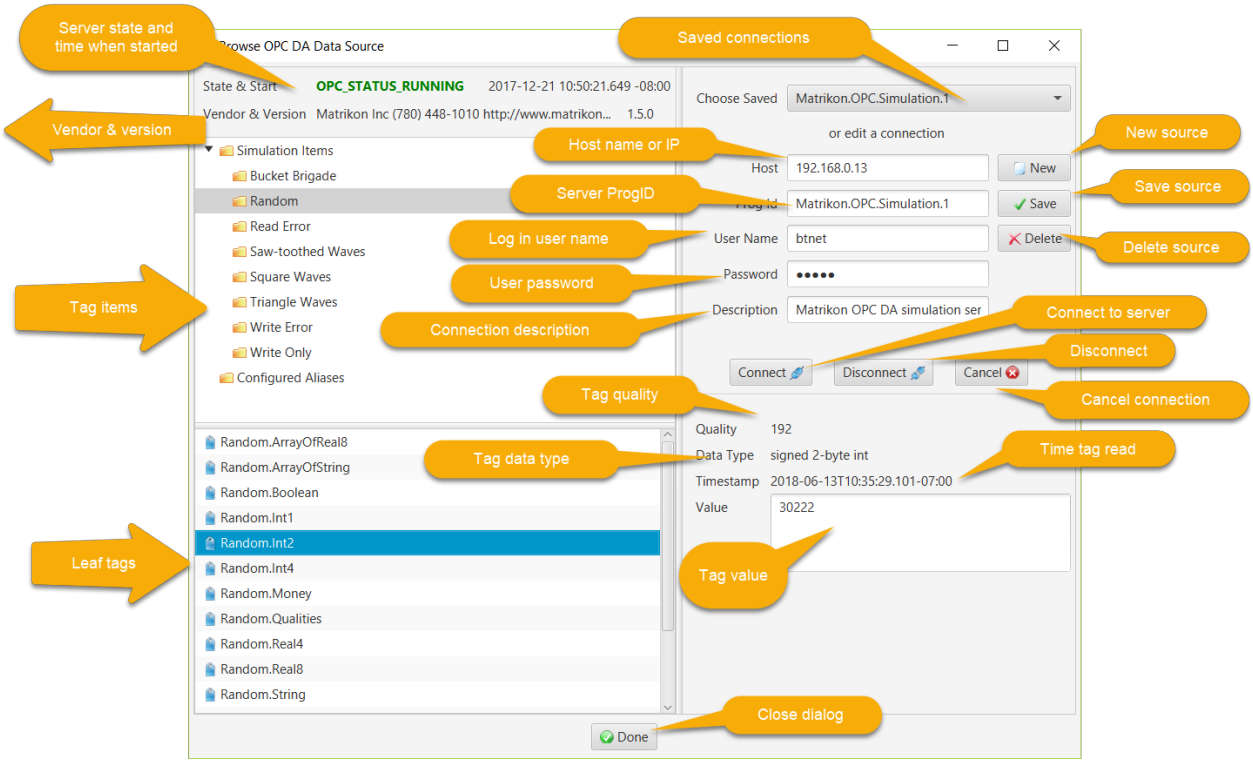


The beginning date and time of day can be set as well as the ending date and time of day. Both date/times are optional. Clicking the Refresh button will fetch records matching the date/time range from the database and display them in the event table and in the trend chart below.

OPC DA Data Source

Browser

The OPC DA data source browser dialog is launched from the toolbar or from the Data Collection tab after an equipment object with an OPC DA data source has been selected in the physical model. It is used to browse to the tag providing the input value. This dialog looks like:



In this example, the browser is connected to the Matrikon OPC simulation server on host 192.168.0.13 with a ProgID of Matrikon.OPC.Simulation.1 and the “btnet” user and password (note that the user name can include a Windows domain name).

The actions for an OPC DA data source browser are:

- *New*: clear the editing controls to define a new data source
- *Save*: save the data source to the database
- *Delete*: delete the data source from the database

The actions for establishing a connection are:

- *Connect*: connect to the data source
- *Disconnect*: disconnect from the data source
- *Cancel*: cancel an unsuccessful connection attempt

After a connection is established, the server tags can be browsed. Selection of a parent item of a leaf tag will display the children below the tree view. Selecting a leaf tag will display the tag’s current value and information about it to the right of the tree view.

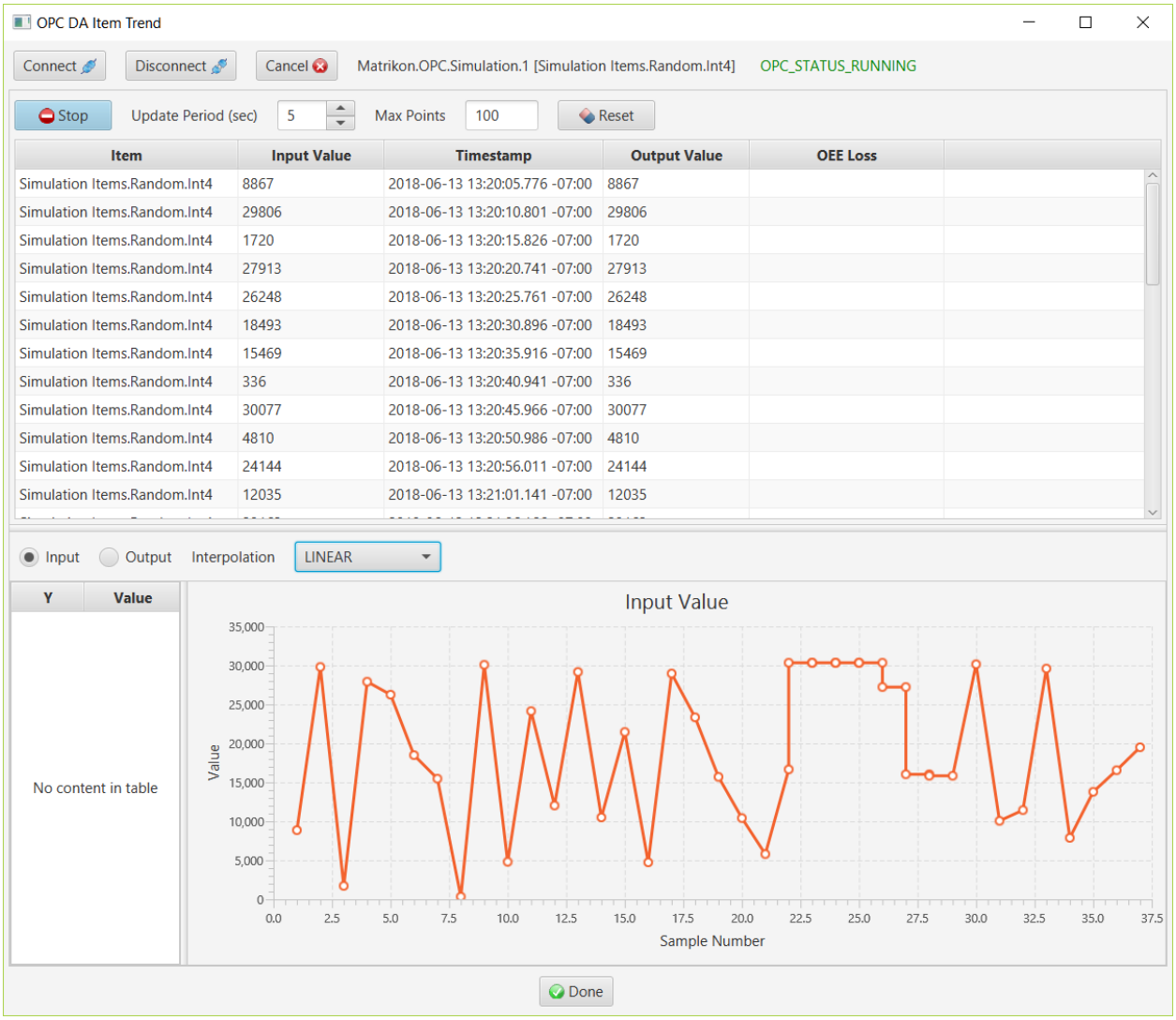
Clicking the Done button will assign the selected tag as the OPC DA script resolver’s input source.

Trending

By clicking the Watch button for an OPC DA resolver, the execution of the script can be observed. A trend chart for an OPC DA source for a 4-byte integer good production count with a pass-through resolver script of:

```
return value;
```

looks like:

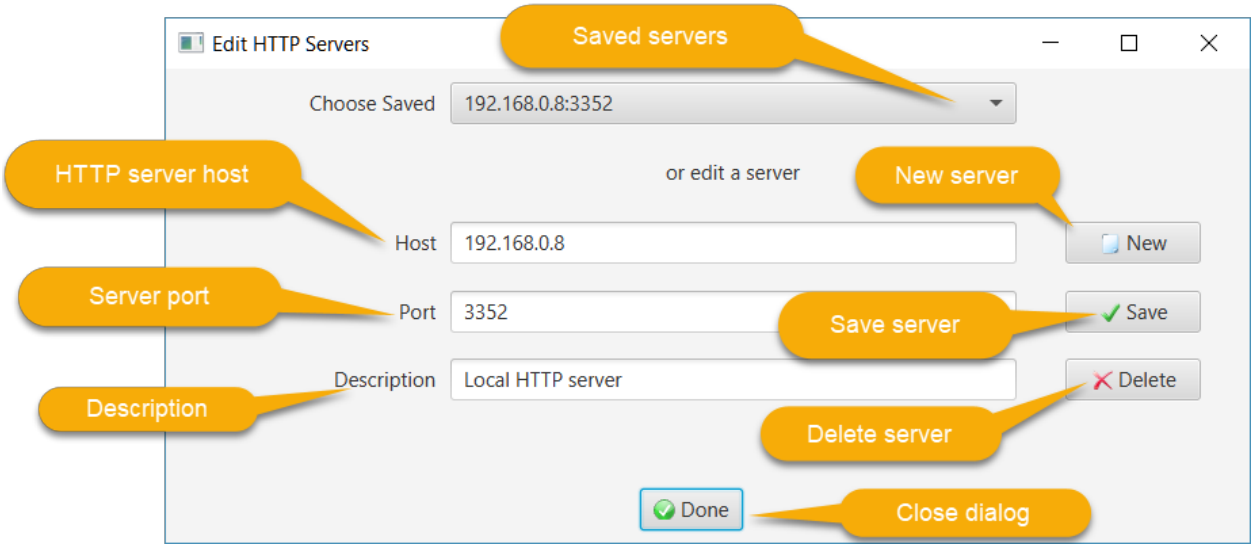


HTTP Web Service Data Source

Definition

The HTTP data source definition dialog is launched from the toolbar or from the Data Collection tab after an equipment object with an HTTP source has been selected in the physical model. It is used to define the host and port for the NanoHTTPD embedded HTTP server in the data collector.

This dialog looks like:



The actions for an HTTP data source are:

- *New*: clear the editing controls to define a new data source
- *Save*: save the data source to the database
- *Delete*: delete the data source from the database
- *Test*: connect to the data source. A dialog will be presented indicating success or failure

Clicking the Done button will assign the HTTP server as the script resolver's input source.

When the data collector is started on the specified host (192.168.0.8 in this example), it will listen to the specified port (3352) ready to receive POST requests.

Post Content

The POST request has the EquipmentEventRequestDto JSON serialized DTO (Data Transfer Object) as a body (sourceId, value and timestamp fields). This request is for an availability, production of material, setup or job change event.

There are three fields:

- sourceId (required): the source identifier as defined in the data collection script resolver
- value (required): the data value
- timestamp (optional): event time in ISO 8601 format

For example:

{"sourceId":"EQ1.HTTP.AVAILABILITY","value":"Running","timestamp":"2019-03-19T11:28:13.143-07:00"}

The HTTP server responds with the corresponding EquipmentEventResponseDto JSON body (status and errorText fields).

The body for no error is similar to:

```
{"status":"OK", "errorText":"OK"}
```

Java Client Example

An HTTP Java client can post an equipment event request. For example to loop-back test in the HTTP trend dialog executes this code:

```
@FXML
private void onLoopbackTest() {
        HttpURLConnection conn = null;
        try {
                // get the HTTP data source
                EventResolver eventResolver = trendChartController.getEventResolver();
                HttpSource dataSource = (HttpSource) eventResolver.getDataSource();

                // build the URL for an equipment event
                URL url = new URL(
                        "http://" + dataSource.getHost() + ":" + dataSource.getPort() + '/' +
OeeHttpServer.EVENT_EP);

                // create a connection for a JSON POST request
                conn = (HttpURLConnection) url.openConnection();
                conn.setDoOutput(true);
                conn.setRequestMethod("POST");
                conn.setRequestProperty("Content-Type", "application/json");

                // the value to send (must match the configured resolver)
                String value = tfLoopbackValue.getText();

                // timestamp when sent
                String timestamp = DomainUtils.offsetDateTimeToString(OffsetDateTime.now());

                // create the data transfer event object
                EquipmentEventRequestDto dto = new EquipmentEventRequestDto(eventResolver.getSourceId(),
value, timestamp);

                // serialize the body
                Gson gson = new Gson();
                String payload = gson.toJson(dto);

                // make the request
                OutputStream os = conn.getOutputStream();
                os.write(payload.getBytes());
                os.flush();

                if (logger.isInfoEnabled()) {
                        logger.info("Posted equipment event request to URL " + url + " with value " + value);
                }

                // check the response code
                int codeGroup = conn.getResponseCode() / 100;

                if (codeGroup != 2) {
                        String msg = "Post failed, error code : " + conn.getResponseCode() + "\nEquipment
event response ...";
                        BufferedReader br = new BufferedReader(new
InputStreamReader((conn.getInputStream())));
                        String output;

                        while ((output = br.readLine()) != null) {
                                msg += "\n" + output;
                        }
                        throw new Exception(msg);
                }
        } catch (Exception e) {
                AppUtils.showErrorDialog(e);
        } finally {
                conn.disconnect();
        }
}
```

Database Trigger Example

For another example, a database table insertion trigger can be used to asynchronously post equipment event messages to an HTTP collector. For example, SQL Server supports creating a stored procedure in C#. This procedure can then be executed in a trigger. The C# codes makes the HTTP request and receives the response. For simplicity, the values inserted into an EQUIPMENT_EVENT table row will be input to the stored procedure and then posted to the HTTP collector at the specified URL.

The EQUIPMENT_EVENT data table is created as:

```
CREATE TABLE [dbo].[EQUIPMENT_EVENT] (
    [Id]         INT                NOT NULL,
    [SOURCE_ID]  NVARCHAR (64)      NOT NULL,
    [VALUE]      NVARCHAR (32)      NOT NULL,
    [EVENT_TIME] DATETIMEOFFSET (3) NOT NULL
);
```

Suppose that a pass-through availability script resolver with source id = "e1.avail" and data value = "r1" has been created. "r1" is a reason with a loss category. When the following row is inserted into the EQUIPMENT_EVENT table, we want to call the stored procedure to make the HTTP request:

```
insert into EQUIPMENT_EVENT (Id, SOURCE_ID, VALUE, EVENT_TIME) values (1, 'e1.avail', 'r1', SYSDATETIMEOFFSET())
```

The insertion database trigger for the table is created as:

```
CREATE TRIGGER [ON_EVENT]
    ON [dbo].[EQUIPMENT_EVENT]
    FOR INSERT
    AS
    BEGIN
        SET NOCOUNT ON
        -- event endpoint
        declare @url nvarchar(128)
        set @url = 'http://machine_ip:8184/event'
        declare @response nvarchar(1024)
        declare @sourceId nvarchar(64)
        declare @value nvarchar(64)
        declare @timestamp datetimeoffset(3)
        declare @event_time nvarchar(64)
        select @sourceId = i.SOURCE_ID, @value = i.VALUE, @timestamp = i.EVENT_TIME from inserted i
        select @event_time = convert(nvarchar(64), @timestamp, 126)
        exec PostEquipmentEvent @url, @sourceId, @value, @event_time, @response output
    END
```

Here the HTTP data collector is running at "machine_ip" address on port 8184. The data to be sent to the collector is obtained from the "inserted" row and then passed into the PostEquipmentEvent stored procedure. The collector's JSON response is returned in the @response output parameter.

The PostEquipmentEvent stored procedure is written in C# as:

```
public partial class StoredProcedures

{

    [Microsoft.SqlServer.Server.SqlProcedure]

    public static void PostEquipmentEvent(string url, string sourceId, string value, string
timestamp, out string result)

    {

                // POST equipment event

                // json content

                string content = "{\"sourceId\":\"" + sourceId + "\",\"value\":\"" + value +
"\",\"timestamp\":\"" + timestamp + "\"}";

                // create Http request

                HttpWebRequest request = (HttpWebRequest)WebRequest.Create(url);

                byte[] data = Encoding.ASCII.GetBytes(content);

                request.Method = "POST";

                request.ContentType = "application/json";

                request.ContentLength = data.Length;

                // make the request

                Stream postStream = request.GetRequestStream();

                postStream.Write(data, 0, data.Length);

                // wait for the response

                HttpWebResponse response = (HttpWebResponse)request.GetResponse();

                result = new StreamReader(response.GetResponseStream()).ReadToEnd();

                response.Close();

                postStream.Close();

        }

}
```

iOS/Android Example

The HTTP URL can be called from an IOS or Android mobile application. In this case, the user interface is built using the native IDE (XCode and Swift for iOS, Android Studio and Java for Android). An HTTP client API is then called to make a request and receive a response.

For example, a Swift function for a POST request is:

```
    // send an HTTP POST request with body data

    private func sendPostRequest(_ url: String, body: String) -> NSError? {
```

```
        if let error = validateRequest() {
            return error
        }
        let nsUrl = URL(string : url)!
        var request = URLRequest(url: nsUrl)
        request.httpMethod = "POST"
        let bodyData : Data = body.data(using: String.Encoding.utf8)!
        request.httpBody = bodyData
        dataTask = dataSession.dataTask(with: request, completionHandler: {
            data, response, error in

            // flag that task is done
            self.dataTask = nil
            // call back handler
            self.handler!.handleResponse(nsUrl, data: data, error: error)
        })
        dataTask?.resume()
        return nil
    }
```

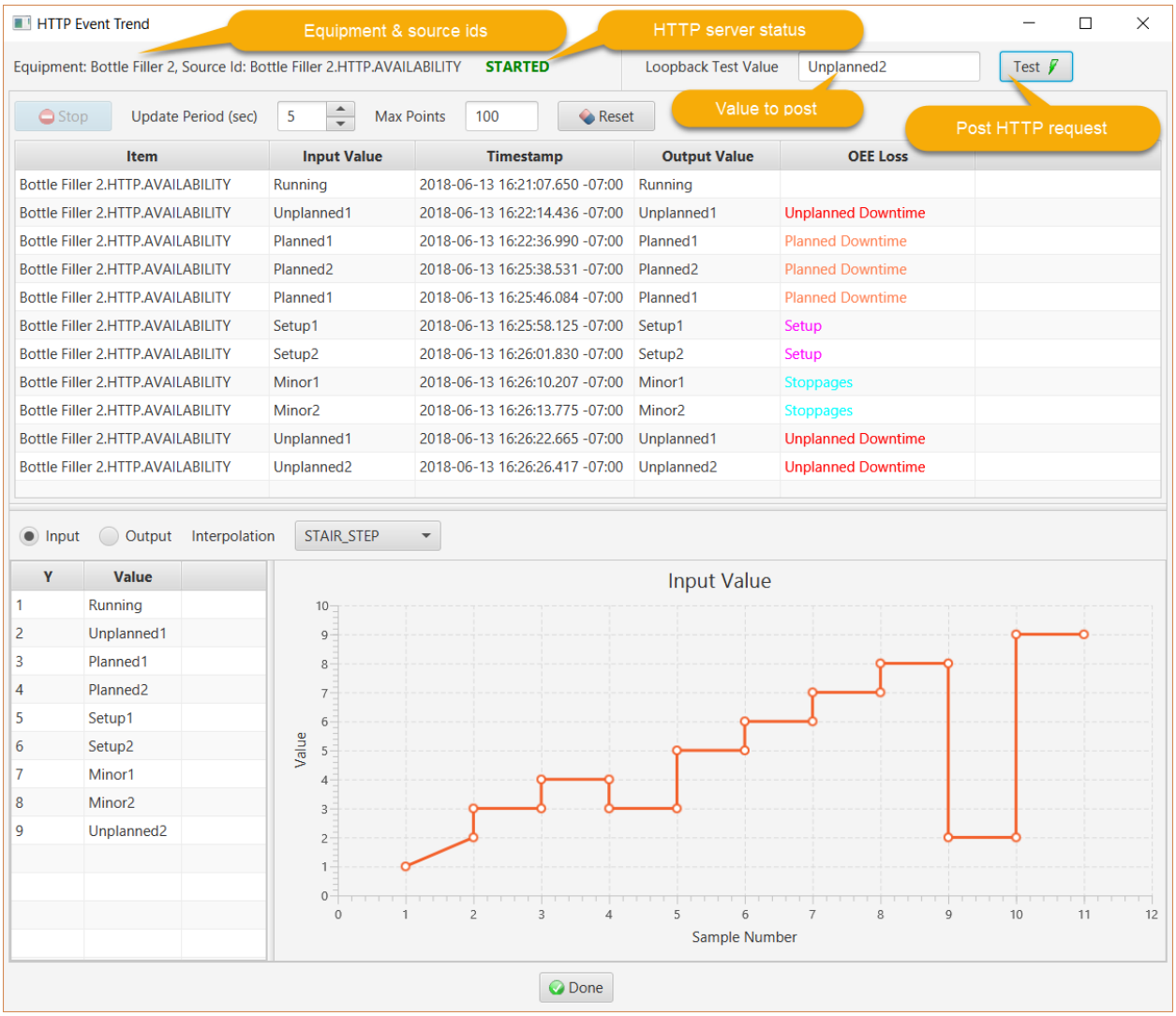
The caller of this function provides the URL with the endpoint (e.g. “event”) and the JSON serialized body.

Trending

By clicking the Watch button for an HTTP resolver, the execution of the script can be observed. An HTTP source for equipment availability with a pass-through resolver script of:

```
return value;
```

looks like:



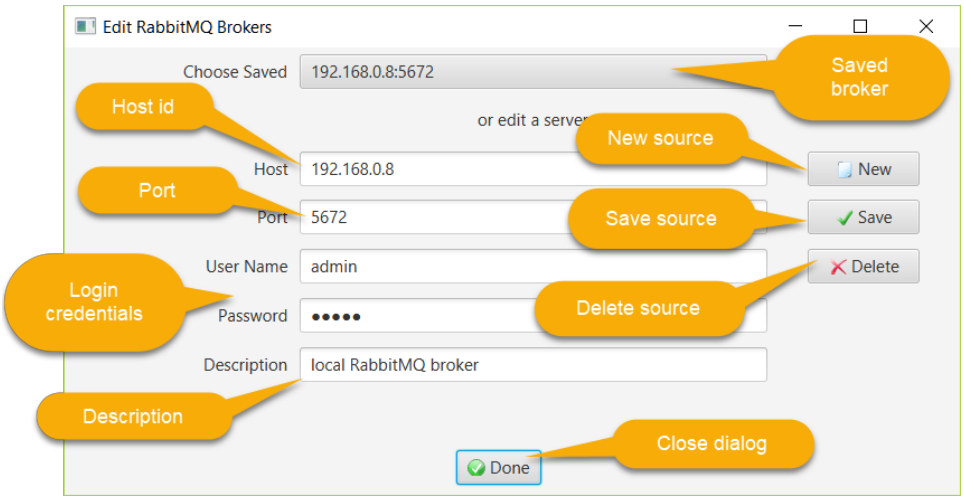
In this example, reasons have been entered into the loop-back test field and the Test button clicked to send a POST request to the HTTP server embedded in the controller for this dialog.

RMQ Messaging Data Source

Definition

The RMQ messaging data source definition dialog is launched from the toolbar or from the Data Collection tab for a RMQ messaging resolver after an equipment object has been selected in the physical model. It is used to define the RabbitMQ broker host, port and login credentials. By default the RMQ broker uses the AMQP protocol.

This dialog looks like:



For this example, the RabbitMQ broker is running on host 192.168.0.8 on the default port of 5672. The client will login as the "admin" user.

The actions for a messaging data source are:

- *New*: clear the editing controls to define a new data source
- *Save*: save the data source to the database
- *Delete*: delete the data source from the database
- *Test*: connect to the data source. A dialog will be presented indicating success or failure

Clicking the Done button will assign the broker as the script resolver's input source.

Message Content

The body of the RMQ message is a JSON-serialized EquipmentEventMessage with four fields:

- sourceId (required): the source identifier as defined in the data collection script resolver
- value (required): the data value
- messageType (required): must be "EQUIPMENT_EVENT"
- timestamp (optional): event time in ISO 8601 format

For example:

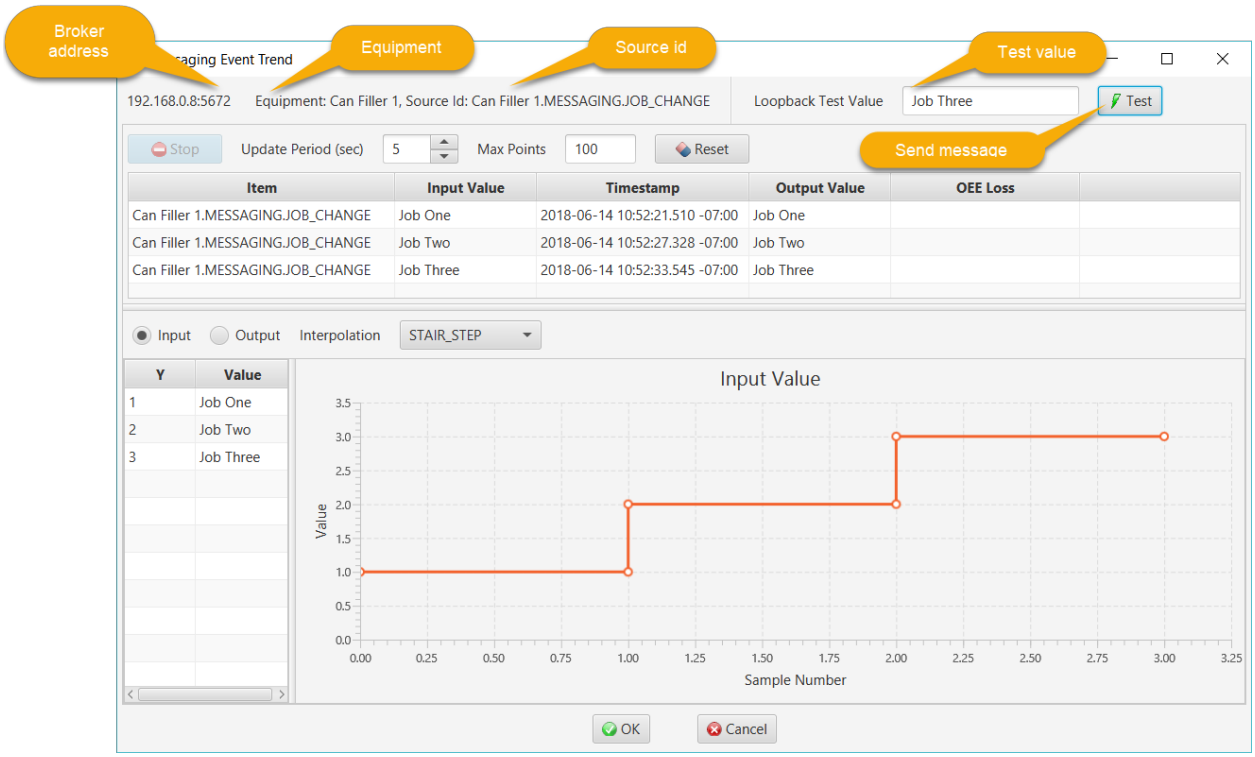
{"sourceId":"EQ1.MESSAGING.PROD_STARTUP","value":"1","messageType":"EQUIPMENT_EVENT","time-stamp":"2019-03-19T11:24:22.923-07:00"}

Trending

By clicking the Watch button for an messaging resolver, the execution of the script can be observed. A trend for a messaging source for a job change with a pass-through resolver script of:

```
return value;
```

looks like:



In this example, job identifiers have been entered into the loop-back test field and the Test button clicked to send a JSON serialized EquipmentEventMessage to the specified RabbitMQ broker. The messaging trend controller is listening for these messages from the Point85 exchange and routed to its queue.

The Java code is:

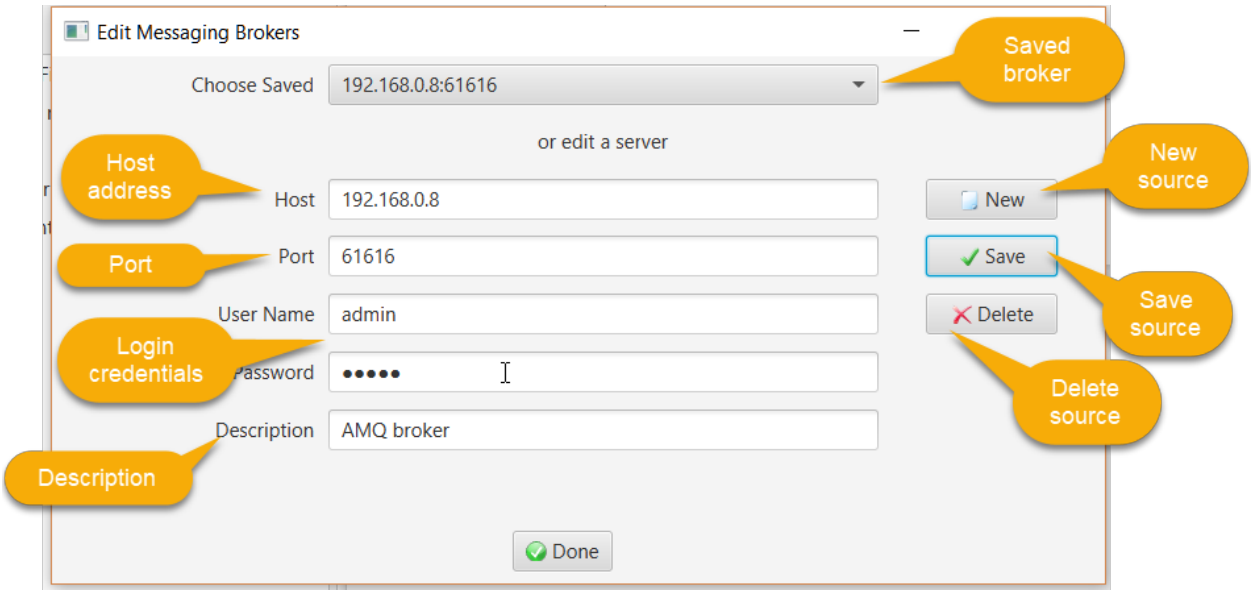
```
@FXML
private void onLoopbackTest() {
        try {
                if (pubSub == null) {
                        throw new Exception("The trend is not connected to an RMQ broker.");
                }
                EventResolver eventResolver = trendChartController.getEventResolver();
                String sourceId = eventResolver.getSourceId();
                String value = tfLoopbackValue.getText();
                EquipmentEventMessage msg = new EquipmentEventMessage();
                msg.setSourceId(sourceId);
                msg.setValue(value);
                pubSub.publish(msg, RoutingKey.EQUIPMENT_SOURCE_EVENT, 30);
        } catch (Exception e) {
                AppUtils.showErrorDialog(e);
```

```
            }
        }
```

JMS Data Source

Definition
The JMS data source definition dialog is launched from the toolbar or from the Data Collection tab for a JMS resolver after an equipment object has been selected in the physical model. It is used to define the JMS broker host, port and login credentials. By default the JMS client uses the AMQP protocol.

This dialog looks like:



For this example, the ActiveMQ broker is running on host 192.168.0.8 on the default port of 61616. The client will login as the “admin” user.

The actions for a JMS data source are:

- *New*: clear the editing controls to define a new data source
- *Save*: save the data source to the database
- *Delete*: delete the data source from the database
- *Test*: connect to the data source. A dialog will be presented indicating success or failure

Clicking the Done button will assign the JMS broker as the script resolver’s input source.

Message Content
The body of the JMS message is a JSON-serialized EquipmentEventMessage with four fields:

- sourceId (required): the source identifier as defined in the data collection script resolver

- value (required): the data value
- messageType (required): must be “EQUIPMENT_EVENT”
- timestamp (optional): event time in ISO 8601 format

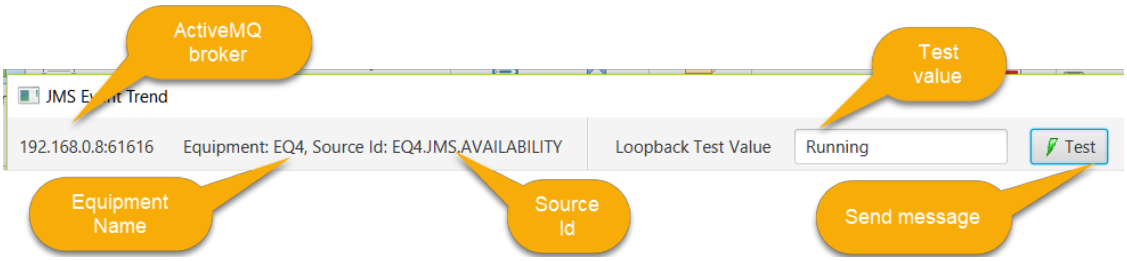
For example:

{"sourceId":"EQ1.JMS.PROD_GOOD","value":"1","messageType":"EQUIPMENT_EVENT","timestamp":"2019-03-19T11:13:45.977-07:00"}

Trending

By clicking the Watch button for an JMS resolver, the execution of the script can be observed.

A trend for a JMS source is similar to the RMQ messaging trend chart. In this case however, the top portion of the dialog looks like:

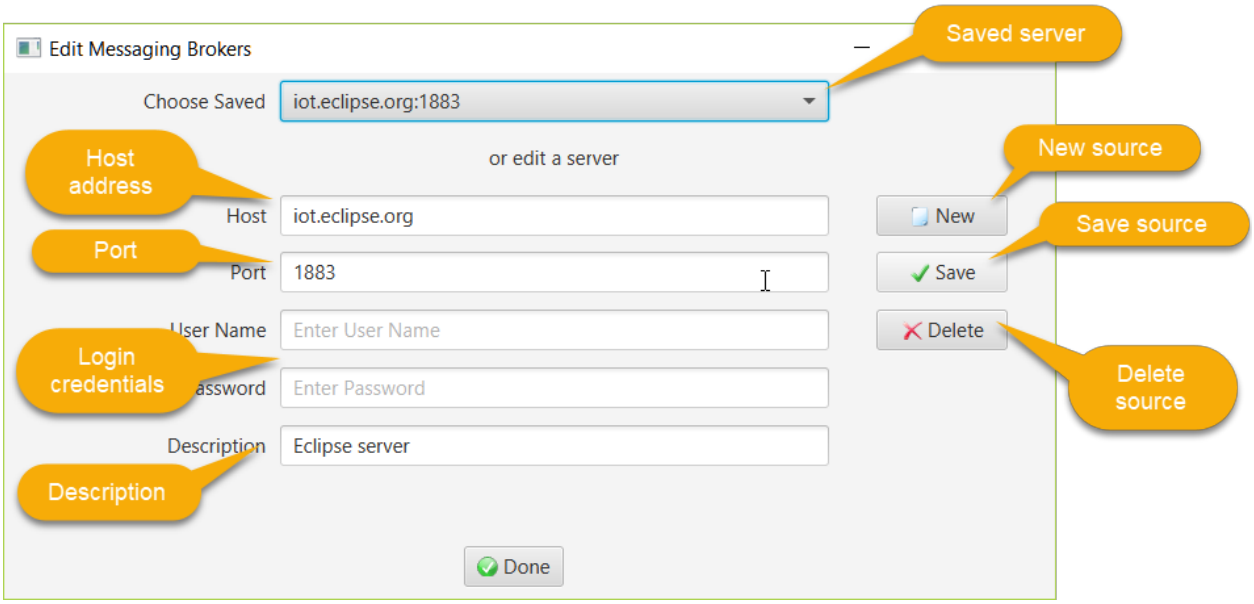


MQTT Data Source

Definition

The MQTT data source definition dialog is launched from the toolbar or from the Data Collection tab for an MQTT resolver after an equipment object has been selected in the physical model. It is used to define the MQTT server host, port and login credentials.

This dialog looks like:



For this example, the MQTT server is running on host iot.eclipse.org on the default port of 1883. The client is anonymous.

The actions for an MQTT data source are:

- *New*: clear the editing controls to define a new data source
- *Save*: save the data source to the database
- *Delete*: delete the data source from the database
- *Test*: connect to the data source. A dialog will be presented indicating success or failure

Clicking the Done button will assign the MQTT server as the script resolver's input source.

Message Content

The body of the MQTT message is a JSON-serialized EquipmentEventMessage with four fields:

- sourceId (required): the source identifier as defined in the data collection script resolver
- value (required): the data value
- messageType (required): must be "EQUIPMENT_EVENT"
- timestamp (optional): event time in ISO 8601 format

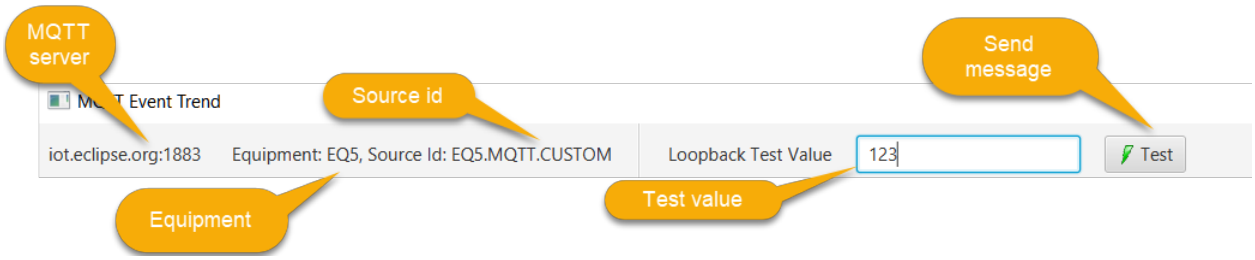
For example:

{"sourceId":"EQ1.MQTT.PROD_REJECT","value":"1","messageType":"EQUIPMENT_EVENT","timestamp":"2019-03-19T11:02:32.240-07:00"}

Trending

By clicking the Watch button for an MQTT equipment resolver, the execution of the script can be observed.

A trend for an MQTT source is similar to the RMQ and JMS messaging trend charta. In this case however, the top portion of the dialog looks like:

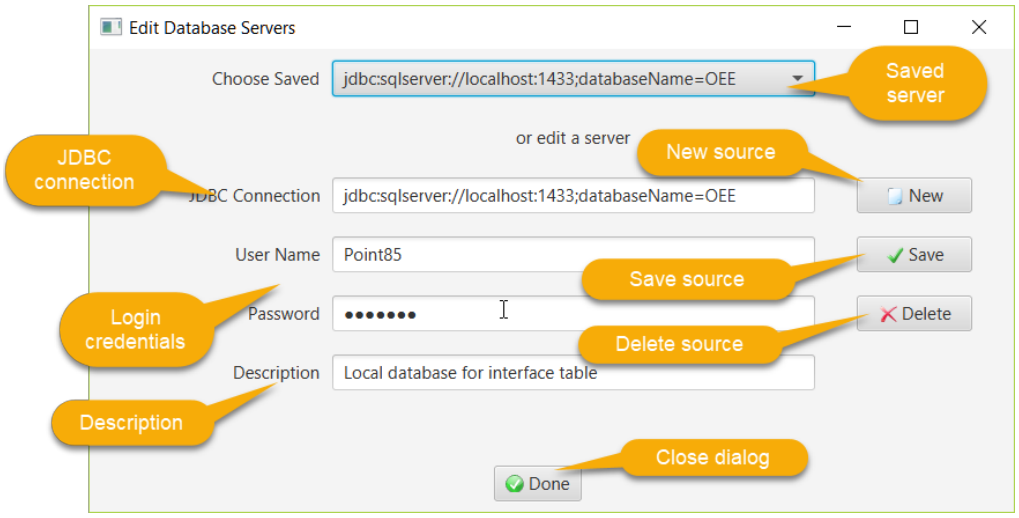


Database Table Data Source

Definition

The database interface table data source definition dialog is launched from the toolbar or from the Data Collection tab for a database table resolver after an equipment object has been selected in the physical model. It is used to define the database server JDBC connection string and login credentials.

This dialog looks like:



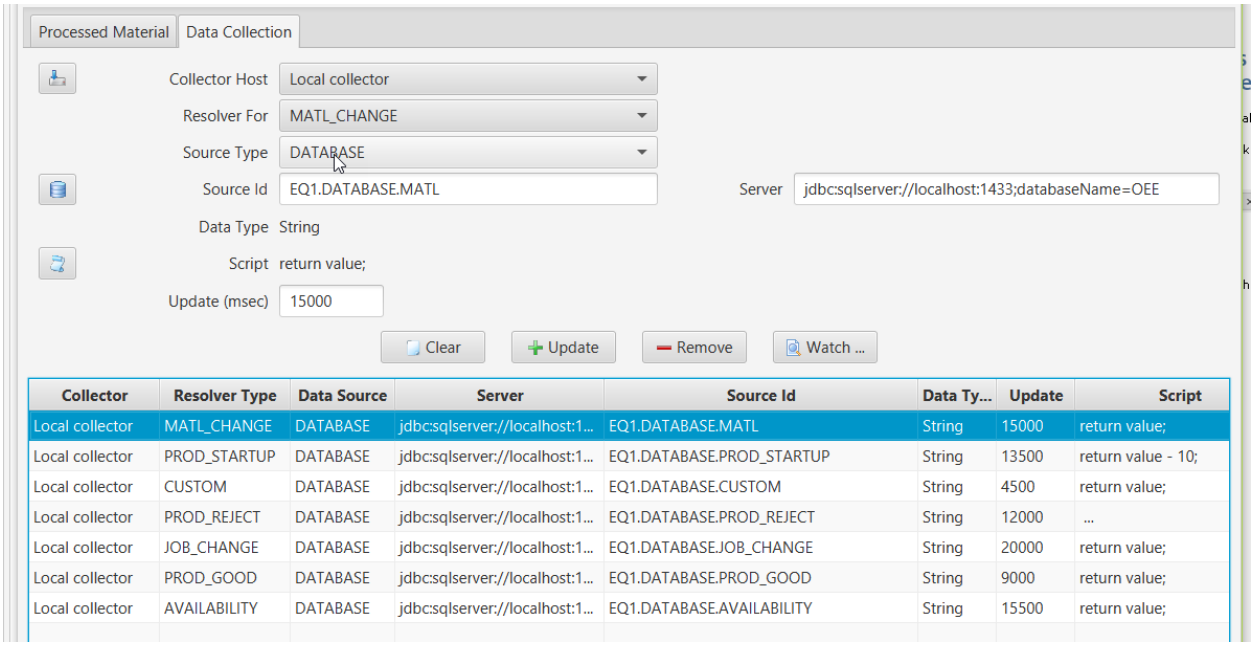
For this example, the SQL Server is running on localhost on the default port of 1433. The client will login as the "Point85" user to the OEE database where the DB_EVENT table has been created.

The actions for a database data source are:

- *New*: clear the editing controls to define a new data source
- *Save*: save the data source to the database
- *Delete*: delete the data source from the database
- *Test*: connect to the data source. A dialog will be presented indicating success or failure

Clicking the Done button will assign the DB_EVENT table as the script resolver's input source.

This table will be queried every N msec where N is the update period defined in the equipment resolver(s). For example, there are 7 resolvers defined for this equipment with a source type of "DATABASE":



Collector	Resolver Type	Data Source	Server	Source Id	Data Ty...	Update	Script
Local collector	MATL_CHANGE	DATABASE	jdbc:sqlserver://localhost:1...	EQ1.DATABASE.MATL	String	15000	return value;
Local collector	PROD_STARTUP	DATABASE	jdbc:sqlserver://localhost:1...	EQ1.DATABASE.PROD_STARTUP	String	13500	return value - 10;
Local collector	CUSTOM	DATABASE	jdbc:sqlserver://localhost:1...	EQ1.DATABASE.CUSTOM	String	4500	return value;
Local collector	PROD_REJECT	DATABASE	jdbc:sqlserver://localhost:1...	EQ1.DATABASE.PROD_REJECT	String	12000	...
Local collector	JOB_CHANGE	DATABASE	jdbc:sqlserver://localhost:1...	EQ1.DATABASE.JOB_CHANGE	String	20000	return value;
Local collector	PROD_GOOD	DATABASE	jdbc:sqlserver://localhost:1...	EQ1.DATABASE.PROD_GOOD	String	9000	return value;
Local collector	AVAILABILITY	DATABASE	jdbc:sqlserver://localhost:1...	EQ1.DATABASE.AVAILABILITY	String	15500	return value;

A material change event will be looked for every 15 seconds and a good production record every 9 seconds.

DB_EVENT Table Schema

The create_event_table.sql script in the \database\mssql folder will create this table for SQL Server. The create_event_table.sql script in the \database\oracle folder will create this table for Oracle. For MySQL the script is in the \database\mysql folder, for PostgresQL in the \database\postgresql folder and for HSQLDB in the \database\hsql folder.

For example, for SQL Server the schema is:

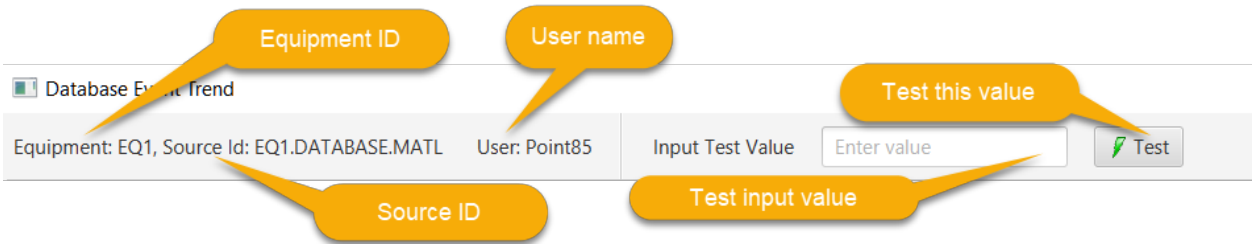
```
CREATE TABLE [dbo].[DB_EVENT](
        [EVENT_KEY] [bigint] IDENTITY(1,1) NOT NULL,
        [SOURCE_ID] [nvarchar](128) NOT NULL,
        [IN_VALUE] [nvarchar](64) NOT NULL,
        [EVENT_TIME] [datetime2](3) NULL,
        [EVENT_TIME_OFFSET] int NULL,
        [STATUS] [nvarchar](16) NOT NULL,
        [ERROR] [nvarchar](512) NULL
) ON [PRIMARY]
```

The column values are as follows:

- *EVENT_KEY*: identity for each record inserted into the table.
- *SOURCE_ID*: must match that defined in the associated equipment resolver (e.g. EQ1.DATABASE.MATL for a material change as above).
- *IN_VALUE*: a string value that can be converted to the data type required by the resolver. Availability, material, job and custom inputs are passed directly into the JavaScript resolver as a string. Good, reject and startup amounts are converted to double values.
- *EVENT_TIME*: the local date and time of day when the event occurred (e.g. 2018-11-28 21:30:07.670).
- EVENT_TIME_OFFSET: the time zone offset in seconds from UTC when the event occurred (e.g. -28800)
- STATUS: one of READY, PROCESSING, PASS or FAIL. The record must be inserted with a status of READY. The status is set to PROCESSING before the script is executed. If the JavaScript resolver successfully processes the record, the status will be updated to PASS. If there is an error during processing, the status will be updated to FAIL and the ERROR column will contain text explaining the error. The status can be set back from FAIL to READY in order to retry the event. It is the responsibility of the orginator to delete PASSed or FAILed records when they are no longer of any interest.
- ERROR: this column will contain text explaining the error if the record was not successfully processed.

Trending

By clicking the Watch button for an database table resolver, the execution of the script can be observed. A trend for a database source is similar to the other trend charts. In this case however, the top portion of the dialog looks like:



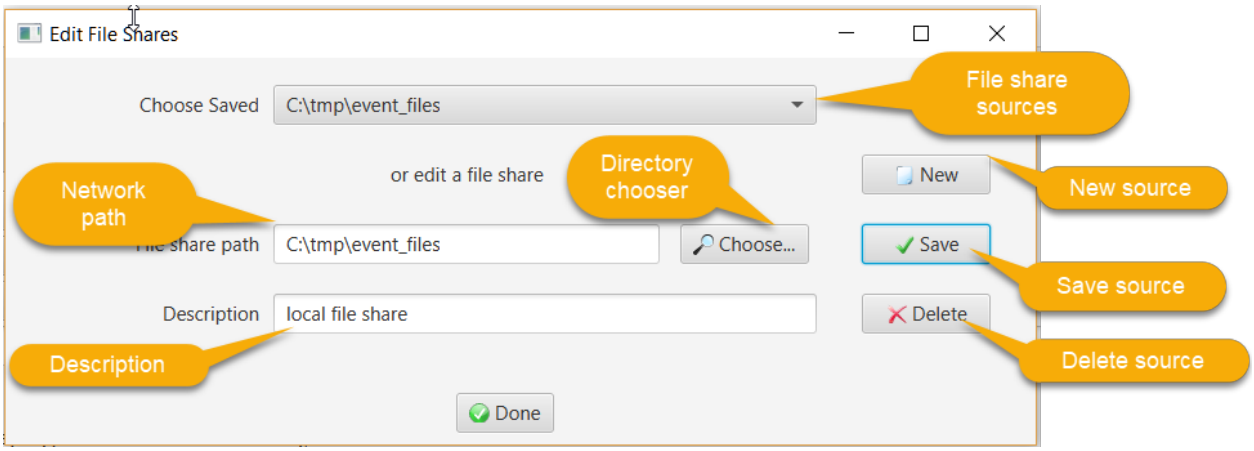
Entering a value, then clicking the Test button will write a record into the DB_EVENT table with the current system time. It will be read on the next polling cycle and processed. A successful execution of the script resolver will display the point in the trend chart. A failure will result in an error dialog being displayed and a status of FAIL in the table.

File Share Data Source

Definition

The file share data source definition dialog is launched from the toolbar or from the Data Collection tab for a file share resolver after an equipment object has been selected in the physical model. It is used to define the network path to the file share server where the event files are stored.

This dialog looks like:



For this example, the root folder is called “events” on the C: drive. Subfolders must be named the same as the source identifier in the equipment resolver. Under the source id folder are folders containing the event files and are named “ready”, “processing”, “pass” and “fail” as explained below. Read/write permissions must be granted to these folders for the Designer application or standalone collector.

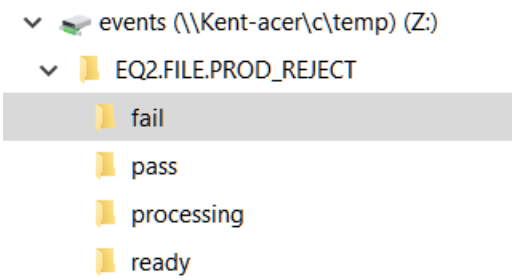
The actions for a file share source are:

- *New*: clear the editing controls to define a new data source
- *Save*: save the data source to the database
- *Delete*: delete the data source from the database

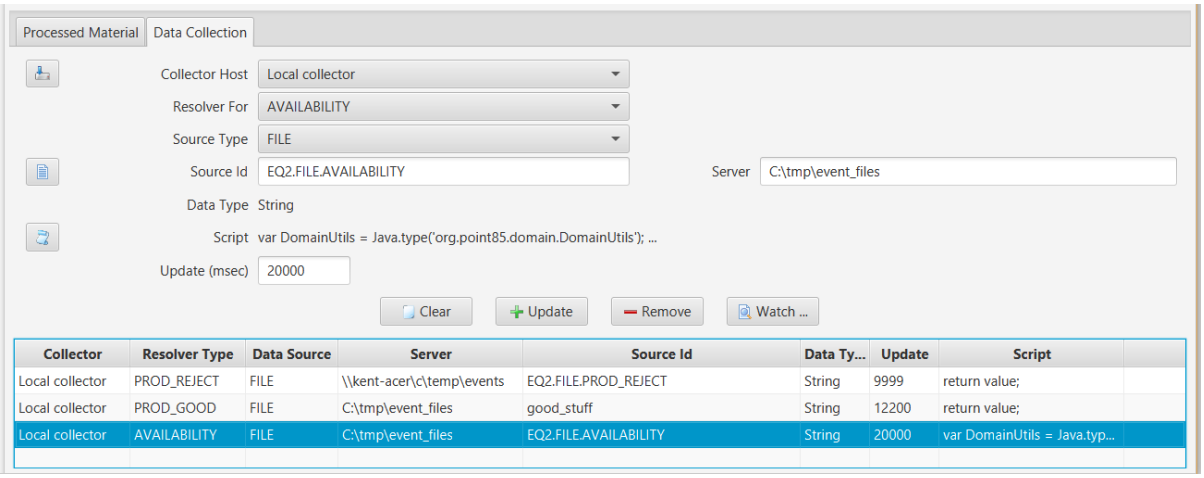
Clicking the Done button will assign the a file event source named the same as the share network path.

Directory Structure

The folder structure for the file share source defined above looks and equipment with a source id of “EQ2.FILE.PROD_REJECT” is:



The “ready” sub-folder will be queried every N msec where N is the update period defined in the equipment resolver(s). For example, there are three resolvers defined for this equipment with a source type of “FILE”:



On the remote server, reject production event files will be looked for every 9999 milli-seconds. On a local file share, good production files will be polled for every 12.2 seconds and availability files every 20 seconds.

When a new file is found in the “ready” folder, the file is read and its contents input as a string to the equipment resolver’s JavaScript function as the “value” variable. The script must parse this string and return a value consistent with the resolver’s type (e.g. for availability, this is the name of a reason and for good, reject or startup a production count).

The JavaScript can optionally set the event timestamp on the equipment resolver. For example, this script obtains the timestamp as an ISO 8601 string and then sets into the resolver:

```
resolver.setIsoTimestamp("2019-02-24T10:10:10.000-08:00");
```

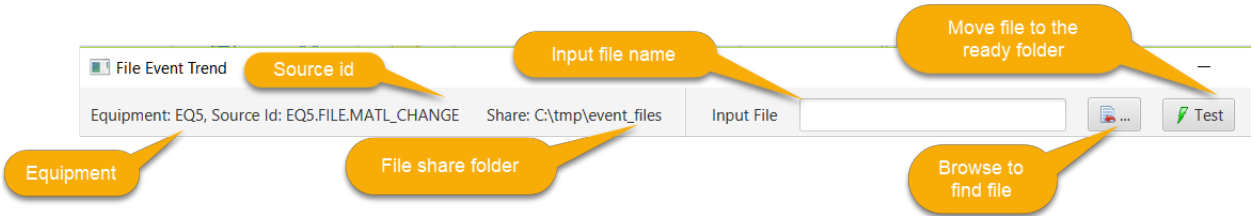
Files in the “ready” folder are processed oldest first according to the file’s last modified time. If the resolver’s timestamp is set, then the time set by the script will be used instead of the last modified time.

Before the equipment resolver’s JavaScript is invoked, the file is moved to the “processing” folder. If the script execution completes successfully, the file is moved to the “pass” folder. If script execution fails, the file is moved to the “fail” folder. In addition a text file with the same name as the event file, but with an ”.error” extension will contain information about the exception.

The application writing the event files is responsible for deleting files in the “pass” and “fail” folders when they are no longer of any interest.

Trending

By clicking the Watch button for an file resolver, the execution of the script can be observed. A trend for a file source is similar to the other trend charts. In this case however, the top portion of the dialog looks like:



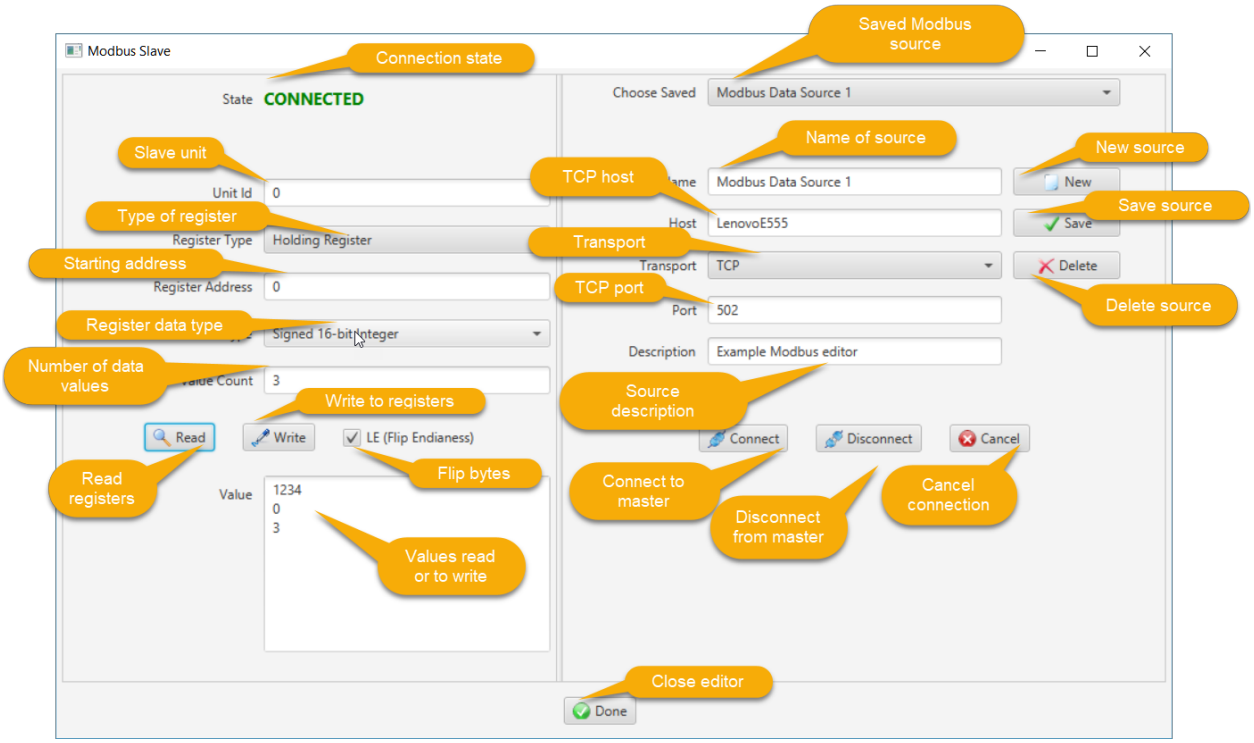
Browsing to the event file, then clicking the Test button will write it to the "ready" folder under a folder named the same as the source identifer (EQ5.FILE.MATL_CHANGE in this example). The file will be read on the next polling cycle and processed. A successful execution of the script resolver will display the point in the trend chart. A failure will result in an error dialog being displayed and files in the "fail" folder.

Modbus Slave Data Source

Definition

The Modbus data source definition dialog is launched from the toolbar or from the Data Collection tab for a file share resolver after an equipment object has been selected in the physical model. It is used to define a slave register's address and data type where the value is read from. The master polls the slave periodically at the defined frequency.

This dialog looks like:



For this example, a TCP connection is used to a Modbus master running on the "LenovoE555" host on port 502. The transport choices are:

- TCP: TCP connection

- UDP: datagram
- Serial: serial connection with 9600 baud, 8 data bits, 1 stop bit and no parity

The actions for a Modbus source are:

- *New*: clear the editing controls to define a new data source
- *Save*: save the data source to the database
- *Delete*: delete the data source from the database
- *Connect*: connect to the data source. The connection status is shown in the left-hand panel.
- *Disconnect*: disconnect from the data source
- *Cancel*: cancel an in-progress connection

Clicking the Done button will assign this data source to a resolver if launched from the data collection tab.

The Modbus connection can be tested by reading data from or writing data to a modbus slave serviced by this master. The information is:

- Unit Id: the identifier of the slave (0 -255, default is 0)
- Register Type: the type of register to read or write data:
    - Coil - R/W boolean value
    - Discrete - RO discrete value
    - Holding Register - R/W data register
    - Input Register - RO data register
- Register Address: starting register for read/write operations. If a data value exceeds one word (16 bits), sequential registers will be used
- Data Type: the type of data for read/write operations
    - Discrete (1 bit)
    - Low Byte (1 byte)
    - High Byte (1 byte)
    - Signed 16-bit integer (2 bytes)
    - Unsigned 16-bit integer (4 bytes)
    - Signed 32-bit integer (4 bytes)
    - Unsigned 32-bit integer (8 bytes)
    - Signed 64-bit integer (8 bytes)

- Single precision float (4 bytes)
- Double precision float (8 bytes)
- String (UTF8, 1 byte per character)

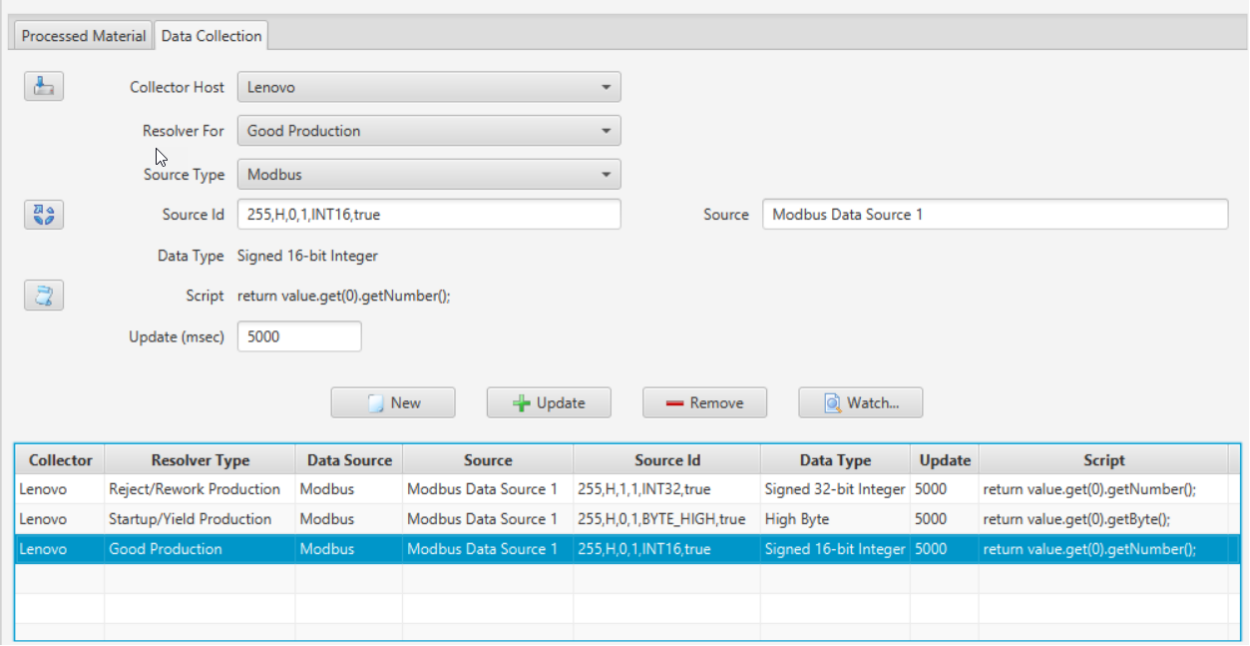
- Value Count: number of values to read. For a string, this is the character (byte) count.
- LE (Flip Endianness) : reverse the bytes in the data value for the case where the Modbus slave and collector machines have different byte orders, i.e. little endianess (LE) vs. big endianess (BE).

The actions are:

- Read: read the data values from the starting register and display them as decimals or a string in the "Value" text area
- Write: write the list of data values in the "Value" text area (one per line) to the starting register. Only one string is supported.

Event Resolver

The equipment event resolver is similar to the other data sources. Like OPC DA and OPC UA, the source id is a generated value and cannot be changed. The source id is a comma-separated list of slave endpoint information. For example, this screen shot shows three Modbus sources for production counts:



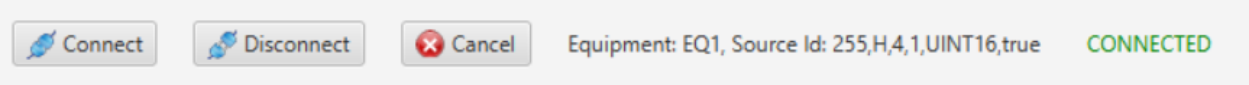
All three will be read every 5 seconds. The "value" argument in the resolution script is a list of ModbusVariants. See the "Scripting" section 9 for example scripts.

In the resolver script, note that a handshake should be implemented between the Modbus master and data collector to reset the data after a successful read for example by writing "true" to a coil (see the

"Scripting" section 9). Since production values are always positive, the variant value returned from a read operation should be checked for being a positive number, e.g. value.get(0).isPositiveNumber(). If the value is not valid, the script can return null. For availability reason code, material id and job id, the last value can be checked to see if the new polled value has changed by calling resolver.getLastValue(). If it has not changed, the script should return null.

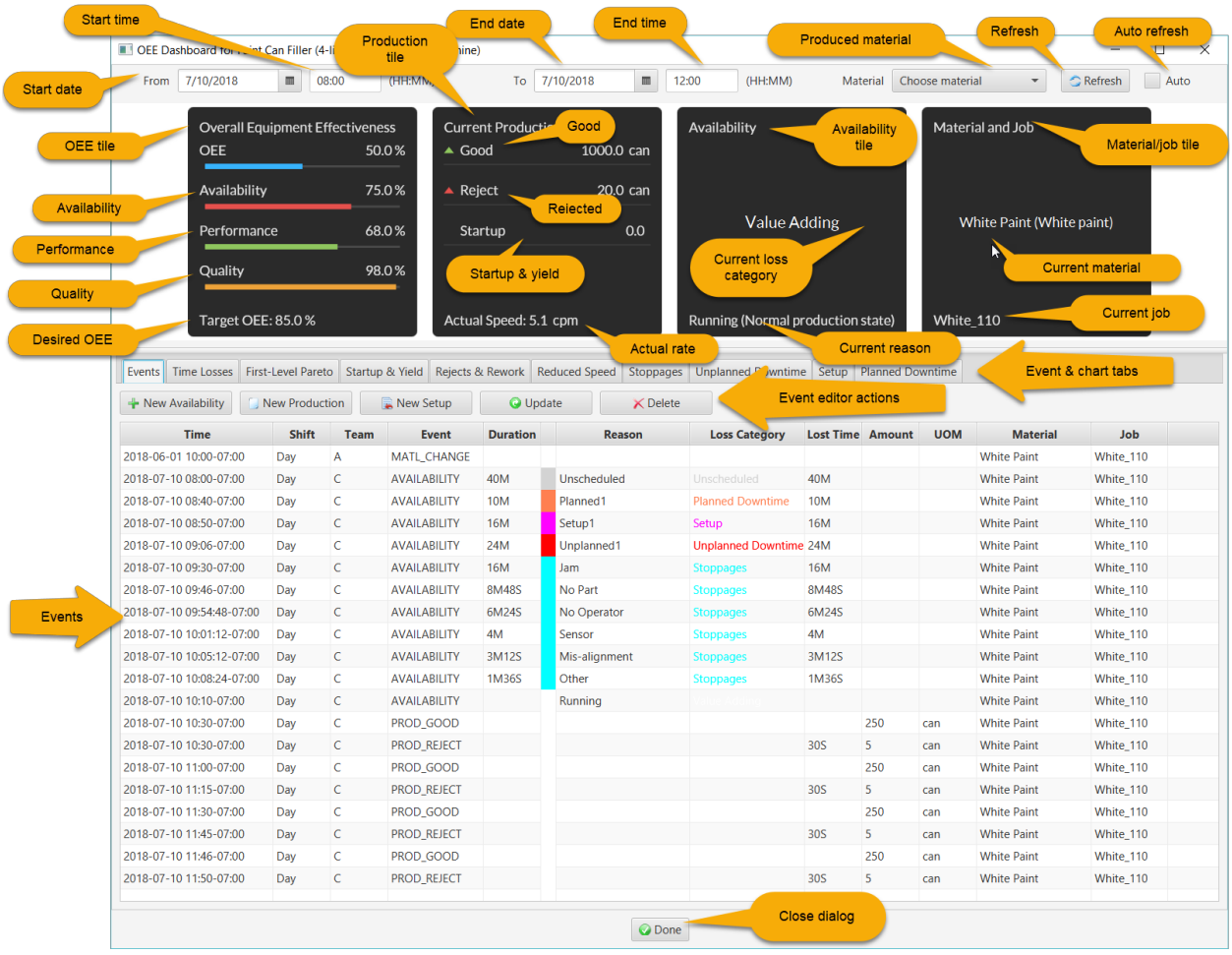
Trending

By clicking the Watch button for a Modbus resolver, the execution of the script can be observed. A trend for a Modbus slave source is similar to the other trend charts. In this case however, the top portion of the dialog looks like:



DASHBOARD

After equipment is selected, the dashboard can be displayed. This form consists of four tiles at the top that display OEE, availability, production counts, material and job. The bottom portion has tabs for event history, time losses by category and various Pareto charts:



This dashboard is for a paint can filling machine as discussed in *[Kennedy]*. A time range is first selected from a starting date and time of day to and ending date and time of day. In the above example, the time period is 4 hours during a single day. A specific material that has setups can be selected in the combobox, or all materials with setups during the specified time period. Clicking the refresh button will query the event records from the database and compute the OEE with its three components. In this case, the OEE is 50% where availability = 75%, performance = 68% and quality = 98%. The paint can fillter machine has a desired OEE of 85%. If the "Auto" checkbox is checked, the form will refresh with a period in seconds as entered in the text box to the right of the checkbox. The default is every 60 seconds.

The current production tile displays the cumulative good (1000 cans), reject (20 cans) and startup counts (0 cans) from the 8 event records.

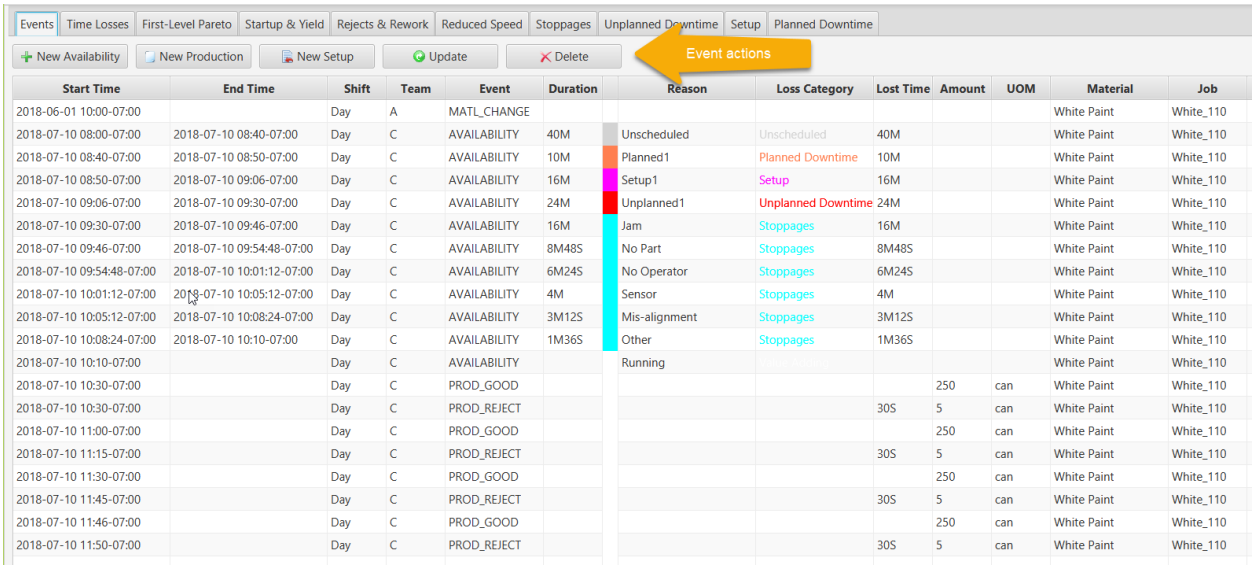
The availability tile displays the last availability event (a Value Adding loss category) with a reason of "Running" and description. Note that in this example, the availability events were entered in temporal sequence for a 4 hour period starting at 8 am and ending at 12 noon. It is also possible to enter these events in summary form (where the event duration includes multiple events for the same reason).

The material and job tile displays the current material being run (White Paint) and job name (White_110).

Below the tiles the following tabs have more detailed information.

Events

This tab displays the event history in a table:



Start Time	End Time	Shift	Team	Event	Duration	Reason	Loss Category	Lost Time	Amount	UOM	Material	Job
2018-06-01 10:00-07:00		Day	A	MATL_CHANGE							White Paint	White_110
2018-07-10 08:00-07:00	2018-07-10 08:40-07:00	Day	C	AVAILABILITY	40M	Unscheduled	Unscheduled	40M			White Paint	White_110
2018-07-10 08:40-07:00	2018-07-10 08:50-07:00	Day	C	AVAILABILITY	10M	Planned1	Planned Downtime	10M			White Paint	White_110
2018-07-10 08:50-07:00	2018-07-10 09:06-07:00	Day	C	AVAILABILITY	16M	Setup1	Setup	16M			White Paint	White_110
2018-07-10 09:06-07:00	2018-07-10 09:30-07:00	Day	C	AVAILABILITY	24M	Unplanned1	Unplanned Downtime	24M			White Paint	White_110
2018-07-10 09:30-07:00	2018-07-10 09:46-07:00	Day	C	AVAILABILITY	16M	Jam	Stoppages	16M			White Paint	White_110
2018-07-10 09:46-07:00	2018-07-10 09:54:48-07:00	Day	C	AVAILABILITY	8M48S	No Part	Stoppages	8M48S			White Paint	White_110
2018-07-10 09:54:48-07:00	2018-07-10 10:01:12-07:00	Day	C	AVAILABILITY	6M24S	No Operator	Stoppages	6M24S			White Paint	White_110
2018-07-10 10:01:12-07:00	2018-07-10 10:05:12-07:00	Day	C	AVAILABILITY	4M	Sensor	Stoppages	4M			White Paint	White_110
2018-07-10 10:05:12-07:00	2018-07-10 10:08:24-07:00	Day	C	AVAILABILITY	3M12S	Mis-alignment	Stoppages	3M12S			White Paint	White_110
2018-07-10 10:08:24-07:00	2018-07-10 10:10-07:00	Day	C	AVAILABILITY	1M36S	Other	Stoppages	1M36S			White Paint	White_110
2018-07-10 10:10-07:00		Day	C	AVAILABILITY		Running					White Paint	White_110
2018-07-10 10:30-07:00		Day	C	PROD_GOOD					250	can	White Paint	White_110
2018-07-10 10:30-07:00		Day	C	PROD_REJECT				30S	5	can	White Paint	White_110
2018-07-10 11:00-07:00		Day	C	PROD_GOOD					250	can	White Paint	White_110
2018-07-10 11:15-07:00		Day	C	PROD_REJECT				30S	5	can	White Paint	White_110
2018-07-10 11:30-07:00		Day	C	PROD_GOOD					250	can	White Paint	White_110
2018-07-10 11:45-07:00		Day	C	PROD_REJECT				30S	5	can	White Paint	White_110
2018-07-10 11:46-07:00		Day	C	PROD_GOOD					250	can	White Paint	White_110
2018-07-10 11:50-07:00		Day	C	PROD_REJECT				30S	5	can	White Paint	White_110

Note that a job change without a corresponding material change is not shown since it does not affect the OEE calculation. The starting and ending date and times of day are displayed. Current events do not have an ending time (e.g. the setup that changed to the current material and job).

If a work schedule is defined for this equipment, the shift and team working that shift will be shown. The duration of an event is the availability time period or the total time period for production events. Therefore, for availability events, the lost time is equal to the duration. But, for reject or startup production, the counts are converted into the equivalent time period as per the OEE time loss model.

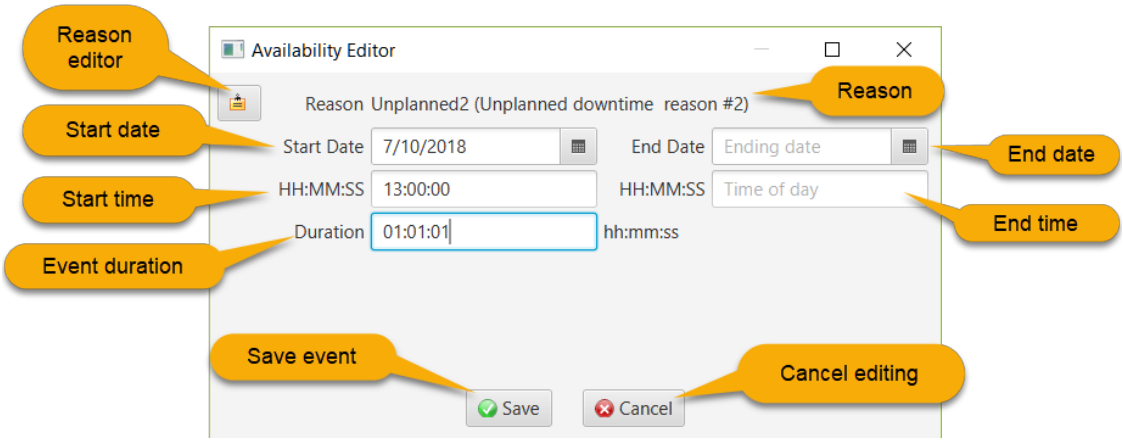
The availability reason is shown and its color-coded loss category. Production events have the amount and unit of measure. The last table columns show the material and job when the event ocurred.

The following actions are available:

- *New Availability*: create an availability record. The dialog discussed below will be displayed to enter the event information.
- *New Production*: create a production record. The dialog discussed below will be displayed to enter the event information.
- *New Setup*: create a set up record. The dialog discussed below will be displayed to enter the event information.
- *Update*: edit an existing availability, production or setup record. The dialog discussed below will be displayed to enter the event information.
- *Delete*: delete an existing set up record.
- *Trend*: display a line chart of production and availability events for this time period.

Availability Editor

To create an availability event or to edit an existing event, the following dialog is used:



If an existing event is being edited, the fields will be populated with current data.

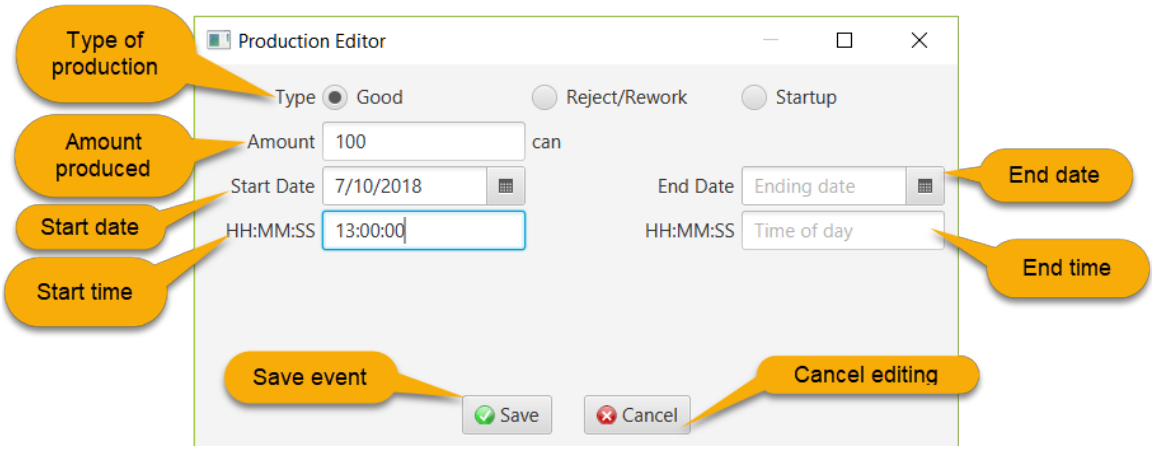
A reason must be chosen by clicking on the reason editor button and selecting an existing reason or creating a new reason. A starting date and time of day is required as is the duration of the event.

An ending time is not required if the events are being entered in chronological order as they happened. On the other hand, if the event is being summarized over a period of time, the ending date and time of day is required.

Clicking the Save button inserts a record into the database. Cancel will exit the editor without making any changes.

Production Editor

To create a production event or to edit an existing event, the following dialog is used:



If an existing event is being edited, the fields will be populated with current data.

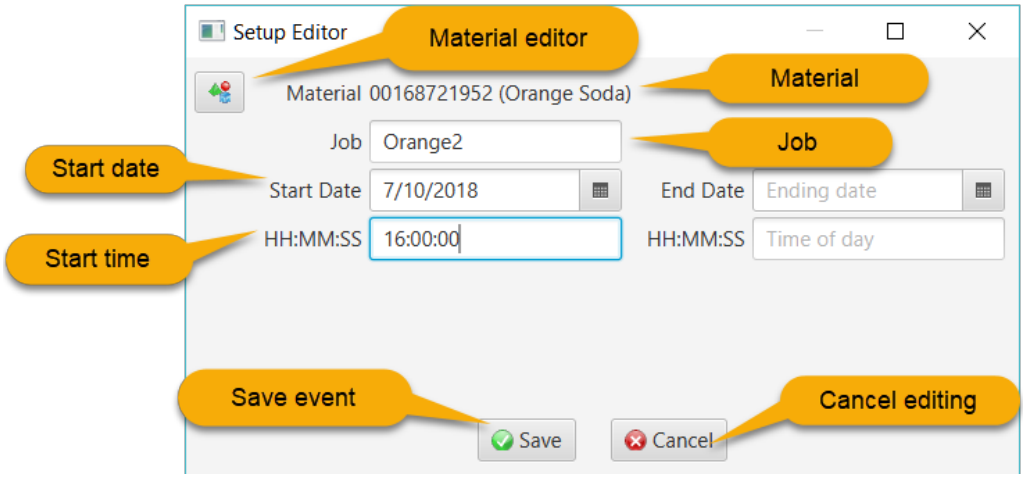
A type of production must be selected in the radio buttons and the amount produced. The unit of measure is obtained from the UOM configured for the equipment.

An ending time is not required if the events are being entered in chronological order as they happened. On the other hand, if the event is being summarized over a period of time, the ending date and time of day is required.

Clicking the Save button inserts a record into the database. Cancel will exit the editor without making any changes.

Setup Editor

To create a setup event or to edit an existing event, the following dialog is used:



If an existing event is being edited, the fields will be populated with current data.

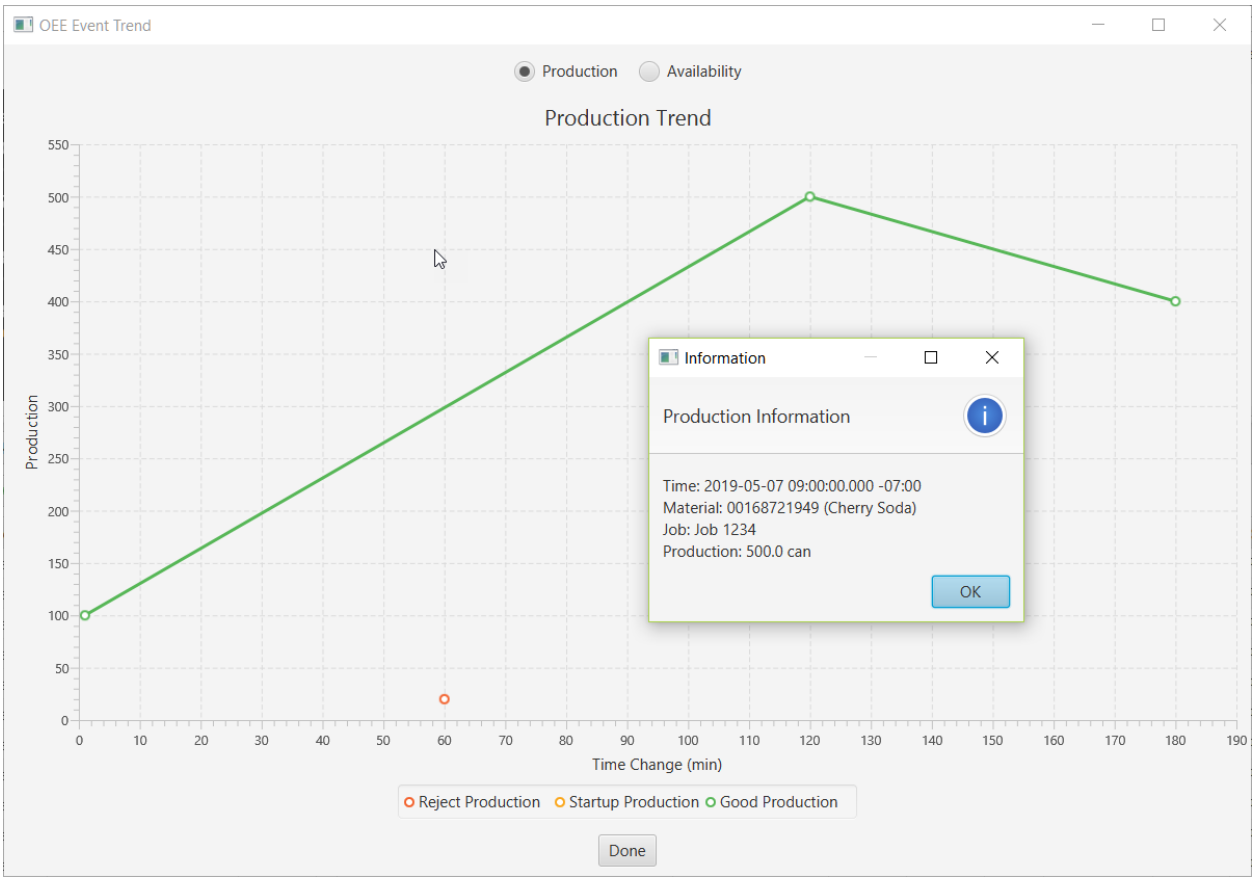
The material must be chosen by clicking on the material editor button and selecting an existing material or creating a new material. The name of a job/order is optional. A starting date and time of day is required.

An ending time is not required if the events are being entered in chronological order as they happened. On the other hand, if the event is being summarized over a period of time, the ending date and time of day is required. Note that there must be at least one open setup event since OEE data is dependent upon knowing what material is being produced.

Clicking the Save button inserts a record into the database. Cancel will exit the editor without making any changes.

Trend

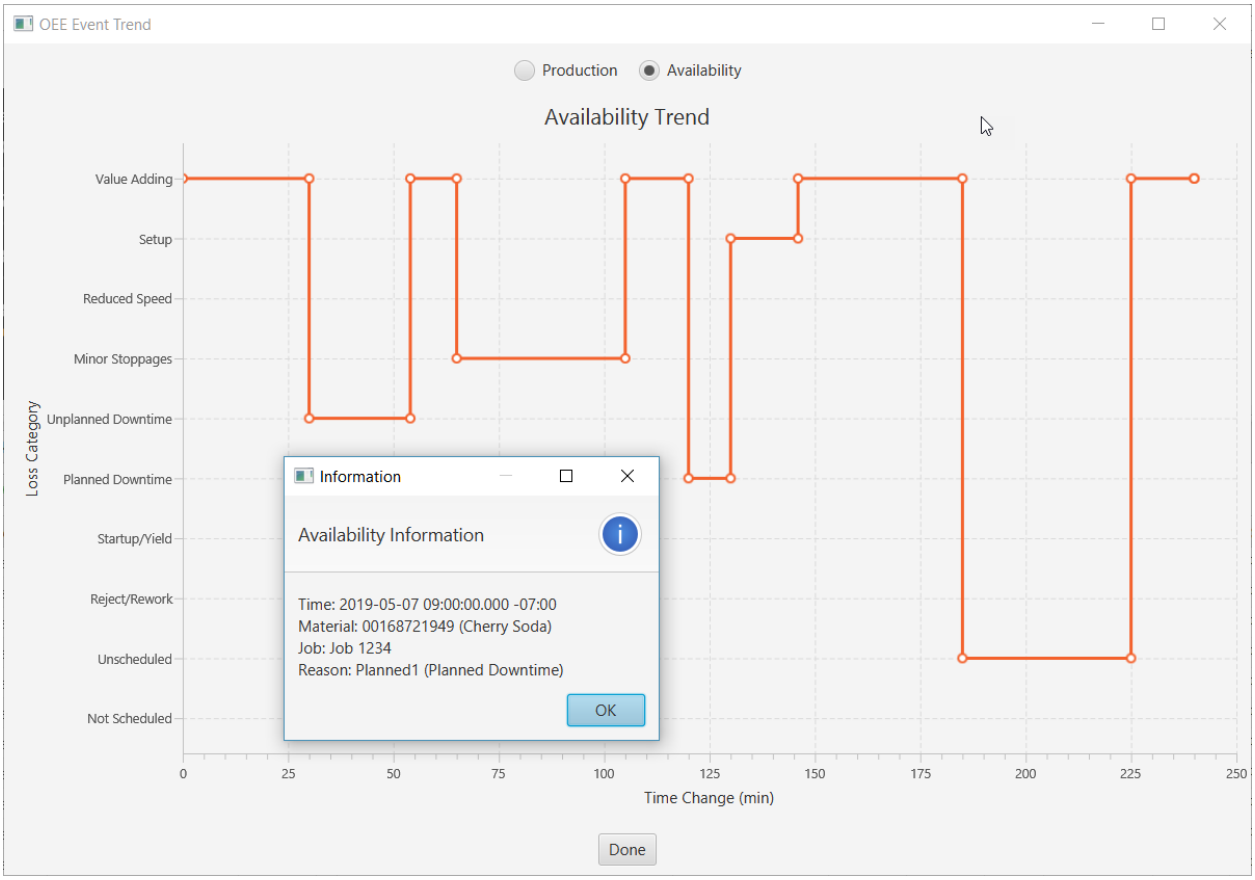
Clicking the Trend button displays a dialog with two radio buttons for showing a line chart of either (1) good, reject/rework and startup/yield production events, or (2) availability events. For example, a production chart looks like:



The x-axis is the time in minutes from the start of the time period of interest until the last production event (3 hours later in this example). The y-axis is the produced amount in the unit of measure defined as the numerator of the design speed for this equipment ("can" in this example). If the reject quantity's UOM differs from the design speed UOM, it will be converted.

Clicking on a point displays a dialog with more information about the event: exact time, material being produced, the job identifier and the quantity.

For example, an availability chart looks like:

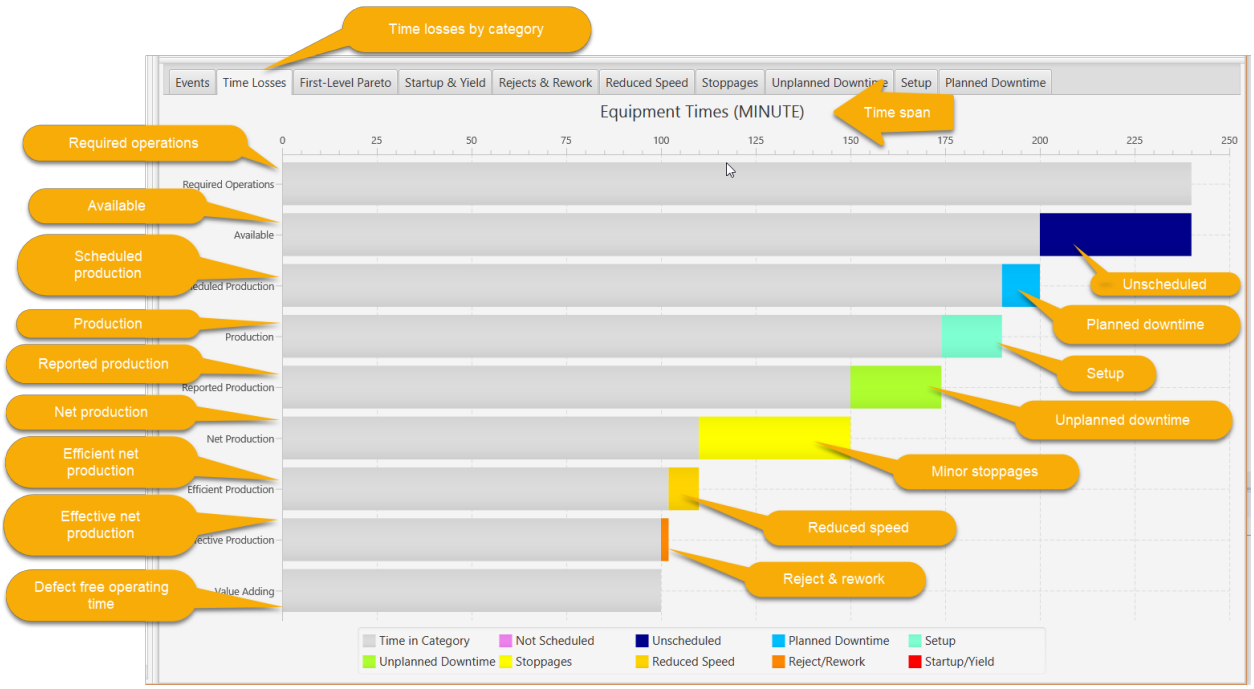


The x-axis is the time in minutes from the start of the time period of interest until the end of the period (4 hours in this example). The y-axis is the loss category, or “Value Adding” if there is no loss.

Clicking on a point displays a dialog with more information about the event: exact time, material being produced, the job identifier and the reason for the event.

Time Losses

The time losses tab displays a bar chart of of the losses encountered before arriving at the net defect free or value adding time (see [Kennedy]).



The bars represent:

- *Required Operations*: the time period of interest (4 hours or 240 minutes in this example) minus the Not Scheduled time (also 4 hours since there is no Not Scheduled time)
- *Available*: the required production time that subtracts the Unscheduled time (40 minutes)
- *Scheduled Production*: available time less Planned Downtime (10 minutes)
- *Production*: scheduled production time less the Setup time (16 minutes)
- *Reported Production*: production time less the Unplanned Downtime time (24 minutes)
- *Net Production*: reported production time less the Minor Stoppages time (40 minutes)
- *Efficient Net Production*: net production time less the Reduced Speed time (8 minutes)
- *Effective Net Production*: effecient net production time less the Reject/Rework time (2 minutes)
- *Value Adding, Defect Free or Ideal Speed*: effective net production time less the Startup & Yield time (0 minutes)

Hovering the mouse over a bar chart segment displays the time in the category.

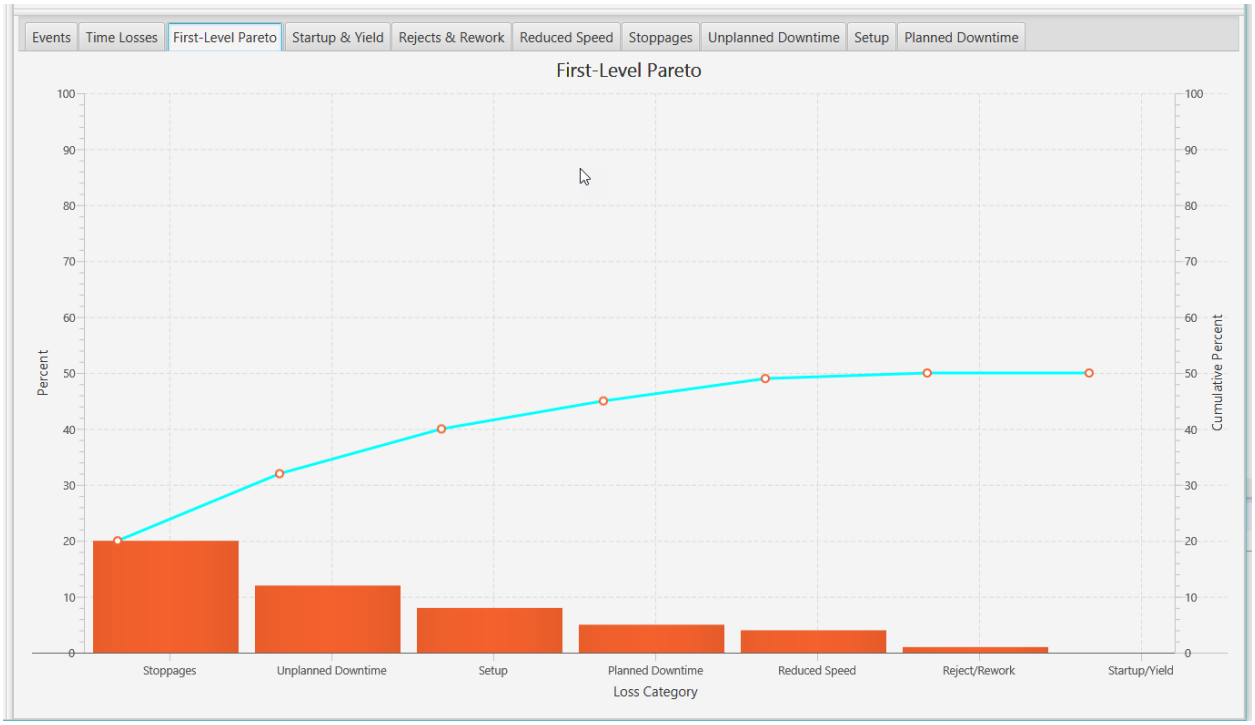
First-Level Pareto Chart

The first-level pareto chart displays the percentage of Available Time consumed by each of the 7 OEE losses:

1. Planned Downtime (10 minutes)
2. Setup (16 minutes)

3. Unplanned Downtime (24 minutes)
4. Minor Stoppages (40 minutes)
5. Reduced Speed (8 minutes)
6. Rejects and Rework (2 minutes)
7. Startup and Yield (0 minutes)

The total time lost in these 7 categories is thus 100 minutes.

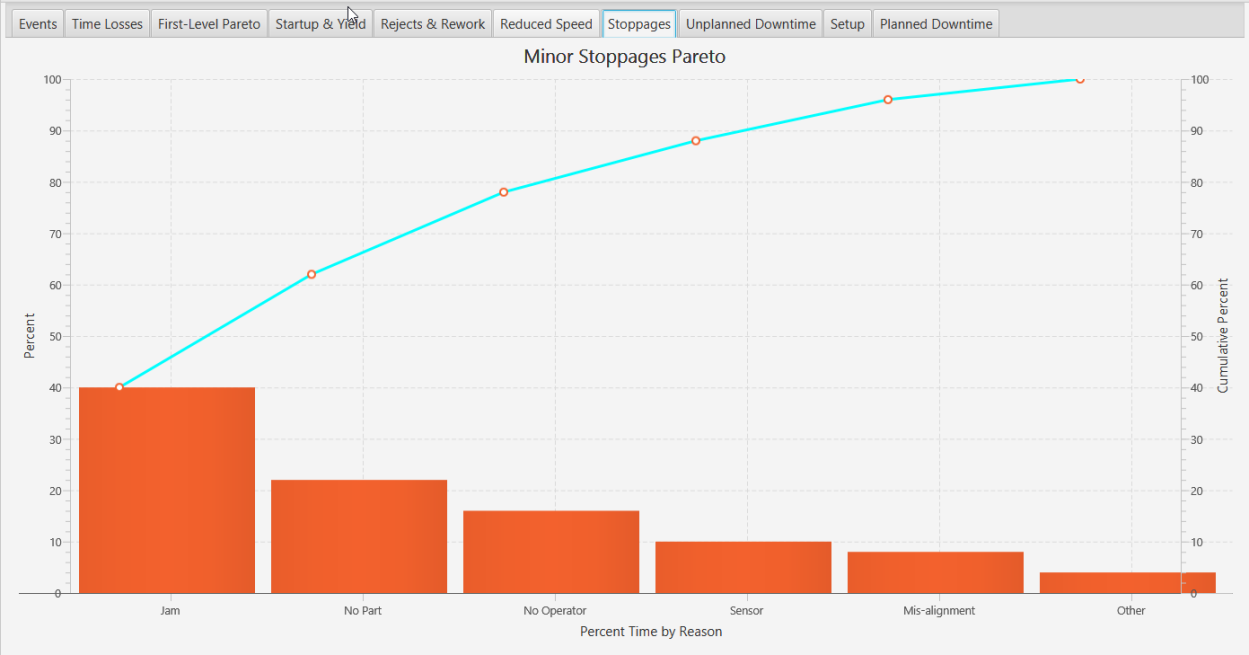


The y-axis shows the 7 loss categories. For the example above, minor stoppages consumed 20% (40 minutes/ 200 minutes), whereas startup & yield has no losses.

This Pareto chart also shows the cumulative percentage increasing from 20% (40/200) to 50% (100/200).

Second-Level Pareto Charts

A Pareto chart for each of the 7 loss categories is available by clicking on the color-coded bar chart segment in the time loss chart, or by selecting the tab of interest. For example, the minor stoppages Pareto looks like this:



The y-axis shows the top 10 reasons for each minor stoppage (6 in this example). For example, 40% of the minor stoppage losses were due to jams and 4% due to other reasons.

This Pareto chart also shows the cumulative percentage increasing from 40% (16 minutes/40 minutes) to 100% (since there were only 6 reasons for all of the minor stoppages losses).

COLLECTOR APPLICATION

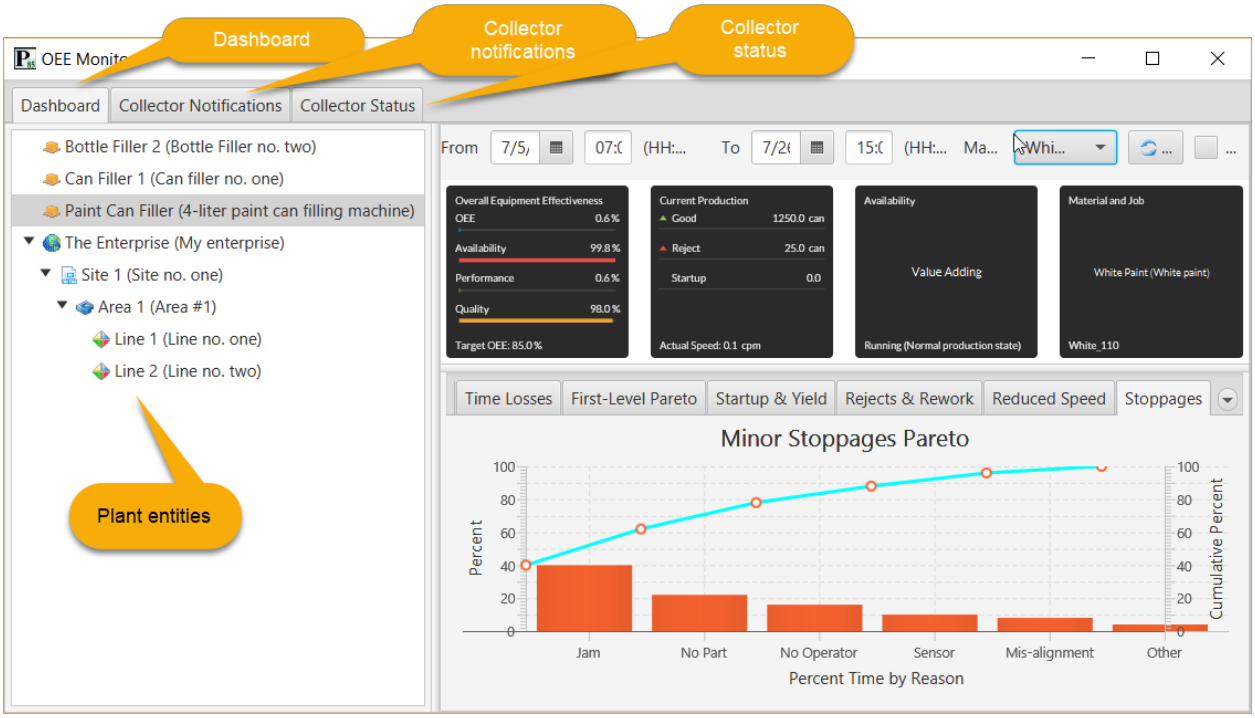
The collector application runs as a Windows service or Unix daemon on the configured host computer. A collector application executes equipment event resolver scripts upon receipt of an input value and stores the availability, production, material or job change event data in the database. This data is used for OEE calculations.

The Tanuki Java Service wrapper provides the infrastructure for the Windows service or Unix daemon. The JVM is 64-bits for all supported O/S's.

MONITOR APPLICATION

The monitor application has three main functions, to observe:

- Equipment performance via metrics available in the dashboard.
- Notifications from the data collectors for abnormal conditions
- Data collector status.



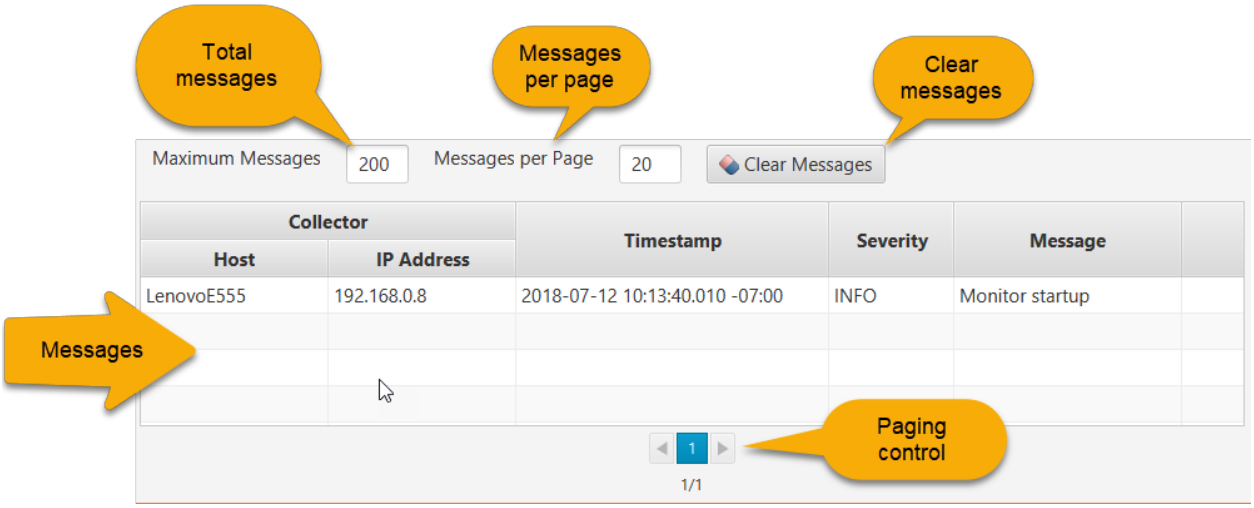
DASHBOARD

The dashboard is displayed by selecting the Dashboard tab. The plant entity hierarchy is displayed in the tree view on the left. After selecting a piece of equipment, the dashboard is shown on the right. For details on the dashboard, see the Designer dashboard section above.

The dashboard will update asynchronously as equipment event messages are received from the RabbitMQ broker (if so configured). Otherwise, the auto-refresh feature can be enabled to periodically query the database.

COLLECTOR NOTIFICATIONS

Data collector notifications are displayed by selecting the Collector Notifications tab:



If the collector is configured for messaging, when a notification event occurs, a message is sent to the RabbitMQ broker and delivered to all notification subscribers. In the example above, the Monitor sends an informational startup message to itself.

The total number of messages to retain can be specified (e.g. 200). If more than this number of messages is received, the oldest messages will be discarded. The number of messages to display in the table can be specified (e.g. 20). If the number of messages exceeds this page count, the paging control can be used to move forward or backward through them.

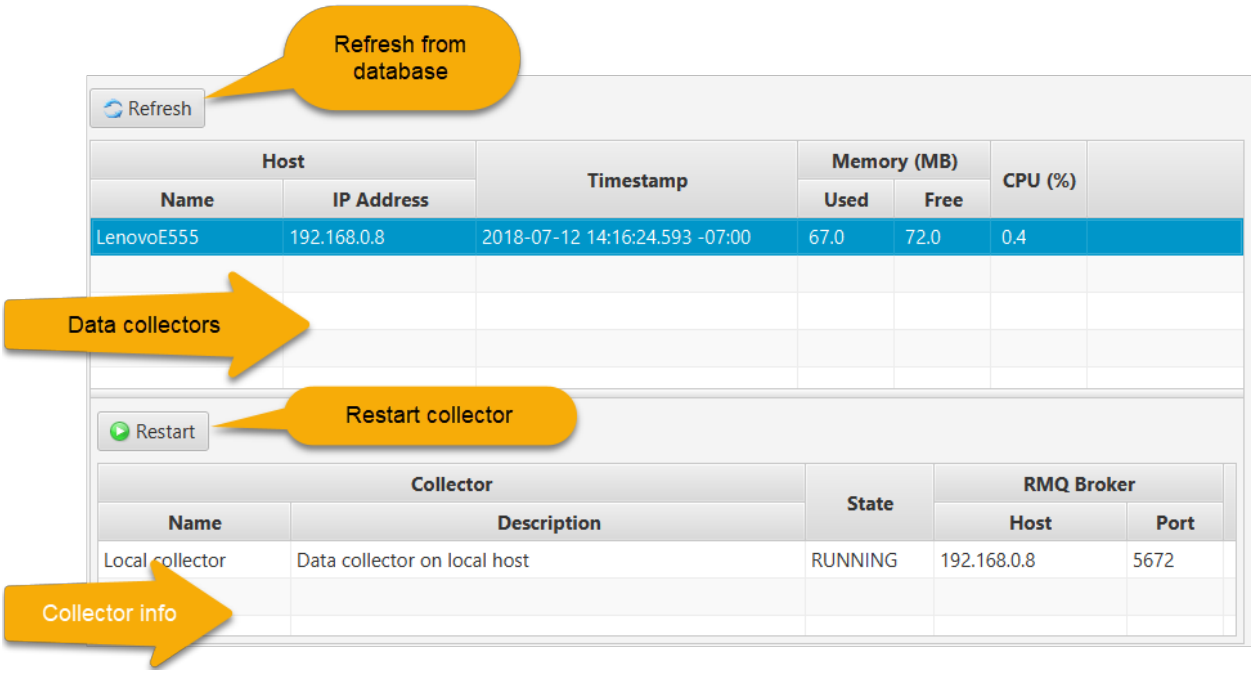
All messages can be removed by clicking on the Clear Messages button.

Information shown for each message is:

- *Host*: the name of the computer on which the collector is running
- *IP Address*: IP address of collector
- *Timestamp*: date and time of day with time zone offset when the message was sent
- *Severity*: severity of message (ERROR, WARNING, INFO)
- *Message*: the text of the message

COLLECTOR STATUS

Data collector status is displayed by selecting the Collector Status tab:



The top table shows the following information about each of the data collectors:

- *Name*: collector host computer name
- *IP Address*: collector host computer IP address
- *Timestamp*: date and tinme of day with zone offset when the status message was sent
- *Used Memory*: heap memory allocated by the collector's JVM
- *Free Memory*: free JVM heap memory
- *CPU*: current CPU load

After selecting a host computer, the following information is shown:

- *Name*: collector name
- *Description*: collector description
- State: collector state - one of DEV, READY or RUNNING
- *RMQ Broker Host*: the host computer for the collector's RabbitMQ broker
- *RMQ Broker Port*: the TCP/IP port of the collector's RabbitMQ broker

Operator Application

The desktop operator application allows a user to manually enter availability, performance, production, material change and job events. The events can be recorded in chronological order as they happened

("By Event") or in summary form ("By Time Period") over a period of time by duration of event. Value adding (running) time is assumed in summary form for availability.

For example, during a time period from 07:00 to 11:00, the chronological events might be:

1. 07:30 - Unplanned downtime with reason #1
2. 08:00 - Running again
3. 09:00 - Good production of 100 units
4. 09:15 - Reject production of 10 units
5. 09:45 - Planned downtime for preventive maintenance with reason #2
6. 10:00 - Running again
7. 10:30 - Good production of 50 units

These 7 events would be entered in chronological order.

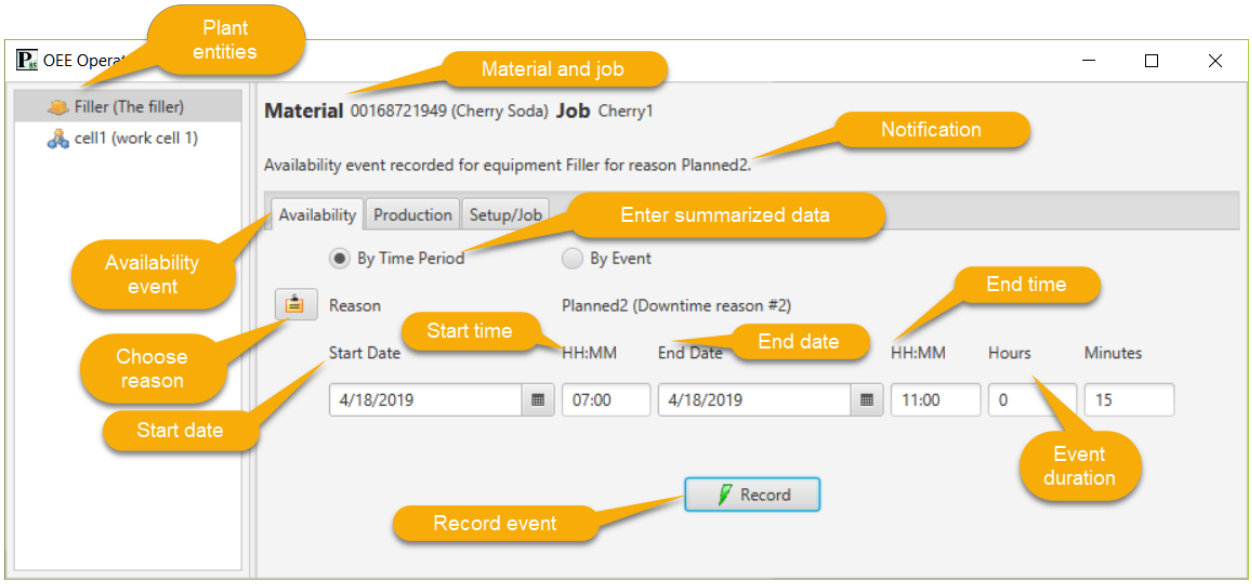
Rather than enter individual events in chronological order, the data for the 07:00 to 11:00 time period could be entered in summarized form as:

1. Good production of 1000 units
2. Reject production of 20 units with a reason
3. Planned downtime of 10 minutes with a reason
4. Unplanned downtime of 24 minutes with a reason
5. Unscheduled downtime of 40 minutes with a reason
6. Setup time of 16 minutes with a reason
7. Minor stoppages of 40 minutes with a reason

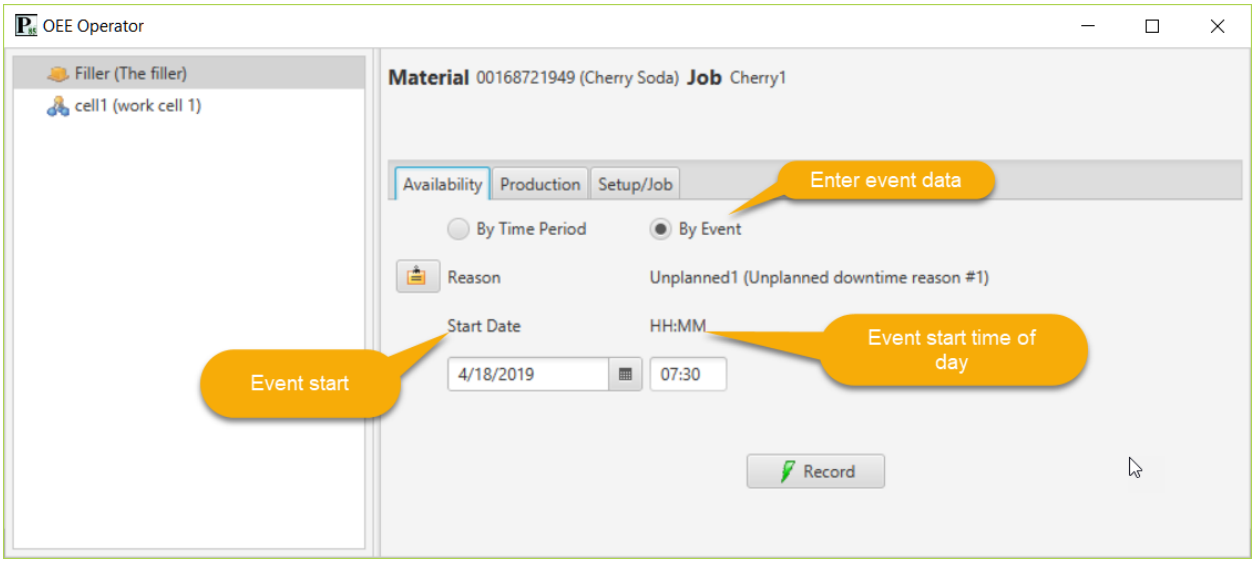
If the equipment producing this material has an ideal speed of 10 units/minute, the OEE for this 4 hour period wil be 50% with an availability of 75%, performance of 68% and quality of 98%.

User Interface

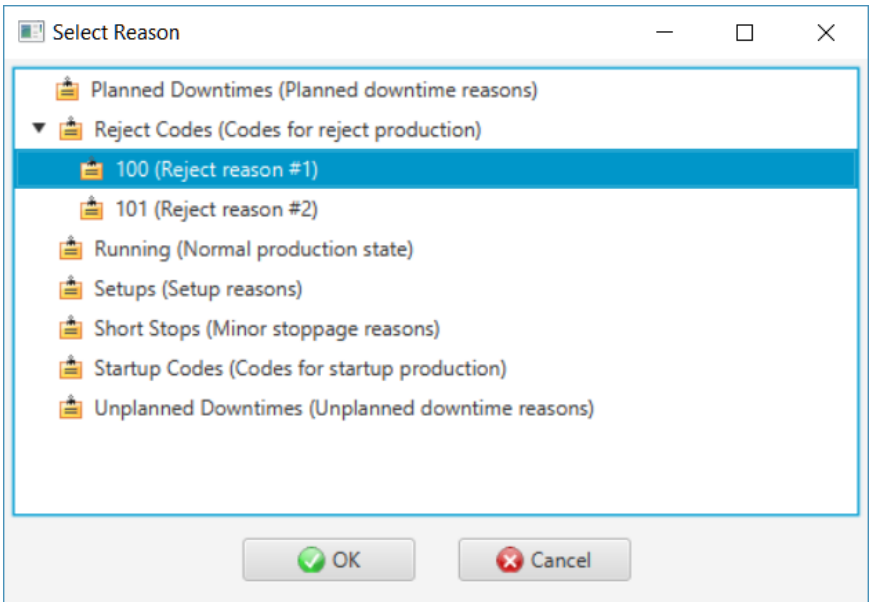
The user interface for availability/performance tab for a summarized event looks like:



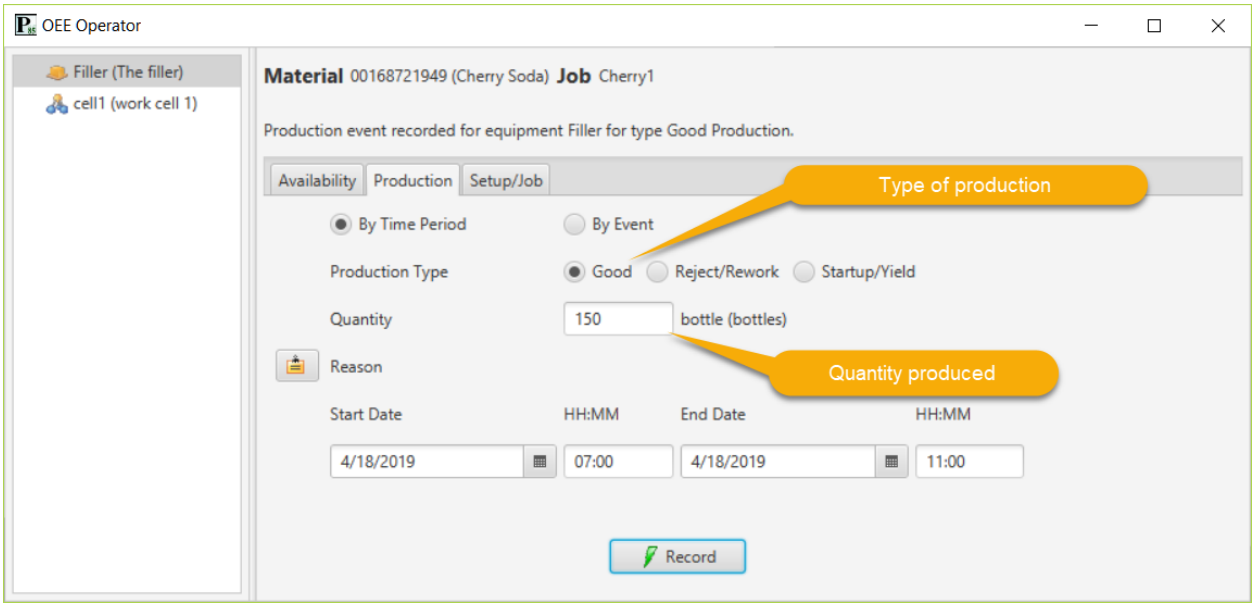
Note that if “By Event” is selected, the UI will change to allow entry of only the date and time of day when the availability event occurred:



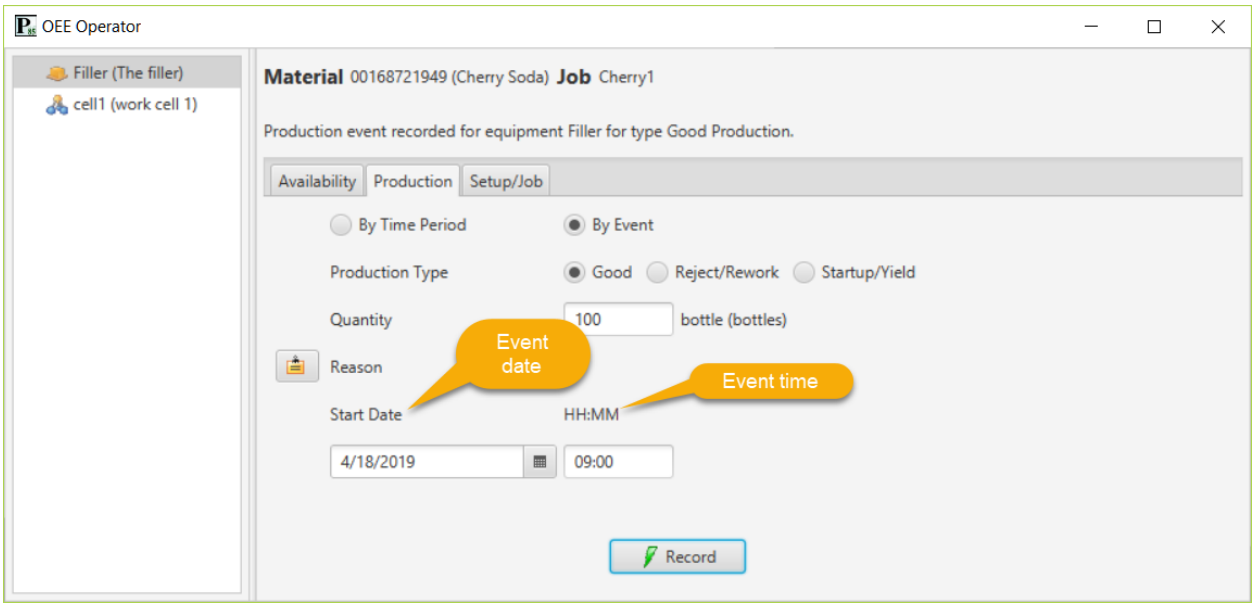
An availability reason can be choose by clicking the “Reason” button and selecting from the reason hierarchy:



The production tab for a summarized production event is shown below. For reject and rework as well as startup and yield events, a reason can be entered as well:

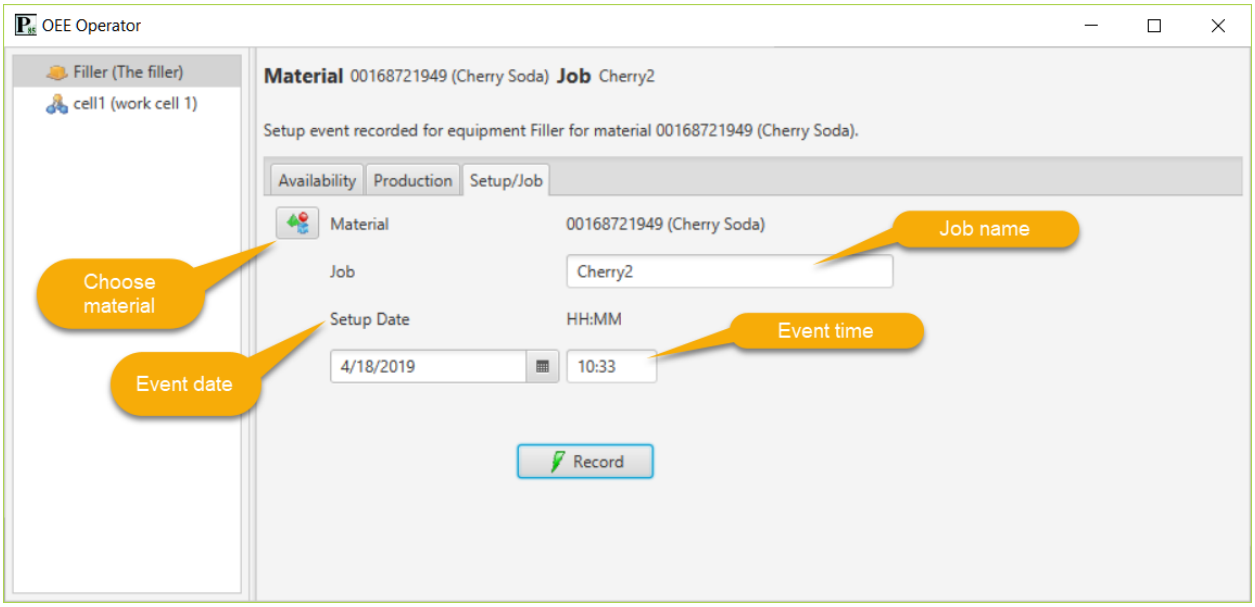


Note that if “By Event” is selected, the UI will change to allow entry of only the date and time of day when the production event occurred:

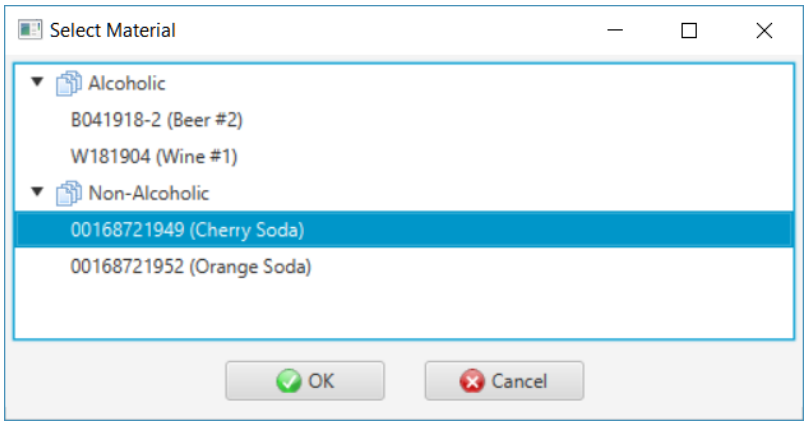


An production reason can be choose by clicking the “Reason” button and selecting from the reason hierarchy.

The material and job change tab looks like:



The produced material is chosen from the pre-defined materials by clicking on the “Material” button:

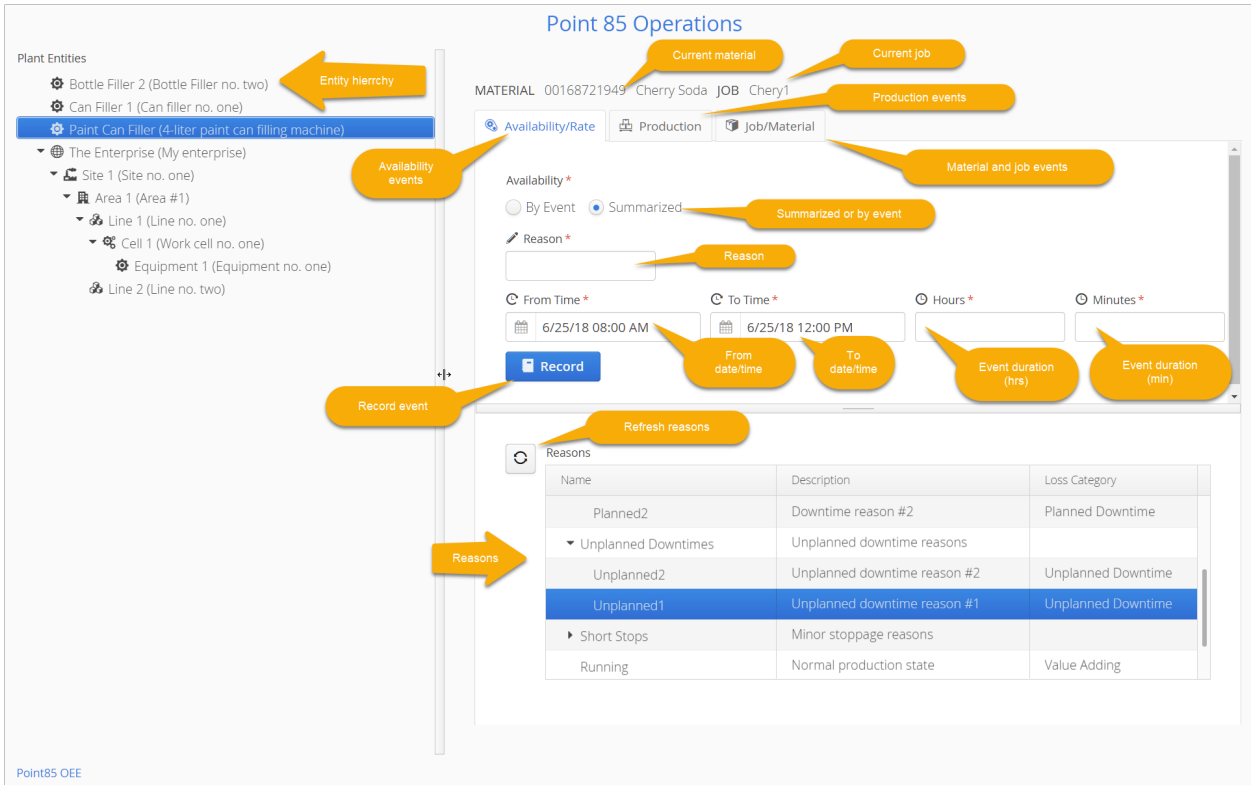


Operator Web Application

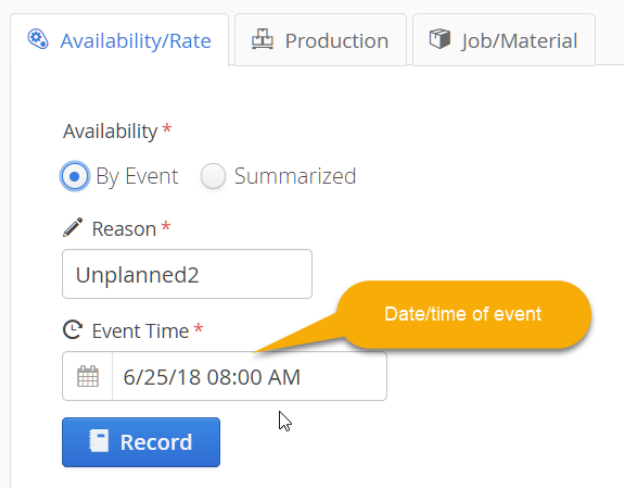
The operator web application is browser-based and allows a user to enter availability, performance, production, material change and job events. The events can be recorded in chronological order as they happened ("By Event") or in summary form ("Summarized") over a period of time by duration of event. Value adding time is assumed in summary form for availability.

User Interface

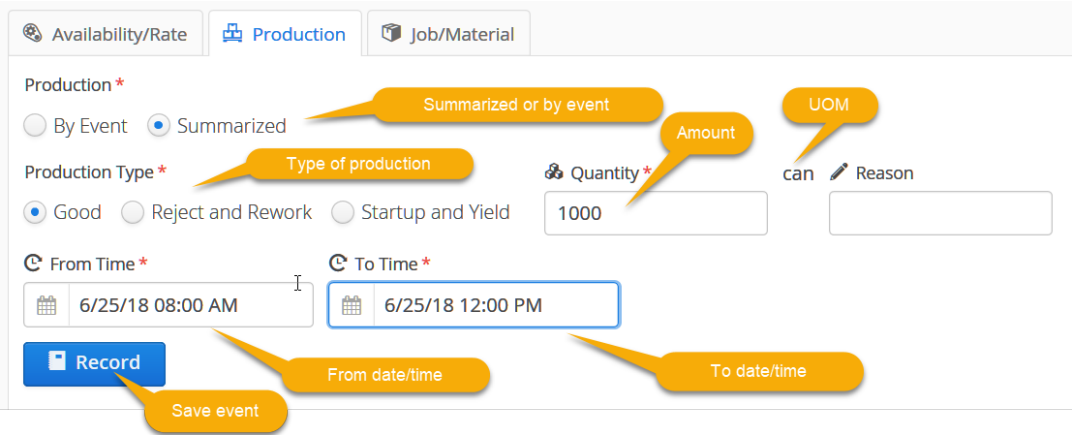
The user interface for availability/rate tab for a summarized event looks like:



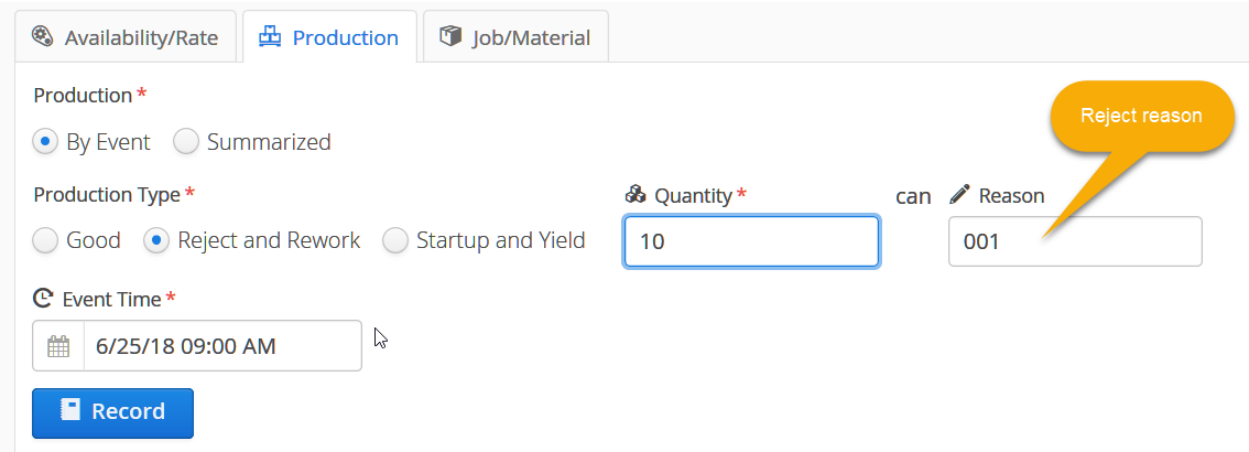
Note that if “By Event” is selected, the UI will change to allow entry of only the date and time of day when the availability event occurred:



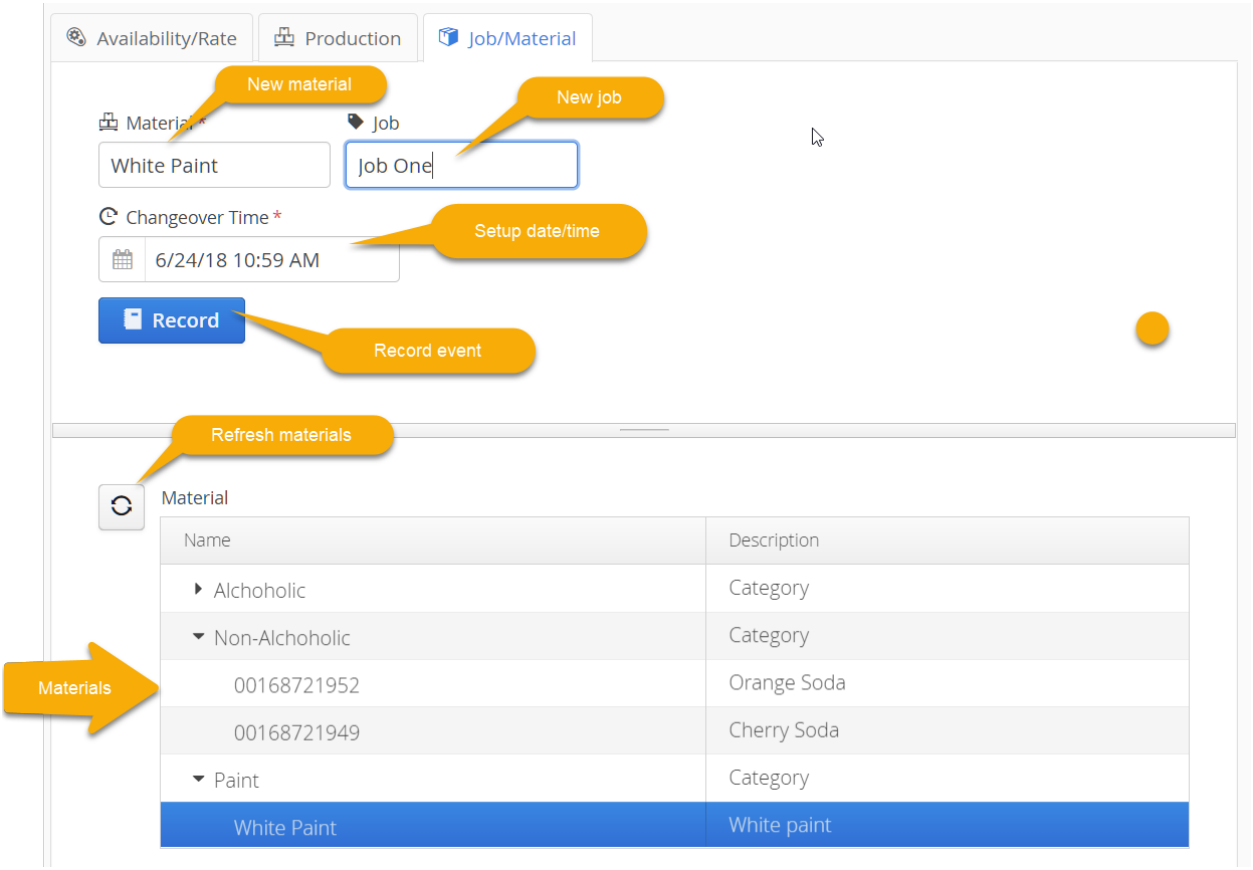
The production tab for a summarized event looks like:



Note that if “By Event” is selected, the UI will change to allow entry of only the date and time of day when the production event occurred. For reject and rework as well as startup and yield event, a reason can be entered as well:



The material and job change tab looks like:



Web Service

Equipment availability and production events can be POSTed to the collector's HTTP server. The plant entity hierarchy, reasons, materials, data sources and data source ids are also accessible by a GET request.

The table below lists the web service requests and responses. The Java DTO (Data Transfer Object) is serialized into a JSON string with a timestamp in ISO 8601 format.

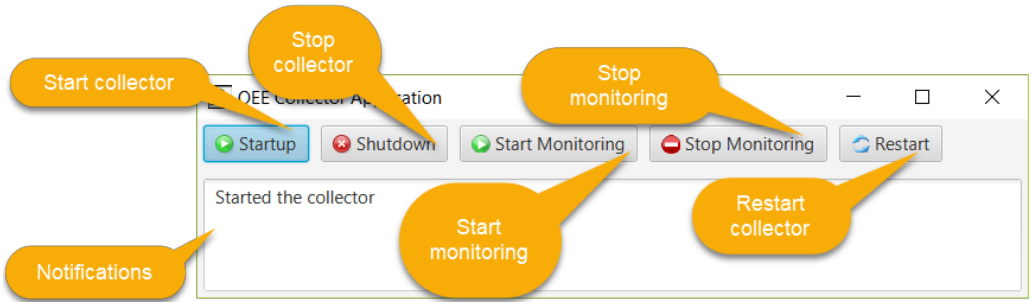
Endpoint	Verb	Request Class	Response Class
/event	POST	EquipmentEventRequestDto (sourceId, value and timestamp) for availability, production of material, setup or job change event	EquipmentEventResponseDto (status and errorText)
/reason	GET	N.A.	ReasonResponseDto (list of ReasonDto with name, description, loss category, parent and children)

/material	GET	N.A.	MaterialResponseDto (list of MaterialDto with name, description and category)
/entity	GET	N.A.	PlantEntityResponseDto (list of PlantEntityDto with name, description, level, parent and children)
/data_source	GET	N.A.	DataSourceResponseDto (list of DataSourceDto with name, description, host and port)
/source_id	GET		SourceIdResponseDto (list of source ids)

Testing Applications

Collector User Interface

This application provides a user interface for a data collector and is used for testing purposes. The application is launched from a host computer that has configured data sources. After the initial splash screen, the main form is displayed:



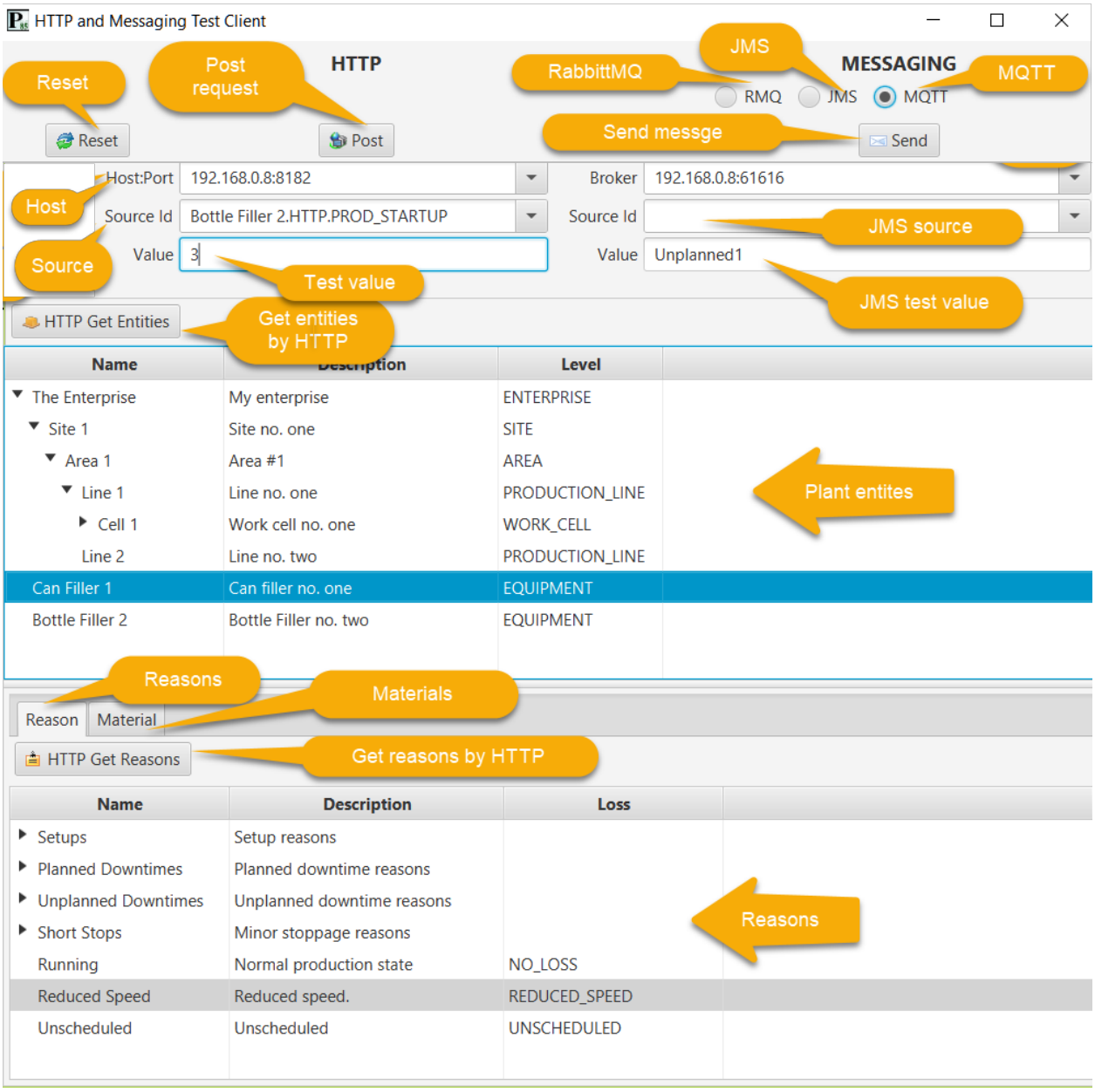
The actions are:

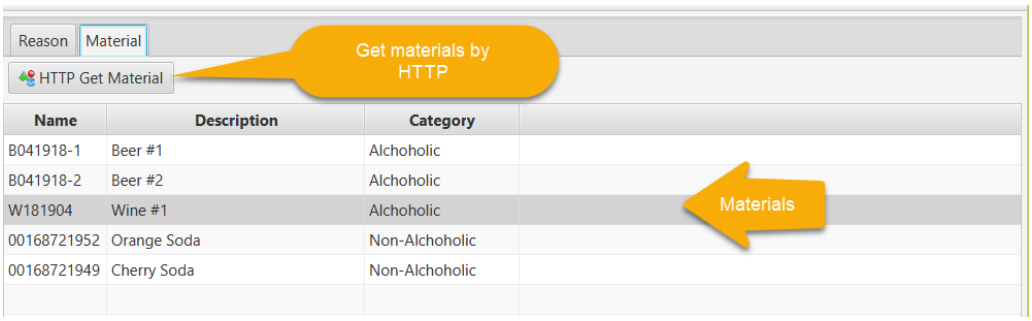
- *Startup*: Start the collector. It will connect to all OPC DA and OPC UA servers and be prepared to listen to HTTP requests as well as receive messages. It is in the monitoring state.
- *Shutdown*: Stop the collector. It is in the shutdown state.
- *Start Monitoring*: Start monitoring data input after having been stopped.
- *Stop Monitoring*: Stop monitoring all data inputs.
- *Restart*: Stop monitoring then restart monitoring.

HTTP and Messaging

This application provides a user interface to send HTTP requests as well as RabbitMQ, JMS or MQTT messages to a data collector configured with these data sources. It is used for testing purposes. It also uses the HTTP web service APIs for fetching the plant entities, reasons and materials.

After the initial splash screen, the main form is displayed with the HTTP server and RabbitMQ/JMS/MQTT broker combobox listing these the selected data source:





Clicking the *Reset* button re-queries the database for HTTP servers and RabbitMQ/JMS/MQTT brokers and clears the source id and value fields.

HTTP

The configured HTTP servers will be listed in the combobox. Choose one to send requests to it. The actions are:

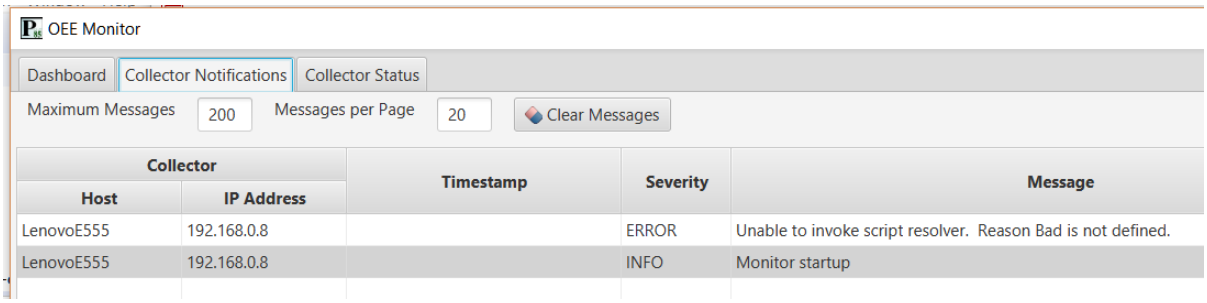
- *HTTP Get Entities*: get the plant entities and display them in the tree view. A GET request is made to the "entity" endpoint and PlantEntityResponseDto serialized object is returned. Selecting an equipment entity will populate the source id comboboxes with HTTP and messaging data sources.
- *HTTP Get Reasons*: get the reasons and display them in the tree table. A GET request is made to the "reason" endpoint and ReasonResponseDto serialized object is returned. Selecting a reason will populate the value text fields with the name of the reason.
- *HTTP Get Materials*: get the materials and display them in the table. A GET request is made to the "material" endpoint and MaterialResponseDto serialized object is returned. Selecting a material will populate the value text fields with the name of the material.
- *Post*: Make an HTTP POST equipment event request to the selected server with the event data.

Messaging

Select either the RMQ, JMS or MQTT radio buttons. The configured RabbitMQ/JMS/MQTT brokers will be listed in the combobox. Choose a broker and source id to send messages to it. The actions are:

- Send: Send an equipment event message to the selected broker with the event data.

Note that the Point85 log should be checked for a successful action, or a Monitor application launched during testing. If an exception occurs, it will appear in the list under "Collector Notifications". For example, reason "Bad' does not exist:



LOCALIZATION

All applications with user-visible text use resource bundles for localization. The locale is the default locale of the desktop or web server machine. Logging records are not localized. Each application has two default resource bundles, one for text named *<app name>Lang.properties* and one for errors/exceptions named *<app name>Error.properties* with US English text.

For the domain classes, in the \i18n directory in the oee-domain-<version>.jar file are the following files:

- DomainLang.properties and DomainError.properties

In the \org\point85\i18n directory in the oee-apps-<version>.jar file are the following files:

- DesignerLang.properties and DesignerError.properties
- MonitorLang.properties and MonitorError.properties
- CollectorLang.properties and CollectorError.properties
- OperatorLang.properties and OperatorError.properties
- TesterLang.properties and TesterError.properties

In the \WEB-INF\classes\i18n\ directory in the OEE-Operator-<version>.war file are the following files:

- WebOperatorLang.properties and WebOperatorError.properties

The jar and war files can be opened in a zip file manager (such as 7-Zip) and the default files edited or translated files added to the archive.

DATABASE

The Java Persistence 2.2 API (JPA) as implemented by the Hibernate ORM framework together with the Hikari connection pool is used to persist OEE information to the database.

Hibernate and JPA abstract-away database specific aspects of inserting, updating, reading and deleting records in the tables. The API is designed to work with any relational database supported by Hibernate. In particular, Microsoft SQL Server 2012, Oracle 12c/18c Express Edition, MySQL 8, PostgresQL 11 and HSQLDB 2.4.1 have been tested.

DESIGN SCHEMA

The following sections document the design-time database schema. Note that foreign key relationships are not defined in the schema. Rather, referential integrity is enforced in java code in the PersistenceService class.

COLLECTOR Table

This table contains the data describing each data collector.

Column Name	Description
COLLECT_KEY	Primary key
VERSION	Optimistic locking version
NAME	Collector name
DESCRIPTION	Collector description
STATE	Current state of collector
HOST	Computer host name or IP address of the collector
BROKER_HOST	RabbitMQ broker host computer name or IP address
BROKER_PORT	RabbitMQ broker TCP/IP port
BROKER_USER	RabbitMQ broker user name
BROKER_PWD	RabbitMQ broker user password

DATA_SOURCE Table

This table contains the data describing each source of data for OEE events.

Column Name	Description
SOURCE_KEY	Primary key
VERSION	Optimistic locking version
NAME	Data source name
DESCRIPTION	Data source description
TYPE	Source type (OPC_DA, OPC_UA, HTTP or MESSAGING)
HOST	Computer host name or IP address of the source
USER_NAME	Name of authenticated user
PASSWORD	Password of authenticated user
PORT	Source TCP/IP port
END_PATH	OPC UA server path name
SEC_POLICY	OPC UA server security policy
MSG_MODE	OPC UA message mode

KEYSTORE	OPC UA java keystore name
KEYSTORE_PWD	OPC UA java keystore password

EQUIPMENT_MATERIAL Table

This table contains the data describing material produced by an equipment entity.

Column Name	Description
EM_KEY	Primary key
MAT_KEY	Primary key of produced material
EQ_KEY	Primary key of equipment
OEE_TARGET	Desired OEE
RUN_AMOUNT	Design speed or ideal run rate amount
RUN_UOM_KEY	Primary key of the design speed or ideal run rate unit of measure
REJECT_UOM_KEY	Primary key of the rejected/reworked material's unit of measure
IS_DEFAULT	True if this material is the default material produced by the equipment

EVENT_RESOLVER Table

This table contains the data describing the JavaScript event resolvers.

Column Name	Description
ER_KEY	Primary key
ENT_KEY	Primary key of equipment
SOURCE_KEY	Primary key of the data source
COLLECT_KEY	Primary key of data collector
SOURCE_ID	Data source identifier
SCRIPT	JavaScript function body
PERIOD	OPC DA update period, OPC UA publishing interval
ER_TYPE	Event resolver type (availability, production, material or job)
DATA_TYPE	The source's native data type

PLANT_ENTITY Table

This table contains the data for the plant entity hierarchy.

Column Name	Description

ENT_KEY	Primary key
VERSION	Optimistic locking version
NAME	Entity name
DESCRIPTION	Entity description
PARENT_KEY	Primary key of parent entity
HIER_LEVEL	Level in S95 hierarchy
WS_KEY	Primary key of work schedule
RETENTION	Event data retention period

MATERIAL Table

This table contains the data for the materials produced by equipment.

Column Name	Description
MAT_KEY	Primary key
VERSION	Optimistic locking version
NAME	Material name
DESCRIPTION	Material description
CATEGORY	Material category

NON_WORKING_PERIOD Table

This table contains the data for the non-working periods in a work schedule.

Column Name	Description
PERIOD_KEY	Primary key
WS_KEY	Primary key of work schedule
NAME	Non-working period name
DESCRIPTION	Non-working period description
START_DATE_TIME	Period starting date and time of day
DURATION	Duration of non-working period
LOSS	Loss category for non-working period

REASON Table

This table contains the data for the OEE loss reasons.

Column Name	Description

REASON_KEY	Primary key
VERSION	Optimistic locking version
NAME	Reason name
DESCRIPTION	Reason description
PARENT_KEY	Parent reason
LOSS	Loss category

ROTATION Table
This table contains the data for a work schedule rotation in a shift.

Column Name	Description
ROTATION_KEY	Primary key
NAME	Rotation name
DESCRIPTION	Rotation description
WS_KEY	Primary key of work schedule

ROTATION_SEGMENT Table
This table contains the data for a portion of a work schedule rotation.

Column Name	Description
SEGMENT_KEY	Primary key
ROTATION_KEY	Primary key of rotation
SHIFT_KEY	Primary key of shift
SEQUENCE	The order of the sequence with a rotation
DAYS_ON	Number of days working the shift
DAYS_OFF	Number of days not working the shift

SHIFT Table
This table contains the data for a shift within a work schedule.

Column Name	Description
SHIFT_KEY	Primary key
WS_KEY	Primary key of work schedule
NAME	Shift name
DESCRIPTION	Shift description
START_TIME	Time of day when the shift begins

DURATION	Duration of shift

TEAM Table

This table contains the data for a team working a shift.

Column Name	Description
TEAM_KEY	Primary key
WS_KEY	Primary key of work schedule
ROTATION_KEY	Primary key of shift rotation
NAME	Team name
DESCRIPTION	Team description
ROTATION_START	Date when the rotation starts for this team

UOM Table

This table contains the data for a unit of measure.

Column Name	Description
UOM_KEY	Primary key
VERSION	Optimistic locking version
NAME	Unit of measure name
DESCRIPTION	Unit of measure description
SYMBOL	Unit of measure symbol
CATEGORY	‘System’ or user-defined category
UNIT_TYPE	Type or dimension, e.g. ‘LENGTH’
UNIT	Identifier for system-defined UOM
CONV_FACTOR	Linear conversion factor
CONV_UOM_KEY	Abscissa UOM primary key
CONV_OFFSET	Linear conversion offset
BRIDGE_FACTOR	Linear conversion factor to a UOM in a different system, e.g foot to metre
BRIDGE_UOM_KEY	Target UOM primary key
BRIDGE_OFFSET	Target UOM offset
UOM1_KEY	Scalar, dividend, multiplicand or base UOM primary key
EXP1	First UOM exponent
UOM2_KEY	Divisor or multiplier UOM primary key
EXP2	Second UOM exponent

WORK_SCHEDULE Table

This table contains the data for a work schedule.

Column Name	Description
WS_KEY	Primary key
VERSION	Optimistic locking version
NAME	Schedule name
DESCRIPTION	Schedule description

EXECUTION SCHEMA

The following sections document the runtime database schema.

OEE_EVENT Table

This table contains the data for the OEE availability, production, setup and job change events. Rows are deleted according to the retention period for a plant entity.

Column Name	Description
EVENT_KEY	Primary key
ENT_KEY	Primary key of equipment plant entity
MATL_KEY	Primary key of produced material
REASON_KEY	Primary key of loss reason
SHIFT_KEY	Primary key of shift
TEAM_KEY	Primary key of team
AMOUNT	Amount of production
UOM_KEY	Primary key of unit of measure for production
JOB	Job/order
START_TIME	Local date and time of day for start of event
START_TIME_OFFSET	Time zone offset for start time
END_TIME	Local date and time of day for end of event
END_TIME_OFFSET	Time zone offset for end time
DURATION	Duration of event
EVENT_KEY	Type of event (availability, production, material or job change)
SOURCE_ID	Event resolver source identifier
REASON_KEY	Primary key of the reason for the production

INSTALLATION

JAVAFX APPLICATIONS

The JavaFX applications are packaged in the oee-<version>.zip file in the OEE-Designer's dist folder. Expand the zip archive into the following folder structure:

- root: oee-apps-*<version>*.jar (JavaFX Designer, Monitor, Collector and Tester apps), oee-collector-*<version>*.jar (data collector in-process app), run-collector-app.bat (example Windows shell script for executing the data collector test UI), run-designer-app.bat (example Windows shell script for executing the designer application), run-monitor-app.bat (example Windows shell script for executing the monitor app), run-tester-app.bat (example Windows shell script for executing the tester application). The corresponding Unix bash scripts have the same file name with the ".sh" extension. The program arguments are:
    - [0]: application id (e.g. "DESIGNER")
    - [1]: JDBC connection string
    - [2]: user name
    - [3]: user password
    - [4]: optional name of a collector if more than JVM is running on the same host machine. Only applies to a collector application.
- config > logging: log4j.properties configuration file
- database
    - import: example CSV import files (reasons.csv and materials.csv)
    - mssql: create_tables.sql and create_event_table.sql - SQL scripts to create the Microsoft SQL Server database tables
    - oracle: create_tables.sql and create_event_table.sql - SQL scripts to create the Oracle database tables
    - mysql: create_tables.sql and create_event_table.sql - SQL scripts to create the MySQL database tables
    - postgresql: create_tables.sql and create_event_table.sql - SQL scripts to create the PostgresQL database tables
    - hsql: create_tables.sql, create_event_table.sql, create_indexes.sql and create_event_table_indexes.sql - SQL scripts to create the HSQLDB database tables and indexes. Note that if the default local OEE database is being used, these scripts have already been executed. run_hsql_server.bat - Windows shell script to launch the HSQLDB server or ".sh" for Unix. The database files are in the "data" folder.

- lib: contains oee-domain-<*version*>.jar domain classes plus dependent jars
- logs: empty folder to contain the Log4j and Java Service Wrapper logging files
- wrapper
    - Win
        - bin: 64-bit Tanuki Java Service Wrapper community edition (wrapper.exe), install-oee-collector.bat (Windows shell script to install the data collector as a Windows service), uninstall-oee-collector.bat (Windows shell script to uninstall the data collector Windows service), oee-collector.bat (Windows shell script to execute the wrapper as a console app)
        - conf: wrapper.conf (Java Service Wrapper configuration file)
        - lib: wrapper.dll and wrapper.jar for Java Service Wrapper
    - MacOSX
        - bin: 64-bit Tanuki Java Service Wrapper community edition (wrapper), oee-collector (OS X shell script to execute the wrapper as a console app)
        - conf: wrapper.conf (Java Service Wrapper configuration file)
        - lib: libwrapper.jnilib and wrapper.jar for Java Service Wrapper
    - Linux
        - bin: 64-bit Tanuki Java Service Wrapper community edition as built by Simon Krenger (wrapper), oee-collector.sh (Linux bash shell script to execute the wrapper as a console app or deamon)
        - conf: wrapper.conf (Java Service Wrapper configuration file)
    - lib: libwrapper.so and wrapper.jar for Java Service Wrapper

The Java Service Wrapper wrapper.conf file requires that the following parameters be defined:

- wrapper.java.command: path to a Windows 64-bit Java 8 JRE compatible with the 64-bit Java Service Wrapper (or Unix 64-bit JRE compatible with a 64-bit Java Service Wrapper), e.g. for Windows:
    - set.JAVA_HOME=C:/jdk/jdk1.8.0_202-64/jre
    - wrapper.java.command=%JAVA_HOME%/bin/java
- program arguments for the JDBC connection string and autenticated user. For example for Microsoft SQL Server running on localhost at port 1433 and connecting to the OEE database with SQL Server authenticated user “Point85” and password “Point85”:
    - wrapper.app.parameter.2=jdbc:sqlserver://localhost:1433;databaseName=OEE
    - wrapper.app.parameter.3=Point85

- wrapper.app.parameter.4=Point85
- wrapper.app.parameter.5=*<optional name of collector>*

The 5th parameter is optional and specifies the name of a collector if more than one JVM is running on the same host machine. If not specified, then all collectors for the host machine will be run.

For Oracle 12c, the JDBC connection string would be similar to jdbc:oracle:thin:@localhost:1521:orcl SYSTEM admin (and "xe" for 18c Express Edition). For MySQL, the JDBC connection string would be similar to jdbc:mysql://localhost:3306/oee Point85 Point85. For PostgresQL, the JDBC connection string would be similar to jdbc:postgresql://localhost/oee Point85 Point85 and for HSQLDB to jdbc:hsqldb:hsql://localhost/OEE Point85 Point85.

The steps to run the JavaFX applications are:

- Create a database and then initialize it by executing the create_tables.sql script for SQL Server, Oracle, MySQL, PostgresQL or HSQLDB. If using an interface table as a data source, execute the create_event_table.sql script.
- Edit the run *.bat (or *.sh) scripts to set the JDBC connection and user credentials.
- Edit the config/logging/log4j.properties file to set the location of the Point85.log file and logging levels.
- Execute the run-designer-app.bat (or .sh) script and define the plant model.
- Optionally, download and install the RabbitMQ broker from https://www.rabbitmq.com. The monitor application now can be used.
- Optionally execute the collector and tester applications.

DATA COLLECTOR

For your operating system (wrapper/MacOSX, wrapper/Linux or wrapper/Win), the in-process data collector can be deployed as follows:

- Edit the conf/wrapper.conf file to set JAVA_HOME to a 64-bit JRE or JDK and the database JDBC connection, user name and password properties (wrapper.app.parameter.2, 3 and 4). Parameter 5 is the optional name of a data collector if more than one collector is to run on the same machine.
- Execute the shell script to install the collector as a Windows service (Win/bin/install-oee-collector.bat and uninstall-oee-collector.bat), Unix daemon (MacOSX/bin/oee-collector.sh, Linux/bin/oee-collector.sh) or Windows console program (Win/bin/oee-collector.bat).

OPERATOR WEB APPLICATION

Download the operator web application's war file (OEE-Operator-<version>.war) from the latest Git release link for the Operations project (https://github.com/point85/OEE-Operations/releases) . The web.xml file in the war needs to be edited for the database connection information. To do this use a zip

file manager application such as 7-Zip to edit WEB-INF/web.xml's jdbcConn, userName and password and collectorName parameters. For example:

```
<init-param>

  <param-name>jdbcConn</param-name>

  <param-value>jdbc:sqlserver://localhost:1433;databaseName=OEE</param-value>

</init-param>

<init-param>

  <param-name>userName</param-name>

  <param-value>Point85</param-value>

</init-param>

<init-param>

  <param-name>password</param-name>

  <param-value>Point85</param-value>

</init-param>

<init-param>
  <param-name>collectorName</param-name>
  <!-- ALL, NONE or a specific collector name -->
  <param-value>ALL</param-value>
</init-param>
```

The collectorName parameter can have the following values:

- ALL: all collectors defined for this machine will be run
- NONE: no collectors will be run even if some are defined for this machine
- <specific collector>: the named collector for this machine will be run

If using Apache Tomcat, run the Tomcat Web Application Manager. In the section of the web page titled "WAR file to deploy," browse to the war file and click the Deploy button. Under the Applications section, the path will be "/OEE-Operator-<version>".

The Point85 operator application URL is http://<host>:<port>/<war_file_name>/. If Tomcat is installed locally on the default port of 8080, the URL will be http://localhost:8080/OEE-Operator-<version>/.

PROJECT STRUCTURE

There are four Maven projects:

- OEE-Domain: domain logic with no user interface code
- OEE-Designer: JavaFX user interface code for the Designer, Monitor, Operator, Collector and Tester desktop applications

- OEE-Collector: the Windows service or Unix daemon in-process data collector with the Java Service Wrapper
- OEE-Operations: the Vaadin operator web application.

OEE-DOMAIN

The OEE-Domain GitHub Maven project contains the OEE domain logic - there is no user interface code. The folders and files are:

- root: pom.xml, README.md, LICENSE, install-opc-da-jars.bat (Windows shell script for local Maven repository of OPC DA jars), install-opc-domain-jar.bat (Windows shell script for building the local Maven repository of the domain jar)
- lib: non-Maven Central jars stored in the "maven_repo" local repository.
    - opcda: j-Interop and openSCADA jars
    - oracle: Oracle database JDBC driver jar
- src
    - main > java: java code
    - main > resources: Unit.properties (resource bundle for units of measure), UomMessage.properties (resource bundle for UOM error exceptions), WorkScheduleMessage.properties (resource bundle for work schedule exceptions)

OEE-DESIGNER

The OEE-Designer GitHub Maven project contains the OEE JavaFX user interface code for the Designer, Monitor, Collector and Tester applications. It depends on the OEE-Domain project. The folders and files are:

- root: pom.xml, README.md, LICENSE, build-jfx-app.bat (Windows shell script for building the JavaFX application jar), build-distro.bat (Windows shell script for building the oee.zip file distribution), run-designer-app.bat (example Windows shell script for executing the Designer application for a SQL Server database), run-monitor-app.bat (example Windows shell script for executing the Monitor application for a SQL Server database), run-collector-app.bat (example Windows shell script for executing the Collector application for a SQL Server database), run-tester-app.bat (example Windows shell script for executing the HTTP & messaging application for a SQL Server database), install-oracle-jdbc.bat (example Windows shell script for installing the Oracle JDBC driver jar in a local Maven repository). The javafx 8 applications can also be executed from a Unix bash shell from the corresponding ".sh" scripts.
- config
    - logging: log4j.properties configuration file

    - security: copy the point85.keystore (java OPC UA keystore file) built in the ssl folder to here
- database
    - import: example CSV import files (reasons.csv and materials.csv)
    - mssql: SQL scripts to create the Microsoft SQL Server database tables
    - oracle: SQL scripts to create the Oracle database tables
    - mysql: SQL scripts to create the MySQL database tables
    - postgresql: SQL scripts to create the PostgresQL database tables
    - hsql: SQL scripts to create the HSQLDB database tables and run a local server
- docs: this document (Point85 OEE User Guide.tmdx) and the getting started guide
- fxbuild: build.xml (ant build file)
    - archive: Point85 OEE.zip (distribution file)
    - dist: build folder
- src
    - main > java: java code
    - main > resources: .css stylesheets, .png images, .otf fonts
- ssl: example Windows shell scripts for creating an X509 certificate and a java keystore

OEE-Collector

The OEE-Collector GitHub Maven project contains the source code for the Windows service or Unix daemon in-process data collector with the Java Service Wrapper. It depends on the OEE-Domain project.

- root: pom.xml, README.md, LICENSE, build-collector.bat (Windows shell script for building the collector jar)
- config
    - logging: log4j.properties configuration file
    - security: point85.keystore (java OPC UA keystore file)
- src
    - main > java: java code
- wrapper
    - Win

        - bin: 64-bit Tanuki Java Service Wrapper community edition (wrapper.exe), install-oee-collector.bat (Windows shell script to install the data collector as a Windows service), uninstall-oee-collector.bat (Windows shell script to uninstall the data collector Windows service), oee-collector.bat (Windows shell script to execute the wrapper as a console app)
        - conf: wrapper.conf (Java Service Wrapper configuration file)
        - lib: wrapper.dll and wrapper.jar for Java Service Wrapper
    - MacOSX
        - bin: 64-bit Tanuki Java Service Wrapper community edition (wrapper), oee-collector (OS X shell script to execute the wrapper as a console app or daemon)
        - conf: wrapper.conf (Java Service Wrapper configuration file)
        - lib: libwrapper.jnilib and wrapper.jar for Java Service Wrapper
    - Linux
        - bin: 64-bit Tanuki Java Service Wrapper community edition as built by Simon Krenger (wrapper), oee-collector.sh (Linux bash shell script to execute the wrapper as a console app or deamon)
        - conf: wrapper.conf (Java Service Wrapper configuration file)
    - lib: libwrapper.so and wrapper.jar for Java Service Wrapper

OEE-OPERATIONS

The OEE-Operations GitHub Maven project contains the source code for the Vaadin operator web application.

- root: pom.xml, README.md, LICENSE, build-operator.bat (Windows shell script for building the operator war)
- dist: war distribution file
- src
    - main > java: java code
    - main > webapp > WEB-INF: web.xml deployment descriptor file. The jdbcConn, userName and password must be defined.

BUILDING

Builiding Point85 OEE projects require that the ant and Maven tools be installed first. In the Maven setting.xml file, change to the local repository “maven_repo”:

```
<localRepository>C:/maven_repo</localRepository>
```

The build steps are:

1. Execute install-opc-da-jars.bat in the OEE-Domain project to install the OPC DA jars into a local Maven repository
2. Execute install-oee-domain-jar.bat in the OEE-Domain project to build the domain jar and install it into a local Maven repository
3. Execute install-orcle-jdbc.bat in the OEE-Designer project to install the Oracle JDBC driver jar into a local Maven repository
4. Execute build-jfx-app.bat in the OEE-Designer project to build the OEE JavaFX application
5. Execute build-collector.bat in the OEE-Collector project to build the data collector
6. Execute build-operator.bat in the OEE-Operations project to build the operator Vaadin application. The war file is in the "dist" folder and can be deployed to a web server.
7. Execute build-distro.bat in the OEE-Designer project to build the oee-<version>.zip distribution file in the "dist" folder. The zip archive contains the JavaFX applications and the in-process Java Service Wrapper collector.

Note that these steps are combined in the build-all.bat script.

CONTRIBUTING TECHNOLOGY

The author wishes to acknowledge the following software upon which the OEE applications are built.

https://github.com/eclipse/milo	Milo is an open-source implementation of OPC UA. It includes a high-performance stack (channels, serialization, data structures, security) as well as client and server SDKs built on top of the stack.
j-interop.org	j-Interop is a Java Open Source library (under LGPL) that implements the DCOM wire protocol (MSRPC) to enable development of Pure, Bi-Directional, Non-Native Java applications which can interoperate with any COM component.
openscada.org	openSCADA is an open source Supervisory Control And Data Acquisition System. It is platform independent and based on a modern system design that provides security and flexibility at the same time.
https://github.com/NanoHttpd/nanohttpd	NanoHTTPD is a light-weight HTTP server designed for embedding in other applications, released under a Modified BSD licence.
http://hibernate.org	Hibernate ORM enables developers to more easily write applications whose data outlives the application process. As an Object/Relational Mapping (ORM) framework, Hibernate is concerned with data persistence as it applies to relational

	databases (via JDBC).
https://brettwooldridge.github.io/HikariCP/	HikariCP is a “zero-overhead” production-quality connection pool.
https://www.rabbitmq.com/	RabbitMQ is an open source message broker software (sometimes called message-oriented middleware) that originally implemented the Advanced Message Queuing Protocol (AMQP) and has since been extended with a plug-in architecture to support Streaming Text Oriented Messaging Protocol (STOMP), Message Queuing Telemetry Transport (MQTT), and other protocols.
www.erlang.org	Erlang is a general-purpose, concurrent, functional programming language, as well as a garbage-collected runtime system.
http://activemq.apache.org	Apache ActiveMQ ™ is the most popular and powerful open source messaging and Integration Patterns server.
https://www.eclipse.org/paho	The Eclipse Paho project provides open-source client implementations of MQTT and MQTT-SN messaging protocols aimed at new, existing, and emerging applications for the Internet of Things (IoT).
https://mvnrepository.com/artifact/com.google.code.gson/gson	Gson JSON serializer and deserializer
https://vaadin.com/	Vaadin is an open-source platform for web application development.
https://wrapper.tanukisoftware.com	The Java Service Wrapper (JSW) enables a Java Application to be run as a Windows Service or UNIX Daemon. It also monitors the health of your Application and JVM. The 64-bit Windows version is by Simon Krenger (https://www.krenger.ch/blog/java-service-wrapper-3-5-38-for-windows-x64/)
https://github.com/HanSolo/tilesfx	A JavaFX library containing tiles that can be used for dashboards.
https://www.bouncycastle.org	Bouncy Castle is a collection of APIs used in cryptography.
http://logging.apache.org/log4j/1.2/	Apache Log4j is a Java-based logging utility.
https://mvnrepository.com/artifact/org.slf4j	Log4j logging facade
https://github.com/steveohara/j2mod	j2Mod is an enhanced Modbus library implemented in the Java programming language.

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