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Contents

1 Welcome to the Arena Packaging Template

What is the Arena Packaging template?

Arena Packaging is a simulation system developed by Rockwell Automation for the performance analysis of high-speed, high-volume manufacturing systems.

The initial design of the Packaging template was developed by Ouroumoff Diffusion (a consulting firm headquartered in Lyon, France) during a consulting engagement with Pechiney CRV to analyze canning lines. The core algorithms of the product involved vital input from the engineering staff at Pechiney. The final design of the Packaging template then involved significant input by staff at Rockwell Automation as well as Michigan State University's School of Packaging.

Intended audience

The Arena Packaging template is designed for manufacturing or business process consultants and analysts and industrial or systems engineers. It is typically deployed as an enterprise business analysis and productivity tool.

We assume that you are familiar with the basic concepts and terms used in these types of systems. You are interested in improving business or manufacturing productivity and are responsible for evaluating and predicting the impact of proposed strategic and tactical changes to help improve performance. A familiarity with computers and the Microsoft® Windows® operating system is assumed. A familiarity with the concepts and terms used in simulation is also helpful.

Where can I go for help?

Our commitment to your success starts with the suite of learning aids and assistance we provide for Arena. Whether you're new to simulation or a seasoned veteran putting a new tool to use, you'll quickly feel at home with Arena Packaging.

Reference the user's guides

The documentation set includes this manual, *Arena Packaging Template User's Guide*, which cover the product basics as well as the *Arena User's Guide,* which covers the standard product modules and offers an easy, "click-by-click" tutorial, and the *Variables Guide*, a separate reference booklet providing complete descriptions of Arena variables found in the Arena product templates.

DOCUMENT CONVENTIONS

Throughout the guides, a number of style conventions are used to help identify material. New terms and concepts may be emphasized by use of italics or bold; file menu paths are in bold with a (>) separating the entries (e.g., go to **Help > Arena Help**); text you are asked to type is shown in Courier Bold (e.g., in this field, type **`Work Week`**), and dialog box and window button names are shown in bold (e.g., click **OK**).

Explore our examples

Arena is accompanied by a number of sample models that illustrate many of the commonly used approaches for capturing the essence of manufacturing processes. Examples are provided for both job shop and flow shop environments. For a description of and list of Arena's examples, go to **Help > Arena Help**. On the **Contents** tab, choose **Model Building Basics**, and then select **Viewing Arena Example Models**.

Get help

Online help is always at your fingertips! Arena incorporates the latest in help features, including *What's This?* help that displays a brief description of fields in dialog boxes, context-sensitive help on menu and toolbar buttons, and a help button on each of Arena's modules. Just refer to the Arena help table of contents and index for a list of all help topics.

Use the HSMARTs library

As you craft models of your own manufacturing processes, use our HSMARTs library to explore how to best use Arena. HSMARTs are a collection of small, self-contained models that illustrate different aspects of modeling in Arena Packaging. We recommend you go through these small files to see how concepts are implemented in actual models. For a list of categories and their related HSMARTS, go to **Help > Arena Help.** On the **Contents** tab, choose **Template Help** > **Packaging** > **Arena Packaging Template > Learning Arena Packaging Template with the HSMART Files**.

Access the Arena Symbol Factory

Arena animations can be enhanced using Arena Symbol Factory's extensive library of over 4,000 symbols. These symbols can be used for entity, resource, transporter or global pictures; or as graphic symbols within a model window. You can copy these symbols directly to the Arena model window, add them to your own libraries (*.plb* files), or add them to any of the Arena picture library files.

Get phone support

Rockwell Automation's support team of outstanding professionals provides top-notch technical support—monitoring and tracking your experience with our simulation products to pave the road to your success in understanding and improving your performance.

Rockwell Automation provides full support for the entire Arena family of products. Questions concerning installation, how modules work, the use of the model editor, and the use of the software are handled by technical support.

Arena technical support includes:

- (for users on active maintenance) a technical support hotline and e-mail address staffed by full-time, experienced professionals
- help with installation problems or questions related to the software's requirements
- troubleshooting
- limited support regarding the interaction of Arena with other programs
- support of the Arena Object Model, which is used in Microsoft Visual Basic for Applications.

If you call the support line (1.440.646.3434), you should be at your computer and be prepared to give the following information:

- the product serial number
- the product version number
- the operating system you are using
- the exact wording of any messages that appeared on your screen
- a description of what happened and what you were doing when the problem occurred
- a description of how you tried to solve the problem.

Get Web support

In addition to phone support, the Rockwell Automation Customer Support Center offers extensive online knowledgebases of tech notes and frequently asked questions for support of non-urgent issues. These databases are updated daily by our support specialists.

To receive regular e-mail messages with links to the latest tech notes, software updates, and firmware updates for the products that are of interest to you or to submit an online support request, go to support.rockwellautomation.com/supportrequests.

And be sure to check the Arena User Zone section of our Web site at www.ArenaSimulation.com. The User Zone links to a peer-to-peer forum on Arena topics and has a link to a download page where you can check for possible software updates (patches). If you can't find the answer you need, contact your local representative or Arena technical support.

Get training

Do you need training? Rockwell Automation offers a standard training course comprised of lecture and hands-on workshops designed to introduce you to the fundamental concepts of modeling with Arena.

We also offer customized training courses designed to meet your specific needs. These courses can be held in our offices or yours, and we can accommodate one person or twenty. You design the course that's right for you! Simply contact our consulting services group to discuss how we can help you achieve success in your simulation efforts.

Get consulting services

Rockwell Automation provides expert consulting and turnkey implementation of the entire Arena product suite. Please call our offices for more information or e-mail Arena-Info@ra.rockwell.com.

Contact us

We strive to help all of our customers become successful in their manufacturing improvement efforts. Toward this objective, we invite you to contact your local representative or Rockwell Automation at any time that we may be of service to you.

Support E-mail: Arena-Support@ra.rockwell.com
Corporate E-mail: Arena-Info@ra.rockwell.com
Support Phone: 1.440.646.3434
URL: www.ArenaSimulation.com
URL: www.rockwellautomation.com

2 General Concepts

Template overview

Arena Packaging is one of a family of application solution templates (ASTs) built on the Arena simulation system. It is designed specifically for performing accurate and efficient simulations of high-speed, high-volume manufacturing systems, where the processing rates take place at hundreds, even thousands, of entities per minute. The Packaging template enables users to build and run simulation models of high-speed processing lines quickly and easily, and to analyze the results that these models produce.

To use the Arena Packaging template, you attach the *Packaging panel* to the Arena development environment. The Packaging panel contains a collection of objects or *modules*. Each module defines the logic, data, animation, and/or statistics collection for a particular element in a model (e.g., machines, conveyors, operators).

The Packaging panel contains the following modules:

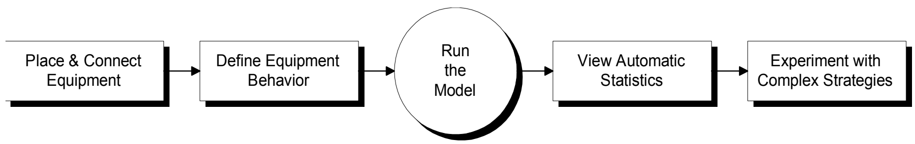
- A **Machine** module for modeling the physical components of a line where the actual processing or conversion of units takes place.
- A **Conveyor** module for modeling the accumulating conveyors between machines where units are transferred and buffered.
- **Machine Link** and **Conveyor Link** modules for linking machines and conveyors directly together.
- **Merge**, **Split**, and **Switch** modules for modeling transfer points between conveyors where product flow is split or combined (i.e., flow controls).
- **Operator**, **Operator Group**, and **Operator Schedule** modules for modeling the availability and organization of labor in the system.
- **Palletizer** and **Storage** modules for modeling the physical components of a line where units are stored on or removed from pallets.
- **Valve** and **Tank** modules for modeling fluid constraints of filling operations.
- **Product** and **Production Plans** modules for defining multiple products processed in a system and their requirements.
- An **Actions** module for performing actions on a high-speed system (e.g., changing run speeds of machines, adjusting valves, adding pallets to a storage) using discrete entities and logic.
- A **Label** module for labeling a particular portion of the model logic, whereby discrete entities may be sent easily to the label from other locations in the model.

- A **Simulate** module for advanced model options (e.g., units of measure, statistic collection switches).

Template framework and modeling methodology

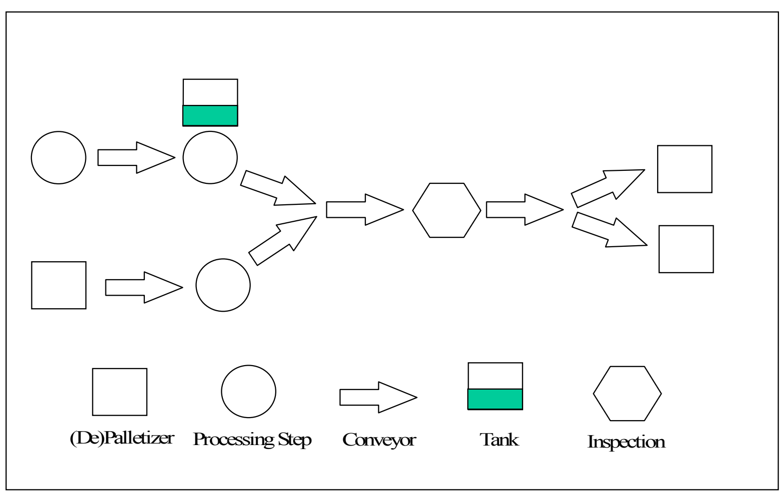
Simulation studies are initiated because a decision maker or group of decision makers face a problem and need a solution. You should begin a simulation project by first collecting enough information and data to provide an adequate understanding of both the problem and the system to be studied. Once that step is complete, you are then ready to formulate models.

This section introduces a five-step modeling methodology for developing those simulation models in Arena Packaging. The steps of the methodology are illustrated in the following diagram.

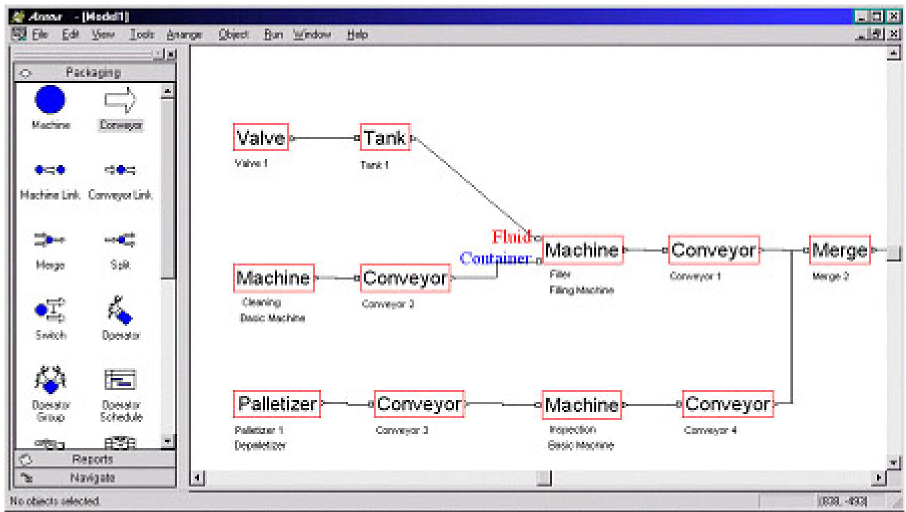


Step 1 • Place and connect equipment

First, flowchart on paper the step-by-step sequence of your line as raw goods are converted into finished product. For example, you might construct flowcharts of the machines, conveyors, palletizers, merges, splits, etc., in your line similar to the flowchart below.



Once you have flowcharted your process, duplicate that flowchart in Arena by graphically placing and connecting appropriate modules from the Packaging panel into an Arena model window. To select a module, you simply drag and drop an icon in the panel onto the workspace region where you want the module to be placed.



HSMARTs are a collection of small models that illustrate modeling techniques. To learn combinations of Packaging modules that are appropriate for specific situations, it is useful to refer to the HSMART examples for Step 1.

- **Step 1 • Place and Connect Equipment**
  - **Processing**
    - HSMART01: Basic Processing Operation
    - HSMART02: Basic Processing Operation Using a Non-accumulating Conveyor
    - HSMART03: Assembly Operation
    - HSMART04: Packing Operation
    - HSMART05: Filling Operation
    - HSMART06: Inspection Operation
    - HSMART07: Linking Two Machines
    - HSMART08: Modeling a Supply Constraint for an Operation
    - HSMART09: Modeling a Machine as Two or More Separate Components

- **Conveyors and Flow Control**
  - HSMART10: Accumulating Conveyors
  - HSMART11: Linking Two Accumulating Conveyors
  - HSMART12: Splitting Conveyor Flow by Count
  - HSMART13: Merging Conveyor Flow
  - HSMART14: Modeling a Surge Area or Table
  - HSMART15: Modeling a Secondary Line
  - HSMART16: Modeling Rework
- **Tanks and Valves**
  - HSMART17: Simple Tank and Valve
  - HSMART18: Tank Farm
- **Fronts (Sources) and Ends (Sinks) of Lines**
  - HSMART19: Using Palletizers to End a Line
  - HSMART20: Using Depalletizers to Begin a Line
  - HSMART21: Storage Example Using Palletizer/Depalletizer

Step 2 • Define equipment behavior

The next step is to specify the basic run parameters (e.g., run speeds), characteristics (e.g., reliability, loss), and dimensions (e.g., length, width, capacity) for each individual element in the line. For example, you might have collected and organized data about the equipment in your line as follows.

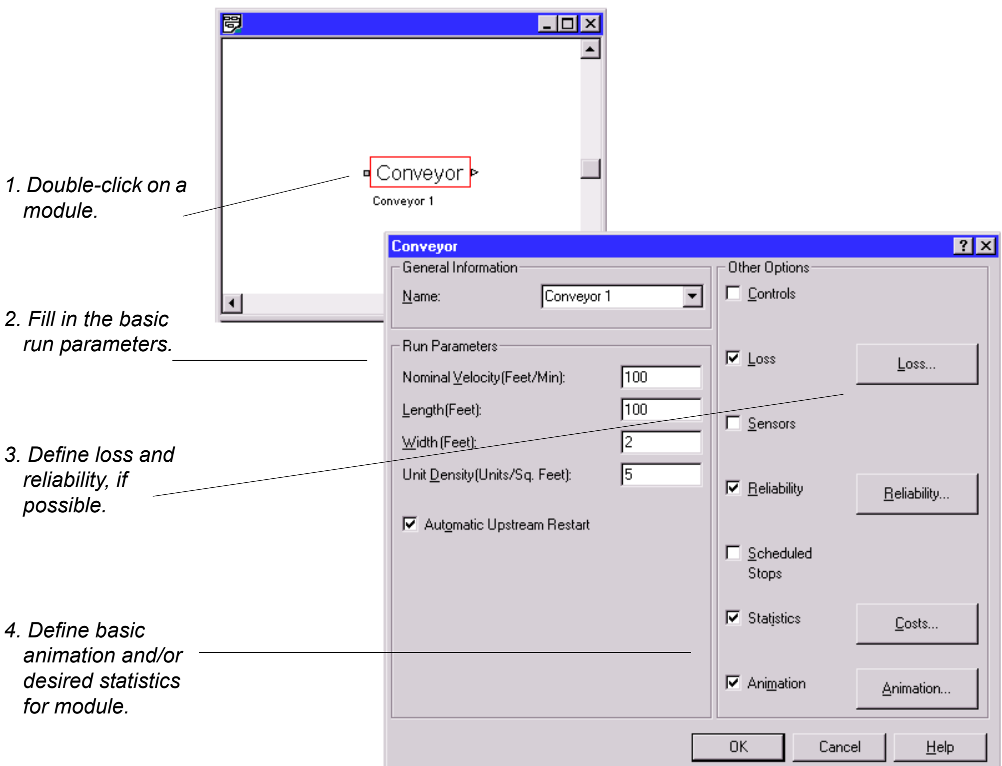
Processing Elements:

Element Name	Nom. Run Speed (units/min)	Unit Loss	Reliability for a Week
Cleaner	500	.01%	.97
Filler	650	.01%	.99
Inspector	500	1.0%	.98
Depalletizer	600	.01%	.99

Conveyor Elements:

Conveyor Name	Nom. Velocity (ft/min)	Length (ft)	Width (ft)	Unit Density (units/ft^2)	Unit Loss	Reliability for a Week
Conveyor 1	100	200	3	10	.01%	.995
Conveyor 2	90	100	2	10	.01%	.995
Conveyor 3	90	100	2	10	.01%	.995
Conveyor 4	100	150	2	10	.01%	.995
Conveyor 5	95	50	3	10	.01%	.995

In Arena Packaging, you define equipment parameters such as those listed above by double-clicking on modules and filling in the descriptive information in the module dialogs. For example, the main dialog box of the Conveyor module is shown below.



All module dialogs are self-contained and designed with terminology for high-volume applications. The graphical "point-and-click" interface allows you to develop models of sophisticated systems without writing any code. You just answer the questions in the dialog boxes.

It is also easy to define basic animation and statistics for a module. Arena Packaging allows you to generate animation and statistics (e.g., production summary, costing, or state statistics) for modules automatically by clicking on the Animation and Statistics check boxes. Animation is placed upon exiting the dialog box. It can then be enhanced by using symbols from Arena's picture libraries, Arena Symbol Factory, or from other graphics files such as Clip Art or AutoCAD®.

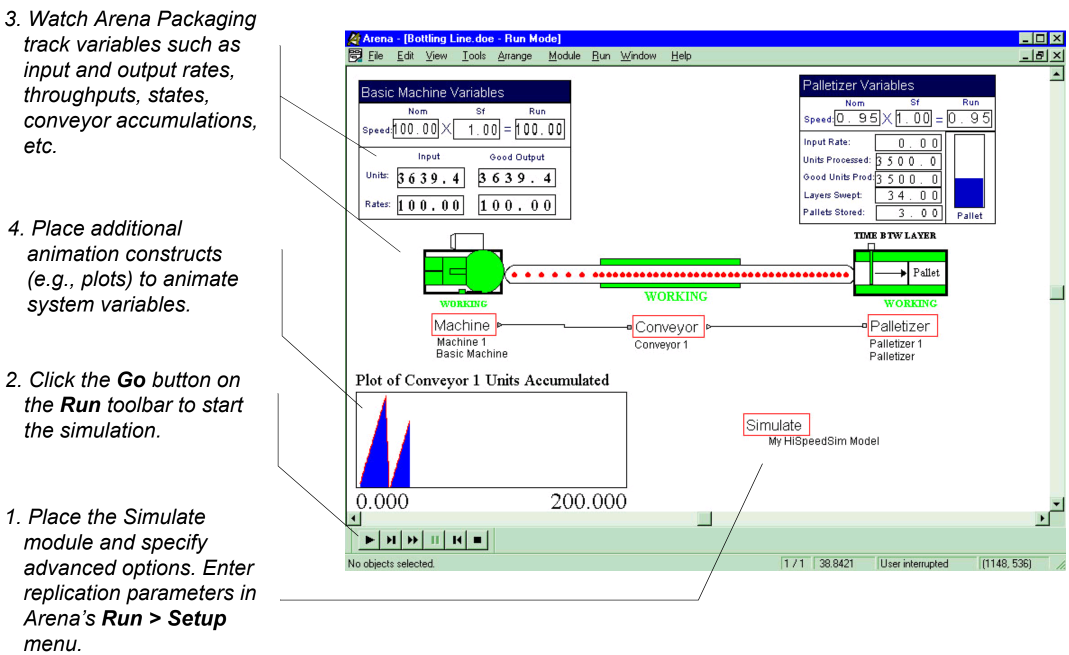
To learn more about defining basic behavior for the Arena Packaging template's modules, refer to the module descriptions in Chapter 3 or the HSMART examples listed below.

- **Step 2 • Define Equipment Behavior**
  - HSMART22: Defining Event-Based Loss
  - HSMART23: Defining Production-Based Loss
  - HSMART24: Modeling Reliability Using Expected Uptime
  - HSMART25: Modeling Reliability Using Reliability
  - HSMART26: Modeling Reliability Using Multiple Failure Streams

Step 3 • Run the model

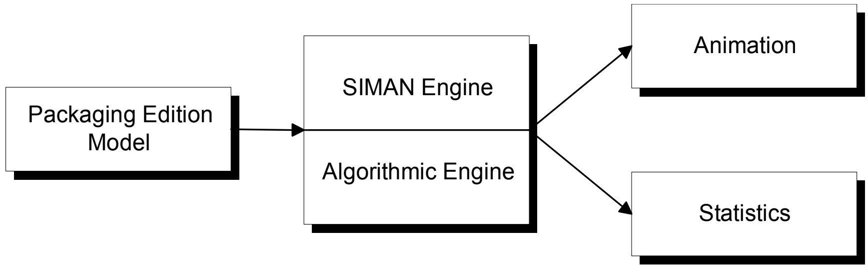
At this stage, while you're probably not ready to reach significant conclusions yet with your model, you do have a complete tool that you can now build on as your project progresses. It is a good idea to run this first model to verify that your basic logic is working correctly. Animation is a great tool for verifying model logic. You can also gain valuable insight on further detail to add and future strategies with which to experiment.

In Arena Packaging, to run a model, you must first place a Simulate module. This module defines which categories of Packaging module statistics will be collected as well as additional information such as units of measure. Before starting a simulation run, you will want to specify the simulation project parameters, such as the number of replications, the run length, and base time units. This is done by choosing the **Run > Setup** menu option from Arena's **File** menu. This opens the Run Setup dialog box. Enter the replication and project parameters. Then use the **Go** command (**Run** menu) to start the simulation run.



When a simulation run begins, Arena Packaging first processes the data and logic of the system as defined by the modules in the model. Special-purpose variables called Arena Packaging variables are automatically created for each module. These variables are dynamic quantities that describe the state of the system. Examples of Arena Packaging template variables include equipment states, run speeds, input and output rates, throughputs, conveyor accumulation levels, tank levels, etc. A more detailed discussion and list of the Arena Packaging template variables can be found in Chapter 5 of this user's guide.

The model of the system is then input into a simulation engine specifically designed for simulating high-speed, high-volume flow. This engine utilizes two distinct technologies: SIMAN and an algorithmic kernel. The SIMAN portion of the engine manages discrete system events such as equipment failures, changeovers, and stops, as well as system resources such as operators. SIMAN is the core language of the Arena development environment and has been designed, developed, and successfully used since 1982 to conduct discrete-event simulations.



The algorithmic portion of the Arena Packaging template's engine manages the complex logic and statistics associated with high-speed, high-volume flow. Specifically designed for simulating high-speed processes, it allows Arena Packaging to simulate the performance of a high-volume system accurately and efficiently without using entities to represent individual units or batches of units.

As the simulation begins, unit flow starts at the front of lines and moves downstream. The simulation then automatically tracks, updates, and collects statistics on the Arena Packaging variables for the length of the simulation run. Numeric values, plots, and levels of Arena Packaging template variables can be viewed during the simulation using Arena's animation constructs.

For more information, refer to the HSMART examples for Step 3.

- **Step 3 • Run the Model**
  - HSMART28: Updating Arena Packaging Template Variables Automatically
  - HSMART29: Animating Arena Packaging Template Variables
  - HSMART31: Custom Pictures for Conveyor Animation

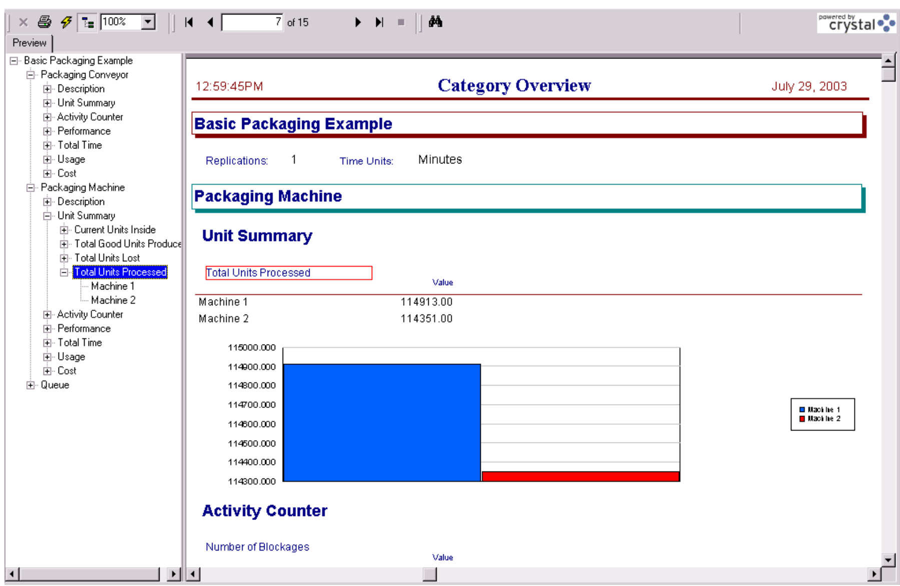
Step 4 • View automatic statistics

A primary objective of most simulation studies is to generate statistics about a system's performance so that you can make the "right" decisions.

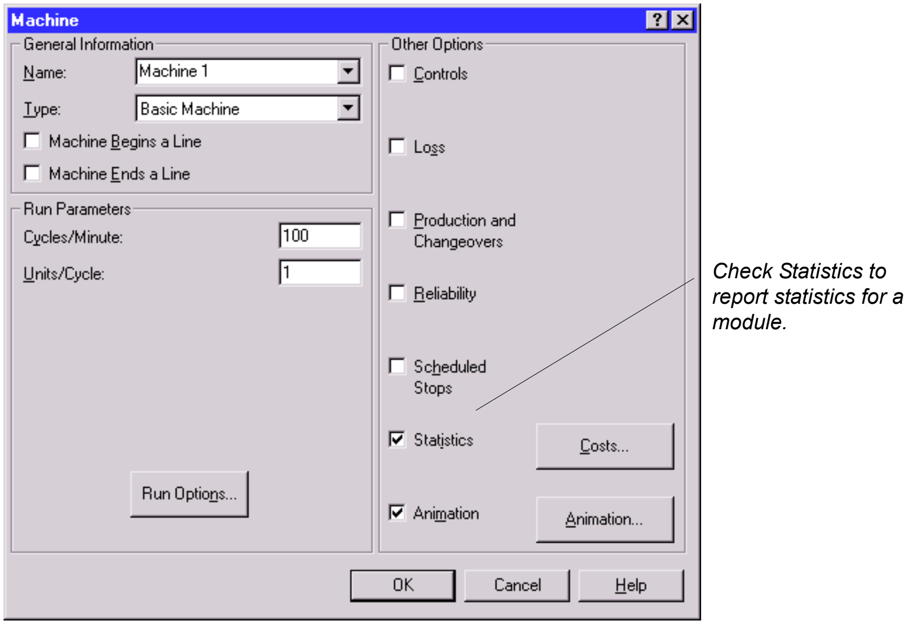
When an Arena Packaging template model (i.e., *.doe* file) is run, the simulation results are stored in a Microsoft Access database (*.mdb*) file by the same name (e.g., the simulation results for *CandyLine.doe* are stored in *CandyLine.mdb*).

Arena Packaging then utilizes Crystal Reports® to display the statistics stored in the report database. The Category Overview report displays information for system resources defined using the Packaging template modules, such as machines, palletizers, conveyors, storages, etc. It also displays information for system resources defined using the Arena template modules.

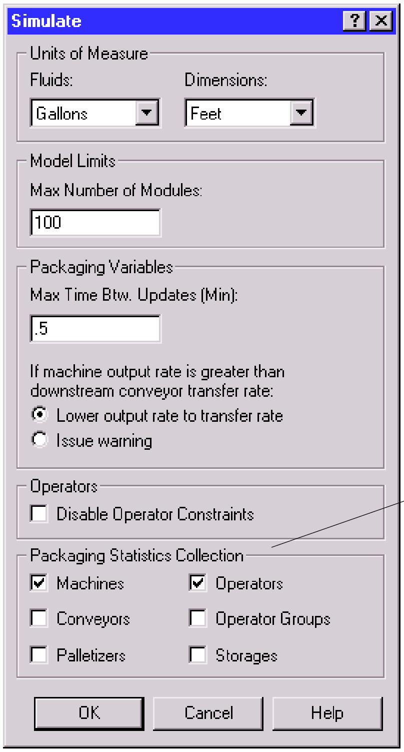
Each major section of the report pertains to a type of system resource (e.g., machines, conveyors, palletizers, storages). Within these sections, statistics are listed by module and grouped into categories. The categories are Description, Unit Summary, Activity Counter, Total Time, Cost, Performance, Usage, and Other.



Module statistics are not generated by default. Instead, Arena Packaging allows you to choose which statistics you want to collect, write to the report database, and see in Crystal Reports. You specify that a module's statistics are included in the reports by selecting the Statistics option in the module dialog box.



It is also easy to turn off statistics for all modules of a particular type (e.g., turn off statistics for all conveyors, or all machines). Within the Simulate module, there are check boxes for collecting statistics on Machines, Conveyors, Palletizers, Operators, Operator Groups, and Storages. When one of those prompts is checked, statistics will be reported for all modules of that type that have their individual module-level statistics check box selected. When one of those prompts is not checked, no modules of that type will have statistics reported, regardless of whether the individual module-level statistics are selected.



Turn on/off statistics for all modules of a particular type in the Simulate module.

Refer to the HSMART examples for Step 4 for more information.

- **Step 4 • View Automatic Statistics**
  - HSMART30: Generating Cost Statistics

Step 5 • Experiment with complex strategies

In the first four steps of the methodology, you built a base model of your system's process; defined basic equipment behavior such as run speeds, loss, and reliability; and performed an initial simulation run.

Once that base model and study are completed, you can utilize additional features in Arena Packaging to experiment with more complex strategies and issues in your line. For discussion purposes, these strategies and feature sets have been divided into five main topics.

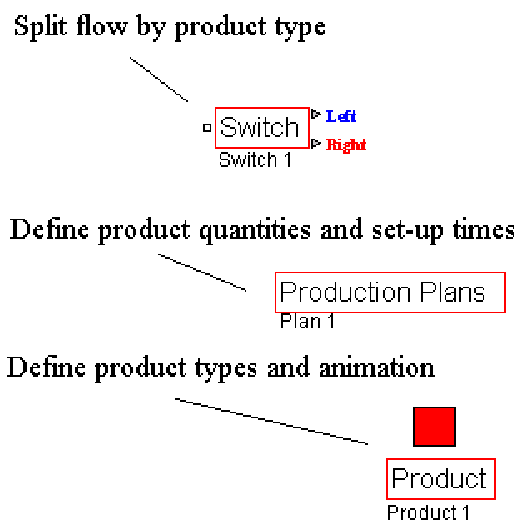
The five topics are introduced briefly below.

- **Products, production plans, and changeovers**

  By default, the Arena Packaging template's algorithms simulate the flow of a "generic" or single product type through the system. Optionally, you can model the flow of multiple product types and thus incorporate product-related issues such as changeovers, set-up times, product-dependent run speeds, etc.

  The Product and Production Plans modules are available for defining multiple products processed in a system and their requirements. The Production and Changeovers option in Machine and Palletizer modules is where you assign changeover times or production plan data to those elements.

  The Switch module can be used to split unit flow based on product type.



- **Scheduled stops**

  Arena Packaging has options for defining scheduled downtimes or maintenance for machines, conveyors, and palletizers in the system. Scheduled stops are considered to be planned downtimes and thus are reported and tracked separately from the failures that occur due to equipment reliability. Unlike failures, scheduled stops are also not factored into utilization.

The Scheduled Stops option in Machine, Palletizer, and Conveyor modules is where you define scheduled downtimes for those elements.

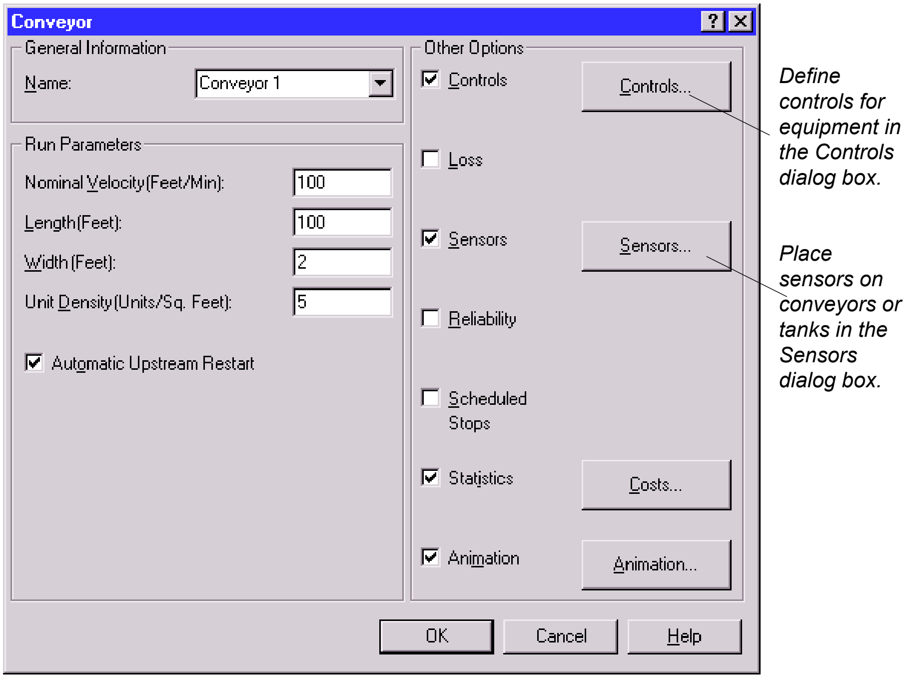
- **Dynamic line control**

Dynamic line control is often necessary for regulating or directing particular situations and events in a system. It can be a critical factor of a line's design, impacting system utilization and performance.

The Arena Packaging template has options for placing controls and sensors on equipment such that the details of your functional control system can be incorporated into the model logic. A control is a function that monitors system status for one or more conditions. When a condition is true, one or more actions can be taken (e.g., change the speed factor of a machine). Sensors are devices that can be placed anywhere along the lengths of conveyors and tanks to monitor accumulation levels of units or fluids. When a sensor is either covered or uncovered, it is triggered and one or more actions can be taken.

The Controls option in Machine, Palletizer, and Conveyor modules is where you define controls for those elements. The Sensors option in Conveyor and Tank modules is where you define sensors for those elements.

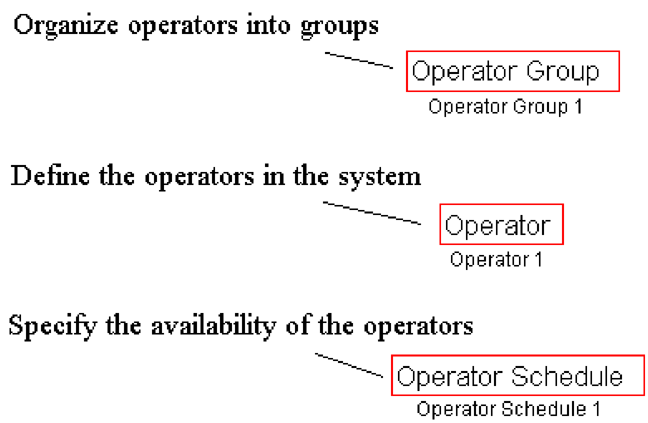
The Actions module is also available for performing actions on the system using discrete entities and logic rather than controls or sensors.



- **Labor**

  The availability and training of personnel connected to a high-speed line can be critical to the line's success. It can have a direct effect on issues such as utilization, machine maintenance, and output.

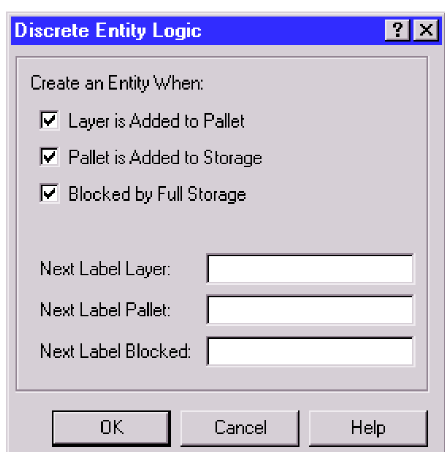
  Arena Packaging provides the Operator, Operator Group, and Operator Schedule modules for modeling the availability and organization of labor in the system. You can assign operators to failure repairs, scheduled stops, and/or changeover activities in the equipment modules.



- **Discrete entity creation and logic**

  The Arena Packaging template supports the modeling of discrete or “low-speed” logic in your system. There are several options for creating entities at discrete times during high-speed simulations, such as when a sensor or control is activated, or when a palletizer completes a pallet.

  The Actions module can also be used to perform actions on the high-speed system (e.g., changing run speeds of machines, opening or closing valves, adding pallets to a storage, etc.) using discrete entities and logic. Therefore, this module facilitates the integration of discrete logic built with constructs from the general-purpose Arena template.



Refer to the HSMART examples for Step 5 for illustrations.

- **Step 5 • Experiment with Complex Strategies**
  - **Operators**
    - HSMART32: Modeling Operators and Operator Groups
    - HSMART33: Modeling Operator Schedules
  - **Control Logic**
    - HSMART34: Adjusting Equipment Speeds Using Controls
    - HSMART35: Adjusting Equipment Speeds Using Conveyor Sensors
    - HSMART36: Adjusting Equipment Speeds Using the Actions Module
    - HSMART37: Writing Detailed Data to Files Using Controls
    - HSMART38: Writing Detailed Data to Files Using Sensors
    - HSMART39: Opening and Closing Valves Using Tank Sensors
  - **Products and Changeovers**
    - HSMART40: Using Products and Production Plans (Plan-based Equipment Changeover)
    - HSMART41: Modeling Equipment Changeovers (Product-based Equipment Changeover)
    - HSMART42: Defining Loss for Changeovers
    - HSMART43: Product Flow Controls Using the Switch Module
    - HSMART44: Adjusting Equipment Speeds Based on Product Type
    - HSMART45: Adjusting Container Volumes at a Filler Based on Product Type
  - **Scheduled Stops**
    - HSMART46: Modeling Scheduled Stops
    - HSMART47: Defining Loss for Scheduled Stops
  - **Integrating with the Arena Template**
    - HSMART48: Creating Discrete Entities
    - HSMART49: Referencing Arena Packaging Template Variables in Arena Modules
    - HSMART50: Modeling the Delivery of Raw Material to an Arena Packaging Template Line
    - HSMART51: Modeling Discrete Deliveries of Fluid to a Tank

3 The Packaging Panel

Panel modules

This chapter contains a detailed description of each of the Packaging panel modules, including prompt descriptions and remarks on module usage.

Actions module

Description

The Actions module is useful for modeling discrete entity logic that alters the status of the system, but which is not directly dependent upon equipment sensors or controls. When an entity enters this module, it performs the set of actions defined in the Actions repeat group. The Actions module is similar to the Actions dialog box found in the Controls and Sensors dialog boxes of Machines, Conveyors, and Palletizers. There is no time delay associated with this module.

Remarks

The Actions dialog boxes found in the Controls and Sensors dialog boxes of Machines, Conveyors, and Palletizers allow you to alter system status when controls and/or sensors are activated. The Actions module provides similar functionality as those Actions dialog boxes in the equipment modules. It provides additional system control by allowing you to initiate actions using discrete entities.

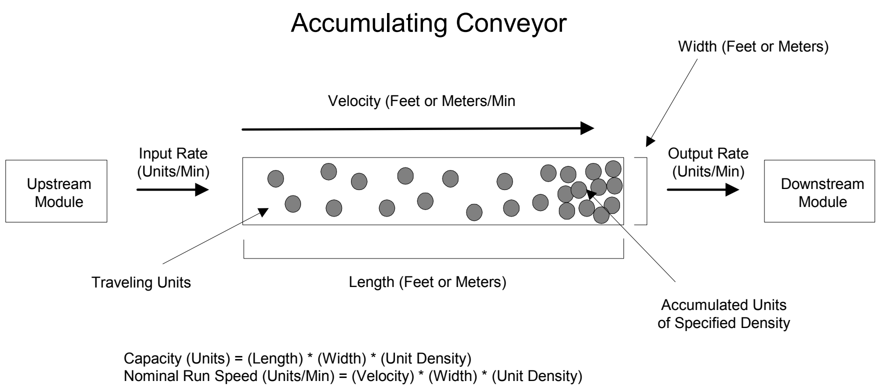
The Arena Packaging template provides a set of Packaging variables for several of the Packaging modules. These special-purpose variables are automatically defined and assigned values over the course of a simulation by the Arena Packaging engine. They reference both dynamic and static information of a modeled system (e.g., equipment run speeds, input and output rates, conveyor accumulation levels, throughput quantities, storage and tank levels, etc.).

Use the Update HiSpeedSim Variables action to make sure that all packaging-related variables reflect the current state before using them. This is especially useful if you will be making decisions based on variable values, writing them, or using them in calculations. Note that the action is named “Update HiSpeedSim Variables” rather than “Update Packaging Variables” to maintain compatibility with models built in earlier versions of the software.

Conveyor module

DESCRIPTION

This module defines the accumulating conveyor elements that move product through the system. Accumulating conveyors allow products to move on the conveyor even if products at the end of the conveyor are stopped. They are typically used as buffers to level out line fluctuations caused by machine stoppages, failures, differences in run speeds, etc. The following figure shows some basic terminology and attributes for accumulating conveyors.



Products enter the conveyor from the upstream module and travel along the conveyor's length. If the Output Rate off of the conveyor is less than the Input Rate onto the conveyor, then products accumulate in front of the downstream module.

You can also specify optional characteristics for conveyors such as sensors, controls, loss, reliability, and scheduled stops.

REMARKS

Refer to the Sensors, Controls, Loss, Reliability, Scheduled Stops, Costs, and Animation dialog boxes for more information on these options.

Accumulating conveyors are always initially active with a speed factor of 1 at the beginning of a simulation run.

A conveyor's run parameters may be specified in either metric or English units of measure, depending on what is selected for Units of Measure in the Simulate module. See the "Simulate module" on page 36 for further information.

Conveyor modules may not be linked directly to other Conveyor modules. The Conveyor Link module must be used to model adjoining conveyors.

To model non-accumulating conveyors, use a Machine module of type Conveyor Machine.

The Split and Merge modules may be used to model splitting product flow across multiple conveyors or merging the product flow of multiple conveyors onto a single conveyor.

The Switch module may be used to direct flow off a single inbound conveyor onto one of two possible outbound conveyors (i.e., flow goes "left" or "right").

Conveyor Link (CLink) module

DESCRIPTION

The Conveyor Link module is used to connect two Conveyor modules directly.

REMARKS

You may open or close a conveyor link using the Actions dialog box to permit or prohibit material from passing between conveyors.

Label module

DESCRIPTION

The Label module may be used to identify a particular portion of the model logic, whereby discrete entities may be sent easily to the label from other locations in the model.

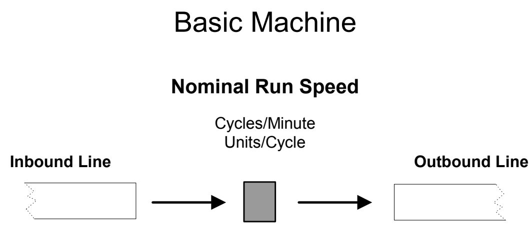
The name of a label module can be referenced in a "Send to Label" field (e.g., in a Sensor dialog box) to send discrete entities to this module. Upon arriving to the Label module, each entity will immediately proceed to the next module that is graphically connected to the Label module's exit point.

Machine module

DESCRIPTION

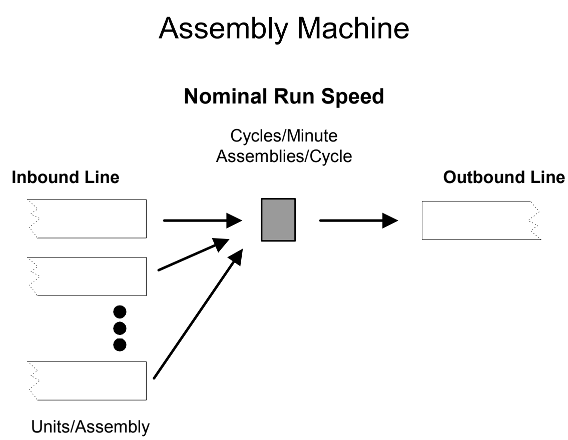
The Machine module defines the processing elements of the system. Four general types of machines are available for modeling purposes. These types are Basic Machines, Assembly Machines, Filling Machines, and Conveyor Machines (standard or single-file). Each is detailed below.

- **Basic Machines** for standard processing. Examples include labeling, inspecting, and packaging operations that do not involve multiple inbound lines. The nominal run speed of the machine is defined in terms of cycles/min and units/cycle. Basic machines do not have capacity; the process is instantaneous and capacity is 0.

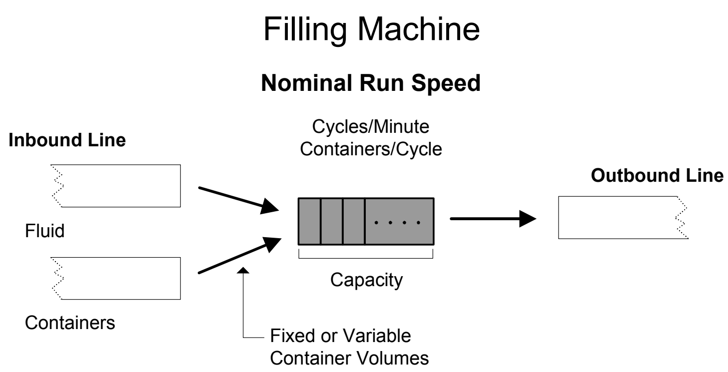


- **Assembly Machines** for merging input from two or more inbound lines (non-fluid). Examples include capping and packaging operations. The nominal run speed of the machine is defined in terms of cycles/min and assemblies/cycle. In addition to the run speed of the assembly operation, output rates from the inbound lines are dependent on the units/assembly required from each line.

  A single inbound line can also be defined for an assembly machine to model a batching operation (e.g., shrink-wrapping inbound units). Assembly machines do not have capacity; the process is instantaneous and capacity is 0.

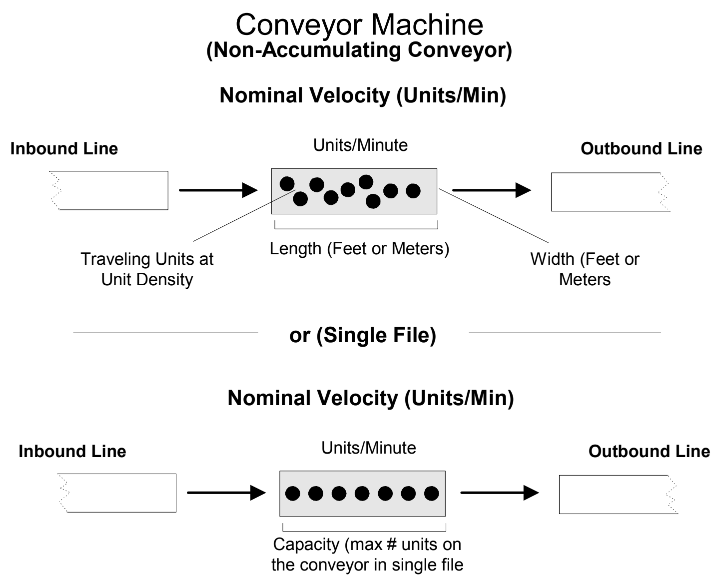


- **Filling Machines** for specifically merging an inbound fluid line (i.e., a tank module) with an inbound container line. The nominal run speed of the machine is defined in terms of cycles/minute and containers/cycle. To model product movement during the filling operation, a Machine Capacity may be specified. The volumes of the containers can be constant (Fixed) or vary by product type (Variable).



- **Conveyor Machines** are useful for modeling processes that involve significant product movement on a non-accumulating conveyor. Examples include washing and drying operations. You may specify the run parameters of the conveyor in two ways. If the units on the conveyor always travel in single file, then you may specify the machine Type as "Conveyor Machine (Single File)" and directly specify the nominal run speed of the machine and its capacity (i.e., max length of the single file). Or, specify the machine Type as simply "Conveyor Machine" and enter the nominal velocity, length, width, and unit density parameters for the conveyor.

See the diagrams below for further illustration of the Conveyor Machine run parameters.



For all the machine types in this module, optional characteristics such as loss, scheduled stops, changeovers, reliability, and controls may be defined.

REMARKS

All of the machine types have the same dialog boxes for Run Options, Controls, Loss, Production and Changeovers, Reliability, Scheduled Stops, Costs, and Animation. Refer to these dialog boxes for more information.

The nominal run speed is usually thought of as the maximum speed at which the machine can maintain a consistent production of quality units.

The module connected to the input line(s) of a Basic, Assembly, or Conveyor Machine must be a Conveyor or Machine Link module. See the "Filling Machines" notes below regarding connecting modules to the inputs of a Filling Machine.

The module connected to the output line of any Machine module must be a Conveyor or Machine Link module.

Machine modules may not be directly linked to other machine modules. Use a Machine Link module to connect two machines directly together (i.e., there is a negligible accumulator between the machines).

Assembly Machines. A maximum of 10 entry lines may be specified for the Assembly Machine type. Note that the first entry line always defines the outbound product name. For example, if units from the first entry line have the product name “bottles,” and units from the second entry line have the product name “caps,” the product name for the assembled units is “bottles.”

Filling Machines. For Filling Machines, the container input line always defines the outbound product name.

The module connected to the fluid input line of a Filling Machine must be a Tank module from either the Packaging or Flow Process panel. The Flow Process Tank module is recommended when modeling advanced tank-related logic such as semi-continuous batch processes feeding a high-speed packaging line.

The module connected to the container input line of a Filling Machine must be a Conveyor or Machine Link module.

If using a filling machine, note that all volumetric data in the model, such as tank capacities, valve maximum rates, and container volumes, must be specified in the same units of measure (e.g., gallons, liters, fluid ounces, etc.).

Conveyor Machines. A Conveyor Machine is a non-accumulating conveyor. You may specify the run parameters of the conveyor in two ways. If the units on the conveyor always travel in single file, then you may specify the machine Type as “Conveyor Machine (Single File)” and directly specify the nominal run speed of the machine and its capacity. Or, specify the machine Type as simply “Conveyor Machine” and enter the velocity, length, width, and unit density parameters for the conveyor.

Machine Link (MLink) module

DESCRIPTION

The Machine Link (ML) module may be used to connect two Machine modules directly. Use this module if there is no buffer between the machines. If accumulation can occur between the machines, then use the Conveyor module to model the accumulator.

A Machine Link module may only be connected to Machine modules. If your logic requires that two non-Machine modules be connected without a buffer in between, then use a Conveyor module. Define the Nominal Velocity to a high rate (e.g., 100,000 feet/min) and the Length, Width, and Unit Density so the conveyor capacity is 1 unit. This approach models a negligible buffer.

Merge module

DESCRIPTION

The Merge module merges two or more incoming streams from accumulating conveyors into a single outgoing stream. A product name may be assigned to the outgoing stream.

REMARKS

Only Conveyor modules can be connected to a Merge module. There is no limit on the number of incoming conveyors that may be connected to the input of the merge.

If the downstream conveyor cannot accept all of the flow from the upstream conveyors, each will be adjusted proportionally. Proportions are recalculated any time any flow rate of any of the conveyors change.

For example, if three conveyors (A, B, and C) each capable of producing 100 units/minute were merged onto a single conveyor with a flow rate of 150 units/minute, then A, B, and C would each have a flow rate of (100 * (150/(100+100+100)) = 50 units/minute. If at a later time, the flow of conveyor A were to stop (perhaps it is starved), then B and C will each be adjusted to a flow rate of (100 * (150/(100+100)) = 75 units/minute.

Operator module

DESCRIPTION

The Operator module defines an operator that may be allocated to activities in the system. Activities include device changeovers (specified in Production and Changeovers dialogs), device repairs (specified in Reliability dialogs), and scheduled stops of devices (specified in Scheduled Stops dialogs).

REMARKS

If a schedule name is specified for an operator, that schedule should be defined using the Operator Schedule module.

The Operators module may be used in conjunction with the Operator Group module to define a set of operators that may be referenced with a common name. For example, the operators Bill, Mary, and Joe may be grouped into a set of operators named Mechanics.

There are three automatic *operator states* for operators: *On-Duty Idle, Working* (or User-Defined), and *Off-Duty*. An operator is in the state *On-Duty Idle* whenever the operator is not busy, but it is on-shift. Upon being allocated to an activity, an operator is automatically assigned the state *Working*. The *Working* state may be replaced with a user-defined state for any activity through a Machine, Conveyor, or Palletizer Operator dialog box (for the specific activity).

The state *Off-Duty* is automatically assigned to an operator when the operator follows an Operator Schedule and that schedule has the operator unavailable. This includes any *Break* and *Lunch* periods specified by the schedule.

If cost statistics are used, operators accrue cost whenever they are available, busy, or in a lunch or break.

If an operator follows an Operator Schedule and is scheduled for either *Off-Duty*, *Lunch*, or *Break* at a specific time, the task will be suspended immediately. The task will wait until the specific operator (or another operator from the group if a group was specified) becomes available. At that point, the task will resume with the remaining time adjusted by the appropriate labor skill factors.

Statistics may be obtained and displayed for operator states by checking the Statistics toggle. Refer to the Statistic dialog box for more information.

The following table summarizes how the states relate to each other, when they are entered, and the costing considerations.

Operator State	When Assigned	Cost Applied?
Working or User-Defined	Upon allocation to any activity	Yes
On-Duty Idle	When the operator is scheduled, but not busy	Yes
Off-Duty (including Lunch and Break)	When operator is unavailable due to the Operator Schedule	Yes–Lunch and Break No–Otherwise

Activities that may require operators include changeovers (specified in Production and Changeovers dialog boxes), failure repairs (specified in Reliability dialog boxes), and scheduled stops (specified in Scheduled Stops dialog boxes). Refer to these dialog boxes and the Operators dialog box for information on specifying operator requirements.

Operator Group module

Description

The Operator Group module may be used in conjunction with the Operator module to define a group of operators that may be referenced with a common name. For example, the operators Bill, Tom, and Joe may be grouped into a set of operators named Mechanics. Statistics for the operator group may be collected and reported by checking the Statistics option.

REMARKS

If an operator is selected for an activity from an operator set, the skill factor of that operator as defined in the Operator Group module will be used for that operator for that activity.

A common use of Operator Groups is to form a group of people who can perform certain tasks. For example, you might have an Electricians group and a Mechanics group. Some tasks might require just an Electrician, some tasks might require just a Mechanic, and some tasks might require multiple Electricians and Mechanics.

Another common use is to create groups of primary and alternate people. For example, you might form a group called Repairmen that consists of Journeyman, Apprentice, and Supervisor (in that order). Then when you specify that an activity needs someone from the Repairmen group, you can specify Preferred Order for the selection rule. This will select Journeyman (if available); otherwise, Apprentice (if available); otherwise, Supervisor. If none are available, it will wait for the first of the three that becomes available.

Operator Schedule module

DESCRIPTION

The Operator Schedule module defines schedules to which operators (individual or groups) can be assigned. The schedule is based on the *planning horizon structure*, with an operator availability state associated with each timeslot. A timeslot is the smallest time period that can be scheduled (e.g., 15 min., 30 min., or 1 hour).

The defined availability states include On-Duty, Lunch, and Break. If a shift does not define one of these states for any period of time, the operator is presumed to be Off-Duty.

REMARKS

By default, all timeslots are initialized to an Off-Duty availability state. Therefore, operator shifts need only be defined for those time intervals that are not Off-Duty.

The starting and ending times for shifts must coincide with the starting and ending times of timeslots within the planning horizon.

Overlapping operator shift intervals are not allowed. For example, a shift from 8:00 AM to 3:00 PM and a shift from 2:00 PM to 5:00 PM on the same day is invalid.

Shifts are defined for each calendar day. Therefore, a shift that spans two days must be defined in two separate segments (e.g., Monday: 8:00 PM – midnight; Tuesday: midnight – 6:00 AM).

An entry must be made in the Daily Schedule for each day of the week, although no shifts need to be defined for any day. For example, if everyone is Off-Duty on the weekends, no shifts need to be defined for Saturday and Sunday, although Saturday and Sunday must appear in the Daily Schedule list.

The beginning of the simulation (time 0.0) is midnight before the first day. If days are specified, the first day simulated will be Monday.

If costing is being applied to operators, costs are assigned only to Working (User-Defined), Lunch, On-Duty Idle, and Break times.

Palletizer module

DESCRIPTION

Palletizers model the physical ends of a line where units are stored onto or removed from pallets. Each module defines either a palletizing or depalletizing piece of equipment. Palletizers are one of the possible interfaces to the discrete world. A palletizer turns individual units from a high-speed process into discrete pallets. A depalletizer turns discrete pallets into units for high-speed processing.

A depalletizer is located at the front of a high-speed line. It removes pallets from storage and then sweeps units off the pallets onto the downstream conveyor. A palletizer is located at the end of a high-speed line. It sweeps units off the upstream conveyor onto pallets, and then places the pallets into storage.

It is important to note that Machine modules may also be used to model basic sources or sinks of a processing line. Machine modules are more efficient than Palletizer modules with regard to model execution speed. Therefore, if an end element can be modeled as a simple “rate-in” or “rate-out” process with reliability, scheduled stop, or changeover constraints, the Machine module is recommended.

Palletizer modules are most useful when:

- Discrete batching of units onto or off of the line is a key issue in your problem solving. The Palletizer module easily allows you to discretize high-speed, high-volume flow into layers and pallets. Discrete entities representing these layers or pallets can be received from or sent to “low-speed” portions of your modeled system.
- You have supply or storage constraints in your model. In conjunction with the Storage module, the Palletizer module allows you to model the starvation of depalletizing equipment at the front of a high-speed line due to inadequate supplies of raw material. Similarly, you can model the blockages of palletizing equipment at the end of a high-speed line due to inadequate storage space for finished product.

REMARKS

Palletizers and depalletizers are always connected to Conveyor modules.

If the Palletizer Type is Palletizer, then units accumulate in front of the Palletizer and are removed at a maximum rate of approximately (Units/Layer)*(Nom. Run Speed) units/min (assuming speed factor of 1) off the conveyor and stored in the storage area (a pallet at a time) until the maximum capacity of the storage area is reached.

Run parameters include the number of units per layer and the number of layers per pallet. The Time Between Layers is the setup time before the next layer can be filled, and the Time Between Pallets is the setup time before the first layer of a pallet can be filled. The palletizer cannot remove units from the upstream conveyor during these delays. Note that filling, time between layers, and time between pallet operations are halted if the speed factor of the palletizer is set to zero (e.g., due to a failure, scheduled stop, or changeover).

There is no module exit label if the Palletizer Type is Palletizer unless one or more discrete entity options are enabled.

A Palletizer may be initially active or inactive, depending on what is specified in the Run Options dialog box.

Storage capacity is assumed to be infinite unless a Storage module specifies a limit.

If the Palletizer Type is Depalletizer, then units are introduced from the Palletizer into the accumulation conveyor (or Machine Link) at the rate of approximately (Units/Layer) * (Nom. Run Speed) units/min (assuming speed factor of 1), unless the Palletizer is shut down or there is no inventory in the storage area. The run parameters of the Depalletizer are similar to the Palletizer, with the difference being that units are getting introduced back into the system from storage rather than being removed.

There is no module entry label if the Palletizer Type is Depalletizer.

A Depalletizer initially may be active or inactive, depending on what is specified in the Run Options dialog box.

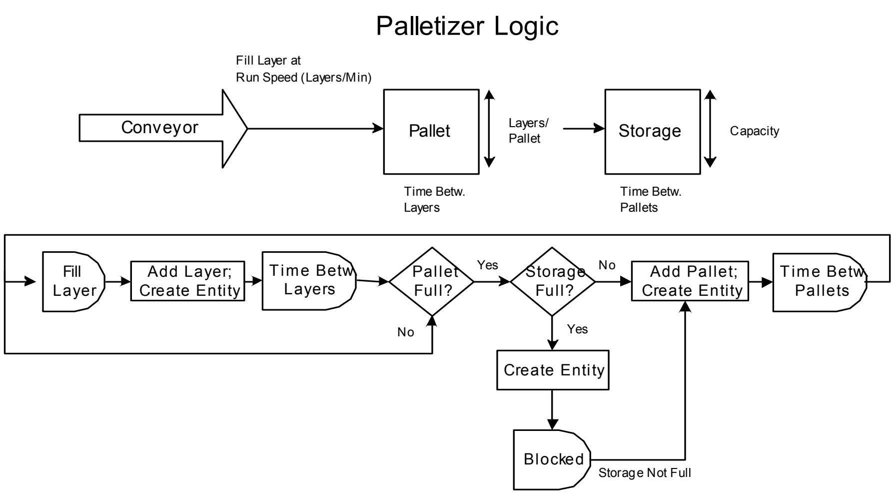
The inventory in Storage Name may also be incremented or decremented (by pallets) independent of the palletizer's operation via the Actions dialog box or Actions module. Refer to the Actions dialog box description for more information.

Refer to the Controls, Loss, Reliability, Run Options, and Scheduled Stops dialog boxes for more information on these options.

Both types of palletizers interface between discrete operations and non-discrete, high-speed unit flow. Because each discrete operation causes system updates, use of a palletizer with many discrete operations can slow the execution speed of the entire model. Often the internal workings of a palletizer are not important to the system being modeled. If this is the case, model execution speed can be improved dramatically by reducing the discrete interactions to the minimum level. One way of doing this is to assume (for modeling purposes) that there is only one layer per pallet. Then set Units/Layer to the total number of units on a pallet, Time Between Layers to 0.0, and Layers/Pallet to 1.0. Of course, if the internal workings of the palletizer are important, then you should use all the available options to model it accurately.

PALLETIZER LOGIC

The following diagram and discussion illustrate the detailed internal workings of a palletizer.



First, the palletizer takes units off the upstream conveyor at its run speed and fills a layer. The run speed of the palletizer is calculated as follows:

Run Speed (layers/min) = Nom. Run Speed (layers/min) * Sf

or

Run Speed (units/min) = Nom. Run Speed (layers/min) * Sf * Units/Layer.

S_f is the speed factor of the palletizer. The speed factor can be dynamically assigned values using the Change Speed Factor of Palletizer action. Nom. Run Speed and Units/Layer are defined in the Run Parameters section of the Palletizer main dialog box.

3 • Packaging Panel

As an example, suppose a palletizer has a Nom. Run Speed of 3 layers per minute and the Units/Layer is 150. Assume the speed factor of the palletizer is 1. When filling a layer, the palletizer takes units off the conveyor at a rate of 450 units per minute (i.e., 3 layers/min * 150 units/layer). Therefore, if enough units are available on the conveyor, it takes 20 seconds to fill a layer.

After a layer is filled, the palletizer can delay for a specified amount of time (i.e., the Time Between Layers). Normally, this period represents the time required to sweep the layer of units onto the pallet. It can also represent any other type of time required before the next layer is filled.

The Time Between Layers is defined in the Run Parameters section of the Palletizer main dialog box. It can be a constant or sampled from a random distribution. Note that the input rate of the palletizer is zero during the Time Between Layers. A palletizer only accepts units from the upstream conveyor when it is filling a layer.

After Time Between Layers, the palletizer checks whether the pallet is full. The Layers/Pallet parameter defines the pallet size. If the number of layers on the pallet is fewer than Layers/Pallet, then the palletizer starts filling another layer. If the number of layers on the pallet is equal to Layers/Pallet (i.e., the pallet is full), then the palletizer tries to place the completed pallet into storage.

The Storage Name operand in General Information specifies the location where pallets are stored. This operand may or may not reference the name of a Storage module. If Storage Name *does not* reference a Storage module, the palletizer assumes an infinite pallet capacity for the storage. In this case, the pallet is automatically added to the storage. The palletizer can also create a discrete entity when a pallet is added.

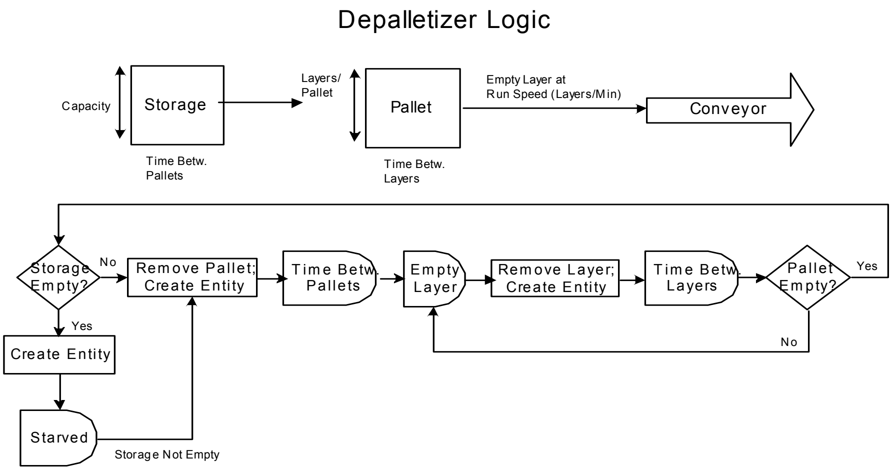
If Storage Name *does* reference a Storage module, then the palletizer must check whether the storage is full before adding the pallet. Storage modules have a pallet capacity. If the storage is full, then the palletizer cannot add the pallet and it is *blocked*. It remains blocked until space is available in the storage. Note that in Discrete Entity Logic you can create a discrete entity when a palletizer is blocked.

After a pallet is stored, the palletizer can delay for a specified amount of time (i.e., the Time Between Pallets). Normally, this period represents the time required to store the pallet and then setup the next one. It can also represent any other type of time required before the first layer of the next pallet is filled.

The Time Between Pallets is defined in the Run Parameters section of the Palletizer main dialog box. It can be a constant or sampled from a random distribution. Note that the input rate of the palletizer is still zero during the Time Between Pallets. A palletizer only accepts units from the upstream conveyor when it is filling a layer.

DEPALLETIZER LOGIC

The figure below illustrates the basic operating behavior and characteristics of a depalletizer:



The operation is parallel to the operation discussed previously for palletizers.

Product module

DESCRIPTION

The Product module defines the name of a product being produced in the system. Product names may be referenced for changeovers, switches, production plans, and may be assigned to product names in a model. Example names include “candy bars,” “demo boxes,” “packaging,” “16 ounce,” “32 ounce,” etc.

REMARKS

Product names entered into this module are placed onto a product name drop-down list.

If product names are not defined or referenced in the model, the Arena Packaging template assumes a single generic product is being produced. Thus, Product and Production Plans modules are not required in a model. These modules are useful if different products are being processed in the system and there is product-dependent logic (e.g., changeovers or product-dependent run-speeds, etc.). You must place one Product module for each product referenced in your model.

If you double-click on the default product animation (a red box), you can replace or customize it to display your own product.

Production Plans module

Description

The Production Plans module defines the parameters for production plans. These plans may be referenced and implemented by machines via the Production and Changeovers dialog box.

Remarks

If a machine is using a product plan, then the plan is executed as follows:

1. Incur the setup time.
2. Produce quantity of product name.
3. Go to next step in plan.

When all the steps of a plan are finished, the process automatically loops back to the first step in the plan until the simulation run is complete.

During the setup time, the state of the equipment is set to *Changeover*.

Refer to the Production and Changeovers dialog box for more information on how a machine implements a production plan.

Simulate module

Description

The Simulate module defines advanced run options for a simulation experiment such as units of measure, model limits, and statistics collection.

This is a required module.

Remarks

In previous versions of this software, the Simulate module also defined project and run parameters such as analyst name, project title, number of replications, and replication length. That information is now defined in Arena's **Run > Setup** tab.

The Module Array Size fixes the maximum number of devices you can place in a model. This number may have to be increased for large models.

Split module

DESCRIPTION

The Split module splits a single incoming product stream into two or more outgoing streams. Percentages are used to determine the outbound flow proportions. Outbound product names may also be assigned.

REMARKS

The sum of all the specified percentages must equal 100% or a run-time error will result.

A Fixed Split will always divide the product with the exact percentages you have specified. It will not maximize flow, but rather, will reduce the output of all branches as necessary to maintain the specified percentages. For example, assume you have two incoming conveyors with maximum flows of 100 and 200, and an outbound conveyor with maximum flow of 300. If you specify a 40%/60% fixed split, then the output of the second conveyor would be limited to ((60/40) * 100) = 150. If any outbound conveyor cannot accept product (perhaps due to accumulation or equipment failure), then all output from the Split will be turned off.

An Adjustable Split will automatically adjust the output of each branch to maximize flow. It will account for any constraints while attempting to achieve the designated percentages. For example, if you have three conveyors each designated at 33.33% and one conveyor is stopped, then the other two conveyors will each get 50% of the flow. A special case of the Adjustable Split is available if you specify 100% for one line and 0% for every other output. This is useful for modeling primary and secondary flow (such as a surge table or backup line) where the secondary line is only used when the primary line is unable to take the full Split output.

Storage module

DESCRIPTION

The Storage module allows you to specify the parameters of a storage area as well as animation and statistics. The Storage module is used in conjunction with the Palletizer module. If a Storage module is not placed, then the default storage area has infinite capacity and no animation.

REMARKS

In many cases, the storage is not a significant part of the model. If an infinite capacity storage with no statistics or animation is acceptable, then no Storage module is necessary.

One way to keep a depalletizer's storage replenished is to create an entity every time it becomes empty, then make a connection from the *Storage is Empty* connection point to the discrete logic that represents the activities necessary to replenish the storage (for example, a Server module). Then that entity could connect to the *Add a Pallet* connection point. If you wanted to add several pallets at a time, instead of using the Add a Pallet connection, you would connect to an Actions module and specify the Add Pallets to Storage action.

Likewise, you can use discrete logic to keep a Palletizer's storage full. Simply create an entity every time it becomes full, then make a connection from the Storage is Full connection point to the discrete logic that represents the activities necessary to empty the storage (for example a Process module). Then that entity could connect to the Remove a Pallet connection point. If you wanted to remove several pallets at a time, then instead of using the Remove a Pallet connection, you would connect to an Actions module and specify the Remove Pallets from Storage action.

Refer to the Discrete Entity Logic dialog box in the Palletizer module for other related options for creating discrete entities.

Switch module

DESCRIPTION

The Switch module may be used to regulate the flow of a single incoming stream into two outgoing streams (a "left" stream and "right" stream). The flow can be regulated either by product waves, by discrete action, or by unit counts. There may be a delay time associated with the switch.

REMARKS

If *Switch On Product Name* is specified, any unlisted product name that comes through the switch will always go to the left branch.

If the switch Type is Action, then a "Change Direction of Switch" action in an Actions dialog box or the Actions module may be used to alter the direction of the switch.

Tank module

DESCRIPTION

The Tank module may be used to represent a container or holding area for any fluid-like material. It is typically used in combination with one or more valves and a filling machine.

REMARKS

Tanks may only be connected directly to valves or a filling machine. A common configuration is to have a valve controlling flow into a tank, which is in turn connected to a filling machine.

Units of measure for the fluid volumes may be specified in the Simulate module.

Valve module

DESCRIPTION

The Valve module regulates the flow of fluids into or out of a tank, or between two tanks.

REMARKS

You can open or close a valve using an "Open Valve" or "Close Valve" action in an Actions dialog box or the Actions module. Units of measure for fluid volumes may be specified in the Simulate module.

Common module dialogs

Many of the Packaging modules have similar sections in the module dialog box user interface. For example, the Machine, Conveyor, and Palletizer modules all include the Reliability dialog box, where you can define the reliability characteristics of the equipment.

We'll now detail these common module dialog boxes.

Actions dialog

DESCRIPTION

The Actions dialog box allows you to specify one or more actions to take that will influence the system operation. The Actions dialog box is found in the Controls and Sensors dialog boxes of Machines, Conveyors, and Palletizers, as well as in the Actions module. The action is activated by the appropriate sensor or control being activated, or by an entity entering the Actions module.

Animation dialog

DESCRIPTION

The Animation dialog box appears in most constructs to provide on-screen indicators of model operation as the simulation executes. Depending on the construct, different options are available. Possible options include a state indicator, blocked/starved symbols, a product picture, and a variables table. In some cases, a module will have an Animation check box without an Animation button/dialog box. This indicates that there is only one type of animation available, and it is enabled/disabled using the Animation check box.

REMARKS

Product symbols must be defined using Product modules before they can be animated with the Product Picture option.

Double-clicking on State Indicators and Product Pictures (Product module) allows you to customize their appearance.

Note that the rate variables displayed in a variables table are always the base time units variables and thus may show different numbers than what is entered as the "per minute" run speed in the module dialog boxes. For example, you might define the nominal run speed of a machine as 100 units per minute in the module dialog box. However, since the variable Name_BaseNomRunSpeed is what is animated in the machine's variables table, if the base time units in Arena's Run > Setup > Replication Parameters is specified as "Hours," then the animation will display a nominal run speed of "6000" (60 minutes * 100 units per minute) at run-time.

The pictures used to animate traveling and accumulated units on conveyors (or conveyor machines) may be customized. By default, the distributed fill level animation shows green disks for traveling units and red disks for accumulated units. You can replace those default disk pictures with customized pictures by enabling the Use Picture option in the Level dialog box. HSMART31 illustrates this feature.

Note that additional animation, such as plots, histograms, and variables, is available from the Animate toolbar.

Controls dialog

DESCRIPTION

The Controls dialog box defines controls for machines (all types), accumulating conveyors, and palletizers. This dialog box specifies when the controls are evaluated, the conditions for each control that is evaluated, and the set of actions taken when all the conditions of a control are true. Multiple controls may be defined for a single machine, conveyor, or palletizer.

REMARKS

Controls are evaluated at discrete times, NOT continously. By default, control conditions are evaluated every time the status of the equipment changes. You can also specify that control conditions are evaluated every X time units or X units processed or conveyed.

More frequent evaluations may make the control more accurate, but also may slow the execution speed of the model. We suggest that you use the check boxes to target evaluation as closely as possible to obtain the accuracy needed without having unnecessary evaluations performed.

A control is activated whenever it is evaluated and becomes true. It is only activated when it changes from false to true. If it stays true across several evaluations, it will only be activated once. It will not be activated again until it first changes to false for at least one evaluation and then back to true again.

Within a single Control, all of the conditions must be true in order to activate the control. In other words, all of the conditions are ANDed together. If you want more complex conditions or conditions that are connected by OR, you may use the Other Condition parameter. This provides additional flexibility for more advanced users to specify any valid conditions.

Costs dialog

DESCRIPTION

The Costs dialog box defines cost rates for calculating the total cost of a piece of equipment or operator accrued during the simulation run. This dialog box is not applicable if the module's Statistics option has not been selected.

REMARKS

For a description of the statistics reported for each type of module, refer to Chapter 4, "Statistics."

Loss dialog

DESCRIPTION

The Loss dialog box allows you to specify the amount of product that is lost (waste) during device operation. This lost product will show up in the production statistics and the yield statistics. Loss can be specified in two different categories. Event-Based Loss only occurs when a specific event occurs. Production-Based Loss occurs whenever the device is producing product.

REMARKS

The Lost Production percentage can be changed dynamically using a Change Lost Production of Equipment action.

Operators dialog

DESCRIPTION

The Operators dialog box defines the operators required for the processing and delay of a particular activity. These activities include changeovers (specified in Production and Changeovers dialogs), failures (specified in Reliability dialogs), and scheduled stops (specified in Scheduled Stops dialogs). An activity does not begin until all operators are available simultaneously. Priorities may be given to separate activities using the *Priority* field.

The operators for a given activity may include individual operators or members from operator sets.

REMARKS

Individual operators are defined in the Operators module, and operator groups are defined in the Operator Groups module.

The *Operators* repeat group determines the operators required for the processing and delay of the activity. All operators must be available and allocated simultaneously for the activity to begin. After the delay time of the activity, the operators are automatically released.

When an operator becomes available, the *Priority* field for an activity determines the activity to which the operator will be allocated if more than one activity is waiting for the operator. Activities with lower-value priorities are serviced before activities with higher-value priorities. If multiple activities with equal priorities request the same operator, the activity with the longest waiting time is allocated the operator. The *Priority* applies to all operators listed in the *Operators* repeat group.

For example, suppose there is a failure at Machine 1 with a priority of 1, and a failure at Machine 2 with a priority of 2. If both failures require the same operator, and the operator is currently busy, the operator will be allocated to the failure at Machine 1 when the operator becomes available.

After an operator is allocated to the activity, it is assigned the *Operator State* specified. The default state is Working, but may be changed to reflect either the type of activity (i.e., Working on Failures) or the machine/equipment (i.e., Working at Machine 1).

The Operator State is assigned to all operators listed in the Operators repeat group. Refer to the “Operator module” on page 28 for more information on operator states.

Skill factors for operators are defined in the Operator module. If the Skill Adjustment check box is checked, then the inverse of the mean skill factors of these operators is multiplied by the delay time of the activity (e.g., the set-up time of a changeover, the repair time for a failure, etc.). Thus, the higher the skill factor, the shorter time it takes an operator to complete an activity. If multiple operators are specified in the Operators repeat group, and Skill Adjustment is checked, the average skill factor is used.

For example, suppose the operator Bill has a skill factor of 1.2, and the operator Tom has a skill factor of 0.8. If Bill were to do a task that nominally required 10 minutes, and Skill Adjustment is checked, it would take Bill (10 / 1.2) = 8.33 minutes. If Tom were to do that task instead, it would take him (10 / 0.8) = 12.5 minutes. If both Bill and Tom were required for the activity, and Skill Adjustment is checked, then the average skill factor would be (1.2 + 0.8 /2) = 1.0 and the activity would take (10 / 1.0) = 10 minutes.

Operator groups may be specified in the Operators repeat group. A member of an operator group may be specified for an activity in one of two ways. The member of the group may be selected using a selection rule, such as Cyclical, Random, or Preferred Order. With this method, when an operator is required for an activity, the rule is used to select among available operators. If only one member of the group is available at the time, the rule is irrelevant. Cyclical means that the activity load between members of the group will try to be balanced. For example, if three operators are specified in a group, they will be allocated in the following order. First, Operator 1 will be utilized; then Operator 2; and then Operator 3; then 1, 2, 3 and so on. With the Random selection rule, the operator in the group is selected randomly among those available operators. Using the Preferred Order rule, the first operator in the group is always allocated before any other operators.

For example, in a group of three operators, Operator 1 will be allocated if available. If Operator 1 is not available, Operator 2 will be allocated. If both Operators 1 and 2 are not available, Operator 3 will be allocated to the activity.

When selecting from an operator set, a Specific Member may be utilized. Utilizing this method, the member index (or number) within the set is specified. This value is based on the order that the operators in the group are specified in the Operator Group module. The set member may be specified as an expression, which will be evaluated to an integer.

Production and Changeovers dialog

DESCRIPTION

The Production and Changeovers dialog box allows you to specify the parameters for product changeovers. Changeovers can be specified according to a production plan or in response to different products coming from upstream equipment. For both options, you can designate the time required for the change to a particular product, as well as whether operator intervention is required.

Remarks

The check box for changeover operators can be overridden by the Disable Operator Constraints option in the Simulate module.

Suppose that loss occurs as the equipment and product is being produced according to a production plan. If you want the production plan's quantities to refer to the quantities of good units actually sent downstream, reference the plan quantities as Good Units Produced in this dialog box.

Reliability dialog

Description

The Reliability dialog box allows you to define random downtimes (i.e., failures) for machines, conveyors, or palletizers. You can define reliability logic using the expected percent uptime of the equipment, the probability the equipment will not fail over some period (i.e., Reliability Over a Time Span), or individual failure streams.

Remarks

The check box for repair operators can be overridden by the Disable Operator Constraints option in the Simulate module.

During a failure, the state variable of the equipment is set to Failed and the _FailureNumber variable is set to the Failure Number value (if using individual streams) or "1" (if using Expected Uptime or Reliability).

Run Options dialog

Description

The Run Options dialog box allows you to define the initial speed factor of a Machine or Palletizer module.

Remarks

If the Initially Active operand is not checked, the equipment's speed factor will be zero at the beginning of the simulation run. Otherwise, specify the initial speed factor of the equipment in the Initial Speed Factor field.

Scheduled Stops dialog

Description

The Scheduled Stops dialog box defines scheduled downtimes (e.g., maintenance) for machines, conveyors, or palletizers. Scheduled stops are different from failures in that these downtimes are “planned” and do not impact cost or utilization statistics.

Remarks

The check box for stoppage operators can be overridden by the Disable Operator Constraints option in the Simulate module.

Arena Packaging generates the stops in the Scheduled Stops repeat group sequentially as they are listed. If the simulation duration is greater than the sum of the Time Before Stops and Stop Durations, you can repeat the list by checking the Repeat the Stops operand.

During a scheduled stop, the state variable of the equipment is set to Stopped.

Scheduled stops can only occur when a piece of equipment is running (i.e., the speed factor and run speed of the module are greater than zero). If Arena Packaging generates a scheduled stop for a piece of equipment and that equipment is currently stopped (i.e., blocked, failed, or in a changeover), the scheduled stop waits until the equipment begins running before setting the state variable to Stopped and beginning its downtime. The length of the Stop Duration is not affected.

The downtimes of scheduled stops are not included in operating costs or utilization calculations.

Sensors dialog

Description

The Sensors dialog box may be used to define sensors for accumulating conveyors. The sensor locations are defined offset from the conveyor length, in terms of either distance from the downstream end of the conveyor or a percentage of the total conveyor length. Once a sensor has been activated, it may either take actions, create a discrete entity, or do both.

Remarks

Automatic sensors are included that will block the upstream machine (set its speed factor to 0) when the conveyor becomes full. If the Automatic Upstream Restart option is checked on the main dialog box, another sensor is provided that will restart (restore the speed factor) of the upstream machine when the conveyor becomes empty. If you want the upstream machine to restart sooner, simply add a sensor at the appropriate position and specify that it restart the upstream machine when it becomes uncovered.

Similar to a real system, sensors located too close together (including the automatic sensors) can cause oscillation and system degradation. For example, if you locate a sensor at 99% that restarts the upstream machine, this may cause the upstream machine to oscillate between blocked and working.

4 Statistics

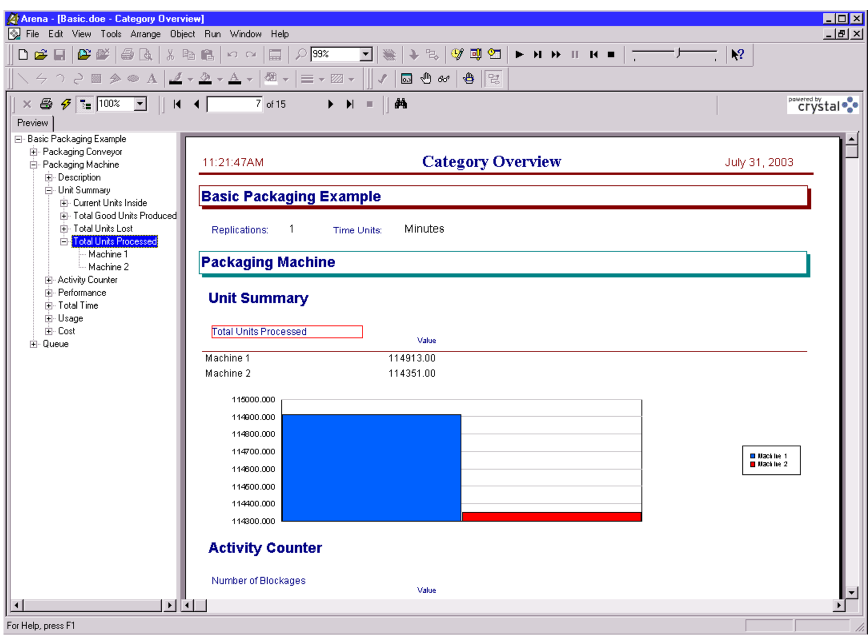
Overview

A primary objective of most simulation studies is to generate statistics about a system's performance so that you can make the "right" decisions.

When an Arena Packaging template model (i.e., *.doe* file) is run, the simulation results are stored in a Microsoft® Access database (*.mdb*) file by the same name (e.g., the simulation results for *CandyLine.doe* are stored in *CandyLine.mdb*).

Arena Packaging then utilizes Crystal Reports® to display the statistics stored in the report database. The Category Overview report (shown below) displays information for system resources defined using the Packaging template modules, such as machines, palletizers, conveyors, storages, etc. It also displays information for system resources defined using the Arena template modules.

Each major section of the report pertains to a type of system resource (e.g., machines, conveyors, palletizers, storages, etc.). Within these sections, statistics are listed by module and grouped into categories. The categories are Description, Unit Summary, Activity Counter, Total Time, Cost, Performance, Usage, and Other.

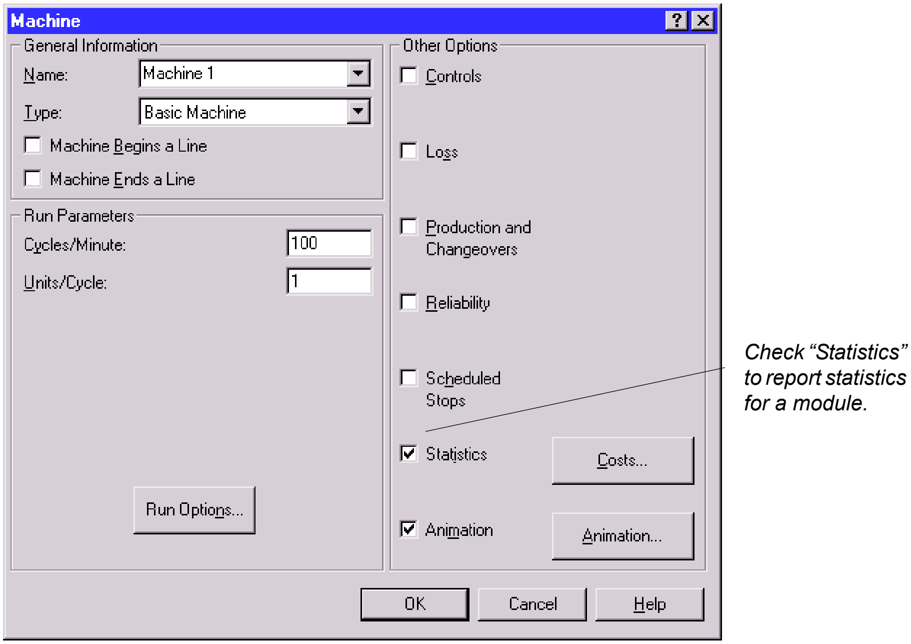


This chapter describes options for selecting the module statistics to collect and report for a simulation run. The statistics that are reported for each module type are also described in detail.

There are two main sections to describe the module statistics. The first is "Selecting the statistics to report," which describes options for selecting the module statistics to collect and report for a simulation run. The second section, "Statistics descriptions," describes the statistics that are reported for packaging-related modules in Arena's Category Overview report. The statistics are described by module (e.g., Machine, Conveyor, Palletizer, etc.).

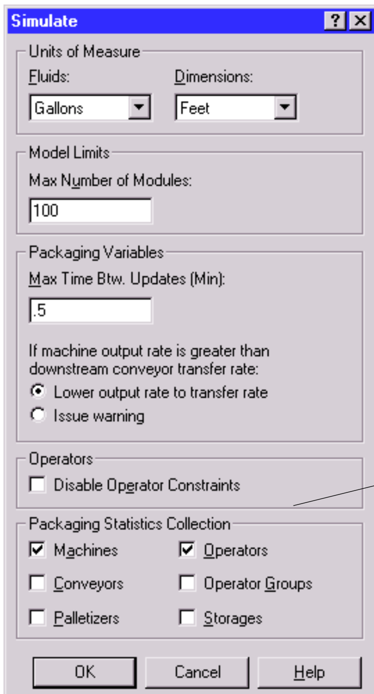
Selecting the statistics to report

Module statistics are not generated by default. Instead, Arena Packaging allows you to choose which statistics you want to collect, write to the report database, and see in Crystal Reports. You specify that a module's statistics are included in the reports by selecting the Statistics option in the module dialog box.



It is also easy to turn off statistics for all modules of a particular type (e.g., turn off statistics for all conveyors or all machines). Within the Simulate module, there are check boxes for collecting statistics on Machines, Conveyors, Palletizers, Operators, Operator

Groups, and Storages. When one of those prompts is checked, statistics will be reported for all modules of that type that have their individual module-level statistics check box selected. When one of those prompts is not checked, no modules of that type will have statistics reported, regardless of whether the individual module-level statistics are selected.



Turn on/off statistics for all modules of a particular type in the Simulate module.

Statistic descriptions

This section describes the packaging statistics that are stored in the report database and displayed in the Category Overview report.

Machine statistics

The Category Overview statistics for a machine are described below. Machine Name refers to the symbol name of the machine entered in the main module dialog box.

Note: All times and rates are reported in base time units.

Description

Nominal Run Speed—This statistic reports the machine's nominal run speed (Units/BaseTimeUnit).

Type—This statistic reports the machine type (i.e., Basic, Conveyor, Assembly, or Filling).

Unit Summary

Total Units Processed—This statistic reports the total number of units, assemblies, or containers that have entered the machine and completed or at least started processing. The following expression holds:

Total Units Processed = Total Good Units Produced + Total Units Lost + Current Units Inside

The value of this statistic is the last value of the machine variable Machine Name_UnitsProcessed.

Total Good Units Produced—This statistic reports the total number of units, assemblies, or containers that completed processing and were produced as good output by the machine.

The value of this statistic is the last value of the machine variable Machine Name_GoodUnitsProd.

Total Units Lost—This statistic reports the total number of units, assemblies, or containers that completed processing but were produced as loss or scrap by the machine.

Current Units Inside—This statistic reports the total number of units that have started processing but are still in the machine at the current time (usually the end of the simulation). This statistic will always be zero for basic and assembly machine types, because those types of machines do not have a capacity.

The value of this statistic is the last value of the machine variable Machine Name_UnitsInside.

Activity Counter

Number of Failures—This statistic reports the number of failures that occurred at the machine.

The value of this statistic is the last value of the machine variable Machine Name_NumFailures.

Number of Changeovers—This statistic reports the number of changeovers that occurred at the machine.

The value of this statistic is the last value of the machine variable Machine Name_NumChangeovers.

Number of Scheduled Stops—This statistic reports the number of scheduled stops that occurred at the machine.

The value of this statistic is the last value of the machine variable Machine Name _NumScheduledStops.

Number of Blockages—This statistic reports the number of blockages that occurred at the machine (i.e., number of times speed factor equaled 0 for reason other than failure, changeover, or scheduled stop).

Performance

Average Speed Factor Greater Than 0—This statistic reports the average speed factor of the machine when the machine was running (i.e., had a speed factor greater than zero). The average speed factor is equivalent to the average run speed of the machine divided by its nominal run speed.

The value of this statistic is the time-weighted average of the machine variable Machine Name_SpeedFactor over the time the machine had a speed factor greater than zero.

Average Output Rate Greater Than 0—This statistic reports the average output rate of the machine when the output rate was greater than zero (Units/BaseTimeUnit).

The value of this statistic is the time-weighted average of the machine variable Machine Name_OutputRate over the time the machine had an output rate greater than zero.

Average Output Factor—This statistic reports the ratio of the Average Output Rate Greater Than 0 statistic to the nominal run speed of the machine.

Yield—This statistic reports the efficiency of the machine for producing good product. This statistic is calculated as follows:

Yield = ((Total Good Units Produced)/(Total Good Units Produced + Total Units Lost)) * 100

Performance Index (PI)—This statistic reports an overall rating for the machine. Under ideal conditions, the PI value is greater than or equal to 100. This statistic is calculated as follows:

PI = ((Yield) * (Utilization) * (Average Output Factor))/100

Therefore, a PI of “100” means that the machine had no loss, and was always delivering product to the downstream process at its nominal run speed during its scheduled time. Normally, the PI for a machine will be less than 100. Locating and eliminating the source of low PI can improve productivity.

Total Time

Total Time Fast—This statistic reports the total time the machine was in the Fast state (i.e., had a speed factor greater than 1).

The value of this statistic is the total time the machine variable Machine Name_State had a value of Fast(-1).

Total Time Working—This statistic reports the total time the machine was in the Working state (i.e., had a speed factor equal to 1).

The value of this statistic is the total time the machine variable Machine Name_State had a value of Working(3).

Total Time Slow—This statistic reports the total time the machine was in the Slow state (i.e., had a speed factor less than 1 and greater than zero).

The value of this statistic is the total time the machine variable Machine Name_State had a value of Slow(4).

Total Time Starved—This statistic reports the total time the machine was in the Fast, Working, or Slow state but was starved (i.e., input rate into the machine was zero).

The value of this statistic is the total time the machine variable Machine Name_Starved had a value of Yes(1).

This statistic is a subset of the time span Total Time Slow + Total Time Working + Total Time Fast.

Total Time Blocked—This statistic reports the total time the machine was in the Blocked state due to being blocked (i.e., had a speed factor of zero for a reason other than a failure, changeover, or scheduled stop).

The value of this statistic is the total time the machine variable Machine Name_State had a value of Blocked(0).

Total Time Failed—This statistic reports the total time the machine was in the Failed state (i.e., was down due to failures).

The value of this statistic is the total time the machine variable Machine Name_State had a value of Failed(1).

Total Time Changeover—This statistic reports the total time the machine was in the Changeover state (i.e., was down due to changeovers).

The value of this statistic is the total time the machine variable Machine Name_State had a value of Changeover(2).

Total Time Stopped—This statistic reports the total time the machine was in the Stopped state (i.e., was down due to scheduled stops).

The value of this statistic is the total time the machine variable Machine Name_State had a value of Stopped(5).

Total Time Speed Factor Greater Than 0—This statistic reports the total time the speed factor of the machine was greater than zero.

Total Time Output Rate Greater Than 0—This statistic reports the total time the output rate of the machine was greater than zero.

USAGE

Utilization—This statistic reports the percentage of time during the simulation run that the machine was actually producing loss and/or good product (i.e., the output rate was greater than zero). Only scheduled time is considered. This statistic is calculated as follows:

> Utilization = (Total Time Output Rate Greater Than 0)/(Simulation Run Length – Total Time Stopped)
>
> where
>
> Simulation Run Length is the duration of the simulation run and Total Time Stopped is the reported total time the machine was in a scheduled stop.

COST

Equipment Operating Cost—This statistic reports the fixed operating cost of the machine over its scheduled time. This statistic is calculated as follows:

> Equipment Operating Cost = (Simulation Run Length – Total Time Stopped) * (Cost/Hour)
>
> where
>
> Simulation Run Length is the duration of the simulation run, Total Time Stopped is the reported total time the machine was in scheduled stops, and Cost/Hour is the cost factor entered in the Costs dialog box.

Cost of Good Product—This statistic reports the variable cost of producing good product at the machine. This statistic is calculated as follows:

> Cost of Good Product = Total Good Units Produced * Cost/Good Unit
>
> where
>
> Total Good Units Produced is the reported total of good units produced by the machine, and Cost/Good Unit is the cost factor entered in the Costs dialog.

Cost of Lost Product—This statistic reports the variable cost of producing lost product at the machine. This statistic is calculated as follows:

> Cost of Lost Product = Total Units Lost * Cost/Lost Unit
>
> where
>
> Total Units Lost is the reported total of units lost at the machine, and Cost/Lost Unit is the cost factor entered in the Costs dialog box.

Total Cost—This statistic reports the total operating cost of the machine. This statistic is calculated as follows:

Total Cost = Equipment Operating Cost + Cost of Good Product + Cost of Lost Product

Conveyor statistics

The Category Overview statistics for a conveyor are described below. Conveyor Name refers to the symbol name of the conveyor entered in the main module dialog box.

Note: All times and rates are reported in base time units.

DESCRIPTION

Capacity—This statistic reports the total number of units the conveyor can hold at any given time. This value is calculated using the following equation: unit density * length * width.

Nominal Run Speed—This statistic reports the nominal transfer rate of the conveyor (Units/BaseTimeUnit). This value is calculated using the following equation: unit density * width * nominal belt velocity.

UNIT SUMMARY

Total Units Conveyed—This statistic reports the total number of units (good and lost) that were taken off the conveyor. The following expression holds:

Total Units Conveyed = Total Good Units Conveyed + Total Units Lost

The value of this statistic is the last value of the conveyor variable Conveyor Name_UnitsConveyed.

Total Good Units Conveyed—This statistic reports the total number of good units that have been taken off the conveyor.

The value of this statistic is the last value of the conveyor variable Conveyor Name_GoodUnitsConveyed.

Total Units Lost—This statistic reports the total number of units that were taken off the end of the conveyor as loss or scrap.

Current Units Inside—This statistic reports the total number of units still on the conveyor at the current time (usually the end of the simulation).

The value of this statistic is the last value of the conveyor variable Conveyor Name_UnitsInside.

ACTIVITY COUNTER

Number of Failures—This statistic reports the number of failures that occurred at the conveyor.

The value of this statistic is the last value of the conveyor variable Conveyor Name_NumFailures.

Number of Scheduled Stops—This statistic reports the number of scheduled stops that occurred at the conveyor.

The value of this statistic is the last value of the conveyor variable Conveyor Name_NumScheduledStops.

Number of Blockages—This statistic reports the number of blockages that occurred at the conveyor (i.e., number of times speed factor equaled 0 for reason other than failure or scheduled stop).

PERFORMANCE

Average Units On When Speed Factor Equaled 0—This statistic reports the average number of units on the conveyor during the periods when the speed factor of the conveyor was zero (i.e., the conveyor was failed or in a scheduled stop, or the conveyor was blocked).

The value of this statistic is the time-weighted average of the conveyor variable Conveyor Name_UnitsInside over the time the conveyor had a speed factor of zero.

Average Units Traveling—This statistic reports the average number of units traveling on the conveyor when the conveyor was running (i.e., had a speed factor greater than zero).

The value of this statistic is the time-weighted average of the conveyor variable Conveyor Name_UnitsTraveling over the time the conveyor had a speed factor greater than zero.

Average Units Accumulated—This statistic reports the average number of units accumulated on the conveyor when the conveyor was running (i.e., had a speed factor greater than zero).

The value of this statistic is the time-weighted average of the conveyor variable Conveyor Name_UnitsAccumulated over the time the conveyor had a speed factor greater than zero.

Average Input Rate—This statistic reports the average input rate of units onto the conveyor when the conveyor was running (i.e., had a speed factor greater than zero).

The value of this statistic is the time-weighted average of the conveyor variable Conveyor Name_InputRate over the time the conveyor had a speed factor greater than zero.

Average Good Output Rate—This statistic reports the average good output rate of units off the conveyor when the conveyor was running (i.e., had a speed factor greater than zero).

The value of this statistic is the time-weighted average of the conveyor variable Conveyor Name_GoodOutputRate over the time the conveyor had a speed factor greater than zero.

Average Supply Time—This statistic reports the average time the conveyor could supply units to the downstream process if the upstream process stopped. Only time that the conveyor was running (i.e., had a speed factor greater than zero) is considered. This statistic is calculated as follows:

Average Supply Time = (Average Units Traveling + Average Units Accumulated)/Average Good Output Rate

Average Buffer Time—This statistic reports the average time the conveyor could accept units from the upstream process if the downstream process stopped. Only time that the conveyor was running (i.e., had a speed factor greater than zero) is considered. This statistic is calculated as follows:

Average Buffer Time = (Capacity - Average Units Traveling - Average Units Accumulated) /Average Input Rate

where

Capacity is the capacity of the conveyor in units.

Average Speed Factor Greater Than 0—This statistic reports the average speed factor of the conveyor when the conveyor was running (i.e., had a speed factor greater than zero). The average speed factor is equivalent to the average run speed of the conveyor divided by its nominal run speed.

The value of this statistic is the time-weighted average of the conveyor variable Conveyor Name_SpeedFactor over the time the conveyor had a speed factor greater than zero.

Yield—This statistic reports the efficiency of the conveyor for transferring good product. This statistic is calculated as follows:

Yield = ((Total Good Units Conveyed)/(Total Units Conveyed)) * 100

Performance Index (PI)—This statistic reports an overall rating for the conveyor. Under ideal conditions, the PI value is greater than or equal to 100. This statistic is calculated as follows:

PI = ((Yield) * (Utilization) * (Average Speed Factor))/100

Therefore, a PI of "100" means that the accumulating conveyor had no loss and was always running at its nominal run speed during its scheduled time. Normally, the PI for a conveyor will be less than 100. Locating and eliminating the source of low PI can improve productivity.

TOTAL TIME

Total Time Fast—This statistic reports the total time the conveyor was in the Fast state (i.e., had a speed factor greater than 1).

The value of this statistic is the total time the conveyor variable Conveyor Name_State had a value of Fast(-1).

Total Time Working—This statistic reports the total time the conveyor was in the Working state (i.e., had a speed factor equal to 1).

The value of this statistic is the total time the conveyor variable Conveyor Name_State had a value of Working(3).

Total Time Slow—This statistic reports the total time the conveyor was in the Slow state (i.e., had a speed factor less than 1 and greater than zero).

The value of this statistic is the total time the conveyor variable Conveyor Name_State had a value of Slow(4).

Total Time Starved—This statistic reports the total time the conveyor was in the Fast, Working, or Slow state but was starved.

The value of this statistic is the total time the conveyor variable Conveyor Name_Starved had a value of Yes(1).

This statistic is a subset of the time span Total Time Slow + Total Time Working + Total Time Fast.

Total Time Blocked—This statistic reports the total time the conveyor was in the Blocked state due to being blocked (i.e., had a speed factor of zero for a reason other than a failure or scheduled stop).

The value of this statistic is the total time the conveyor variable Conveyor Name_State had a value of Blocked(0).

Total Time Failed—This statistic reports the total time the conveyor was in the Failed state (i.e., was down due to failures).

The value of this statistic is the total time the conveyor variable Conveyor Name_State had a value of Failed(1).

Total Time Stopped—This statistic reports the total time the conveyor was in the Stopped state (i.e., was down due to scheduled stops).

The value of this statistic is the total time the conveyor variable Conveyor Name_State had a value of Stopped(5).

Total Time Speed Factor Greater Than 0—This statistic reports the total time the speed factor of the conveyor was greater than zero.

Total Time Speed Factor Equaled 0—This statistic reports the total time the speed factor of the conveyor was equal to zero.

Usage

Utilization—This statistic reports the percentage of time during the simulation run that the conveyor was capable of transferring product. Only scheduled time is considered. This statistic is calculated as follows:

> Utilization = (Total Time Speed Factor Greater Than 0)/(Simulation Run Length – Total Time Stopped)
>
> where
>
> Simulation Run Length is the duration of the simulation run and Total Time Stopped is the reported total time the conveyor was in a scheduled stop.

Cost

Equipment Operating Cost—This statistic reports the fixed operating cost of the conveyor over its scheduled time. This statistic is calculated as follows:

> Equipment Operating Cost = (Simulation Run Length – Total Time Stopped) * (Cost/Hour)
>
> where
>
> Simulation Run Length is the duration of the simulation run, Total Time Stopped is the reported total time the conveyor was in scheduled stops, and Cost/Hour is the cost factor entered in the Costs dialog box.

Cost of Good Product—This statistic reports the variable cost of conveying good product off the conveyor. This statistic is calculated as follows:

> Cost of Good Product = Total Good Units Conveyed * Cost/Good Unit
>
> where
>
> Total Good Units Conveyed is the reported total of good units conveyed, and Cost/Good Unit is the cost factor entered in the Costs dialog.

Cost of Lost Product—This statistic reports the variable cost of conveying lost product off the conveyor. This statistic is calculated as follows:

> Cost of Lost Product = Total Units Lost * Cost/Lost Unit
>
> where
>
> Total Units Lost is the reported total of units lost off the conveyor, and Cost/Lost Unit is the cost factor entered in the Costs dialog box.

Total Cost—This statistic reports the total operating cost of the conveyor. This statistic is calculated as follows:

> Total Cost = Equipment Operating Cost + Cost of Good Product + Cost of Lost Product

Palletizer statistics

The Category Overview statistics for a palletizer are described below. Palletizer Name refers to the symbol name of the palletizer entered in the main module dialog box.

Note: All times and rates are reported in base time units.

DESCRIPTION

Layers Per Pallet—This statistic reports the layers per pallet specified for the palletizer.

Units Per Layer—This statistic reports the units per layer specified for the palletizer.

Type—This statistic reports the palletizer type (i.e., palletizer or depalletizer).

Nominal Run Speed—This statistic reports the nominal run speed of the palletizer (Layers/BaseTimeUnit).

UNIT SUMMARY

Total Units Processed—This statistic reports the total number of units that have entered the palletizer when filling layers or have left the depalletizer when emptying layers. The following expression holds:

Total Units Processed = Total Good Units Produced + Total Units Lost

The value of this statistic is the last value of the palletizer variable Palletizer Name_UnitsProcessed.

Total Good Units Produced—This statistic reports the total number of units that entered the palletizer and actually were placed on pallets (i.e., not scrapped). For a depalletizer, it is the number of units taken off the pallets that were actually sent downstream.

The value of this statistic is the last value of the palletizer variable Palletizer Name_GoodUnitsProd.

Total Units Lost—This statistic reports the total number of units that were lost or scrapped by the palletizer.

Total Layers Swept—This statistic reports the total number of layers added to or removed from pallets.

Total Pallets (Un)Stored—This statistic reports the total number of pallets added to or removed from storage by the palletizer or depalletizer respectively.

ACTIVITY COUNTER

Number of Failures—This statistic reports the number of failures that occurred at the palletizer.

The value of this statistic is the last value of the palletizer variable Palletizer Name_NumFailures.

Number of Changeovers—This statistic reports the number of changeovers that occurred at the palletizer.

The value of this statistic is the last value of the palletizer variable Palletizer Name_NumChangeovers.

Number of Scheduled Stops—This statistic reports the number of scheduled stops that occurred at the palletizer.

The value of this statistic is the last value of the palletizer variable Palletizer Name_NumScheduledStops.

Number of Blockages—This statistic reports the number of blockages that occurred at the palletizer (i.e., number of times speed factor equaled 0 for reason other than failure, changeover, or scheduled stop).

PERFORMANCE

Average Speed Factor Greater Than 0—This statistic reports the average speed factor of the palletizer when the palletizer was running (i.e., had a speed factor greater than zero). The average speed factor is equivalent to the average run speed of the palletizer divided by its nominal run speed.

The value of this statistic is the time-weighted average of the palletizer variable Palletizer Name_SpeedFactor over the time the palletizer had a speed factor greater than zero.

Average Output Rate Greater Than 0—This statistic reports the average output rate of the palletizer when the output rate was greater than zero.

The value of this statistic is the time-weighted average of the palletizer variable Palletizer Name_OutputRate over the time the palletizer had an output rate greater than zero.

Average Output Factor—This statistic reports the ratio of the Average Output Rate statistic to the nominal run speed of the palletizer. This statistic is calculated as follows:

Average Output Factor = (Average Output Rate) / (Nominal Run Speed * Units/Layer)

where

Nominal Run Speed (in layers/basetimeunit) and Units/Layer are run parameters entered in the main dialog.

Yield—This statistic reports the efficiency of the palletizer for processing good product. This statistic is calculated as follows:

Yield = ((Total Good Units Produced)/(Total Units Processed)) * 100

Performance Index (PI)—This statistic reports an overall rating for the palletizer. Under ideal conditions, the PI value is greater than or equal to 100. This statistic is calculated as follows:

PI = ((Yield) * (Utilization) * (Average Output Factor))/100

Therefore, a PI of "100" means that the palletizer had no loss, and was always *a*) filling or emptying units at its nominal run speed, *b*) in a Time Between Layer, or *c*) in a Time Between Pallet during its scheduled time. In other words, the palletizer was never starved or blocked or had any changeovers or failures.

Normally, the PI for a palletizer will be less than 100. Locating and eliminating the source of low PI can improve productivity.

TOTAL TIME

Total Time Fast—This statistic reports the total time the palletizer was in the Fast state (i.e., had a speed factor greater than 1).

The value of this statistic is the total time the palletizer variable Palletizer Name_State had a value of Fast(-1).

Total Time Working—This statistic reports the total time the palletizer was in the Working state (i.e., had a speed factor equal to 1).

The value of this statistic is the total time the palletizer variable Palletizer Name_State had a value of Working(3).

Total Time Slow—This statistic reports the total time the palletizer was in the Slow state (i.e., had a speed factor less than 1 and greater than zero).

The value of this statistic is the total time the palletizer variable Palletizer Name_State had a value of Slow(4).

Total Time Starved—This statistic reports the total time the palletizer was in the Fast, Working, or Slow state but was starved.

The value of this statistic is the total time the palletizer variable Palletizer Name_Starved had a value of Yes(1).

This statistic is a subset of the time span Total Time Slow + Total Time Working + Total Time Fast.

Total Time Blocked—This statistic reports the total time the palletizer was in the Blocked state due to being blocked (i.e., had a speed factor of zero for a reason other than a failure, changeover, or scheduled stop).

The value of this statistic is the total time the palletizer variable Palletizer Name_State had a value of Blocked(0).

Total Time Failed—This statistic reports the total time the palletizer was in the Failed state (i.e., was down due to failures).

The value of this statistic is the total time the palletizer variable Palletizer Name_State had a value of Failed(1).

Total Time Changeover—This statistic reports the total time the palletizer was in the Changeover state (i.e., was down due to changeovers).

The value of this statistic is the total time the palletizer variable Palletizer Name_State had a value of Changeover(2).

Total Time Stopped—This statistic reports the total time the palletizer was in the Stopped state (i.e., was down due to scheduled stops).

The value of this statistic is the total time the palletizer variable Palletizer Name_State had a value of Stopped(5).

Total Time Speed Factor Greater Than 0—This statistic reports the total time the speed factor of the palletizer was greater than zero.

Total Time Output Rate Greater Than 0—This statistic reports the total time the output rate of the palletizer was greater than zero (i.e., the palletizer was actually filling or emptying layers with units).

For palletizer-type equipment, it may be easier to think of this statistic as the total time the input rate was greater than zero. The input and output rates of palletizers are always equivalent.

Total Time Between Layers—This statistic reports the total time the output rate (input rate) of the palletizer was zero because of the Time Between Layers specification.

Total Time Between Pallets—This statistic reports the total time the output rate (input rate) of the palletizer was zero because of the Time Between Pallets specification.

Usage

Utilization—This statistic reports the percentage of time during the simulation run that the palletizer was actually filling or emptying layers with units (i.e., the output rate was greater than zero), or was not processing units because of the Time Between Layers and Time Between Pallets specifications. Only scheduled time is considered. This statistic is calculated as follows:

> Utilization = (Total Time Output Rate Greater Than 0 + Total Time Betw. Layers + Total Time Betw. Pallets)/(Simulation Run Length – Total Time Stopped)
>
> where
>
> Simulation Run Length is the duration of the simulation run and Total Time Stopped is the reported total time the palletizer was in a scheduled stop.

Cost

Equipment Operating Cost—This statistic reports the fixed operating cost of the palletizer over its scheduled time. This statistic is calculated as follows:

Equipment Operating Cost = (Simulation Run Length – Total Time Stopped) * (Cost/Hour)

where

Simulation Run Length is the duration of the simulation run, Total Time Stopped is the reported total time the palletizer was in scheduled stops, and Cost/Hour is the cost factor entered in the Costs dialog box.

Cost of Good Product—This statistic reports the variable cost of processing good product at the palletizer (i.e., adding good units to pallets or removing good units from pallets). This statistic is calculated as follows:

Cost of Good Product = Total Good Units Produced * Cost/Good Unit

where

Total Good Units Produced is the reported total of good units processed by the palletizer, and Cost/Good Unit is the cost factor entered in the Costs dialog box.

Cost of Lost Product—This statistic reports the variable cost of losing product at the palletizer. This statistic is calculated as follows:

Cost of Lost Product = Total Units Lost * Cost/Lost Unit

where

Total Units Lost is the reported total of units lost at the palletizer, and Cost/Lost Unit is the cost factor entered in the Costs dialog.

Cost of Layers Swept—This statistic reports the variable cost of layers added to or removed from pallets. This statistic is calculated as follows:

Cost of Layers Swept = Total Layers Swept * Cost/Layer

where

Total Layers Swept is the reported total of layers added to or removed from pallets, and Cost/Layer is the cost factor entered in the Costs dialog box.

Cost of Pallets (Un)Stored—This statistic reports the variable cost of pallets added to or removed from storage. This statistic is calculated as follows:

Cost of Pallets (Un)Stored = Total Pallets (Un)Stored * Cost/Pallet

where

Total Pallets (Un)Stored is the reported total of pallets added to or removed from storage, and Cost/Pallet is the cost factor entered in the Costs dialog.

Total Cost—This statistic reports the total operating cost of the palletizer. This statistic is calculated as follows:

> Total Cost = Equipment Operating Cost + Cost of Good Product + Cost of Lost Product + Cost of Layers Swept + Cost of Pallets (Un)Stored

Storage statistics

The Category Overview statistics for a storage are described below. Storage Name refers to the symbol name of the storage entered in the main module dialog box.

DESCRIPTION

Capacity—This statistic reports the maximum number of pallets the storage can hold.

Initial Inventory—This statistic reports the number of pallets in the storage at the beginning of the simulation.

Cost Per Pallet Per Day—This statistic reports the cost of holding a pallet in the storage for one day.

PERFORMANCE

Storage Level—This statistic reports the maximum, minimum, and average number of pallets in the storage during the simulation.

COST

Total Cost—This statistic is the total cost of storing the pallets in storage. This statistic is calculated as follows:

> Total Cost = Avg. Inventory * Cost/Pallet/Day * Simulation Run Length
>
> where
>
> Avg. Inventory is the reported average number of pallets in storage, and Simulation Run Length is the length of the simulation in days.

Operator statistics

The Category Overview statistics for an Operator module are described below.

DESCRIPTION

Cost Per Hour—This statistic reports the fixed operating cost of the operator per hour. This cost factor is entered in the Costs dialog box.

Skill Factor—This statistic reports the skill factor of the operator.

USAGE

Percent Scheduled—This statistic reports the percentage of total simulation time that the operator was available for equipment repairs, changeovers, or scheduled stops. Essentially, this is the percentage of time that the operator was on duty.

For example, if an operator is on duty for 440 minutes out of 480 simulated minutes, the availability percentage of the operator is 440/480 or 91.67%.

Scheduled Utilization—This statistic reports the percentage of scheduled time that the operator was actually busy working on a failure, changeover, or stop.

For example, suppose an operator was on-duty for 440 minutes out of 480 simulated minutes. If the operator was actually busy for 120 of those 440 minutes, then the operator's scheduled utilization is 120/440 = 27.27%.

COST

Total Cost—This statistic reports the fixed operating cost of the operator over his or her scheduled time. The scheduled time of an operator includes lunch and break times, but not off-duty time. This statistic is calculated as follows:

> Total Cost = (Simulation Run Length – Off-Duty Time) * (Cost/Hour)
>
> where
>
> Simulation Run Length is the duration of the simulation run and Off-Duty Time is the total time the operator is off-duty.

Operator Group statistics

The Category Overview statistics for an operator group are described below.

DESCRIPTION

Number In Group—This statistic reports the number of operators in the operator group.

USAGE

Number Scheduled—This statistic reports the maximum, minimum, and average number of operators in the group that were on duty during the simulation.

Percent Scheduled—This statistic reports the average percentage of the group that was on duty during the simulation. This statistic is calculated as follows:

> Percent Scheduled = 100 * (Average Number Scheduled/Number Operators in Group)

Number Busy—This statistic reports the maximum, minimum, and average number of operators in the group that were busy during the simulation.

Scheduled Utilization—This statistic reports the average percentage of the operators available in the group that were busy during the simulation. This statistic is calculated as follows:

Scheduled Utilization = 100 * (Average Number Busy/Average Number Scheduled)

5 Variables

Overview

Variables are quantities that describe the state of a system. Modeling with the Arena Packaging template often requires the referencing of variables to make control decisions, animate the system state, or write statistics.

The Arena Packaging template provides a set of variables for several of the Packaging modules. These special-purpose variables are automatically defined and assigned values over the course of a simulation by the Arena Packaging engine. They reference both dynamic and static information of a modeled system (e.g., equipment run speeds, input and output rates, conveyor accumulation levels, throughput quantities, storage and tank levels, etc.).

During a simulation, you can assign, update, or reference Arena Packaging template variables for logic or presentation purposes.

This chapter contains a description of each of the Arena Packaging template variables. Special-purpose variables that refer to the standard Arena and SIMAN template constructs can be found in the *Arena Variables Guide* and in Arena's online help.

Organization

Assigning and referencing Arena Packaging template variables

This section discusses the assignment and referencing of Arena Packaging variables. In general, Arena Packaging template variables *are not* user-assignable. However, they can be referenced for animation or control logic purposes.

Updating Arena Packaging template variables

During a model run, Arena Packaging template variables are not updated continuously. By default, they are updated only when current values are required by the Arena Packaging engine. This default updating is sometimes insufficient for use in animation or discrete logic. This section discusses how to update the variables frequently for smoother animation and how to update the variables at discrete times using the Actions module.

Variables

This section contains descriptions of all of the Arena Packaging template variables. The variables are grouped into categories by module (e.g., Machine, Conveyor, etc.).

Assigning and referencing variables

Assigning values to variables

You may not assign values to most of the Arena Packaging template variables. Most variables are automatically tracked and updated by the Arena Packaging engine. In general, Arena Packaging template variables are available for reference and animation purposes only (i.e., status information).

The ONLY Arena Packaging variables to which you may assign values are SpeedFactor and LostProduction for machines, conveyors, and palletizers. Changing these variables allows you to change dynamically both the run speeds of equipment as well as their loss rates.

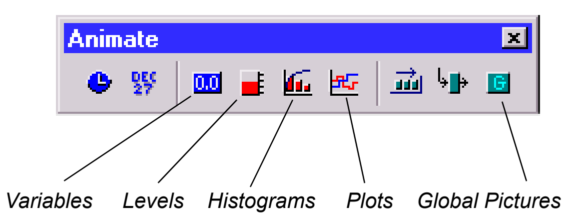
SpeedFactor variables can be assigned values using the Change Speed Factor action in Actions modules or dialog boxes. LostProduction variables can be assigned values using the Change Lost Production action in Actions modules or dialog boxes.

Referencing variables

It is often useful to reference Arena Packaging variables for model animation or control logic purposes.

REFERENCES IN ANIMATION OBJECTS

You can animate Arena Packaging variables using Arena animation objects. This allows you to display graphically the status and dynamics of your processing line, and thus "see" the effects of complex, interrelated aspects of your system. In particular, status displays such as *variables*, *levels*, *histograms*, *global pictures*, and *plots* are especially useful for showing the values of variables in numeric or graphical form. You can add status displays to a model using Arena's Animate toolbar.

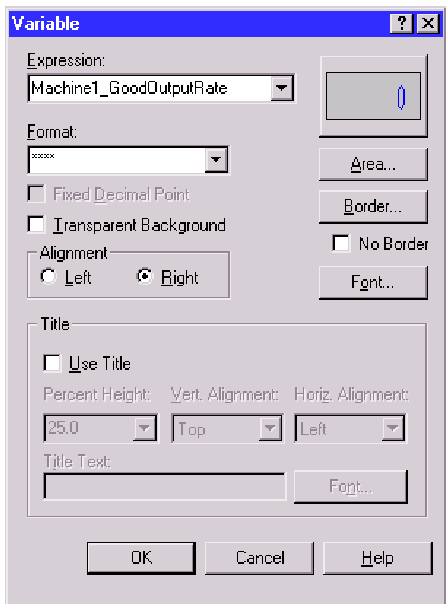


EXAMPLE

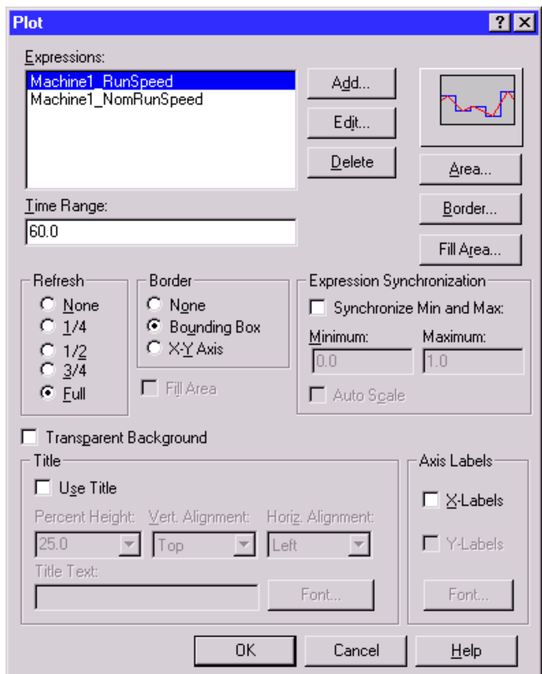
Suppose you have a Machine module in your model named Machine 1. How would you animate the following?

- The output rate of good units from Machine 1 in numeric form.
- The run speed of Machine 1 versus its nominal run speed over time.

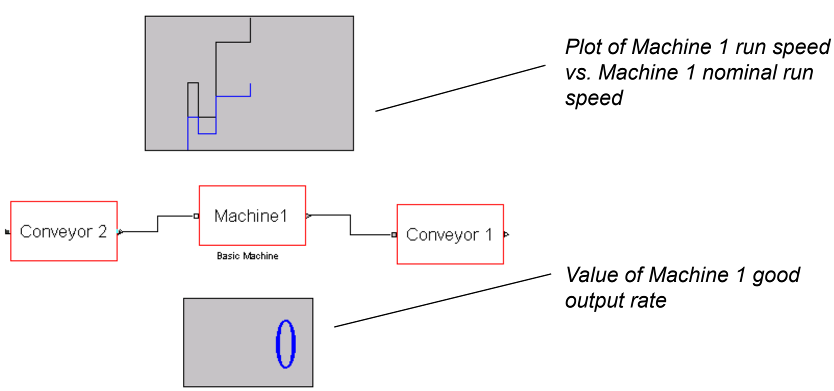
To display the good output rate of Machine 1 in numeric form, you would select the Variables status display from the Animate toolbar and fill in the dialog box as follows:



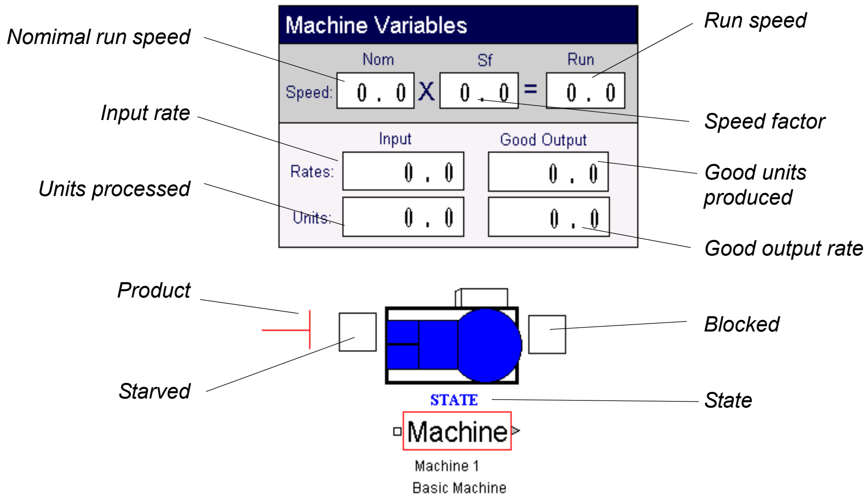
To display the run speed of Machine 1 versus its nominal run speed over time, you would select the Plots status display from the Animate toolbar and fill in the dialog as follows:



Then, you might place the plot and variables status displays in your model window as shown below. The animation will be updated dynamically as the model runs.



The above example shows how to place animation manually. Arena Packaging also has several features for placing default animation of variables automatically. Simply double-click into the main dialog box of a module and check the Animation options. For example, if you selected all the animation options for a basic machine, the following default animation would be placed:



References in Arena and SIMAN template modules

Arena Packaging variables can be referenced in a number of places in the Arena and SIMAN templates. This is useful when integrating discrete system logic using those general-purpose tools. Some examples using modules from the Basic Process and Advanced Process panels are shown below.

- Use the Assign module from Basic Process to assign the values of Packaging variables to your own user-defined variables.
- Use the ReadWrite module from Advanced Process to write the values of Packaging variables to the screen or external files.
- Use the Decide module from Basic Process to branch entities according to conditions based on Packaging variables.
- Use the Hold block from Advanced Process to hold an entity until a condition based on Packaging variables is true.

Essentially, any module that can reference a variable or expression can potentially reference variables for logical purposes. For a detailed discussion of the modules in the Arena template, refer to the *Arena User's Guide* or online help.

References in Arena Packaging template modules

Arena Packaging template variables can also be referenced in certain dialog box prompts of Packaging modules. The two most common areas where the variables are referenced are:

- Control conditions for machines, conveyors, and palletizers.
- Additional conditions for Conveyor sensors.

The variables can also be referenced in any other dialog prompt that accepts an expression.

Note: Take advantage of Arena's Expression Builder. When referencing Arena Packaging variables in a module or animation object, note that the names and syntax of the variables may be accessed easily using Arena's Expression Builder. To load the Expression Builder, first select the expression field you want to edit. Then right-click the mouse and select "Build Expression…" from the right-click menu.

Updating variables

During a model run, Arena Packaging template variables are not updated continuously. By default, they are updated only when current values are required by the Arena Packaging engine for statistical or logical purposes.

This minimization of updates is the most efficient approach in terms of model run speed. However, you may consider it insufficient for animation. In particular, variable values for conveyor accumulation levels and equipment throughputs might appear "choppy" and thus hard to visualize.

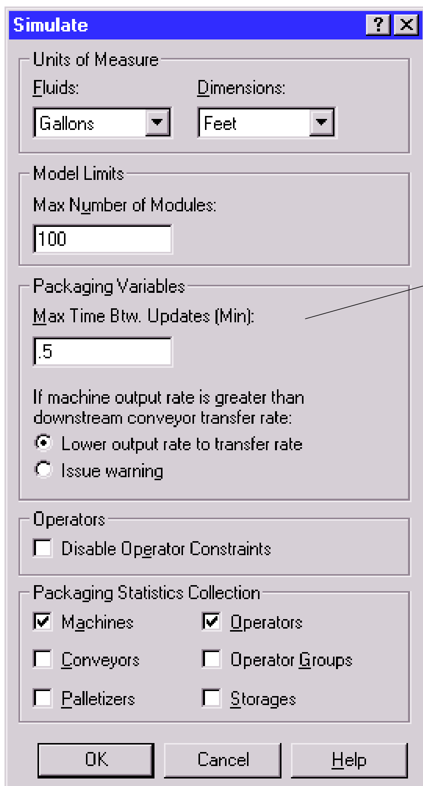
Also, when incorporating discrete logic into your model, an entity may require the current values of variables at a specific time for logical purposes (e.g., branching, assignments, etc.). In these cases, the last values updated by the internal engine could be too outdated.

The next two sections describe features in the Arena Packaging template that address these issues.

Updating variables for animation

Arena Packaging allows you to force regular updates of the Packaging variables (and thus system status) just for animation purposes. You do this by specifying the Max Time Btw. Updates within the Simulate module. These updates are performed in addition to the necessary updates required by the Packaging template's algorithms.

The additional updates have no effect on the statistics generated by the model. However, the more frequent the updating (i.e., the smaller the time interval entered), the slower the model run speed. Because of this, it is recommended that the Max Time Btw. Updates field be set to a high value when only statistics are desired and a low value when smooth animation is desired for a presentation.



The Simulate module allows you to specify regular updates of the Arena Packaging template variables.

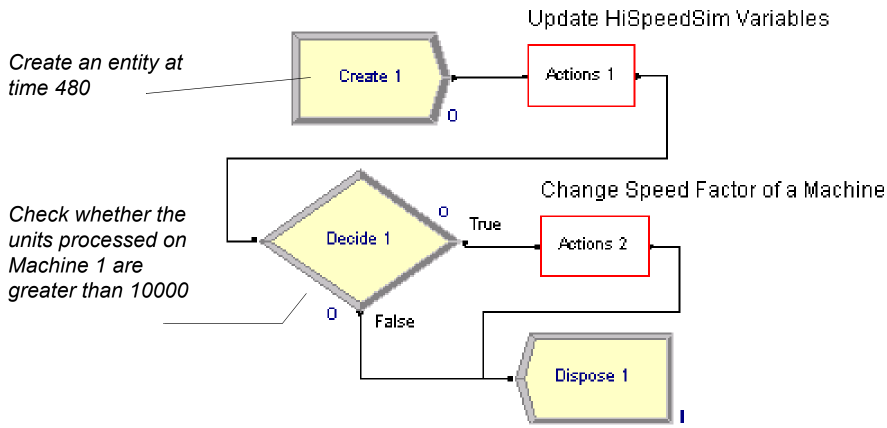
Updating variables at a specific time—The Update action

To update the status of a system discretely, use the Update HiSpeedSim Variables action in the Actions module. This action sets all of the Arena Packaging variables to their current values. Note that the action is named “Update HiSpeedSim Variables” rather than “Update Packaging Variables” to maintain compatibility with previous versions of the software.

EXAMPLE

Suppose you have a Machine module in your model named Machine 1. At time 480, you need to know the exact number of units processed at this machine. If the number of units is greater than 10000, then you want to slow down an upstream machine.

The figure below shows an example submodel for this problem. An entity is created at time 480. It then enters an Actions module where the HiSpeedSim variables (including the variable Machine 1_UnitsProcessed) are updated to their current values. The entity then enters a Decide module from the Arena template where the condition Machine 1_UnitsProcessed>10000 is evaluated. If the condition is true, the entity goes to another Actions module to slow down the machine upstream.



Variables

This section contains descriptions of all the Arena Packaging variables. The variables are grouped into categories by module (e.g., Machine, Conveyor, etc.)

Variable descriptions are organized as follows:

Name of variable

Type of values variable returns. *This is either a unit of measure (e.g., feet, units/min, units) or a discrete set of values (e.g., Yes(1)/No(0)). Note that the numeric equivalents of discrete values are given in ().*

Conveyor Name_Blocked [Yes(1)/No(0)]—Returns whether the conveyor is currently blocked. A conveyor is considered blocked if its speed factor equals zero for any reason other than a failure of scheduled stop.

Description of variable

Conveyor variables

DESCRIPTION

The Arena Packaging template provides variables that access information about each conveyor in the model. Conveyor Name is the symbol name for the conveyor entered in the main module dialog box.

The only variables that are user-assignable are the SpeedFactor and LostProduction variables. The SpeedFactor variable may be assigned values using the Change Speed Factor of Conveyor action in Actions modules or dialog boxes. The LostProduction variable may be assigned values using the Change Lost Production of Conveyor action in Actions modules or dialog boxes.

VARIABLES

Conveyor Name_Blocked [Yes(1)/No(0)]—Returns Yes(1) if the conveyor is in the Blocked state and No(0) otherwise. A conveyor is considered blocked if its speed factor equals zero for any reason other than a failure or scheduled stop.

Conveyor Name_Capacity [Units]—Returns the capacity of the conveyor. The capacity is calculated from the length, width, and unit density of the conveyor entered in the conveyor dialog box (i.e., length * width * unit density).

Conveyor Name_FailureNumber [Integer>=0]—Returns a 0 if the conveyor is not failed. If the failures for the conveyor are defined using Expected Uptime or Reliability logic, this variable will return a 1 when the conveyor is failed. If the failures for the conveyor are defined using individual failure streams, this variable will return the Failure Number of the stream that has failed the conveyor when it is failed.

Conveyor Name_GoodOutputRate [Units/Min]—Returns the current output rate of good units off of the conveyor.

Conveyor Name_BaseGoodOutputRate [Units/BaseTimeUnit]—Returns the current output rate of good units off of the conveyor.

Conveyor Name_GoodUnitsConveyed [Units]—Returns the total number of good units that have been taken off of the conveyor.

Conveyor Name_InputRate [Units/Min]—Returns the current input rate of units onto the conveyor.

Conveyor Name_BaseInputRate [Units/BaseTimeUnit]—Returns the current input rate of units onto the conveyor.

Conveyor Name_Length [Feet or Meters]—Returns the length of the conveyor as entered in the module dialog box.

Conveyor Name_LostProduction [Percentage]—Returns the lost production of the conveyor (0-100%). The initial value of this variable can be specified in the Loss dialog of the conveyor.

Conveyor Name_NomRunSpeed [Units/Min]—Returns the nominal run speed of the conveyor. The nominal run speed is calculated from the nominal velocity, width, and unit density entered in the module dialog (i.e., nominal velocity * width * unit density).

Conveyor Name_BaseNomRunSpeed [Units/BaseTimeUnit]—Returns the nominal run speed of the conveyor. The nominal run speed is calculated from the nominal velocity, width, and unit density entered in the module dialog (i.e., nominal velocity * width * unit density).

Conveyor Name_NumFailures [Integer>=0]—Returns the number of failures that have occurred at the conveyor.

Conveyor Name_NumScheduledStops [Integer>=0]—Returns the number of scheduled stops that have occurred at the conveyor.

Conveyor Name_OutputRate [Units/Min]—Returns the current total output rate of units off of the conveyor, including conveyor loss.

Conveyor Name_BaseOutputRate [Units/BaseTimeUnit]—Returns the current total output rate of units off of the conveyor, including conveyor loss.

Conveyor Name_Product [Product Name (Symbol number of picture)]—Returns the last product type that has been placed on the front of the conveyor.

Conveyor Name_RunSpeed [Units/Min]—Returns the current run speed of the conveyor. The run speed is calculated from the nominal run speed and the speed factor (i.e., nominal run speed * speed factor).

Conveyor Name_BaseRunSpeed [Units/BaseTimeUnit]—Returns the current run speed of the conveyor. The run speed is calculated from the nominal run speed and the speed factor (i.e., nominal run speed * speed factor).

Conveyor Name_SpeedFactor [Real>=0]—Returns the current speed factor of the conveyor.

Conveyor Name_Starved [Yes(1)/No(0)]—Returns whether the conveyor is currently starved. A conveyor is considered starved if its speed factor is greater than zero and the output rate of the upstream module equals zero.

Conveyor Name_State [Fast(-1)/Working(3)/Slow(4)/Blocked(0)/Failed(1)/Stopped(5)]—Returns the current state of the conveyor. The six states are exclusive (i.e., the conveyor can only be in one of these states at any given time). A conveyor is in the Fast state if its speed factor is greater than 1. A conveyor is in the Working state if its speed factor is equal to 1. A conveyor is in the Slow state if its speed factor is less than 1 and non-zero. A conveyor is in the Blocked state if its speed factor is zero and the conveyor is not Failed or Stopped.

Conveyor Name_UnitsAccumulated [Units]—Returns the number of units currently accumulated on the conveyor (i.e., units that have stopped moving and are packed at unit density).

Conveyor Name_UnitsConveyed [Units]—Returns the total number of units that have been taken off of the conveyor.

Conveyor Name_UnitsInside [Units]—Returns the number of units currently on the conveyor (i.e., UnitsAccumulated + UnitsTraveling).

Conveyor Name_UnitsTraveling [Units]—Returns the number of units currently traveling on the conveyor.

Conveyor Name_Width [Feet or Meters]—Returns the width of the conveyor as entered in the module dialog box.

Conveyor Link variable

DESCRIPTION

Arena Packaging provides a variable that accesses whether a conveyor link is open or closed. Conveyor Link Name is the symbol name for the conveyor link entered in the main module dialog box.

The variable is not user-assignable.

VARIABLE

Conveyor Link Name_State [Open(1)/Closed(0)]—Returns the current state of the conveyor link.

Machine variables

DESCRIPTION

The Arena Packaging template provides variables that access information about each machine in the model. Machine Name is the symbol name for the machine entered in the main module dialog box.

The only variables that are user-assignable are the SpeedFactor and LostProduction variables. The SpeedFactor variable may be assigned values using the Change Speed Factor of Machine action in Actions modules or dialog boxes. The LostProduction variable may be assigned values using the Change Lost Production of Machine action in Actions modules or dialog boxes.

VARIABLES

Machine Name_Blocked [Yes(1)/No(0)]—Returns Yes(1) if the machine is in the Blocked state and No(0) otherwise. A machine is considered blocked if its speed factor equals zero for any reason other than a failure, changeover, or scheduled stop.

Machine Name_Capacity [Units, Containers, Assemblies]—Returns the capacity of the machine. Basic and assembly machines always have a capacity of zero.

Machine Name_FailureNumber [Integer>=0]—Returns a 0 if the machine is not failed. If the failures for the machine are defined using Expected Uptime or Reliability logic, this variable will return a 1 when the machine is failed. If the failures for the machine are defined using individual failure streams, this variable will return the Failure Number of the stream that has failed the machine when it is failed.

Machine Name_GoodOutputRate [Units/Min]—Returns the current output rate of good units out of the machine.

Machine Name_BaseGoodOutputRate [Units/BaseTimeUnit]—Returns the current output rate of good units out of the machine.

Machine Name_GoodUnitsProd [Units]—Returns the total number of good units that have been produced by the machine.

Machine Name_InputRate [Units/Min]—Returns the current input rate of units into the machine.

Machine Name_BaseInputRate [Units/BaseTimeUnit]—Returns the current input rate of units into the machine.

Machine Name_LostProduction [Percentage]—Returns the lost production of the machine (0-100%). The initial value of this variable can be specified in the Loss dialog box of the machine.

Machine Name_NomRunSpeed [Units/Min]—Returns the nominal run speed of the machine. The nominal run speed is calculated from run parameters entered in the machine dialog box.

Machine Name_BaseNomRunSpeed [Units/BaseTimeUnit]—Returns the nominal run speed of the machine. The nominal run speed is calculated from run parameters entered in the machine dialog box.

Machine Name_NumChangeovers [Integer>=0]—Returns the number of changeovers that have occurred at the machine.

Machine Name_NumFailures [Integer>=0]—Returns the number of failures that have occurred at the machine.

Machine Name_NumScheduledStops [Integer>=0]—Returns the number of scheduled stops that have occurred at the machine.

Machine Name_OutputRate [Units/Min]—Returns the current total output rate of units out of the machine, including machine loss.

Machine Name_BaseOutputRate [Units/BaseTimeUnit]—Returns the current total output rate of units out of the machine, including machine loss.

Machine Name_Product [Product Name (Symbol number of picture)]—Returns the last product type that has been processed by the machine.

Machine Name_RunSpeed [Units/Min]—Returns the current run speed of the machine. The run speed is calculated from the nominal run speed and the speed factor (i.e., nominal run speed * speed factor).

Machine Name_BaseRunSpeed [Units/BaseTimeUnit]—Returns the current run speed of the machine. The run speed is calculated from the nominal run speed and the speed factor (i.e., nominal run speed * speed factor).

Machine Name_SpeedFactor [Real>=0]—Returns the current speed factor of the machine.

Machine Name_Starved [Yes(1)/No(0)]—Returns whether the machine is currently starved. A machine is considered starved if its speed factor is greater than zero, and the output rate of the upstream module equals zero.

Machine Name_State [Fast(-1)/Workng(3)/Slow(4)/Blocked(0)/Failed(1)/Changeover(2)/Stopped(5)]—Returns the current state of the machine. The seven states are exclusive (i.e., the machine can only be in one of these states at any given time). A machine is in the Fast state if its speed factor is greater than 1. A machine is in the Working state if its speed factor is equal to 1. A machine is in the Slow state if its speed factor is less than 1 and non-zero. A machine is in the Blocked state if its speed factor is zero and the machine is not Failed, Change-over, or Stopped.

Machine Name_UnitsInside [Units]—Returns the number of units inside the machine. This variable always returns zero for basic and assembly machine types.

Machine Name_UnitsProcessed [Units]—Returns the total number of units that have entered the machine.

Palletizer variables

Description

Arena Packaging provides variables that access information about each palletizer in the model. Palletizer Name is the symbol name for the palletizer entered in the main module dialog box.

The only variables that are user-assignable are the SpeedFactor and LostProduction variables. The SpeedFactor variable may be assigned values using the Change Speed Factor of Palletizer action in Actions modules or dialog boxes. The LostProduction variable may be assigned values using the Change Lost Production of Palletizer action in Actions modules or dialog boxes.

Variables

Palletizer Name_Blocked [Yes(1)/No(0)]—Returns Yes(1) if the palletizer is in the Blocked state and No(0) otherwise. A palletizer is considered blocked if its speed factor equals zero for any reason other than a failure, changeover, or scheduled stop.

Palletizer Name_FailureNumber [Integer>=0]—Returns a 0 if the Palletizer is not failed. If the failures for the Palletizer are defined using Expected Uptime or Reliability logic, this variable will return a 1 when the Palletizer is failed. If the failures for the Palletizer are defined using individual failure streams, this variable will return the Failure Number of the stream that has failed the Palletizer when it is failed.

Palletizer Name_GoodOutputRate [Units/Min]—Returns the current output rate of good units out of the palletizer.

Palletizer Name_BaseGoodOutputRate [Units/BaseTimeUnit]—Returns the current output rate of good units out of the palletizer.

Palletizer Name_GoodUnitsProd [Units]—Returns the total number of good units that have been produced by the palletizer.

Palletizer Name_InputRate [Units/Min]—Returns the current input rate of units into the palletizer.

Palletizer Name_BaseInputRate [Units/BaseTimeUnit]—Returns the current input rate of units into the palletizer.

Palletizer Name_LayersSwept [Layers]—Returns the number of layers that have been swept on or off pallets by the Palletizer.

Palletizer Name_LostProduction [Percentage]—Returns the lost production of the Palletizer (0-100%). The initial value of this variable can be specified in the Loss dialog of the Palletizer.

Palletizer Name_NomRunSpeed [Layers/Min]—Returns the nominal run speed of the palletizer as entered in the module dialog box.

Palletizer Name_BaseNomRunSpeed [Layers/BaseTimeUnit]—Returns the nominal run speed of the palletizer as entered in the module dialog.

Palletizer Name_NumChangeovers [Integer>=0]—Returns the number of changeovers that have occurred at the palletizer.

Palletizer Name_NumFailures [Integer>=0]—Returns the number of failures that have occurred at the palletizer.

Palletizer Name_NumScheduledStops [Integer>=0]—Returns the number of scheduled stops that have occurred at the palletizer.

Palletizer Name_OutputRate [Units/Min]—Returns the current total output rate of units out of the palletizer, including palletizer loss.

Palletizer Name_BaseOutputRate [Units/BaseTimeUnit]—Returns the current total output rate of units out of the palletizer, including palletizer loss.

Palletizer Name_PalletLevel [Layers]—Returns the number of layers on the current pallet in the palletizer.

Palletizer Name_PalletsStored [Pallets]—Returns the number of pallets the palletizer has placed into storage.

Palletizer Name_Product [Product Name (Symbol number of picture)]—Returns the last product type that has been processed by the palletizer.

Palletizer Name_RunSpeed [Layers/Min]—Returns the current run speed of the palletizer. The run speed is calculated from the nominal run speed and the speed factor (i.e., nominal run speed * speed factor).

Palletizer Name_BaseRunSpeed [Layers/BaseTimeUnit]—Returns the current run speed of the palletizer. The run speed is calculated from the nominal run speed and the speed factor (i.e., nominal run speed * speed factor).

Palletizer Name_SpeedFactor [Real>=0]—Returns the current speed factor of the palletizer.

Palletizer Name_Starved [Yes(1)/No(0)]—Returns whether the palletizer is currently starved. The starved variable behavior depends on the Palletizer Type. A palletizer is considered starved if its speed factor is greater than zero, and the output rate of the upstream module equals zero. A depalletizer is considered starved if its speed factor is greater than zero, it needs to retrieve a pallet from storage, and that storage is empty.

Palletizer Name_State [Fast(-1)/Workng(3)/Slow(4)/Blocked(0)/Failed(1)/Changeover(2)/Stopped(5)]—Returns the current state of the palletizer. The seven states are exclusive (i.e., the Palletizer can only be in one of these states at any given time). A Palletizer is in the Fast state if its speed factor is greater than 1. A Palletizer is in the Working state if its speed factor is equal to 1. A Palletizer is in the Slow state if its speed factor is less than 1 and non-zero. A Palletizer is in the Blocked state if its speed factor is zero and the Palletizer is not Failed, Changeover, or Stopped.

Palletizer Name_UnitsProcessed [Units]—Returns the total number of units that have entered the palletizer.

Palletizer Name_PalletsUnStored [Pallets]—Returns the number of pallets the depalletizer has taken out of storage.

Storage variable

Description

Arena Packaging provides a variable that accesses the current number of pallets in a storage. Storage Name is the symbol name for the storage entered in the main module dialog.

The variable is not user-assignable.

Variable

Storage Name_StorageLevel [Pallets]—Returns the number of pallets currently in the storage.

Switch variable

Description

The Arena Packaging template provides a variable that accesses whether a switch is switched to the right, left, or is currently switching from one direction to another. Switch Name is the symbol name for the switch that appears below the module when it is placed in the model window.

The variable is not user-assignable.

Variable

Switch Name_State [Right(0)/Left(1)/Switching(2)]—Returns the current state of the switch.

Tank variables

DESCRIPTION

Arena Packaging provides a variable that accesses information about each tank in the model. Tank Name is the symbol name for the tank entered in the main module dialog box.

These variables are not user-assignable.

VARIABLES

Tank Name_InputRate [volume/min]—Returns the input rate of fluid into the tank at a "per minute" rate value.

Tank Name_BaseInputRate [volume/BaseTimeUnit]—Returns the input rate of fluid into the tank at a "per BaseTimeUnit" rate value.

Tank Name_OutputRate [volume/min]—Returns the output rate of fluid out of the tank at a "per minute" rate value.

Tank Name_BaseOutputRate [volume/BaseTimeUnit]—Returns the output rate of fluid out of the tank at a "per BaseTimeUnit" rate value.

Tank Name_TankLevel [volume]—Returns the amount of fluid currently in the tank.

Valve variable

DESCRIPTION

Arena Packaging provides a variable that accesses information about each valve in the model. Valve Name is the symbol name for the valve entered in the main module dialog box.

This variable is not user-assignable.

VARIABLE

Valve Name_State [Open(1)/Closed(0)]—Returns the state of the valve. A valve is considered closed if its aperture level is 0%.

A Equipment Reliability and Loss

This appendix provides detailed descriptions on the Arena Packaging template's features for equipment reliability and loss.

Defining reliability

A key characteristic of a piece of equipment is its ability to perform without failing (i.e., its reliability). Equipment failures result in lost production time and product and can dramatically impact system design and performance.

Arena Packaging provides three approaches for defining random downtimes of machines, conveyors, or palletizers. To implement one of the approaches, simply check Reliability in the Other Options section of the module's main dialog box. Then click on the Reliability dialog box.

Each of the three options is described below.

Using expected uptime

- "I expect the filler to be failed about 1% of the time."
- "The conveyor is running about 97% of the time."

When selecting this option, specify the *percentage* of available operational time that you expect the equipment to be up (i.e., Expected Uptime) and the *mean* time to repair a failure when one occurs (i.e., Time to Repair). The word *mean* is emphasized because Time to Repair must be specified here as a real value and not a random distribution.

This simple way of describing equipment reliability is useful when you do not require or have the data for more detailed analysis. An uptime percentage is sometimes referred to as the "Availability" of the equipment.

When the simulation begins, Arena Packaging creates a single random failure stream for the piece of equipment. The times between failure arrivals are sampled from the stochastic distribution Exponential (MTBF), where MTBF (i.e., the mean time between failures) is calculated using the equation

MTBF = Time to Repair * (Expected Uptime % / (100 – Expected Uptime %)).

It is important to emphasize that this MTBF is not calendar time. For machines and palletizers, the MTBF is interpreted as the mean *processing time* between failures (i.e., time that the machine or palletizer is running and not starved). For conveyors, the MTBF is interpreted as the mean *running time* between failures (i.e., time that the conveyor's belt is actually moving).

As the simulation run length and number of replications goes to infinity, the failures generated by the failure stream will cause the equipment to be operational for approximately the specified percent of total available operational time.

For example, suppose you entered an Expected Uptime of 93% and a Time to Repair of 5 minutes for a conveyor. At runtime, Arena Packaging would create a single random failure stream for the conveyor. Each failure would have a duration of 5 minutes, and the times between failures would be sampled from the distribution exponential (5*(93/7)) or exponential (66.43 minutes).

If you ran the above model for a long time period (e.g., 30 days), then the following equation will approximately be true:

Total Time Running/(Total Time Running + Total Time Failed) = .93

where the total running time is the total time the conveyor's speed factor was greater than zero (i.e., its belt was moving).

When a failure occurs, the equipment is stopped and its state is set to Failed. The variable _FailureNumber for the equipment is set to 1. The downtime duration for each failure is the Time to Repair. This duration can be adjusted by operator skill factors if repair operators are used. Refer to the section in Chapter 2 titled "Step 5: Experiment with complex strategies" for more detail on modeling labor in the system.

Using reliability over a time span

In its strictest definition, *reliability* is the probability that a piece of equipment will not fail over some operational time span (e.g., a day's worth of operations or a month's worth of operations). This probability is derived theoretically using the equation

$R = e^{-\lambda t}$

where

R is the reliability, t is the time span, and λ is the failure rate.

Note that t and λ must be in the same time units (e.g., days and failures/day). Reliability is a probability between 0 and 1.

EXAMPLE

Company XYZ collected failure data for a filler machine in its bottling line. The time span for the data collection was six months of total processing time. During that six-month period, the filler failed 10 times. The average downtime for a failure was 22 minutes.

What is the probability that the filler can run for one month of processing time without failing?

Using the above data, the reliability of the filler machine for one month is calculated as follows:

t = 1 month

λ = 10 failures/6 months = 1.667 failures/month

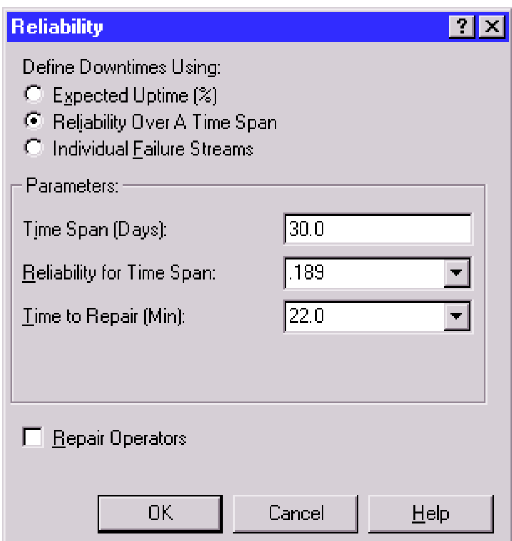
R = e-1.667*1 = .189

Similarly, the probability that the filler machine can run for three months without failing is:

R = e-1.667*3 = .007

Arena Packaging's second option for specifying equipment downtimes implements failures using this probabilistic definition. When selecting this option, specify the time span (*t*) in days, the reliability for the time span (*R*), and the time to repair a failure when it occurs (i.e., Time to Repair). Here, the Time to Repair operand can be specified as a random distribution (e.g., TRIA (15,22,25)).

For example, suppose you needed to model the bottling line at Company XYZ and wanted to use their failure data for the filler machine. You could enter the Reliability dialog of the filler and specify the Time Span, Reliability, and Time to Repair as 30, .189, and 22, respectively.



When the simulation begins, Arena Packaging first calculates the theoretical failure rate 8 for the piece of equipment using the values entered for the Time Span and Reliability for Time Span operands:

R = e-λt

Therefore, λ = -1 *(LN(Reliability for Time Span) / (Time Span)).

Arena Packaging then creates a single random failure stream for the piece of equipment, whereby the time between failure arrivals is sampled from the stochastic distribution exponential (1/λ).

For machines and palletizers, the time between failures is interpreted as the *processing time* between failures (i.e., time that the machine or palletizer is running and not starved). For conveyors, the time between failures is interpreted as the *running time* between failures (i.e., time tht the conveoyr's belt is actually moving).

For the XYZ example, the failure rate 8 of the filler machine would be calculated as λ = -1 * (LN(.189)/30) = 0.0555 failures/day. Thus, the time between failure arrivals would be sampled from the distribution exponential (1/0.0555) or exponential (18 days).

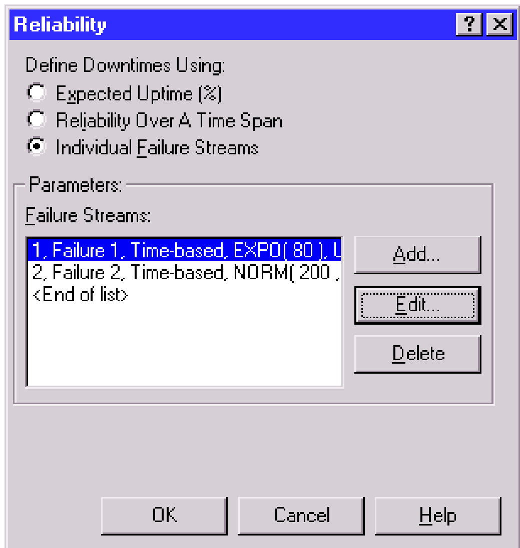
When a failure occurs, the equipment is stopped and its state is set to Failed. The downtime duration for each failure is the Time to Repair. If a random distribution is used, then the Time to Repair is sampled from that distribution at the beginning of each failure. The Time to Repair can also be adjusted by operator skill factors if repair operators are used. Refer to the section "Step 5 • Experiment with complex strategies" on page 15 for more detail on modeling labor in the system.

Using individual failure streams

The third option for modeling the downtime of a piece of equipment is to specify your own individual failure streams. This detailed way of describing equipment reliability is useful when:

- A failure process must be modeled with different arrival rates or downtime distributions than what are provided in the first two options.
- You have several types of failures for a piece of equipment (e.g., rare, frequent, electrical, mechanical, etc.), and each type has unique failure rate and downtime distributions. If labor constraints are incorporated into the model, different sets of repair operators might also be required for the different types.
- You have machine or palletizer failures where the arrival process of the failures is based on unit counts (i.e., throughput) and not time.
- You have time-based failures where the time between failures needs to be specified as calendar time, not processing or running time.

When selecting this option, add individual failure streams to the Failure Streams repeat group. There is no limit on the number of failure streams you can add.

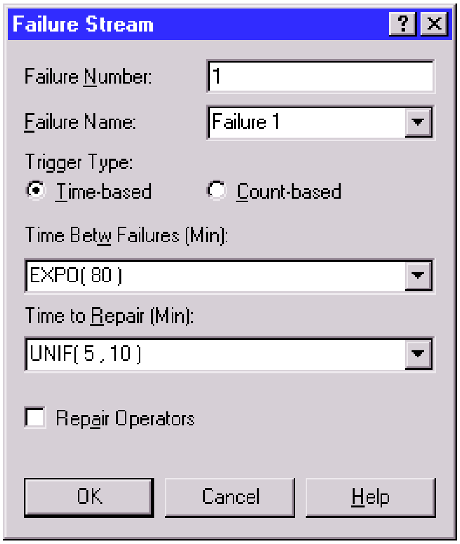


When adding a failure stream, first specify whether the failure arrival rate is based on unit counts or time (i.e., the Trigger Type). This option is available only for machines and palletizers. The failure rates of conveyors must be based on time. Then enter the Time or Count Between Failures and the Time to Repair. These operands can be specified as random distributions.

For time-based failures, the Uptime Type field specifies how the time between failures parameter of a time-absed failure stream is interpreted. For machines and palletizers, the choices are *Calendar Time* or *Processing Time*. Processing Time is the time that the machine or palletizer is running and not starved (i.e., it is processing units). For conveyors, the choices are *Calendar Time* or *Running Time*. Running Time is the time that the conveyor’s belt is actually moving (i.e., run speed is greater than zero).

When the simulation begins, Arena Packaging creates the failure streams specified in the Failure Streams repeat group. The times and counts between failure arrivals are sampled from the Time and Count Between Failures operands.

When a failure occurs, the equipment is stopped and its state is set to Failed. The down-time duration for each failure stream is its Time to Repair. If a random distribution is used, then the Time to Repair is sampled from that distribution at the beginning of each failure. The Time to Repair can also be adjusted by operator skill factors if repair operators are used. Refer to "Step 5 • Experiment with complex strategies" on page 15 for more detail on modeling labor in the system.



Questions and answers about reliability

Q: During the simulation, how do I know a piece of equipment has failed?

A: When a machine, conveyor, or palletizer fails, the state variable of the affected module is automatically set to *Failed*. You can easily animate the state variable for a machine, conveyor, or palletizer by checking Animation in the Other Options section of the main dialog. By default, the picture representing the Failed state is always red. Refer to the *Variables Guide* for a reference on the state variable of a particular module.

Q: What statistics are available for failures?

A: For each equipment module, Arena Packaging automatically tracks statistics on the number of failures that occur, the average downtime per failure, and the total time the equipment is failed.

Q: Is the Time Span field for the Reliability Over A Time Span option specified in calendar time?

A: No. It should be specified as time that the equipment is operational (i.e., time that the machine or palletizer is actually processing units or time that the conveyor is actually running).

Q: What information should I enter in the Expected Uptime field?

A: Enter the percentage of available operational time (not calendar time) that you expect the equipment to be up. Available operational time excludes planned downtimes and times that a machine or palletizer is blocked or starved. Thus, the percentage should be entered as Operational Time/(Operational Time + Failed Time).

Q: Suppose that during runtime a failure is scheduled to occur at a module but the equipment is already stopped due to another failure, scheduled stop, changeover, etc. What happens?

A: Failures can only occur when a piece of equipment is running (i.e., the speed factor and run speed of the module are greater than zero). If Arena Packaging generates a failure for a piece of equipment and that equipment is currently stopped, the failure waits until the equipment begins running before setting the state variable to Failed and beginning its downtime.

The exception to this rule involves scenarios where the equipment is already stopped due to another failure. In those circumstances, the second failure is ignored.

Q: Can you model the loss of product that is associated with failures?

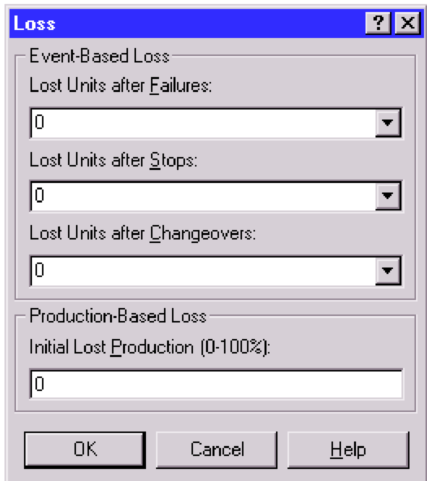
A: Yes. This is discussed in the next section.

Defining loss

Another aspect of equipment behavior is the loss that occurs as units are processed or transferred. This wastage can be expensive and dramatically impact system throughput and performance.

To define loss for a machine, conveyor, or palletizer, simply check Loss in the Other Options section of the module's main dialog box. Then click on the Loss dialog box.

The two types of loss are described below.



Event-based loss

"We waste 500 to 1000 units of product every time we changeover the machine."

"On average, we lose 50 containers every time the filler fails or jams."

"When a conveyor is stopped for maintenance, we throw away all the units on the conveyor."

The first type of loss is the wastage of units that occurs due to discrete *events* at the equipment (e.g., machine jams, changeovers, etc.). Arena Packaging allows you to define loss for three types of events: failures, scheduled stops, and changeovers.

When selecting this option, enter the Lost Units After Failures, Lost Units After Stops, and/or Lost Units After Changeovers. The values for these operands can be constants, random distributions (e.g., UNIF (500,1000)), or expressions (e.g., a variable).

During the simulation, loss quantities are sampled at the end of each failure, scheduled stop, or changeover event. For machines and palletizers, the loss is then immediately produced at 100% of the equipment's input rate (i.e., the next X units to enter the equipment are "lost"). Note that, because filler and conveyor machines have capacities, lost units travel down the length of these machines before being output from the end.

For conveyors, the loss is immediately transferred off the conveyor at 100% of the conveyor's output rate (i.e., the next X units transferred off of the conveyor are "lost").

Production-based loss

"About 1% of the units processed through this machine are lost."

"In general, 2% of the units transferred off this conveyor are lost."

The second type of loss is simply a general loss rate that occurs as the equipment processes or transfers units. This *production-based* loss is defined as a percentage of the equipment's total output rate. You enter the loss percentage in the Lost Production operand.

As an example, if a lost production of 10% was defined for a machine, one unit would be lost for every nine good units produced. For a conveyor, one bad unit would be transferred off the conveyor and lost for every nine good units transferred downstream.

During the simulation, the total output rate of a piece of equipment always equals its good output rate plus its loss rate. In other words, the following equation is always true.

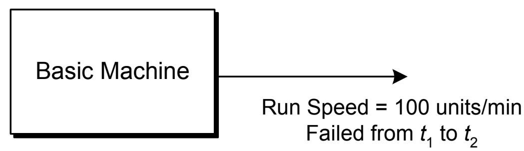
Output Rate = Good Output Rate + (Lost Production % * Output Rate)

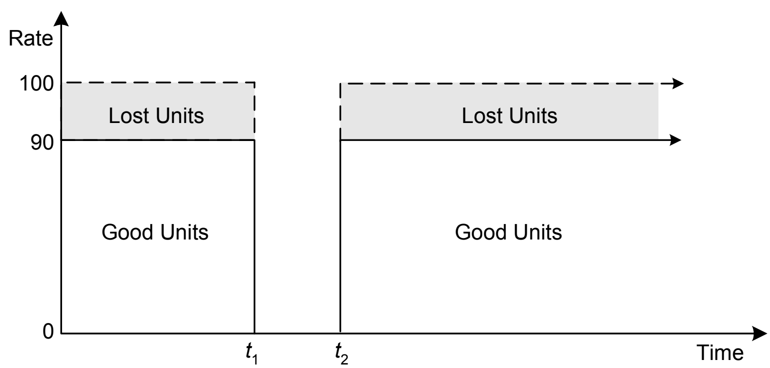
where

(Lost Production % * Output Rate) is the loss rate.

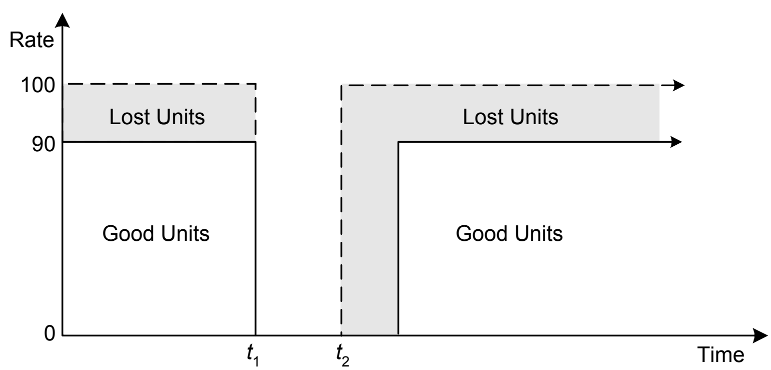
EXAMPLES

The charts below illustrate examples of both event- and production-based loss for a basic machine. Suppose that the basic machine is outputting units at a rate of 100 units per minute and that, from time t_1 to t_2, the machine fails.

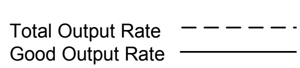




10% Production Loss



10% Production Loss & Lost Units After Failure

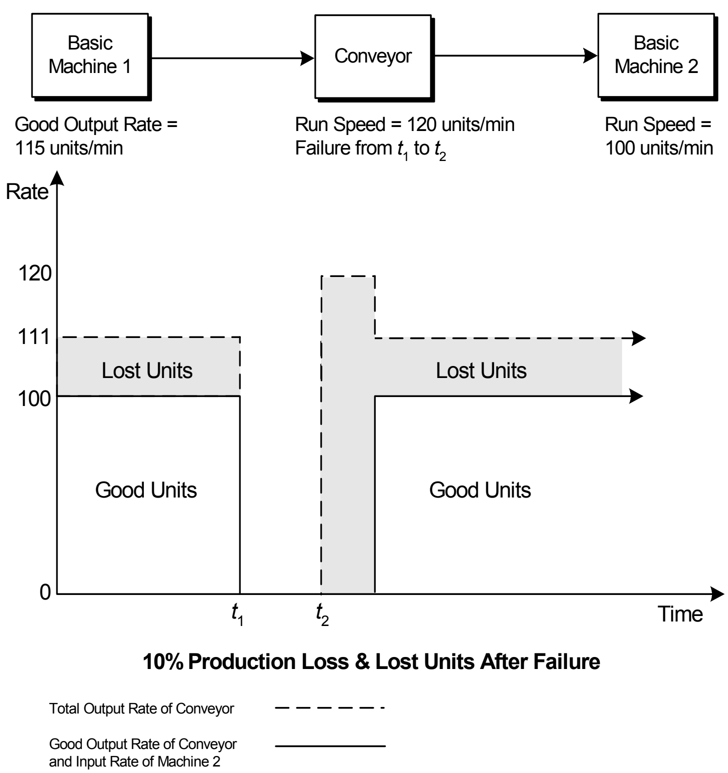


The first chart shows the output rate and good output rate of the machine over time if a 10% production loss is defined. Though the output rate of the machine is 100 units per minute, the good output rate is only 90 units per minute because 10% of the product produced by the machine is wastage. Of course, the machine produces nothing during the failure from t_1 to t_2.

The second chart shows the output rate and good output rate of the machine if, in addition to a general 10% production loss, there are also units lost due to failures. At the end of the failure at time t_2, the machine immediately produces the quantity of Lost Units After Failures. Then, the machine's good output rate returns to 90 units per minute.

CONVEYOR EXAMPLE

The chart below illustrates examples of both event- and production-based loss for an accumulating conveyor. Suppose that the upstream basic machine is outputting good units at a rate of 115 units per minute, the conveyor has a run speed (i.e., maximum transfer rate) of 120 units per minute, and the downstream basic machine is running at 100 units per minute. Suppose also that the conveyor has a 10% production loss, fails from time t_1 to t_2, and loses units when it fails.



10% Production Loss & Lost Units After Failure

The chart above shows the output rate and good output rate of the conveyor over time given the 10% production loss and the units lost after each failure. Let's first examine the operating period before the failure at time t_1. Machine 1 is placing units onto the conveyor at a rate of 115 units per minute. Machine 2 is taking good units off the conveyor at a rate of 100 units per minute.

Because a 10% production loss occurs at the end of the conveyor, the total output rate of the conveyor is calculated as follows:

Output Rate = Good Output Rate + (Lost Production % * Output Rate)
Output Rate = 100 + (.10 * Output Rate)
Output Rate = 100/.90
Output Rate » 111 units/min

Thus, we see that the total output rate from the conveyor consists of 100 good units per minute to Machine 2 and approximately 11 units per minute of loss. Because the output rate of Machine 1 is 115 units per minute, units accumulate on the conveyor.

Let's now examine what occurs after the conveyor fails from time t_1 to t_2. At time t_2, the conveyor immediately transfers off the Lost Units After Failures at 100% of its output rate. Note that this output rate is 120 units per minute. Why 120? The reason is that a significant number of units had accumulated on the conveyor by the time the failure occurred. Therefore, at time t_2, the conveyor transfers the loss from those accumulated units at its run speed of 120 units per minute.

When the quantity of Lost Units After Failures is transferred, the conveyor's output rate returns to 111 units per minute. The good output rate increases to 100 to resume feeding Machine 2.

Questions and answers about loss

Q: What statistics are available for loss?

A: For each equipment module, Arena Packaging automatically tracks statistics on the number of units lost and the yield (i.e., the percentage of good units processed or transferred out of the total units processed or transferred). You can also apply and report costs for loss in the Costs dialog box.

Q: Suppose event-based loss is defined for the scheduled stops or failures on a conveyor. When the stop or failure occurs, there is an amount of WIP on the conveyor (i.e., the number of units accumulated plus the number of units traveling). Can the loss associated with the event be more than this WIP?

A: No. Regardless of what is sampled from the Lost Units After Failures or Lost Units After Stops parameters, the maximum amount of loss that can be taken off the conveyor for an event is the current WIP.

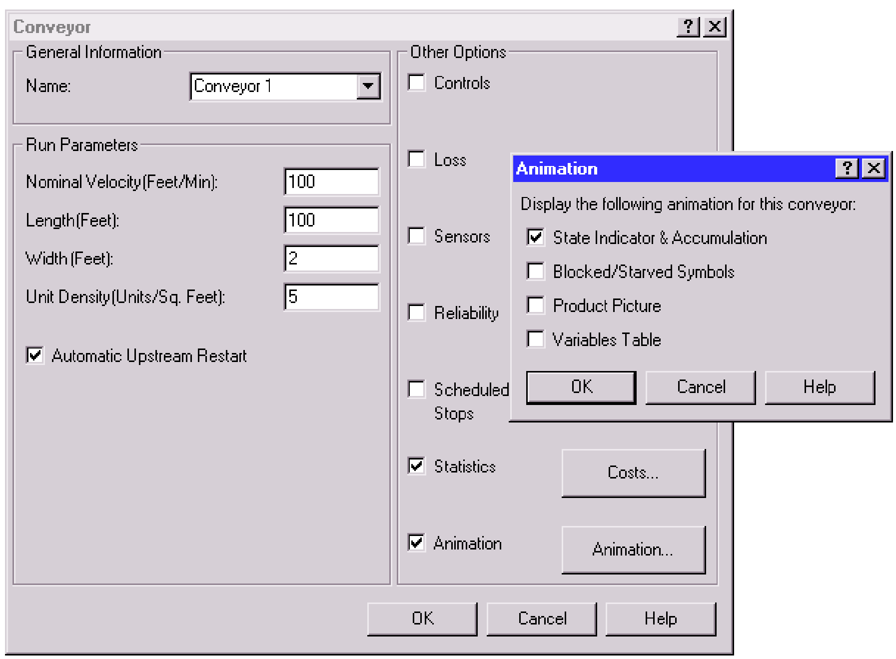
Q: Suppose an unbounded distribution (e.g., a normal distribution) is entered for the Lost Units After Failures, Lost Units After Stops, or Lost Units After Changeovers operands. What happens if a negative number is sampled from the distribution?

A: You cannot have "negative" loss for an event. Arena Packaging converts negative loss quantities to zero.

B Placing Animation

Animation accompanies most of the Arena Packaging modules. As you define the behavior of your system's components, you can use these graphics to build a picture of your system quickly. Later, you can enhance the animation by modifying these symbols or adding your own graphics to the current layout. To learn more about how to use the animation and drawing tools in Arena and Arena Packaging template, refer to the *Arena User's Guide*.

Default animation is placed with most of the Arena Packaging modules. If additional animation options are available, an **Animation** button appears in the main dialog box that will open a sub-dialog. To view the options, simply press the **Animation** button and make your selection from those that appear. If, however, you do not wish to use the default animation, clear the check box in the main dialog box.



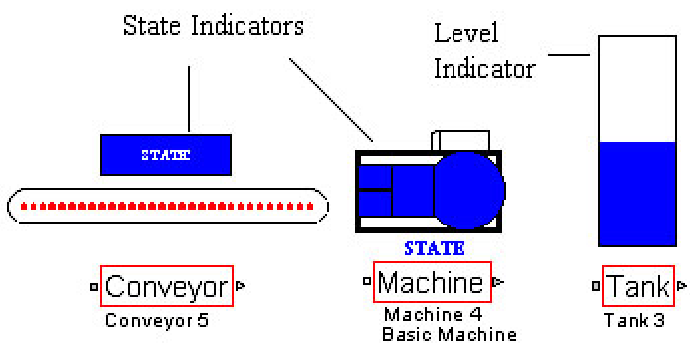
The Animation dialog

The Animation dialog lists the types of default animation that are available for the module. Simply check the default animation you want to place.

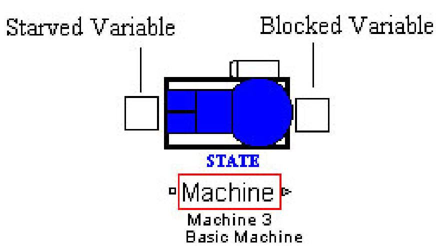
State or Level Indicator

The State Indicator option places a global picture that animates the state variable of the machine, conveyor, palletizer, or operator. If the module has a capacity (i.e., it is an accumulating conveyor, filling machine, or conveyor machine), this option also places a level that animates the distribution of units on the equipment.

The Level Indicator option places a level that animates the amount of pallets or fluid in the storage or tank, respectively.



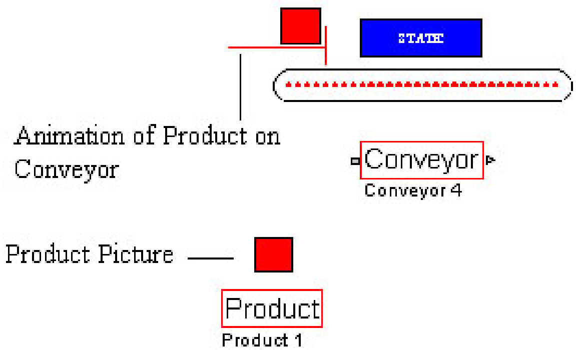
Blocked/Starved symbols



This option places two global pictures that animate the blocked and starved variables of the machine, conveyor, or palletizer.

Product picture

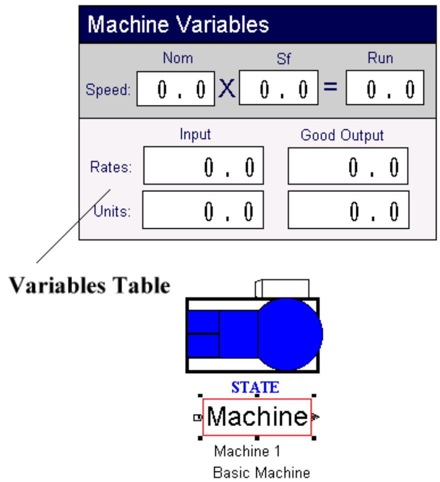
This option places animation that displays the picture of the last product type to be transferred or processed on the machine, conveyor, or palletizer. In other words, it animates the picture of the product variable. The animation consists of a logical queue, whereby a single entity contained in the queue is dynamically assigned the picture of the current product as the model runs.



Note that the actual pictures of products are defined in the Product modules.

Variables or statistics table

This option places a prearranged table or "scoreboard" that animates several of the module's variables and statistics (e.g., run speed, speed factor, input rate, output rate, units processed, tank level, utilization, etc.).



Questions and answers about animation

Q: If I move a module handle in my model window, the default animation for that module moves with it. How can I move a module handle without moving its animation?

A: Press the **SHIFT** key while moving the module handle with your mouse.

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