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TITLE OF THE INVENTION (280 characters max)

SYSTEM AND METHOD FOR AUTOMATED MONITORING AND ASSESSMENT OF FABRICATION FACILITY

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☒ Specification	Number of Pages 77	☐ Small Entity Statement	
☒ Drawing(s)	Number of Sheets 29	☒ Other (specify)	Technical Appendix (75 pages)

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Respectfully submitted,

SIGNATURE [signature]

Date 10/17/2000

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SPECIFICATION

TITLE OF THE INVENTION

SYSTEM AND METHOD FOR AUTOMATED MONITORING AND ASSESSMENT OF FABRICATION FACILITY

BACKGROUND OF THE INVENTION

1) Field of the Invention

The field of the present invention relates to systems and methods for monitoring and assessing the performance and operation of fabrication facilities, such as semiconductor fabrication facilities.

2) Background

The manufacture of microelectronic circuits and/or components on semi-conductor wafers can be a complex and involved process, requiring numerous tools and machines operating in a production sequence according to a specified set of instructions (e.g., a "recipe"). Examples of fabrication processes typically performed in the manufacture of a semiconductor wafer include etching, deposition, diffusion, and cleaning.

Large semiconductor fabrication facility can have dozens or even hundreds of tools, each of which is called upon periodically to perform part of a process as dictated by the selected recipe(s). Some fabrication tools are used for processing semiconductor wafers, while others, known as metrology tools, are generally used for measuring the output of a processing tool. Fabrication tools are often employed in an assembly-line fashion, with each applicable tool having a role in the step-by-step fabrication of a semiconductor wafer. However, due to the nature of the step-by-step manufacturing processes, at least some tools will be idle at any given time, waiting for the output of an upstream tool. Fabrication tools can also be idle for other reasons, such as when needing maintenance, repair or re-programming, or re-configuration with respect to other tools in the plant. The amount of time fabrication tools are idle bears a correlation, directly or indirectly, to the overall efficiency of a semiconductor fabrication facility, and hence a correlation to the profitability of the facility. A challenge for each fabrication facility is thus to reduce idle time of fabrication tools to the maximum extent possible, therefore maximizing production time, yield and profitability.

Moreover, many processing tools and metrology tools are quite expensive, and the collective array of tools brought together at a semiconductor fabrication facility represent a substantial investment. To the extent tools are idle, the investment in these tools is wasted. The floorspace at semiconductor fabrication facilities is also enormously expensive, due to extreme requirements of cleanliness, among other reasons, and so even inexpensive tools which are idle can be costly in terms of wasted floorspace that is being underutilized. Furthermore, large semiconductor fabrication facilities often will have many duplicate tools for performing processes in parallel. If facility engineers can determine that certain duplicate tools are idle for long periods, then some of the duplicate tools can potentially be eliminated, saving both the cost of the tools and the floorspace that they take up. Alternatively, if all of a certain type of tool are operating at maximum efficiency yet still are the cause of a bottleneck in the manufacturing process, production engineers may determine that more tools need to be purchased. Therefore, a tremendous need exists to identify which fabrication tools are active and which idle, and for what reasons. For example, if a fabrication tool was idle for a long period because the upstream process step takes a long time, a production engineer may come to a different conclusion about how to adjust facility resources then if the idle period was due to the fact that the upstream fabrication tool was broken and needed to be repaired. Thus, the reason for tool idleness can be important information for engineers controlling semiconductor manufacturing processes.

To assist production engineers in assessing semiconductor manufacturing efficiency, a variety of informational reporting standards have been promulgated. One of the earliest such standards is known as the E10-0699 Standard for Definition and Measurement of Equipment Reliability, Availability and Maintainability (RAM) (hereinafter the "E10 Standard"), hereby incorporated by reference as if set forth fully herein. This standard, originally put forward around 1986 by Semiconductor Equipment and Materials International (SEMI), defines six basic equipment states into which all equipment conditions and periods of time (either productive or idle time) must fall. Total time for each tool is divided into Operations Time and Non-Scheduled Time. Operations Time is divided into five different categories (Unscheduled Downtime, Scheduled Downtime, Engineering Time, Standby Time, and Productive Time) which, together with Non-Scheduled Time, comprise the six basic equipment states. Equipment Downtime for a given tool is divided into Unscheduled Downtime and

Scheduled Downtime. Likewise, Equipment Uptime for a given tool is divided into Engineering Time, Standby Time and Productive Time. Of these three Equipment Uptime states, Productive Time and Standby Time collectively represent the Manufacturing Time for a given tool.

The E10 Standard also defines a number of reliability, availability and maintainability measurements relating to equipment performance. Such measurements include, for example, mean (productive) time between interrupts (MTBI), mean (productive) time between failures (MTBF), mean (productive) time between assists (MTBA), mean cycles between interrupts (MCBI), mean cycles between failures (MCBF), and mean cycles between assists (MCBA). Mean (productive) time between interrupts (MTBI) indicates the average time that the tool or equipment performed its intended function between interrupts, and is calculated as the productive time divided by the number of interrupts during that time. Mean (productive) time between failures (MTBF) indicates the average time the tool or equipment performed its intended function between failures, and is calculated as the productive time divided by the number of failures during that time. Mean (productive) time between assists (MTBA) indicates the average time the tool or equipment performed its intended function between assists, and is calculated as the productive time divided by the number of assists during that time. Mean cycles between interrupts (MCBI), mean cycles between failures (MCBF), and mean cycles between assists (MCBA) are similar, but relate the number of tool or equipment cycles to the number of interrupts, failures and assists, rather than the productive time. The E10 Standard also provides guidelines for calculating equipment dependent uptime, supplier dependent uptime, operational uptime, mean time to repair (average time to correct a failure or an interrupt), mean time off-line (average time to maintain the tool or equipment or return it to a condition in which it can perform its intended function), equipment dependent scheduled downtime, supplier dependent scheduled downtime, operational utilization, and total utilization. The E10 Standard provides for calculation of two important metrics in particular: Overall Equipment Effectiveness (OEE), and Overall Fabrication Effectiveness (OFE). Traditionally, most of the information used to calculate the metrics in the E10 Standard has been gathered manually – a slow, tedious process prone to potential errors.

Since its inception, the E10 Standard has been refined and improved upon. In recent years, at least two new standards have been proposed or adopted by SEMI, the same entity that originally proposed the E10 Standard. The first of these new standards is known as the E58-0697 Automated Reliability, Availability and Maintainability Standard (ARAMS) (hereinafter the "E58 Standard"), and the second is known as the E79 Standard for Definition and Measurement of Equipment Productivity (hereinafter the "E79 Standard"), both of which are hereby incorporated by reference as if set forth fully herein. The E58 Standard was proposed around 1997 in an attempt to integrate automated machine processes into the E10 Standard. Accordingly, the E58 Standard specifies triggers for state transitions described in the E10 Standard, with the intent of encouraging tool or equipment manufacturers to store and make available trigger information at each tool. As the E58 Standard was apparently envisioned, tool and equipment manufacturers would include special software with their tools and equipment, allowing controllers or monitoring equipment to read information about trigger events that could be gathered and used in the calculations of tool availability, reliability and maintainability. However, very few tool and equipment manufacturers have actually written such special software for their tools and equipment. One possible reason for the reluctance to include such software is that, if productivity information were available to their customers, tool and equipment manufacturers might be required to extend warranty periods for their tools and equipment for periods of time in which the equipment was not up and running. Therefore, tool and equipment manufacturers have an incentive not to provide software that meets the guidelines of the E58 Standard.

More recently, the E79 standard has been proposed. The E79 Standard builds upon the E10 and E58 Standards, and specifies, among other things, a set of metrics for calculating certain reporting items. Two such metrics are referred to as the Overall Equipment Efficiency (OEE) metric and Overall Fabrication Efficiency (OFE) metric. The E79 Standard also specifies metrics for determining, for example, Availability Efficiency, Performance Efficiency, Operational Efficiency, Rate Efficiency, Theoretical Production Time, and Quality Efficiency, among others.

While the E10, E58 and E79 Standards all provide guidelines for assessing equipment availability, reliability and maintainability, they do not describe how to gather and process the necessary information. These tasks can be quite challenging. For example, different platforms are used in different semiconductor fabrication facilities for communicating between supervisory equipment and various processing and measurement tools. Therefore, a single information gathering technique might not be possible for all fabrication facilities. Furthermore, despite the existence of the E58 Standard, few tools actually store the trigger and event information that facilitates the calculation of various performance and efficiency metrics covered by the standards.

Thus, obtaining the necessary data can be difficult. In addition, multi-chamber tools (also known as cluster tools) pose a problem, because they involve equipment with multiple subsidiary tools treated as a single unit. The standards indicate a preference that information concerning the individual subsidiary tools be available, as opposed to merely information about the cluster tool as a whole.

While having an automated way of gathering and processing information useful for monitoring and assessing tool and equipment performance according to the various available standards would be highly beneficial, actual implementations of systems for performing these activities may be undesirable if they require modifications to existing control systems which are deployed in semiconductor fabrication facilities. Owners of such facilities may be very reluctant to make changes that would impact their existing control systems, because of the potential for introducing “bugs” or errors into the system, or causing other unforeseen consequences. Moreover, actual implementations of systems for monitoring or assessing tool and equipment performance according to the various standards may also be undesirable if they require modifications to the existing processing or metrology tools. Tool manufacturers may be quite reluctant to make changes that might impact the performance of their tools, such as changing the message driver of the tools, or that might lead to incompatibilities with existing versions of tools, interface equipment, or control systems. Moreover, tool manufacturers may simply want to avoid the expense of re-designing their tools to provide the functionality that may be required for monitoring or assessing tool and equipment performance.

It would therefore be advantageous to provide a non-intrusive, reliable and comprehensive system or method for monitoring, assessing and reporting the operation and performance of semiconductor or other types of fabrication facilities. It would further be advantageous to provide such a system or method that requires a minimum of modifications to existing control systems, tools or equipment.

SUMMARY OF THE INVENTION

The invention in one aspect provides a system and method for automated monitoring and assessment of the performance and operation of a fabrication facility, such as a semiconductor fabrication facility.

In one embodiment, a system and method for monitoring and assessing operation of a semiconductor fabrication facility includes connecting a monitoring and assessment computer system to a system bus which is also connected, directly or indirectly (e.g., via supervisory workstations), to a manufacturing execution system and a number of semiconductor fabrication tools in the facility. Via a user interface, state models and trigger events are configured for each of the semiconductor fabrication tools. The state models may be based in part upon the trigger events, various external states, and various recipe classifications. Once the state models have been defined, messages transmitted on the system bus between the semiconductor fabrication tools and the manufacturing execution system are monitored by the automated monitoring and assessment computer system. When certain types of messages are observed, the automated monitoring and assessment computer system automatically generates appropriate triggers according to the user specifications, which causes state transitions according to the user-defined state models. The system updates the state model of

each tool affected by a trigger, and logs state transition and any pertinent information regarding the triggering message in a tracking database.

The automated monitoring and assessment system may track state changes for each tool in the system, and may additionally maintain and update real-time status information for each tool that can be viewed on a live status display screen or otherwise. The information in the tracking database may be used as the basis for generating historical reports regarding the operation of all of the tools in the semiconductor fabrication facility.

Further embodiments, variations and enhancements are also disclosed herein.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1 through 3 are top-level diagram illustrating examples of semiconductor fabrication systems in which an automated monitoring and assessment computer may be incorporated.

FIG. 4 is a top-level diagram illustrating further details of a semiconductor fabrication system in which an automated monitoring and assessment computer may be employed.

FIG. 5 is a diagram illustrating one possible state table hierarchy that may be used in the monitoring and assessment software of any of the systems illustrated in FIGS. 1, 2, 3 and 4.

FIG. 6 is a diagram illustrating a software logic flow for processing messages at an automated monitoring and assessment system based upon a transition initiation type.

FIG. 7 is a diagram illustrating a software logic flow for receiving and filtering trigger messages at an automated monitoring and assessment system.

FIG. 8 is a block diagram showing details in accordance with one embodiment of a preferred automated monitoring and assessment system.

FIG. 9 is an example of a screen display illustrating a hierarchical state model structure for an automated monitoring and assessment system.

FIGS. 10A – 10D are examples of a state properties screen display, with different sub-screen tabs selected, as may be presented to a user who has selected a particular state to view its properties.

FIG. 11 depicts a pop-up menu as may be used for selecting various options in connection with the automatic transitions sub-screen depicted in FIG. 10B.

FIG. 12 is an example of a trigger (i.e., symptom) configuration screen display as may be presented to a user via a user interface for associating triggers with default transition states and interrupts for a particular tool.

FIGS. 13A –13C are examples of a trigger (i.e., symptom) properties screen display with various tabs selected, as may be presented to a user for selecting properties for a particular trigger.

FIG. 14 is an example of a screen display (or pop-up window) as may be presented to a user via a user interface for associating an external state response with a trigger for a particular tool.

FIGS. 15A – 15F and 16 collectively illustrate screen displays that may be presented to the user in order to perform mappings between alarm events, collection events, variables and triggers.

FIG. 17 illustrates a relationship between data appearing on a trigger configuration screen (e.g., FIG. 12) and data appearing on a PPID Classification sub-screen.

FIG. 18 illustrates a relationship between data appearing on a trigger configuration screen (e.g., FIG. 12) and data appearing on an external state control sub-screen.

FIGS. 19A – 19F are examples of screen displays as may be presented to a user in order to define tool or chamber specific constants.

FIGS. 20 and 21 are examples of screen displays as may be presented to a user in order to force a manual transition or to modify data in the tracking database, respectively.

FIG. 22 is an example of a screen display as may be presented to a user during live monitoring of tools in the semiconductor fabrication system.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

This application is filed with a Technical Appendix containing further details for implementing a system in accordance with various embodiments as disclosed herein. The Technical Appendix is hereby incorporated by reference as if set forth fully herein.

FIG. 1 is a top-level diagram illustrating an example of a semiconductor fabrication system 100 in which an automated monitoring and assessment computer may be incorporated. As illustrated in FIG. 1, a manufacturing execution system 102 is connected to a system bus 105, along with a plurality of semiconductor fabrication tools 115 (simply labeled "equipment" in FIG. 1), which may include processing tools and/or metrology tools. The manufacturing execution system 102 controls the manufacture of semiconductor wafers or other products according to a programmed recipe, by sending commands to the various semiconductor fabrication tools 115 and monitoring their activity. Also connected to the system bus 105 is an automated monitoring and assessment system 107, which may comprise one or more computers, servers and databases, as further described herein. A bus controller 109 is also connected to the system bus 105, for controlling communication thereover.

Preferably, the system bus 105 comprises a standard communication bus, such as, for example, a Common Object Request Broker Architecture (CORBA) bus, in which case messages sent over it are packaged as CORBA objects. Messages are preferably transmitted over the system bus 105 according to a common standard, such as the Semiconductor Equipment Communication Standard (SECS), which is very well known in the semiconductor industry. The bus controller 109 controls the routing of information over the system bus 105, and the automated monitoring and assessment system 107 preferably "subscribes" to the information needed for performing the monitoring and assessment functions as described later herein. The bus controller 109 may route some, but not all, of the information in each message to the automated monitoring and assessment system 107, by excluding any non-pertinent information. When the automated monitoring and assessment system 107 first becomes actively connected to the system bus 105, it indicates to the bus controller 109 what type of information it is interested in, according to well-known techniques associated with the CORBA standard.

Messages (e.g., SECS messages) transmitted or published over the system bus 105 from the various semiconductor fabrication tools 115 to the manufacturing execution system 102 may include, for example, various alarm messages, event messages, parameter updates (e.g., SVID messages), symptom (or trigger) messages, and the like. The automated monitoring and assessment system 107 receives information from the transmitted or published messages, and uses that information to track the operation states of the various semi-conductor fabrication tools 115, according to techniques described in more detail herein.

FIG. 2 is a top-level diagram illustrating another example of a semiconductor fabrication system 200 in which an automated monitoring and assessment computer may be incorporated. In FIG. 2, similar to FIG. 1, a manufacturing execution system 202 connects to a system bus 205, along with a plurality of semiconductor fabrication tools 215 (labeled "equipment" in FIG. 2), which may include processing tools and/or metrology tools. Preferably, the system bus 205 comprises a standard communication bus, such as a Distributed Common Object Module (DCOM) bus, but it may also comprise a non-standard or proprietary communication bus. The DCOM bus is commonly used in connection with the Windows NT® operating system. As further shown in FIG. 2, also connected to the system bus 205, via a software bridge 208, is an automated monitoring and assessment system 207, which may comprise one or more computers, servers and databases, as further described herein.

In a preferred embodiment, the automated monitoring and assessment system 207 comprises a CORBA interface by which messages packaged as CORBA objects are received from the software bridge 208. The software bridge 208 preferably translates messages transmitted or published over the system bus 205 (e.g., DCOM messages) into a CORBA format, so that the automated monitoring and assessment system 207 can receive them. Thus, in one aspect, the automated monitoring and assessment system 207 in FIG. 2 can be configured identically to the automated monitoring and assessment system 107 shown in FIG. 1, since the automated monitoring and assessment system either (as in FIG. 1) receives messages from a system bus 105 in the monitoring and assessment system's native configuration, or else (as in FIG. 2) receives messages through a software bridge 208 from a system bus 205 which is not otherwise compatible with the monitoring and assessment system's native configuration.

As with the embodiment shown in FIG. 1, messages transmitted or published over the system bus 205 from the various semiconductor fabrication tools 215 to the manufacturing execution system 202 may be sent as SECS messages, and may include, for example, various alarm messages, event messages, parameter updates (e.g., SVID messages), symptom (or trigger) messages, and the like. The automated monitoring and assessment system 207 receives information from the transmitted or published messages, and uses that information to track the operation states of the various semi-conductor fabrication tools 215, according to techniques described in more detail herein.

FIG. 3 is a top-level diagram illustrating yet another example of a semiconductor fabrication system 300 in which an automated monitoring and assessment computer may be incorporated. In FIG. 3, similar to FIG. 2, a manufacturing execution system 302 connects to a first system bus 305, along with a plurality of semiconductor fabrication tools 315 (labeled "equipment" in FIG. 3), which may include processing tools and/or metrology tools. The first system bus 305 preferably comprises a standard or non-standard communication bus of a first type, such as a DCOM bus. Unlike the system 200 shown in FIG. 2, the system 300 shown in FIG. 3 includes a second system bus 306, which preferably comprises a standard communication bus of a second type, such as a CORBA bus. An automated monitoring and assessment system 307, which may comprise one or more computers, servers and databases, as further described herein, is connected to the second system bus 306. The various semiconductor fabrication tools 315 are connected to the second system bus 306 as well as to the first system bus 305. Preferably, the semiconductor fabrication tools 315 include low-level drivers 316 which transmit or publish information on the second system bus 306 at essentially the same time the information is transmitted or published on the first system bus 305.

In a preferred embodiment, the automated monitoring and assessment system 307 comprises a CORBA interface by which messages packaged as CORBA objects are received via the second system bus 306. A bus controller (not shown in FIG. 3) may also be connected to the second system bus 306, to manage communications thereover. In one aspect, the automated monitoring and assessment system 307 in FIG. 3 can be configured identically to the automated monitoring and assessment systems 107 and 207 shown in FIGS. 1 and 2, respectively, since the automated monitoring and assessment system either (as in FIGS. 1 or 3) receives messages from a system bus 105 or 306 in the monitoring and assessment system's native configuration, or else (as in FIG. 2) receives messages through a software bridge 208 from a system bus 205 which is not otherwise compatible with the monitoring and assessment system's native configuration.

Messages transmitted or published over the system buses 305 or 306 from the various semiconductor fabrication tools 315 to the manufacturing execution system 302 or automated monitoring and assessment system 307 may be sent as SECS messages, and may include, for example, various alarm messages, event messages, parameter updates (e.g., SVID messages), symptom (or trigger) messages, and the like. The automated monitoring and assessment system 307 receives information from the transmitted or published messages, and uses that information to track the operation states of the various semi-conductor fabrication tools 315, according to techniques described in more detail herein.

FIG. 4 is a top-level diagram illustrating further details of a semiconductor fabrication system 400 in which an automated monitoring and assessment computer may be employed. As shown in FIG. 4, a manufacturing execution system 402 is connected to a system bus 405. An automated monitoring and assessment system 407 may connect to the system bus 405 also, through a software bridge or other type of interface if necessary. A variety of semiconductor fabrication tools 415 (labeled "equipment" in FIG. 4) may be connected to the system bus 405 through equipment interfaces 420 (which may be supervisory stations), which format and transmit messages over the system bus 405 according to a protocol compatible with the system bus 405, and likewise interpret messages received over the system bus 405 according to the protocol. For example, the equipment interfaces 420 may each comprise a SECS or GEM interface. Semi-conductor fabrication tools 415 may also be connected to an equipment supervisor workstation 425, which may generate information in a standard compatible with the automated monitoring and assessment system 407.

The automated monitoring and assessment system 407 preferably is configured to receive messages according to the CORBA protocol. A database 430 for storing, among other things, information gathered by monitoring the various semiconductor fabrication tools 415 is connected to or incorporated in the automated monitoring and assessment system 407. Also, a web server 435 configured with a variety of application programs may be connected to or incorporated in the automated monitoring and assessment system 407. The web server 435 may be connected to a distributed electronic network 438 – for example, a global electronic network such as the Internet, or a proprietary intranet. Users, preferably connected through any of a variety of web browsers 441, 442, 443 or 445, may receive information from the automated monitoring and assessment system 407 via the web server 435 and the associated application programs. The automated monitoring and assessment system 407 preferably comprises one or more computers which are programmed to perform the functions specified herein. The computer programs run on the automated monitoring and assessment system 407 are preferably written in a platform-independent language such as JAVA®, which may make it convenient to support remote users connected via web browsers 441, 442, 443 or 445, but may be written in any suitable programming language.

Messages (e.g., SECS messages) transmitted or published over the system bus 405 or through the equipment supervisor workstation 425 from the various semiconductor fabrication tools 415 may include, for example, various alarm messages, event messages, parameter updates (e.g., SVID messages), symptom (or trigger) messages, and the like, which may be used in connection with the automated monitoring and assessment system 407 as hereinafter described.

FIG. 8 is a block diagram showing details of one embodiment of a preferred automated monitoring and assessment system 800, as may be employed, for example, in any of the systems 100, 200, 300 or 400 shown in FIGS. 1, 2, 3 and 4, respectively. As shown in FIG. 8, the automated monitoring and assessment system 800 preferably comprises a trigger/event interface 810 for receiving messages and various other event information which may cause state changes to occur. The trigger/event interface 810 may receive sensor events 802, SECS messages 803 (or messages in other formats besides SECS) and MES messages 804, as well as manually entered information 805 via a user interface 820. A state model 815 is defined for the semiconductor fabrication facility and maintained in the automated monitoring and assessment system 800. The state model 815 may be initially set up via the user interface 820. When messages or events occur, the trigger/event interface 810 processes them and forwards them to the state model logic 815 to transition states as necessary, upon which a state change transition logger 823 logs the state change, along with any pertinent information, in a tracking database 830. The user interface 820 may access the tracking database 830 to view stored messages or potentially modify their content (assuming appropriate privileges and authorization). A report generator 835 also may access the information in the tracking database 830 to generate graphs or performance metrics (for which a metric calculation logic 838 may be utilized). Reports may be made according to parameters specified by users via the user interface 820, may be requested manually or automatically generated, and may be e-mailed to users (via a web server or other web interface, not shown in FIG. 8) or optionally be printed out at a local or remote printer 840.

Further details will now be described about the functionality of the automated monitoring and assessment system 400, and a preferred software architecture and software flow for achieving such functionality. While these details are described, for convenience, with respect to the system 400 illustrated in FIG. 4 (or sometimes FIG. 8), it should be understood that the same functionality, software architecture and software flow may be applied to any of the systems 100, 200 or 300 illustrated in FIGS. 1, 2 or 3, respectively, or other automated semiconductor fabrication systems.

In a preferred embodiment, a state table including a set of potential states is defined for each semiconductor fabrication tool 415 in the system 400 for which tracking is desired. Through a user interface managed by the automated monitoring and assessment system 407, the operator of the facility specifies the state transition logic (i.e., triggering events and consequential state transitions) for each tool of interest. When a trigger message is received, the automated monitoring and assessment system 407 transitions the state model for the specific tool or chamber to an appropriate state. The user-specified state transition logic, in one aspect, adaptively modifies the behavior of the monitoring and assessment software, such that state changes are tracked and recorded according to the user-specified criteria. The user-specified state transition logic, in another aspect, acts as a filter for incoming trigger messages, such that preferably only those triggering messages relevant to the user-specified state transition logic cause information to be recorded in the tracking database 430. As a consequence of this filtering aspect, the tracking database 430 can be significantly more compact then if, for example, all triggering messages were recorded and later analyzed.

In a preferred embodiment, the monitoring and assessment software defines a hierarchy of potential states for each semiconductor fabrication tool 415 connected in the system 400. The hierarchy of potential states is preferably based at least in part on the E10 and/or E58 Standards. For example, the hierarchy of potential states may include six top-level states (Unscheduled Downtime, Scheduled Downtime, Engineering Time, Standby Time, Productive Time, and Non-Scheduled Time), a set of intermediate states (e.g., 10 intermediate states) associated with each top-level states, and one or more optional levels of sub-states beneath each intermediate state. FIG. 5 is an illustration of one possible state table hierarchy. Through an editing tool, a system operator may create new sub-states and assign the sub-states within the state table hierarchy.

To distinguish the states within the software structure, each state preferably includes a state identifier ("state ID"). The state ID may comprise an alphanumeric string encoded to represent state information. As just one example, the state ID may be a four digit alphanumeric string, with the first digit identifying the top-level state (encoded as 1 through 6), the second digit identifying the intermediate sub-state according to the E58 Standard (section 9 thereof), the third digit identifying a user-defined third-level sub-state beneath the intermediate sub-state, and the fourth digit identifying a user-defined fourth-level sub-state beneath the third-level sub-state. For convenience to the user (in terms of displayability), the third and fourth digits may each be selected from among the groups of alphanumeric digits a...z, A...Z or 1...9, such that

61 possible sub-states at each of the third and fourth levels are possible (with "0" indicating no sub-state at that level). Thus, state ID's of 51a6 and 51A6 would represent distinct states. State 5112 would be a sub-state of each of the higher-level generic states – that is, states 5110 (the third-level state), 5100 (the intermediate or second-level state), and 5000 (the top-level state). User-defined states are generally not permitted for top-level states or in the absence of intervening sub-states at each level. Thus, for example, states 1011, 1008, 2034, 1208, 3409 and 9902 would all be "illegal" states, whereas states 1000, 1100, 1110, 1320, 3452 and 1919 would all be "legal" states. With more than four digits, additional sub-levels to the state hierarchy may be added. Similarly, more characters than simply the alphanumeric digits a…z, A…Z and 0…9 may be used to represent states, but having four hierarchical levels with up to 61 sub-states at each level is likely to cover the vast majority of implementations in practical settings.

Preferably, each state also has an associated state description and set of state properties. The state description may simply be a text field of, for example, 80 characters. The state properties may include the following:

Automatic Transition Triggers – collectively define the symptoms (i.e., trigger message) which cause a state transition to this state

Cluster Tool Linkage – define the associated state changes to other tools when a state change occurs on the cluster tool. An example would be a state change to

Unscheduled Maintenance of a main tool would automatically change the states of all associated chambers on the cluster tool.

Process Name – identifies the process for Productive states. It is used to associate productivity statistics with a given Productive state. A system operator may input the theoretical and value added information for any process, which can be compared with actual run-time data for metrics calculated according to the E79 Standard.

Enabled/Disabled Bit – when enabled, allows users to select this state when changing equipment states via the user interface (i.e., not by automatic response to a trigger message) to some new state. Disables states might be, for example, the default reserved states in the E10 or E58 Standards.

User/Group Access – specifies the group access levels that can transition from this state when changing equipment states via the user interface to some new state.

Valid User State Transitions – define the list of valid states the user may transition to from this state when changing equipment states via the user interface to some new state. An example might be the Down for Repair state, which might require a transition to a Process Qualification State prior to transition to an Up for Production state (which would hence be an illegal state transition directly from Down for Repair). If the list of Valid user State Transitions is left empty, then all defined states are selectable.

State transition rules among the various states in the state table hierarchy preferably include at least the automatic state transitions defined by the E58 Standard in section 8, table 1 thereof, plus any user-defined state transition rules. Also, a system operator (via the user interface) or the manufacturing execution system may force a transition to a new state at any time, assuming proper privileges and authorization.

The E58 Standard defines fifteen transition rules. The automated monitoring and assessment software allows a system operator to configure the trigger events for each automatic state transition, and to define new state transition rules. The trigger information may vary from tool to tool. When a state transition occurs, it preferably gets logged in the tracking database 430, as further described herein. When a trigger event occurs, the automated monitoring and assessment software preferably tests a variety of criteria to classify the associated transition into a default category, if applicable. The default transition types may be changed by the system operator, or new ones added. The following are possible default transition types, as defined by the E58 Standard:

<u>Transition 1, Power-up/Reset</u>

When a power-up trigger event occurs, the automated monitoring and assessment software transitions to the state defined by this trigger event. The default destination state is Standby ("SBY").

Transition 2, To Manufacturing

Not supported if the automated monitoring and assessment software does not have access to the production criteria for the tools of interest.

Transition 3, To Productive

Defined as an automatic transition from any non-Productive state to a Productive state.

Transition 4, To Standby

Defined as an automatic transition from any non-Standby state to a Standby state.

Transition 5, Fault Detected in Productive

Defined as an automatic transition from a Productive state to an Unscheduled Down state.

Transition 6, Productive Fault Cleared

When a trigger message causes an automatic transition from an Unscheduled Down state to a Productive state.

Transition 7, Fault Detected in Standby

Defined as an automatic transition from a Standby state to an Unscheduled Down state.

Transition 8, Standby Fault Cleared

When a trigger message causes an automatic transition from an Unscheduled Down state to a Productive state.

Transition 9, Scheduled Downtime

When a monitored parameter has reached a pre-defined limit, as indicated by a received message, the automated monitoring and assessment software transitions the tool to the appropriate Scheduled Maintenance sub-state.

Transition 10, User Initiated Transition

A transition caused when a new state is selected via the user interface of the automated monitoring and assessment system, or by the manufacturing execution system via an object interface.

Transition 11, Power-down

No default set, but users may classify a specific trigger type as a power-down event.

Transition 12, Standby to Standby State Change

Defined as any transition from one Standby sub-state to another Standby sub-state.

Transition 13, Productive to Productive State Change

Defined as any transition from one Productive sub-state to another Productive sub-state.

Transition 14, Fault Detected in Engineering State

Defined as an automatic transition from an Engineering state to an Unscheduled Down state.

Transition 15, Engineering Fault Cleared

Defined as when a trigger event causes an automatic transition from an Unscheduled Down state to an Engineering state.

As noted above, preferably all state transitions are logged in a tracking database 430 for later use. In a preferred embodiment, the tracking database 430 is comprised of records which are regularly added to it as a result of state transition events. Each record may include any of a variety of information, such as the following:

Time stamp – local CPU time of received trigger event or message

Transition number – based on the transition types specified above

Unit IDs – a set of text fields (for, e.g., lot IDs or wafer IDs)

Batch ID – text field (if Units are wafers, this is the lot ID, otherwise an optional batch ID)

PPID – text field storing recipe name if sent with the trigger message

PPID Class – text field storing the PPID class, sent either with the trigger message or derived from the automated monitoring and assessment software

Source – origin of transition request (i.e., user, manufacturing execution system or tool server)

Symptom – the symptom or trigger number corresponding to the symptom table (i.e., trigger table)

OEE State Change – set of flags for each state level, set to true if the previous state was a different OEE state, otherwise false

Cycles – the total number of cycles the equipment has processed since install (sent from the tool)

Interrupt – classification of transition to Unscheduled Down Time as equipment Assist or Failure (preferably only recorded when a transition to Unscheduled Down Time occurs from a non-Unscheduled Down Time state)

Interrupt Classification – classify of Interrupt as Chargeable, Non-Chargeable or Non-Relevant

ARAMS State Number – 4-digit ARAMS state code identifying the triggered destination state

External State – set of Boolean states used to denote when external states change, such as no operator available, or SMC violation

THT – Theoretical Production time per unit (only valid in Production states)

ETHT – Engineering Theoretical Production time per unit (only valid in Production states)

VTHT – Value Added Theoretical Production time per unit (only valid in Production states)

Actual Units – actual unit processed (only valid in Production states)

Scrap Units – scrapped units in this process (only valid in Production states)

Rework Units – number of units requiring rework (only valid in Production states)

ALID – recorded ALID (alarm event ID) sent from a SECS compatible driver

ALID Text – recorded alarm text from a SECS compatible driver

CEID – recorded CEID (event ID) sent from a SECS compatible driver

CEID Text – recorded event text from a SECS compatible driver

SVID – recorded SVID number, but only when a transition is logged (SVIDs preferably do not get logged except in transition records)

SVID Number – recorded SVID (system variable ID) value, if numeric

SVID ASCII – recorded SVID value, if in ASCII format

ms1, ms2, ms3, ms4 – time (in milliseconds, e.g.) since the last transition for each state level (assuming 4 state levels)

Text – set of user-defined text fields

Floats – set of user-defined signed float fields

Since reporting the behavior of the tools in a fabrication facility may require intensive time calculations by the automated monitoring and assessment software, the design of the tracking database 430 is preferably optimized to reduce the report generation time. In one embodiment, to arrive at entries for the time entry fields ms1, ms2, ms3 and ms4, the previous record for the particular tool is read out of the tracking database 430 prior to storing a new record. If the previous record contained a state transition, then for the new record the time between the new record's timestamp and the previous record's time stamp is stored in each time entry field (i.e., each of ms1, ms2, ms3 and ms4) corresponding to a changed state. If the previous record did not contain a state transition, then the values from the time entry fields from the previous record are each added with the time between the new and previous records (i.e., between the new record's timestamp and the previous record's timestamp), and the sums stored in the time entry fields (ms1, ms2, ms3 and ms4) for the new record. In this manner, the time since the previous state change is carried forward until a state change occurs.

Triggers generated by the automated monitoring and assessment system 407 that do not result in a state change will nevertheless be logged in an audit trail. The tool name, time stamp, source of the trigger (user, manufacturing execution system, or tool server), event or symptom, and current state number may be recorded in an audit record. Preferably, records may be retrieved from the audit trail in a relatively prompt fashion based on selected groups of tools, states or transitions, or any combination of the above-mentioned stored fields. An editing interface may be provided allowing users to edit audit trail records, in case, for example, incorrect states were selected based upon incorrect input criteria or accidental user selection. Users may edit, delete or insert new records when inaccurate information has been supplied causing state transitions.

In a preferred embodiment, all states and sub-states keep a running total of accumulated time within the state. A convenient unit of measure, such as milliseconds, may be selected for keeping track of time in each state. Preferably, at least the following categories of information are maintained for each state:

1) a timestamp of the last time the state was transitioned into

2) the number of times any state transitioned to this state

3) the total amount of time spent in this state (e.g., in milliseconds) since the last user reset

4) The timestamp of the last user-initiated accumulator reset for this state

A user may reset the total amount of time spent in a state at any time, causing the total count to be reset to 0 milliseconds. The current accumulator information is preferably stored in a table separate from the tracking database 430 for quick access when required, per user or operator request, at a live status screen by which activity of the semiconductor facility may be monitored.

In a preferred embodiment, each message received by the automated monitoring and assessment system 407 includes a transition initiation type code which specifies which element in the message will be used to generate the transition, if any. The encoding of the transition initiation type may be as follows:

0 – "Default" The automated monitoring and assessment system 407 is to use its internal priority to determined which element will cause a transition. The internal priority is 1–Trigger, 2–ALID, 3–CEID, 4–SVID

1 – "ALID" The automated monitoring and assessment system 407 will only evaluate the ALID to generate a transition, all other elements will be logged in the database. The automated monitoring and assessment system 407 will ignore any value sent in the Trigger field.

2 – "CEID" The automated monitoring and assessment system 407 will only evaluate the CEID to generate a transition, all other elements will be logged in the database. The automated monitoring and assessment system 407 will ignore any value sent in the Trigger field.

3 – "SVID" The automated monitoring and assessment system 407 will only evaluate the SVID to generate a transition, all other elements will be logged in the database. The automated monitoring and assessment system 407 will ignore any value sent in the Trigger field.

X – any other value is treated the same as a 0 (i.e, Default)

FIG. 6 is a diagram illustrating a software logic flow for processing messages at the automated monitoring and assessment system 407 based upon the transition initiation type. As shown in FIG. 6, the automated monitoring and assessment system 407 first receives a message or other trigger event in step 601. In step 602, the software determines whether the transition initiation type is a "1", indicating an alarm ID. If so, then, in step 630, the alarm event ID (ALID) is processed. The alarm event ID is added to an alarm event ID table if new; otherwise, the state transition logic is looked up. If a trigger is mapped to the alarm event ID, then the process moves to step 660, wherein the trigger is processed using the state model logic (see FIG. 7 and description hereinafter). After step 660 is complete, or if the trigger is not mapped to the alarm event ID, then the pertinent information is logged in the tracking database 430 and the processing of the message is complete.

If the transition initiation type is not a "1", then the software then determines whether the transition initiation type is a "2", as indicated by step 605. If the transition initiation type is a "2", indicating a collection event ID (CEID), then the process moves to step 650, whereupon the event is processed. The collection event ID is added to a collection event ID table if new; otherwise, the state transition logic is looked up. If a trigger is mapped to the collection event ID, then the process moves to step 660, wherein the trigger is processed using the state model logic. After step 660 is complete, or if the trigger is not mapped to the collection event ID, then the pertinent information is logged in the tracking database 430 and the processing of the message is complete.

If the transition initiation type is not a "2", then the software then determines whether the transition initiation type is a "3", as indicated by step 608. If so, a system variable ID (SVID) type is indicated, and the process moves to step 640, whereupon the system variable ID is processed. The system variable ID is added to a variable ID table if new; otherwise, the state transition logic is looked up. If a trigger is mapped to the system variable ID, then the process moves to step 660, wherein the trigger is processed using the state model logic. After step 660 is complete, or if the trigger is not mapped to the system variable ID, then the pertinent information is logged in the tracking database 430 and the processing of the message is complete.

If the transition initiation type is neither "1", "2" nor "3", then the software determines whether the message contains a trigger. If so, the trigger is processed using the state model logic. If not, the message is checked for an alarm ID, then an event ID, and then a variable ID, in steps 612, 615 and 617, respectively. If any of those IDs are found, processing is similar to described above based upon the transition initiation type. If there is no trigger, transition initiation ID, nor actual ALID, DEIC or SVID, then no information is logged into the tracking database 430, but a message is preferably posted to the audit trail.

An example of operation of the system 400 in response to a transition initiation type code is as follows. Assume a trigger message having the following characteristics and information is received:

Tool = 3

Recipe = "Process abc"

LotID = "Lot 123"

Text_1 = "IC_36_2003"

Float_1 = 22

Transition Initiation Type = 2

Trigger = 15

ALID = 2312

Alarm Text = "Pressure Alarm"

CEID = 4530045

Event Text = "Pressure Alarm Event"

SVID = 3450220

SVID Number = 345.2

SVID ASCII = ""

Initially, the automated monitoring and assessment software preferably evaluates the value of the transition initiation type of the above trigger message. Since, in this example, the value is "2", the transition initiation type is identified as a CEID initiation type. The automated monitoring and assessment software then preferably looks up the CEID in a CEID table. If it is not found, the automated monitoring and assessment software adds the CEID to the CEID table. If the CEID does exist in the table, the automated monitoring and assessment software looks up the mapped trigger from the CEID table. If no trigger is found, the automated monitoring and assessment software logs all of the message parameters in the tracking database 430 without a state change. (In such a case, the trigger number field may be left blank, since no trigger was mapped to the CIED and the trigger is ignored as a result of the initiation type being CEID). If a trigger is mapped to the CEID in the CEID table, the automated monitoring and assessment system may forward the trigger to the state transition logic, which then acts upon the trigger.

FIG. 7 is a diagram illustrating a software logic flow for receiving and filtering trigger messages or other trigger events at the automated monitoring and assessment system. As trigger messages or events are received by the automated monitoring and assessment system 407, the state and trigger properties determine the action taken. In many cases, a trigger will cause the state model to transition to a new state. All trigger messages and events received are preferably recorded in the tracking database 430, as well as any action taken, for purposes of audit trail logging. As shown now in FIG. 7, when the automated monitoring and assessment system 407 receives a trigger, as indicated by step 701, it assesses the state table logic for the particular semiconductor fabrication tool 415 to set any external states keyed to the trigger, as indicated by step 703. External states affect equipment performance but are not directly related to the equipment actions. Examples of external states are: No Operator, No Product, No Support Tool, No Consumables, Process SPC Violation, etc. External states often cause the particular semiconductor fabrication tool 415 to record time in a specific Standby sub-state. The set-up of external states and their effects are described in more detail hereafter.

Certain trigger messages from the manufacturing execution system 402 may be set up to cause a delayed transition between states in a tool's state table logic, by modifying a tool's external state(s). For example, a No Operator or No Product trigger message from the manufacturing execution system 402 may cause a delayed transition. As an illustration of this operation, assume a semiconductor fabrication tool 415 is processing wafers in the Productive state. The manufacturing execution system 402 (or manufacturing execution system) sends a No Product trigger message for the tool 415.

The automated monitoring and assessment software does not transition to a Standby state until the tool 415 has completed processing. However, the tool's external state is modified to reflect the fact that there is no further product. When the tool 415 eventually finishes processing at a later time, the tool 415 will transition to a Standby/No Product state instead of a Standby/Idle state, due to the effect of the No Product trigger previously received. In step 703, the automated monitoring and assessment software sets external states that are keyed to the particular trigger that has been received.

In a next step 705, the automated monitoring and assessment system 407 performs trigger logic to lock or unlock a specified tool state, if appropriate. Any state in the state logic table may be locked, such that it is not affected by triggers. The only way to transition to a new state from a locked state is through the user interface of the automated monitoring and assessment system 407, until the current state becomes unlocked. Locking a state may be useful for Unscheduled Down states that may receive process start and stop triggers as maintenance personnel attempt to fix, re-program or otherwise interact with equipment. Automatic unlocking of a tool state is possible through a trigger message, and is carried out, as shown in FIG. 7, in step 705 if such a message is received.

In a next step 708, the automated monitoring and assessment software determines whether the state logic table for the particular semiconductor fabrication tool 415 which is the subject of the received message is configured for the particular type of trigger. If not, then the process 700 branches to step 730, whereupon the pertinent information relating to the message is stored in the tracking database 430. Otherwise, the process 700 continues to step 710, whereupon the automated monitoring and assessment software determines whether the current state is locked. If so, then again the process 700 branches to step 730, whereupon the pertinent information relating to the message is stored in the tracking database 430.

If the current state is not locked, then the process 700 moves forward to step 715, in which the automated monitoring and assessment software determines whether or not the current state is configured for state branching based upon recipe (PPID) classification responses. If so, then in step 718 a state transition is carried out based upon the recipe (PPID) classification. Otherwise, in step 720 the automated monitoring and assessment software determines whether the current state is configured for state branching based upon the existence of external states. If so, then in step 723 a transition is carried out based upon the external state(s). Otherwise, in step 725 a state transition is carried out based upon the particular trigger.

In some cases, a trigger may initiate a transition from a sub-state causing the state model to return to the previous state. For example, an "Tool Alarm Cleared" trigger may transition the tool from an Unscheduled Down state back to a Production, Engineering or Standby state. The new state may depend upon what state the tool was in prior to the original trigger (e.g., "Tool Alarm") causing the state change to the Unscheduled Down state in the first place. If the state model calls for a transition to a previous state, then the previous state can be looked up from the tracking database 430 (based upon the tool ID), and the previous state will then be used as the new state.

In step 730, the pertinent information regarding the trigger and state transition are recorded in the tracking database 430, as previously described.

In step 735, the automated monitoring and assessment software determines whether the new state is configured for sub-state linkage, as in the case where a cluster tool has a main tool linked to individual modules, or has interlinked modules. Each processing module of a cluster tool is preferably processed with its own independent state model. Any part (i.e., module) of a cluster tool may interact with other tools based on its state model. As an illustration of the effect of this software structure, if a robot failure occurs on a cluster tool, each chamber (i.e., module) should transition to an appropriate Non-Productive state until the robot is repaired. This type of action is implemented through the logic in step 735, which checks for sub-state linkages when a trigger is received and acted upon. If the new state of the current tool is configured for sub-state linkage, then the process 700 (i.e., steps 703 et seq.) are repeated for each linked tool, as indicated by step 738. In some instances, this may lead to nested processing, where a first tool has a sub-state linkage to a second tool, which in turn has a sub-state linkage to a third tool. The automated monitoring and assessment software preferably prohibits a cross-referencing sub-state linkages between tools. That is, if a tool has already been processed according to the steps in process 700, then step 738 is blocked for that particular tool so that the processing will not be repeated for it.

If there are no sub-state linkages for the new state, or if all sub-state linkages have been processed, then the process 700 is complete.

Preferably, manual override of trigger properties is supported by the automated monitoring and assessment system 407, to allow, for example, maintenance personnel to adjust the "reason" for unscheduled down time when their investigation leads to discovery of the problem that caused the down time. Typically, a transition from any

Unscheduled Down state to a Standby state is a manual action initiated by maintenance personnel or a system operator. The user is preferably allows to change the "reason" and "classification" recorded when the state model transitioned to an Unscheduled Down state. For example, a trigger message for "Flow Abort" may be classified as an "Interrupt" and may cause a transition to "Unscheduled Down Time (UDT)/Flow Problem." When the maintenance personnel transition back to "Productive (PRD)/ Normal Production" they may change the classification of the original "Flow Abort" trigger from "Interrupt" to "Assist", if appropriate. Such a change may be made via the user interface of the automated monitoring and assessment system 407.

Preferably, the automated monitoring and assessment system also supports modifications to logged time in various states that are required due to scrap units and reworks that often occur during semiconductor fabrication. For the purposes of tracking performed by the automated monitoring and assessment system 407, any semiconductor fabrication tool 415 which is processing production material is assumed to be producing saleable product wafers when running Production states. However, some process steps may be reworked when a mistake occurs in the process. Rework information typically does not become available until after the actual processing, usually from an inspection step. The automated monitoring and assessment system 407 preferably allows a system operator, via the user interface, to subtract the production state credit when rework is required or product is scrapped. In some cases, the manufacturing execution system 402 may send trigger objects with log IDs, wafer IDs, wafer count, tool ID and recipe name associated with the scrap or rework material. The automated monitoring and assessment system 407 preferably records the rework or scrap material against the reported tool 415 and saves the data with the original run data. The tool 415 used to process the rework material may be given full production credit based on the assumption that the material will process correctly the second time.

Further details will now be described regarding various examples by which the state models for the various tools 415 can be developed and defined. In a preferred embodiment, a user interface is provided for the automated monitoring and assessment system 407 allowing a system operator or other personnel to view the current state model for each tool 415, and to modify it as desired. The user interface is preferably graphically oriented, and may include various graphical screen images displayed on a computer monitor connected directly or indirectly to the automated monitoring and assessment system 407. For example, users may access the state model information (with proper authorization and verification) via a web browser 441, 442, 443 or 445 or equivalent software interface program, over a computer network, which may be a local network or a wide-area network.

In certain embodiments, at least two different techniques for mapping state transitions are provided. First, the automated monitoring and assessment system 407 may be "hooked up" to the semiconductor fabrication system 400 and allowed to monitor messages transmitted among the tools 415, manufacturing execution system 402 and other system components for a certain period of time long enough to be representative of most or all of the states in which the tools 415 will be. Then, the user may review the trigger messages from the tracking database 430, via the user interface, and manually associate each type of trigger with a state transition for a particular tool 415. To facilitate this process, the automated monitoring and assessment software may pre-populate a trigger configuration screen (see, e.g., FIG. 12) listing the triggers received for the particular tool 415 during passive monitoring of the system, allowing the user to define associations between triggers and state changes based in part on the actual experience of the system 400. Alternatively, the user may directly, via the user interface, create associations between state transitions for the various tools 415 based on the various triggers, without the benefit of trigger data gathered by the automated monitoring and assessment system 407 during actual operation of the semiconductor fabrication system 400. Default state transitions may, in either case, be defined according to the E58 Standard, and in particular, section 8.2 thereof.

FIG. 9 illustrates an example of a screen image which may be displayed to a user for editing an existing state model for a particular tool 415. In the example shown in FIG. 9, the tool is identified as "ToolABCMain" in zone "ZoneXYZ". As suggested by the zone identifier in FIG. 9, tools 415 may be grouped into different zones for organizational and reporting purposes. User-defined zones may or may not be based on structural features of the actual semiconductor fabrication system 400. As further illustrated in the example of FIG. 9, the user may initially be presented with a list of the default states as specified by the E10 and/or E58 Standards, including the Productive state (and its sub-states), Standby state (and its sub-states), Engineering state, Scheduled Downtime state, Unscheduled Downtime state (and its sub-states), and Non-Scheduled state. The user may select any of the displayed states by any standard data entry means – for example, by highlighting and/or clicking on a state using a computer mouse. Sub-states for a given state, at each level of the hierarchy, may be expanded out for viewing by selecting (e.g., clicking on) the "+" symbol next to the state.

Conversely, sub-states for a given state may be retracted (i.e., hidden) by selecting the "-" symbol next to the state, which is only possible when the sub-states have been expanded out. If no sub-states exist for a given state, then no "+" or "-" symbol will appear next to the state.

At the top of the state model editor screen shown in FIG. 9, the user is presented with several drop-down menus, including a File menu, Edit menu, Options menu, View menu and Help menu. The File menu includes open, save, reload and print options to the user. Each opened "file" pertains to a particular tool state model definition. Preferably, the top-level state names and second-level state names are pre-defined according to the E58 Standard, and are not subject to editing by the user (and thus may be referred to as "protected states"). However, currently "reserved" states under the E58 Standard may be subject to change and therefore, in certain applications, it may be desirable to allow editing by the user of the top-level and/or second-level state names, or at least the currently reserved top-level and/or second-level state names.

The user is preferably provided with the capability of adding a new state by selecting a state and invoking a pop-up (or drop-down) menu 910 for the selected state (e.g., by right-clicking a highlighted state with the computer mouse). The pop-up menu 901 may provide options to the user of, for example, adding a new sub-state to the currently selected state, editing the name or an existing state or updating any state property information, copying state properties from the currently selected state (i.e., to a clip board), pasting state properties to the currently selected state (i.e., from the clip board), and deleting a state. When selecting a name for a state, a pre-fix comprising the higher-level state names (e.g., "SBY/" or "SBY/No Product/") is automatically added to the newly selected name. When pasting state properties, the state name of the selected state is not overwritten, but all the other state properties are. The state properties for the top-level states 905 preferably may not be set, since they act as grouping mechanisms but cannot be entered without actually entering one of their defined sub-states.

FIG. 10A is a diagram of a state properties screen display 1002 as may be presented to a user who has selected a particular state to view its properties. In the example of the screen display 1002 shown in FIG. 10A, the tool's zone, tool name and parent state may be displayed at the top of the screen, for convenience to the user. The state name may also be presented in a field box 1005, and be subject to editing by the user via the user interface. The state code 1013 (i.e., unique state ID) may also be displayed. A valid transition state indicator 1008 may be enabled or disabled. Setting the valid transition state indicator 1008 to "disabled" effectively removes the state from the state model without deleting it. The reserved states in the E58 Standard are examples of states that might be disabled. A state type property indicator 1009 allows users to define the state as a user (customer) defined state or a vendor defined state. The E58 Standard defines all states to be customer defined states where the third digit of the state ID (i.e., ##x#) is a number between 1 and 9. All states where the third digit is a letter (i.e., a...z or A....Z) are defined as vendor sub-states. The automated monitoring and assessment software preferably creates the numbering for the state ID of each state according to the E58 Standard and the user's choice of "vendor" or "customer" for the state type indicator 1009 on the state properties screen display 1002. Under the E58 Standard, the user is limited to nine third level customer-defined sub-states, since the third digit is limited to 1 to 9 for customer-defined sub-states. The possible selection of state type indicator 1009 as "customer" is preferably dimmed if there are no more customer-defined sub-states left (i.e., there are already nine sub-states defined).

The state properties screen display 1002 may have a number of tabs for convenience to the user, which collectively allow presentation of a manual transitions sub-screen (shown as item 1015 in FIG. 10A), an automatic transitions sub-screen (FIG. 10B), a cluster tool state linkage sub-screen (FIG. 10C), and a productivity sub-screen (FIG. 10D). The manual transitions sub-screen 1015 allows the user to enable some security and control features useful when manually alteration of tool states becomes necessary. The User Group sub-screen 1016 displays the Group Access levels 1025 whose users will be allowed to manually transition from the state (that is, the state being edited – in this example, state 50a1). The Valid Manual Transition States sub-screen 1017 displays a list of states 905, 910 not currently selected for an access group. The current transition states 1030 allowed for an access group 1025 are listed below the group 1025. The user may select (e.g., double click) a state 1030 to move the state from the list on the User Group sub-screen 1016 back to the list on the Valid Manual Transition States sub-screen 1017. A group 1025 from the User Group sub-screen 1016 is preferably selected at all times (the top group may be selected by default), and only groups 1025 defined with access for the specific tool 415 are preferably displayed.

As with the state model editor screen display (FIG. 9), states displayed on the Valid Manual Transition States sub-screen 1017 may be expanded out by clicking on a

"+" symbol next to the state, or the sub-states may be retracted by clicking on a "-" symbol next to the state. Multiple states may be selected by highlighting groups of states, and may be cut and pasted according to standard graphical interface techniques well known in the art. Thus, for example, multiple states 910 may be "clicked and dragged" from the Valid Manual Transition States sub-screen 1017 to one or more groups 1025 appearing on the User Group sub-screen 1016.

FIG. 10B depicts an example of the state properties screen display with the Automatic Transitions tab 1041 selected. The automatic transitions sub-screen 1060 allows a user to add or delete relationships between triggers (or symptoms) 1064 and state transitions (which may be selected as some or all of the trigger responses 1070) in the state model for the particular tool 415. Default automatic transitions may be overridden, if desired, via the Automatic Transitions sub-screen 1060. One or more external conditions 1067 may be associated with various triggers 1064, allowing different state branches depending upon the nature of the external condition. Each external condition 1067 preferably has an associated descriptor 1068 which may be displayed beneath it. External conditions (states) may be added or deleted via a pop-up menu 1061, for example. Note that deleting an external state does not affect the state model. A map trigger selection in the pop-up menu 1061 allows the user to define a trigger response 1070 (which may or may not be in the form of a state transition) for the particular selected trigger 1064 and/or external condition 1067. Group selection capabilities may be provided in a triggers list to allow the users to quickly select many triggers and copy them over to or delete them from the Automatic Transitions sub-screen 1060. The user can also override the action for all triggers at once by selecting a group of triggers.

A pop-up menu (not shown) for any selected trigger 1064 may be brought up by, e.g., right-clicking with a computer mouse on the selected trigger 1064. The pop-up menu may include the following selection options: Enable PPID Class Responses; Enable Operator/Product Available; Add External State Responses; and Override Default Transition. The Enable PPID Class Responses and Enable Operator/Product Available options may be made mutually exclusive. Likewise, the Enabling PPID Class Responses option may be made mutually exclusive of the Adding External State Responses option, such that the user may set up one or the other or none, but not both. The Enable PPID Class Responses option expands the trigger responses to include one additional destination state selection for each defined PPID Classification. The Add External State Responses option allows the addition of external states, and the user may select this option multiple times to add more conditional transitions. The Override Default Transition option allows a user to select a new destination state when the selected trigger occurs in the current state.

A pop-up menu for a PPID Class may also be invoked (e.g., by right-clicking on a selected PPID Class). FIG. 11 depicts a pop-up menu 1102 as may be displayed for a selected PPID Class. The pop-up menu 1102 may display the particular trigger (i.e., symptom) type 1140, and provide selections 1105 for locking or unlocking the state. The pop-up menu 1102 may also provide various Interrupt classification options in an Interrupt Classification section 1120. The pop-up menu 1102 may also allow a choice between a Select Destination State option, by which a transition to one of the available states 1135 may be defined, or else a Return to Previous State option 1122. A "return to previous state" selection will cause the automated monitoring and assessment software to transition to the previous state the tool 415 was in (generally either Standby, Production or Engineering) when the specified trigger 1040 is received, so as to be compliant with the E58 Standard (particularly transitions 6, 8 and 15 thereof).

FIG. 10C depicts an example of the state properties screen display with the Cluster Tool State Linkage tab 1042 selected. The cluster tool state linkage sub-screen 1050 allows the change of a state for one tool to initiate a trigger for a different tool. When the tab 1042 is selected, the user is presented with a display of all tools 1053 in the system. The user can select the trigger 1054 that will be initiated for any of the tools 1053 in the system. In the present example, the trigger "Main_Module_Down" has been selected for the four chambers of cluster tool "ToolABCMain". The automated monitoring and assessment software automatically generates the selected trigger for each tool 1054 according to the relationships defined in the cluster tool state linkage sub-screen 1050 when the state (i.e., state 50a1 in this example) is entered during operation of the system. The state model for each tool 1053 will then control what transitions, if any, will occur in response to the selected triggers 1054.

An example of the usage of this functionality would be if a main tool (e.g., "ToolABCMain") has an fault that causes process interruptions to the robotics module. In such a case, using the linkage information appearing in the cluster tool state linkage sub-screen 1050, the sub tools ("ToolABC_Ch01", etc.) attached to the main tool will also transition to a fault state of some kind.

A pop-up menu 1051 may be invoked when a tool 1053 is selected to set a trigger for that tool 1053 when the current state is entered. A selection of possible triggers similar to that shown in FIG. 11 may be provided to the user, from which only a single one may be selected.

FIG. 10D depicts an example of the state properties screen display with the Productivity tab 1043 selected. If the current state whose state properties are being edited is a Productive state, then access is provided to the Productivity sub-screen 1080; otherwise, the Productivity tab 1043 is dimmed or otherwise unavailable. The Productivity sub-screen 1080 allows the user to enable productivity metrics for the current state. Certain default productivity metrics may be provided, but can be overwritten by the user. Examples of productivity metrics are illustrated in FIG. 10D.

The Copy Through Sub States option 1040 shown in each of FIGS. 10A, 10B, 10C and 10D effectively copies through all state properties except the state name to the various sub-states of the current state. Once the option 1040 is enabled (e.g., checked), any action the user takes thereafter will update the sub-states belonging to the current state. The actual update of the sub-states preferably takes place in real time. The user may, for example, turn on the Copy Through Sub States option 1040, make a change or two, and turn then it off to complete additional changes to the current state without affecting the sub states. This type of capability may be very useful when a new group (Palette) is added and the state models already exist. The user may add changes to all sub states of this state at one time for some properties but not others.

Selecting the Cancel button 1035 cancels all changes, including any changes made to the sub states with the Copy Through Sub States option 1040 being functional. The OK button 1036 saves the changes made.

FIG. 12 shows an example of a trigger (i.e., symptom) configuration screen display 1201 as may be presented to a user via the user interface for associating triggers with default transition states and interrupts for a particular tool 1415. Preferably, the zone 1202 and tool name 1203 are displayed in a visible location on the trigger configuration screen display 1201. In a trigger configuration sub-screen 1204, a list of triggers 1205 for a particular tool 415 and the triggers' associated transition states 1207 and interrupts 1208 are, initially, defined by the user or, if already defined, presented to the user for editing or modification. Examples of triggers 1205 are shown in FIG. 12 as, e.g., Process Start, Step Change, Process End, Gas Pressure Abort, Abort Recovery, Mechanical Abort, and Powerfail. A scroll bar 1209 may be used to navigate through further triggers 1205 which will not fit on the viewable part of the trigger configuration sub-screen 1204.

In some cases, various types of external conditions may be associated with the triggers 1205, leading to different possible branches to various transition states 1207. Examples of such associations are also shown in FIG. 12. Associated with the Process Start trigger are a number of PPID (i.e., recipe) classifications 1206. Thus, when the Process Start trigger is received for ToolXYZ, the next transition state depends upon the recipe classification 1206. If the recipe classification is Production, then the next transition state 1207 is "PRD/Regular Production." If, on the other hand, the recipe classification is Engineering, then the next transition state 1207 is "ENG/Engineering

Tests." The user may edit and change the transition states 1207 as desired, and may associate (or de-associate) recipe classifications 1206 with any triggers 1205 as desired. Preferably, the recipe classifications 1206 have a defined order of priority, such that the recipe classification 1206 with the highest priority is tested first and, if true, its designated branch to the next transition state 1207 occurs, but if false then the recipe classification 1206 with the second highest priority is tested, and so on. In one aspect, therefore, the recipe classifications 1206 comprise a prioritized list of branch conditions for the trigger 1205 (however, they need not be listed on the trigger configuration sub-screen 1204 in their defined order of priority). If none of the recipe classifications 1206 are satisfied, then the default transition state (in this example, "PRD/Regular Production" state 1218 associated with the Process Start trigger) is used as the next state.

In addition to adding recipe classifications 1206, the user may also associate various external states with a particular trigger 1205. An example is shown in FIG. 12 is shown with respect to the Process End trigger, which has external states 1210 and 1211 associated with it. Thus, for example, if the Process End trigger is received for ToolXYZ and the external state is set to No Operator, then the next transition state 1220 is "SBY/No Operator." However, if the external state is set to No Product, then the next transition state 1220 will be "SBY/No Product." The trigger configuration sub-screen 1204 provides a convenient means for requiring multiple external conditions to be satisfied. If several external states 1210 are grouped together in the same entry, as shown in FIG. 12, then each of the external states 1210 needs to be satisfied in order for the transition to occur. Thus, in the example illustrated in FIG. 12, each of the external states Clean1_Unavailable, Clean2_Unavailable, Clean3_Unavailable and Clean4_Unavailable would need to be satisfied (i.e., TRUE) in order for the transition to "SBY/No Support Tool – Wet Bench" state 1215 to occur. Effectively, grouping the external states 1210 together results in an ultimate conditional transition branch based upon a logical (i.e., Boolean) "AND" of the listed external states 1210.

Preferably, the external states 1210, 1211 have a defined order of priority, such that the external state (or group of external states) 1210 or 1211 with the highest priority is tested first and, if true, its designated branch to the next transition state 1215 or 1220 occurs, but if false then the external state (or group of external states) 1210 or 1211 with the second highest priority is tested, and so on. In one aspect, therefore, the external states 1210 and 1211 comprise a prioritized list of branch conditions for the trigger 1205, similar to the recipe classifications 1206 (however, as with the recipe classifications 1206, they need not be listed on the trigger configuration sub-screen 1204 in their defined order of priority). If multiple external states are associated as a group (such as external states 1210), then the group is evaluated according to the highest priority external state 1210 in the group. Since groupings of external states can be formed, the same external state may appear in more than one group. In such a case, the priority of the group depends still upon the highest priority external state therein, but if the same state is the highest priority in more than one group (therefore causing more than one group to have the same priority), the next highest priority external state is compared to determine which group has the highest priority, and so on until it is determined which group has the highest priority. If none of the external states

1210 or 1211 are satisfied, then the default transition state (in this example, "SBY" associated with the Process End trigger) is used as the next state.

Preferably, the same trigger 1205 cannot be associated with both recipe classifications (such as 1206) and external states (such as 1210 and 1211), because the number of permutations make the transition logic difficult. However, it is possible, with the addition of appropriate transition state logic, to support both recipe classifications and external states for the same trigger.

FIG. 17 illustrates a relationship between data appearing on the trigger configuration screen 1201 and data appearing on a PPID Classification sub-screen, described hereinafter, while FIG. 18 illustrates a relationship between data appearing on the trigger configuration screen 1201 and data appearing on an external state control sub-screen, also described hereinafter.

Using the File and Option menu selections appearing on the trigger configuration screen display 1201, the user is preferably permitted to select a new tool (by, e.g., searching through zones) or to save the current tool's trigger list to another tool. To facilitate configuration of triggers for a particular tool, the user interface preferably provides a trigger definition pop-up menu (not shown) which may be invoked by selecting or adding a trigger 1205 to the trigger configuration screen display 1201. The trigger definition pop-up menu may provide options for creating a new trigger, defining trigger properties, expanding the trigger responses to include an additional destination state selection for each defined PPID (recipe) classification, to add or group together external state responses, and to delete a trigger. The user interface preferably provides a Trigger Properties screen display (in the form of, e.g., a pop-up dialog window) when the option of defining trigger properties is selected by the user. FIG. 13A depicts an example of a trigger (i.e., symptom) properties screen display 1301 as may be presented to a user to adjust various trigger properties. The screen display 1301 includes a trigger (i.e., symptom) field 1302 which contains the textual name of the trigger. The screen display further includes several tabs which may be selected by the user, including a Default State Selection tab 1305, a Miscellaneous tab 1306, and an External State Control tab 1307. In FIG. 13A, the Default State Selection tab 1305 is selected, revealing the default state selection sub-screen 1310. The default state selection sub-screen 1310 may also be invoked by, e.g., clicking on a selected PPID Class 1206 on the trigger configuration screen display 1201. Likewise, an external state response pop-up screen (see FIG. 14) may be invoked by, e.g., clicking on a selected external state 1210 or 1211 on the trigger configuration screen display 1201.

From the Default State Selection tab 1305, the user may define the transition to occur when the trigger is received at run time for the particular tool. The user may choose either a single destination state, from the listing of states appearing on the default state selection sub-screen 1310, or else choose a return to the previous state. If a return to the previous state is selected, then at run-time when the trigger is received for this tool, its previous state in the state model will be the new state to which it will transition. The choice between one of the destination states from the default state selection sub-screen 1310 and returning to the previous state is mutually exclusive. The selection of "None" for the default state transition is allowed, in which case when the trigger is received at run time, no state transition will occur.

FIG. 13B depicts an example of the trigger (i.e., symptom) properties screen display with the Miscellaneous tab 1306 selected. The miscellaneous sub-screen allows definition of various properties associated with the trigger. Among these properties are those appearing on an Interrupt Attributes section 1330, including Interrupt Type 1332 and Interrupt Classification 1334. The Requires Comment option 1320 forces the user to input a comment when manually selecting this trigger during run-time. The Lock Tool State option 1321 transitions to the selected state and disables automatic transitions. This functionality may be useful when the manufacturing execution system 402 or tool 415 sends a trigger that is known to force some maintenance activity that will generate false triggers. The Unlock Tool State option 1322 overrides the user lock on a state. This functionality may be useful when the manufacturing execution system 402 or tool 415 sends a trigger to begin automatic state transitions after some maintenance activity. The state will unlock and the trigger transition will occur.

Each trigger may be associated with an optional interrupt type 1332 and classification 1334. By definition, when the tool state transitions to any Unscheduled Downtime (UDT) state from ENG, PRD or SBY, the equipment has failed. A specific symptom or trigger causing the transition to the UDT state defines the interrupt type 1332 and classification 1334. The user may choose between Assist and Failure for the type 1332 of interrupt. For the classification 1334, the user may choose between Chargeable, Non-chargeable and Non-relevant.

FIG. 13C depicts an example of the trigger (i.e., symptom) properties screen display with the External State Control tab 1307 selected. The external state control sub-screen 1340 allows the user to define additional action for the automated monitoring and assessment software to take when the trigger is received. Normally, the trigger may cause a state change for the tool 415; however, the trigger may also set an external state (such as No Operator, or No Product) with or without causing a state transition. Thus, external states may be viewed as events generated external to the process equipment that have an effect on the tool state model. The states are preferably defined for each tool 415 or chamber independently.

External states may be used to conditionally transition the tool state model from one state to another. For example, if a tool 415 is processing wafers and the automated monitoring and assessment system 407 receives a trigger that No Operator is available, the external state indicating No Operator may be set, but it will not have an effect on the tool state until the tool 415 completes processing. Once the tool's process is complete, an End Event trigger from the tool 415 can cause a state transition to "SBY" or to "SBY/ No Operator" conditionally, depending on the external state of "No Operator". The existence of user-definable external states therefore provides a convenient mechanism for accurately tracking external impacts on tool performance and activity.

Examples of external states defined in the E58 Standard are No Operator, No Product and No Support tool. Each of these external states can have a negative impact on tool performance by stopping the flow of product to the tool 415, thus increasing the tool standby time.

The External State Control tab 1307 is used for several purposes. It allows the user to define a number of external states for each tool 415. It also allows a trigger or symptom to set an external state to Active or De-active. During run time, the tool state model preferably examines the status (Active or De-active) of each external state when the appropriate trigger is received, and conditionally transitions to new tool states based at least in part on the external states.

To facilitate tracking of the active/de-active status and priority of various external states, a fixed list of external state records (e.g., 20) per tool 415 may be maintained by the automated monitoring and assessment software. The user may set the priority and name of each external state. Once an external state has been defined, its place in the fixed list is preferably not changed regardless of what priority gets assigned to it, or how many other external states get defined, changed or deleted. The status (represented as an active flag) of each of the external states may be stored by index number, as opposed to priority number, to keep the data consistent over time if and when users modify the external states.

It is possible for a trigger both to set the value of one or more external states and also cause tool state transitions. If the user defines both actions, the automated monitoring and assessment software preferably sets the external states prior to performing the tool state change logic.

A pop-up menu 1350 may be provided via the user interface to allow an external state to be activated or de-activated by the particular trigger, or to prevent the trigger from activating or de-activating the external state ("No Action"), to delete an external state, add a new external state, or change the priority up or down of the external state relative to the other external states. When adding new external states, a pop-up dialog box (as depicted in FIG. 14) showing the available external states may be displayed to the user, from which the desired external state(s) may be selected. If multiple external states are selected at once, then they will be grouped together (like external states 1210 illustrated in FIG. 12) such that all need to be satisfied in order to the overall transition condition to be met.

The user interface of the automated monitoring and assessment system 407 also preferably provides a mechanism for defining system variable ID (SVID), alarm event ID (ALID) and collection event ID (CEID) mappings to various triggers. FIGS. 15A – 15F and 16 collectively illustrate screen displays that may be presented to the user in order to perform such mappings.

As shown now in FIG. 15A, a SECS Message to Trigger Mapping screen display 1501 identifies the particular tool 1504 being edited and its associated zone 1503, and includes a SECS Alarm Mapping tab 1507, a SECS Event Mapping tab 1508, and an SVID Mapping tab 1509. In FIG. 15A, the SECS Alarm Mapping tab 1507 is selected, revealing an alarm mapping sub-screen 1510 listing alarm IDs, their corresponding alarm text, and symptom mapping. Through a pop-up menu 1512, the user may add, edit or delete alarms. Preferably, both an alarm ID and its text are defined before being added. A pop-up window such as shown in FIG. 15C may be used to add or edit alarms. The user may also change the selected tool (and hence the zone), but the default tool is the current tool 415 being configured via the interface using the configuration editor. The Un-Map ALID selection of the pop-up menu 1512 changes the selected alarm's mapped symptom to "None". The Map to Symptom selection opens a symptom selection sub-screen or pop-up window, such as shown in FIG. 15B, from which various alarms may be selected. The Auto Map ALID selection maps the ALID to a symptom having identical text. If a symptom with identical text does not exist, then a new symptom is automatically generated. The Data Mapping selection is available if an ALID is mapped to a trigger; selecting it opens a trigger mapping data utility sub-screen or pop-up window, such as shown in FIG. 16 and described hereinafter.

A SECS message from one tool 415 may generate a trigger on another tool 415, using the definitions set out in the alarm mapping sub-screen 1507. For example, a main tool (of a cluster tool) may generate a different start event trigger for of each its chambers. The automated monitoring and assessment software will thus turn the event (i.e., SECS message) received from the main tool into a trigger for each chamber.

The SECS Event Mapping tab 1508 reveals a sub-screen analogous to alarm mapping sub-screen 1510, but for collection events rather than alarm events.

The SVID Mapping tab 1509 reveals an SVID Mapping sub-screen 1540 as illustrated in FIG. 15D. The SVID mapping is slightly different than the ALID and CEID mapping. The automated monitoring and assessment system 407 can be configured to generate a trigger when an SVID changes from one value to another. This functionality may be particularly useful when an SVID is used to monitor an equipment process state. For example, a process state SVID may be defined that is used to denote when the tool 415 is processing, idle, cleaning, loading, etc.

The user may select any number of items in the list of SVIDs on the SVID Mapping table 1509. A right click on any selected item will reveal a pop up menu generally similar to pop-up menu 1512 shown in FIG. 15A. Selections that may be presented by the SVID pop-up menu include: Add Changed From Value (which opens a selection list such as shown in FIG. 15F of all remaining defined VID values that are not already listed under the currently selected SVID as “Changed From” values), Un-map SVID (which changes all the SVID's transitions mapped symptom to "None"), Edit SVID (which opens the SVID Editor dialog box shown in FIG. 15E), New SVID (which also opens the SVID Editor dialog box shown in FIG 15E), and Delete SVID (which deletes the selected SVID and all its transitions from the list).

Selecting an SVID "Changed From Value" item from the sub-screen 1540 (by, e.g., right-clicking with a computer mouse) may also result in a pop-up menu, with the following options: Add Changed To Value (which opens a selection list such as shown in FIG. 15F of all remaining defined VID values that are not already listed under the currently selected "Changed From Value"), Remove All Changed To Values (which removes all "Changed To" items from the selected "Changed From Value"), and Un-map All Changed To Values (which un-maps all "Changed To" triggers for the currently selected Changed From value).

Selecting an SVID "Changed To Value" item from the sub-screen 1540 (by, e.g., right-clicking with a computer mouse) may likewise result in a pop-up menu, with the following options: Map To Symptom (which opens the symptom selection dialog shown in FIG. 15B, and maps the item to the selected trigger/symptom), Data Mapping (which is only available if the SVID "Changed To Value" is mapped to a trigger, and opens a dialog box such as shown in FIG. 15G), Remove "Changed To Value" (which removes the line from the list), and Un-map Symptom (available if the currently selected "Changed To Value" item is mapped, in which case this selection un-maps the selected item).

The possible values of an SVID should be defined prior to using the SVID transition editor (i.e., the SVID mapping sub-screen 1509). The user preferably lists all the valid SVID values that may be used to initiate a trigger. The SVID transition editor allows the user to define the SVID number, SVID name, SVID type (e.g., ASCII or Float) and up to a predefined number (e.g., 50) valid values for the SVID. A description field for each value is optional.

The valid new and old values (i.e., Changed From and Changed To values) may be presented in lists of data values 1555 as illustrated in FIG. 15E. On the SVID mapping sub-screen 1540, the user may select a wildcard (e.g., "*") for either a Changed From Value or Changed To Value. The wild card will be interpreted as any value, which may be useful if the user is only interested in whether if the SVID changed to or from a particular value. For example, if the SVID changes to a "0" the user in the current example (see FIG. 15E) then the system would know that the tool 415 just went to Idle, and it may be irrelevant what the previous value of the SVID was. Wildcards can also be useful if the SVID includes "continuous" data instead of only discrete values. For example, the user may want to generate a trigger when the SVID value is "603.23", in which case a wildcard in the old value field and 603.23 in the new value field would be used.

The user may select the set up the same VID value for both the Changed From (old) and Changed To (new) fields if desired, which may be useful if a tool, for example, sends the same value periodically when a certain event occurs. The user may also select wildcards for both the new and the old values, which is valid and could be mapped to a trigger. It would then initiate the trigger anytime the SVID changed. Also , if the user sets up a wildcard it might conflict with other SVID transitions. Thus, any fixed SVID transition preferably will override the wild card transition. For example, if the user has set up two triggers as shown below, and the SVID changes from 3 to 4, trigger 76 will be generated, not trigger 102:

SVID	Old Value	New Value	Trigger mapping
100	*	4	102
100	3	4	76

The trigger data mapping sub-screen or pop-up dialog window shown in FIG. 16 may be used for a variety of purposes. When a message is received by the automated monitoring and assessment software, some of the interesting data variables may not be available in the message object. A typical example of this situation is with multi-chamber tools. The object received from an equipment driver may contain the recipe ID, device id and layer when the lot is placed. In subsequent messages for wafer start event on multiple chambers, the lot information may no longer be available. The equipment driver may be able to provide the port used for the lot within each wafer start event for each process chamber. In such a situation, the automated monitoring and assessment software may look up the lot information from within its database to set the lot id, device id and layer for the incoming messages based on the information that was received when the lot was placed on a specific port.

Trigger data mapping allows users to specify certain fields in the trigger to be set at runtime based on existing database fields from any tool 415, using the screen illustrated in FIG. 16. If the Override Data Source field is blank for the particular trigger field name, then the automated monitoring and assessment software will use the data contained in the incoming object; otherwise, it will overwrite the field with the mapped data. Each field may be overwritten with a constant or any field from the database from any tool 415. A pop-up menu may be provided when an item in FIG. 16 is selected to remove any override criteria, allow the user to input a constant for the item, or to map the item to a data source (by allowing the user to select any defined tool and a database field of the same type as the object field).

FIGS. 19A – 19F are examples of screen displays as may be presented to a user in order to define tool or chamber specific constants, including recipe name definitions (PPIDs) and recipe name classifications. The various sub-screens shown in FIGS. 19A – 19F may be accessed by selecting the appropriate tab. Through the File menu, the user may access the parameters for the specific tool of interest. A Tool Setup sub-screen as shown in FIG. 19A allows the user to select units for the cycle counter (which may be displayed real-time on a live status screen to indicate the number of cycles the tool has processed since installation), as well as to select that batch label, unit label and default state for the tool. A Custom Fields sub-screen as shown in FIG. 19B provides a number of additional fields (e.g., 20 additional fields) per record that are configurable by the user. These fields may be used to store additional database partitioning information. For example, various tools in the system may send SECS or other messages containing information pertaining to the user-defined fields – e.g., "Device ID," or "Layer" – which would then be stored in the tracking database 430 along with the rest of the message information, in the appropriate field (e.g., the "Device ID" of the message would be stored in Text Field 01). Later, the user can search through the stored information or otherwise access it using criteria keyed to the user-defined fields, e.g., "Device ID = Pentium III."

A Parameter Lists sub-screen as shown in FIG. 19C may be provided to allow users to specify productivity-related parameters, such as those shown in FIG. 10D. Each production tool state may have its own default productivity data. If a PPID is passed with a trigger during run-time, any defined productivity data will override the default productivity data for the particular state.

A Productivity sub-screen as shown in FIG. 19D may be provided to allow the user a mechanism for generating the theoretical production time per wafer based on the desired combination of inputs such as device ID, wafer ID, PPID and layer. The productivity constants THT, ETHT, VTHT and RTHT (defined by the E79 Standard) may be handled as a hierarchical set of defaults. In general, each tool or chamber has one set of productivity constants. The user may configure the productivity constants for a state that would override the tool's default productivity constants using the state model editor. If a specific recipe or device requires a different set of productivity constants, the recipe- or device-specific productivity constants preferably override the state-specific constants. The Productivity set-up sub-screen allows the user to configure the productivity constants for the tool, and at parameter specific levels.

The user may input the tool/chamber default productivity constants and select Hours, Seconds or Minutes as the time scale. The user may also input parameter-specific productivity constants in the "spreadsheet" portion of the screen display illustrated in FIG. 19D. Up to a predefined limit (e.g., four) parameters may be selected by the user from the available independent parameters (in this example, the PPID, ten user-defined numbers and ten user-defined labels, for twenty-one total). Four “combo boxes” display the names of the parameters as set up in the Custom Fields sub-screen, shown in FIG. 19B.

Once a column name has been chosen by the user, each cell in the column becomes a selection of names as defined in the Parameter Lists sub-screen (see FIG. 19C). The columns may be resizable, and each cell may allow only one entry from the selection list. The selection choice termed “default” is used if the value for that field is not to be used in the run-time selection of the productivity constants. In the example shown in FIG. 19D, any time Process XYZ is run, the productivity constants will be (.25,.2,.08 and .23) independent of the wafer id. Process ABC, on the other hand, does require different productivity constants for “wafer 1” than it does for the rest of the wafers. Preferably, each column may be sorted, in either forward or reverse order, when the user so selects.

A PPID Classification sub-screen as shown in FIG. 19E may be provided to allow the user a mechanism for classifying recipes in to categories. For example, some recipes, such as may be used for engineering tests, maintenance activity or equipment qualifications, may be designed for non-productive runs. The user interface shown in FIG. 19E includes two scroll lists 1930, 1931 and two buttons 1935, 1936. The left scroll list 1930 shows how recipes (PPIDs) are classified into PPID Classification categories. The right scroll list 1931 displays all recipes (PPIDs) that were defined under the Parameter Lists tab (see FIG. 19C) and are not explicitly classified in the PPID Classifications list. The two buttons 1935 and 1936 may be clicked or otherwise selected by the user to move a highlighted recipe from one list 1930, 1931 to the other.

A PPID Classification pop-up menu 1940 may be provided for adding a new PPID Classification (which would appear on the left scroll list 1930), deleting a PPID Classification (i.e., removing the PPID Classification from the left side scroll list back to the right side scroll list 1931, in which case all state transitions in the state model dependant on this PPID classification are removed), to rename a PPID Classificatio, and to Create a Wild Card PPID: Present the user with a simple dialog to input text that will be used to map PPIDs to this currently selected classification. A PPID pop-up menu may be provided to the user when a PPID within the scroll list 1930 is selected, for removing a PPID from classification (and adding it back to the right side of the list). However, a wild card PPID is not moved back to the right side of the scroll list.

An example of wild card characters that may be used are as follows:

"*" May contain no characters or any number of characters.

"?" Must contain one character, may be any single character.

An example process name of "?roc?ss*" would match processABC, PROCESSXYZ and PrOcEsS. It would not match PPROCESS since there are two characters before the "roc" text. A match for PPROCESS could be defined as "??rocess" or "*rocess" or "?*rocess" etc.

A Transitions Configuration sub-screen as shown in FIG. 19F may be provided to allow the user a mechanism for defining classification criteria for transitions. Each tool 415 preferably has its own classification criteria. Certain classifications (such as those defined by the E58 Standard) may be pre-defined in the software. A user may define new classifications or modify the default classifications. These classifications are used each time a state change occurs, and are written to the tracking database 430 to categorize each specific state transition. The criteria are previous state, new state and symptom source.

Up to a predefined number of transitions (e.g., 30 transitions) may be defined by the user. Preferably, the first transition is reserved as a "catch-all" when no other transition classification matches the specific state change, and the last transition is reserved for when a state change from Standby to Productive has occurred and acts as a flag for start of a production run (symptom source is "Don't Care"). The Transition Name is a text field that may be entered by the user. For the Previous State and Next State fields, users may enter numbers, '*' wildcards, '!' (inverse), spaces and commas. They may input multiple 4 character fields of numbers and '*' wildcards separated by commas. The Symptom (Trigger) Source field defines whether the symptom source is part of the classification criteria.

At runtime, the automated monitoring and assessment software searches the list of transition classifications each time a state change occurs. It find a match for the three criteria (Previous State, Next State and Symptom/Trigger Source) and then stores the transition number in the tracking database 430. Since the previous and next states contain wild card characters, the automated monitoring and assessment software may find more than one classification that meets the criteria. The list of transition classifications is therefore preferably sorted or organized by order or "conciseness", and the most concise classification that meets the specific transition will be recorded. In other words, when more than one classification can be applied to a transition, the classification with the fewest wild card settings will be logged in the tracking database 430.

FIGS. 20 and 21 are examples of screen displays as may be presented to a user in connection with forcing a manual transition or to modify data in the tracking database, respectively. The ability to manually transition to a new state follows the state models directed by the symptom and state definitions defined for the particular tool 415. The user may change the state either by selecting a symptom or directly selecting a valid state. Several application specific bits may be provided for controlling what actions the users have access to:

Application Bit A: The user may transition to any enabled state independent to the manual state transition definitions.

Application Bit B: By default, the users may always select symptoms. This bit allows the choice of symptoms or a list of states.

Application Bit C: Forces a comment when the user manually selects a new state.

Application Bit D: Enables or disables the interrupt classification information pane.

Application Bit E: Enables the user to lock the state and prohibit any automated transitions.

Application Bit F: Enables access to enter Scrap and Rework tab (using, e.g., the screen display shown in FIG. 21).

Application Bit G: Enables access to the External State Control tab (see FIG. 13C).

Through a screen display interface (not shown), the user may be provided with the ability either to force a state change or force a trigger. If the user selects a Symptom (i.e., trigger) List, the scroll list changes to the symptoms for the currently selected tool. A "go" button changes from "Log State Change" to "Log Symptom". If the user selects State List or All States, the scroll list changes from the list of symptoms to the list of states and the "go" button text changes to "Log State Change". When the user selects the State List choice, the user is presented with a list of valid states for the tool. The valid states are only the states that are listed in the manual transition attribute for the current state, given the particular user's access level, and that are currently enabled. If the user selects the All States choice, the user is presented with a list of all enabled states independent of the manual transition attribute and the user access level.

The state selection list may be a hierarchical listing with specialized user operations. The user may expand out sub-states and retract sub-states through a conventional "+" or "-" icon next to the current state (but only if the current state has sub0states). When the user selects the "go" button to log the change, the user may be prompted for a comment based on the symptom property for comments and Application Bit C for state changes.

An interrupt classification pane may be accessed, depending upon the setting of Application Bit D and the specific type of state transition. If the interrupt classification pane is displayed, the user may be prompted to classify the interrupt when transitioning from any state to Unscheduled Downtime (UDT), if Application Bit D is set. If the user selected a symptom, then the interrupt classifications will default to the bits defined by the symptom, but can still be overridden by the user. If the user selected the state directly without selecting the symptom, the default settings may be set to Failure and Chargeable, whether the user has access or not.

An optional field may be available for allowing the users to lock the new state. If the new state is locked, automatic triggers will not transition to a new state. The state will require manual intervention to become unlocked or transition to a new state.

When the user transitions from Unscheduled Downtime (UDT) to another state, the field "Interrupt Classification" may display the classification used when the tool originally transitioned to the UDT state. This may require a database search for the instance when the state transitioned to UDT, and a pull of the interrupt classification data. If the user wants to override the interrupt classifications and Application Bit D is set, then the user may set the interrupt classification selection buttons. The new values are stored in place of the value extracted from the tracking database 430. In certain embodiments, the only records in the tracking database 430 that may contain interrupt information are records that store a transition to an Unscheduled Downtime (UDT) state from a PRD, SBY, SDT or ENG state. If the user over rides the Interrupt classifications, it is preferably recorded in the Audit Trail.

Via the screen interface illustrated in FIG. 21, the user may modify data in the tracking database 430. The user may search according to various available criteria. The user may input scrap and rework data, overwriting the current data base entries. When the user saves the changes, the software may automatically verify that the sum of the rework and scrap counts is less than or equal to the actual count for each record in the tracking database 430.

FIG. 22 is an example of a screen display as may be presented to a user during live monitoring of tools in the semiconductor fabrication system. The information appearing on the screen display 2201 of FIG. 22 may be maintained in tables apart from the records in the tracking database 430, which are updated periodically as triggers are received by the automated monitoring and assessment software. As shown in FIG. 22, the tool name 2251 and its current state 2250 may be displayed to the user, along with the last trigger 2252. Also displayed may be state and sub-state information 2260, such as the current and previous states and sub-states, the last productive state and sub-state, along with their corresponding state IDs and descriptions. The transition time into each specific state and sub-state may also be displayed. If the tool 415 is a master tool, then the sub-tool states 2270 may also be displayed for viewing. By clicking on a sub-tool, the sub-tool's live status screen may be accessed. Various time counters 2210 may log the time spent in each state for the tool 415, and a reset button 2213 may be provided to re-start the monitoring period.

The File menu option of the live status screen preferably allows a user to select any defined tool for real-time viewing.

Various historical reports may be generated for viewing by a user, based upon information stored in the tracking database 430 or otherwise. Examples of such reports appear in the Technical Appendix filed herewith. The reports may include all defined E10, 58 and 79 metrics. A report may be viewed on-screen via the user interface, may be sent to a printer, or may be e-mailed to a user. Preferably, the user interface allows the user to specify periodicity of report generation of pre-defined report types. The user may need to specify report parameters such as, for example, time range, tools of interest, metrics of interest, and partitions (i.e., what type of processes or chips/wafers being processed). A wide variety of plots and other graphical presentations of the state information and metrics are preferably provided, as illustrated in the accompanying Technical Appendix.

It is thus apparent that a highly flexible, convenient, comprehensive and user-friendly system has been provided allowing monitoring and assessment of semiconductor fabrication facilities with a minimum of effort. In various embodiments as described herein, little or no changes are required to the existing tools or the manufacturing execution system of the semiconductor fabrication facility. The automated monitoring and assessment system may exist in a passive manner, monitoring the normal flow of message traffic among the tools and the various system control elements, and recording and acting upon information of relevance to the state transition models.

In one or more embodiments as described herein, an automated monitoring and assessment system performs state tracking and logic-based determination of transition states, on a tool-by-tool basis. External states are provided for events that do not necessarily impact the tool at the moment, but can be used to help determine the next transition state when an appropriate trigger occurs. The external states are not necessarily known to the particular tool, but are maintained by the automated monitoring and tracking software. A message from one tool may be used to set a trigger to change the external state or internal state of a second tool, or any number of other tools. External conditions may be aggregated to form a single super-condition requiring all its constituent parts (i.e., conditions) to be satisfied in order to be true. In addition to external conditions, recipe classifications may also be used to select new states based upon trigger events. Thus, state branching may be based upon the current state, trigger, and any external states or recipe classification.

Time values are preferably recorded in a tracking database at each state transition. The number of time values recorded depends upon how deep (i.e., how many levels) the user has specified in the particular category. If lower layers are undefined, 0's are recorded for the time spent therein.

While preferred embodiments of the invention have been described herein, many variations are possible which remain within the concept and scope of the invention. Such variations would become clear to one of ordinary skill in the art after inspection of the specification and the drawings. The invention therefore is not to be restricted except within the spirit and scope of any appended claims.

CLAIMS

What is claimed is:

1. A method for monitoring and assessing operation of a semiconductor fabrication facility, said method comprising the steps of:

connecting a monitoring and assessment computer system to a system bus, the system bus connected directly or indirectly to a manufacturing execution system and a plurality of semiconductor fabrication tools;

configuring, via a user interface, state models for said semiconductor fabrication tools, said state models based upon a set of defined triggers for each tool;

monitoring messages transmitted on the system bus between the semiconductor fabrication tools and the manufacturing execution system;

generating triggers based upon said messages, said triggers selected from the set of defined triggers;

updating the state model of each tool affected by one of said triggers; and

recording state transitions within said state models in a tracking database

2. The method of claim 1, wherein said semiconductor fabrication tools comprise processing tools and metrology tools.

3. The method of claim 1, wherein said step of configuring state models for said semiconductor fabrication tools comprises the step of defining, for each state of each tool, a trigger event that will cause a transition to a new state.

4. The method of claim 3, wherein said step of configuring state models for said semiconductor fabrication tools further comprises the step of defining, for at least one state of one tool, a state transition based upon one or more external states and one or more trigger events.

5. The method of claim 3, wherein said step of configuring state models for said semiconductor fabrication tools further comprises the step of defining, for at least one state of one tool, a state transition based upon one or more recipe classifications and one or more trigger events.

ABSTRACT

A system and method for monitoring and assessing operation of a semiconductor fabrication facility includes a monitoring and assessment computer system connected to a system bus which is also connected, directly or indirectly (e.g., via supervisory workstations), to a manufacturing execution system and a number of semiconductor fabrication tools in the facility. Via a user interface, state models and trigger events are configured for each of the semiconductor fabrication tools. The state models may be based in part upon the trigger events, various external states, and various recipe classifications. Once the state models have been defined, messages transmitted on the system bus between the semiconductor fabrication tools and the manufacturing execution system are monitored by the automated monitoring and assessment computer system. When certain types of messages are observed, the automated monitoring and assessment computer system automatically generates appropriate triggers according to the user specifications, which causes state transitions according to the user-defined state models. The system updates the state model of each tool affected by a trigger, and logs state transition and any pertinent information regarding the triggering message in a tracking database. Information in the tracking database may be used as the basis for generating historical reports regarding the operation of all of the tools in the semiconductor fabrication facility.

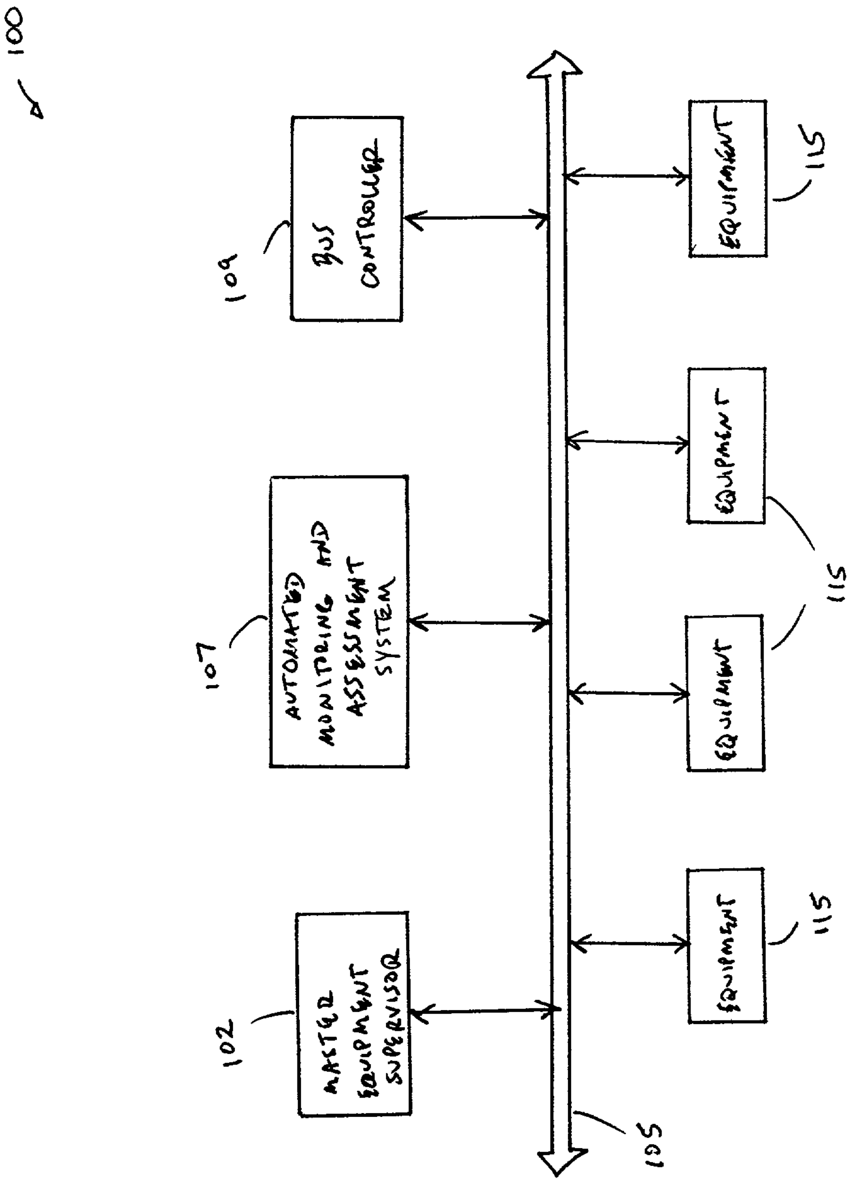

100
MASTER EQUIPMENT SUPERVISOR
102
AUTOMATED MONITORING AND ASSESSMENT SYSTEM
107
BUS CONTROLLER
109
105
EQUIPMENT
EQUIPMENT
EQUIPMENT
EQUIPMENT
115
115
115

FIG. 1

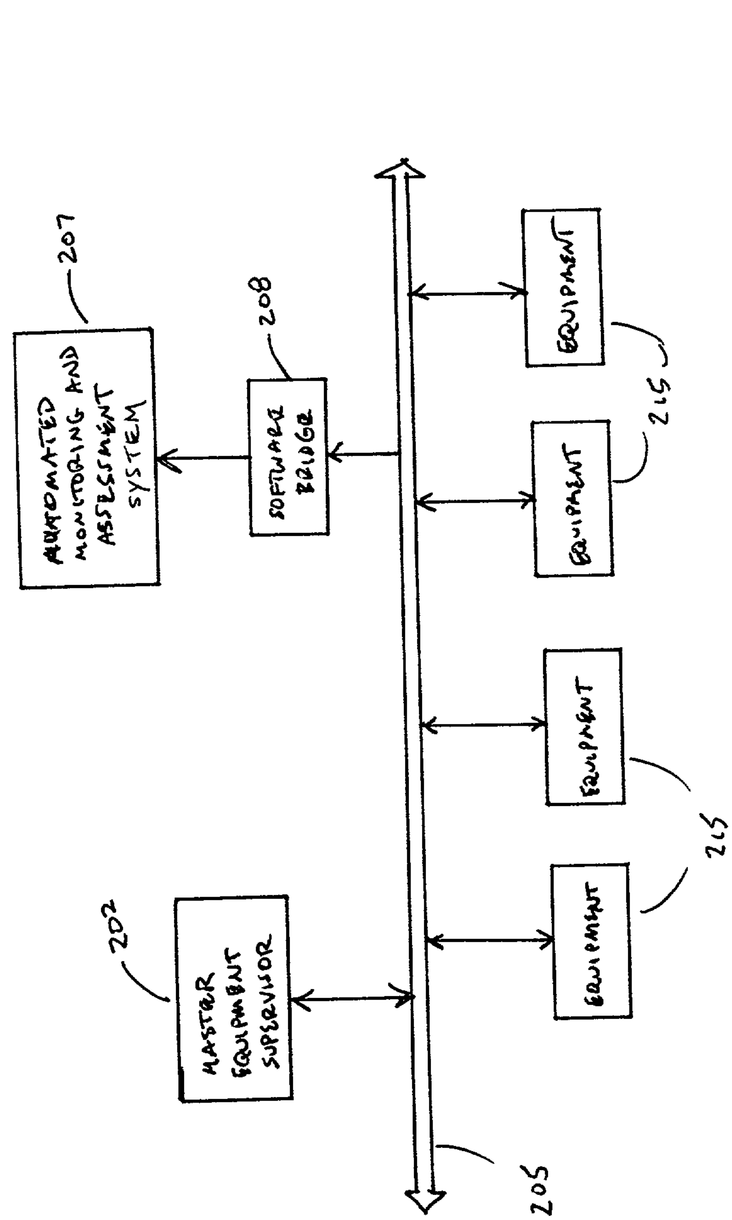

200
AUTOMATED MONITORING AND ASSESSMENT SYSTEM
207
SOFTWARE BRIDGE
208
EQUIPMENT
EQUIPMENT
EQUIPMENT
EQUIPMENT
215
215
MASTER EQUIPMENT SUPERVISOR
202
205

FIG. 2

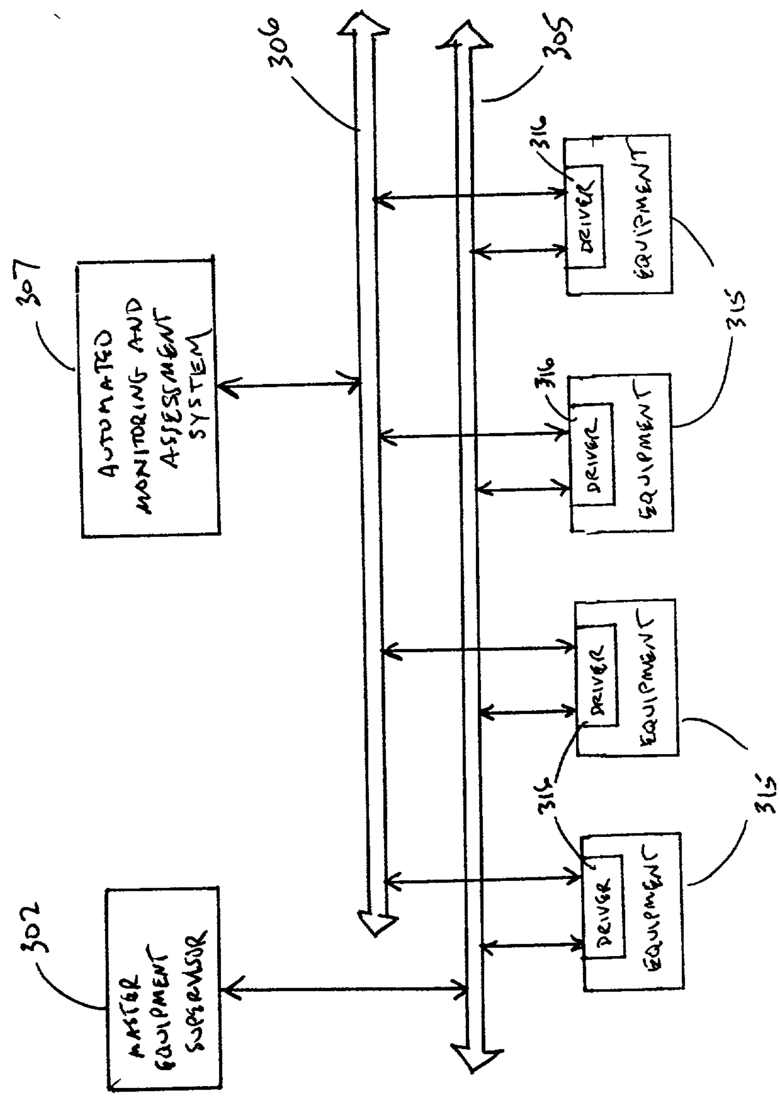

306
305
307
AUTOMATED MONITORING AND ASSESSMENT SYSTEM
316
DRIVER
EQUIPMENT
315
302
MASTER EQUIPMENT SUPERVISOR

FIG. 3

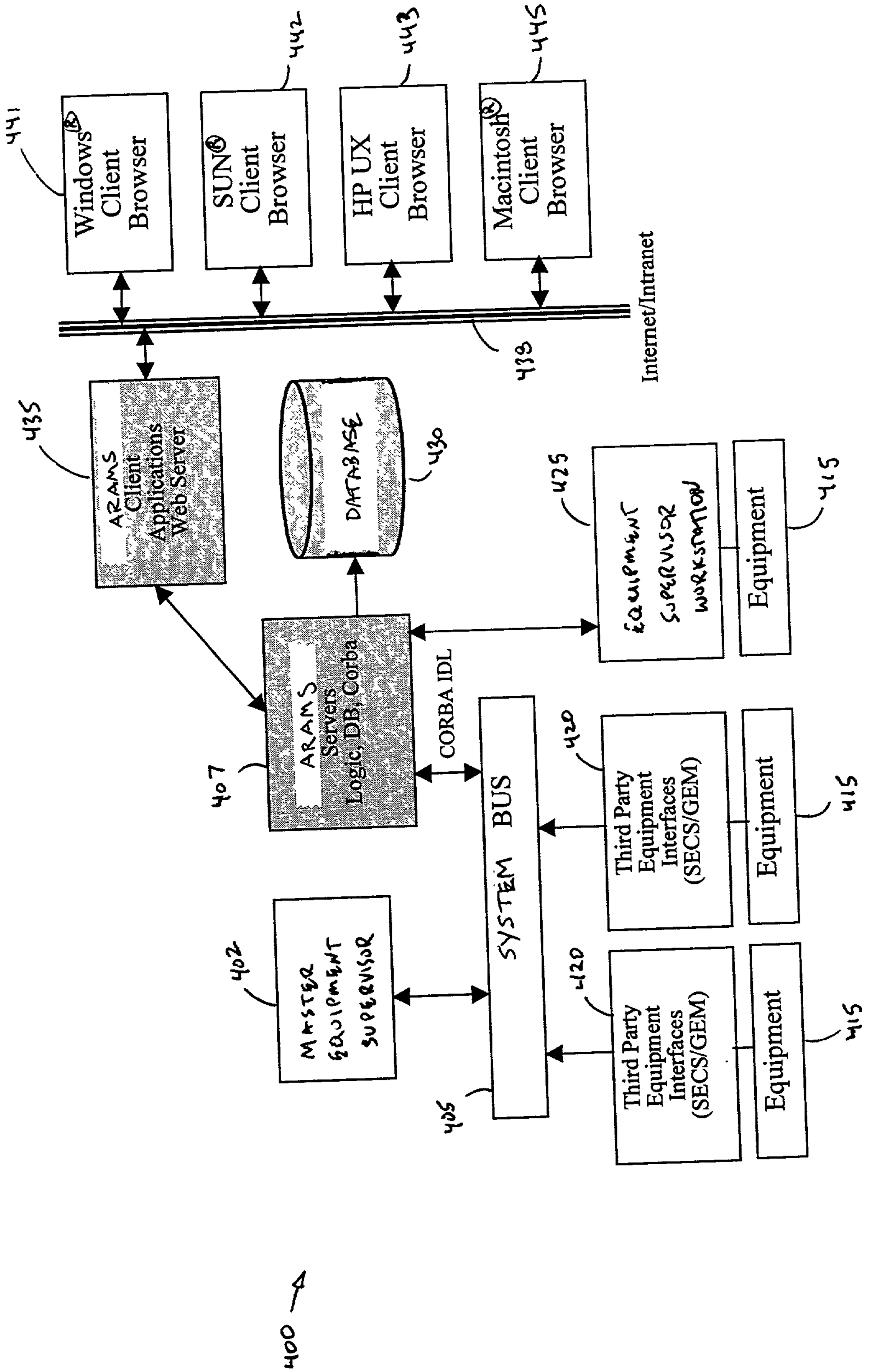

Windows® Client Browser
SUN® Client Browser
HP UX Client Browser
Macintosh® Client Browser
441
442
443
445
Internet/Intranet
438
ARAMS Client Applications Web Server
435
DATABASE
430
ARAMS Servers Logic, DB, Corba
407
CORBA IDL
SYSTEM BUS
405
MASTER EQUIPMENT SUPERVISOR
402
EQUIPMENT SUPERVISOR WORKSTATION
425
Third Party Equipment Interfaces (SECS/GEM)
420
Equipment
415
400

FIG. 4

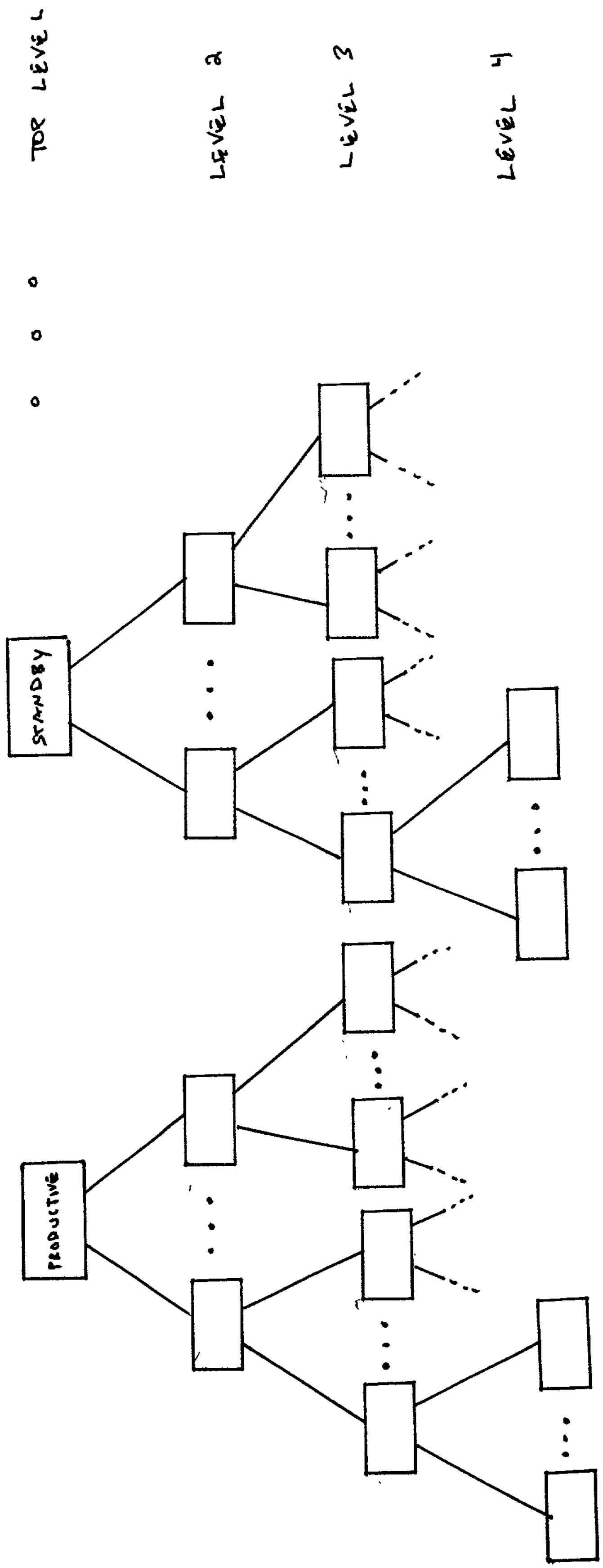


FIG. 5
STATE TABLE HIERARCHY

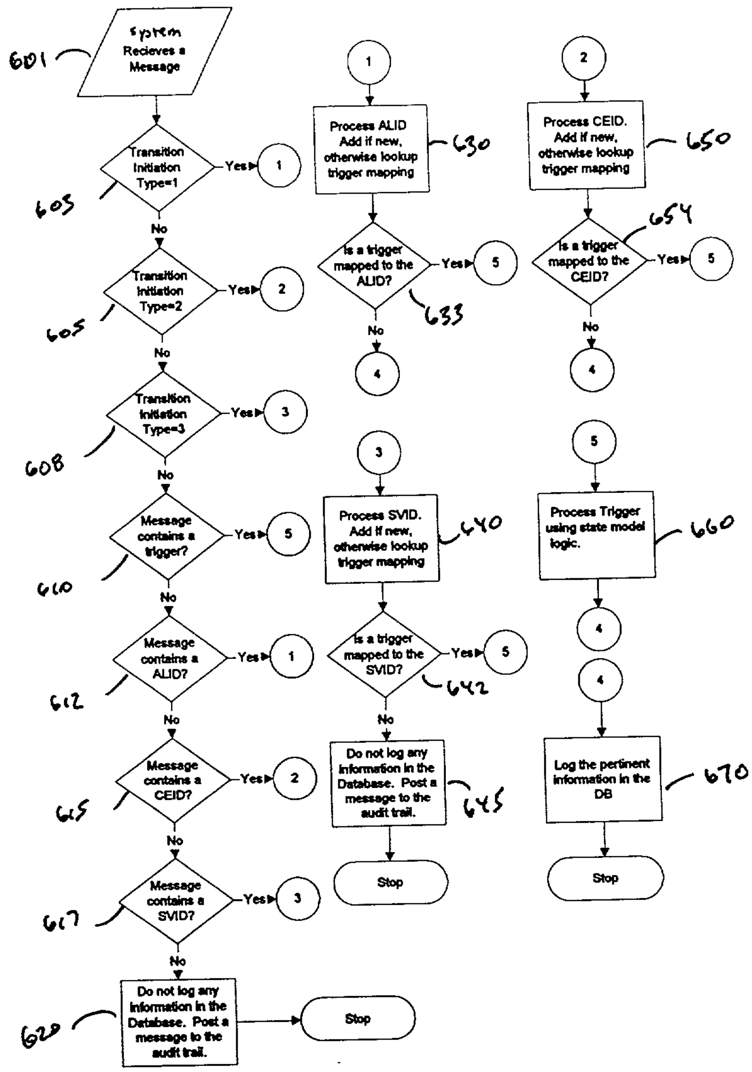

System Recieves a Message
601
Transition Initiation Type=1
603
Transition Initiation Type=2
605
Transition Initiation Type=3
608
Message contains a trigger?
610
Message contains a ALID?
612
Message contains a CEID?
615
Message contains a SVID?
617
Do not log any information in the Database. Post a message to the audit trail.
620
Stop
Yes
No
Process ALID Add if new, otherwise lookup trigger mapping
630
Is a trigger mapped to the ALID?
633
Process CEID. Add if new, otherwise lookup trigger mapping
650
Is a trigger mapped to the CEID?
654
Process SVID. Add if new, otherwise lookup trigger mapping
640
Is a trigger mapped to the SVID?
642
Do not log any information in the Database. Post a message to the audit trail.
645
Process Trigger using state model logic.
660
Log the pertinent information in the DB
670
Stop

FIG. 6

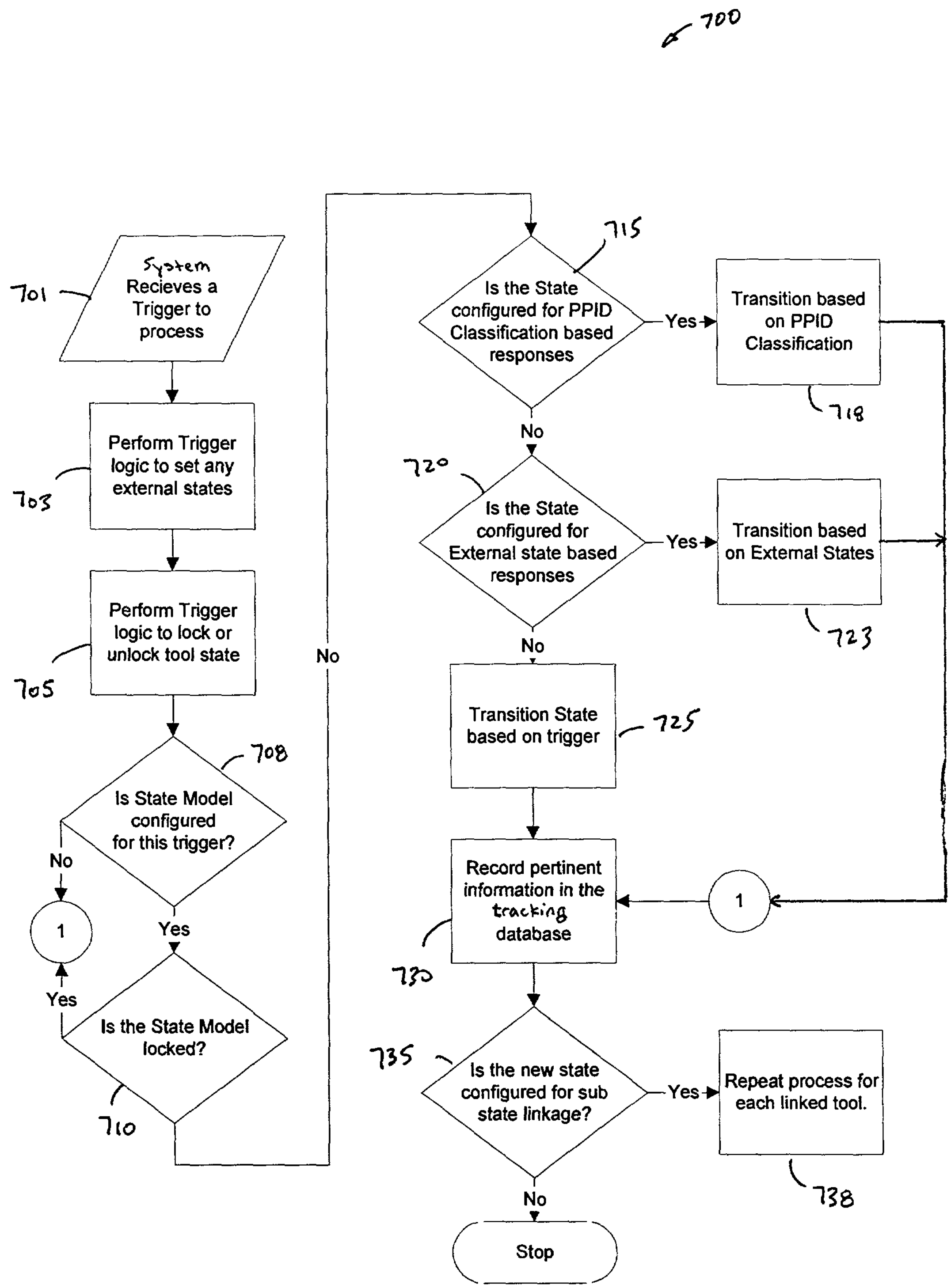
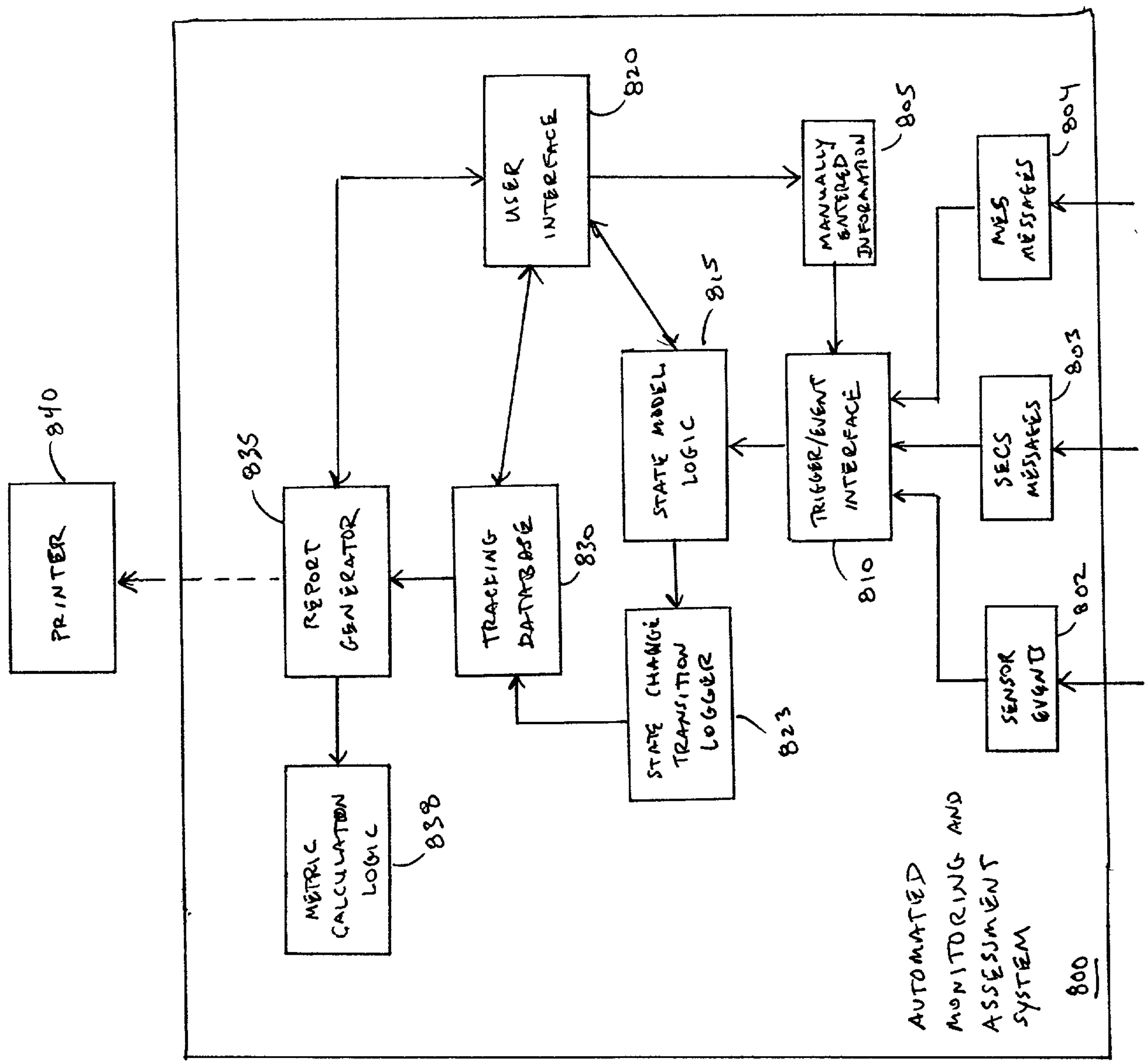

700
701
System Recieves a Trigger to process
Perform Trigger logic to set any external states
703
Perform Trigger logic to lock or unlock tool state
705
Is State Model configured for this trigger?
708
No
1
Yes
Yes
Is the State Model locked?
710
No
Is the State configured for PPID Classification based responses
715
Yes
Transition based on PPID Classification
718
No
720
Is the State configured for External state based responses
Yes
Transition based on External States
723
No
Transition State based on trigger
725
Record pertinent information in the tracking database
730
1
735
Is the new state configured for sub state linkage?
Yes
Repeat process for each linked tool.
738
No
Stop

FIG. 7

FIG. 8


USER INTERFACE
820
MANUALLY ENTERED INFORMATION
805
MES MESSAGES
804
STATE MODEL LOGIC
815
TRIGGER/EVENT INTERFACE
810
SECS MESSAGES
803
SENSOR EVENTS
802
PRINTER
840
REPORT GENERATOR
835
TRACKING DATABASE
830
STATE CHANGE TRANSITION LOGGER
823
METRIC CALCULATION LOGIC
838
AUTOMATED MONITORING AND ASSESSMENT SYSTEM
800

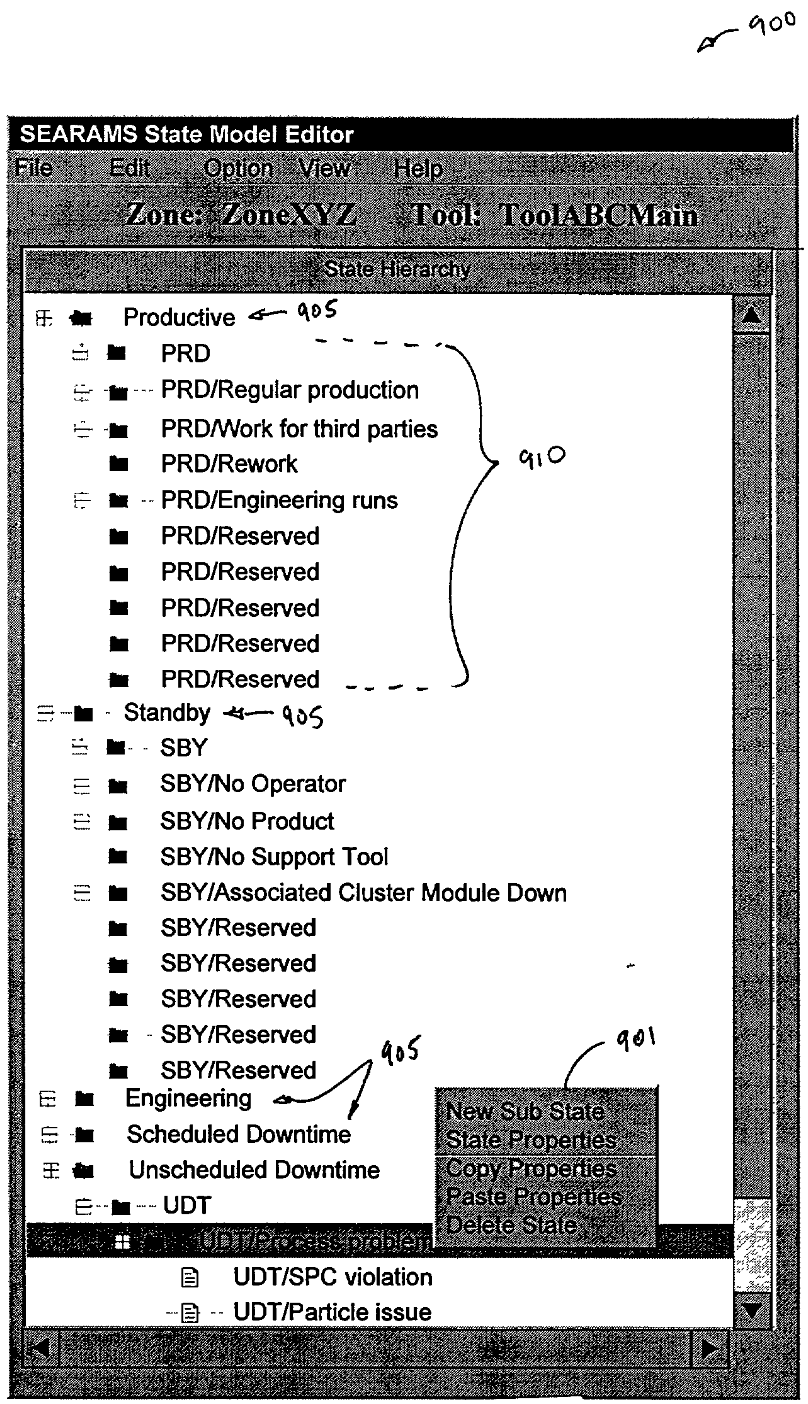

900
SEARAMS State Model Editor
File Edit Option View Help
Zone: ZoneXYZ Tool: ToolABCMain
State Hierarchy
Productive
905
PRD
PRD/Regular production
PRD/Work for third parties
PRD/Rework
PRD/Engineering runs
PRD/Reserved
PRD/Reserved
PRD/Reserved
PRD/Reserved
PRD/Reserved
910
Standby
905
SBY
SBY/No Operator
SBY/No Product
SBY/No Support Tool
SBY/Associated Cluster Module Down
SBY/Reserved
SBY/Reserved
SBY/Reserved
SBY/Reserved
SBY/Reserved
905
901
Engineering
Scheduled Downtime
Unscheduled Downtime
UDT
UDT/Process problem
New Sub State
State Properties
Copy Properties
Paste Properties
Delete State
UDT/SPC violation
UDT/Particle issue

FIG. 9

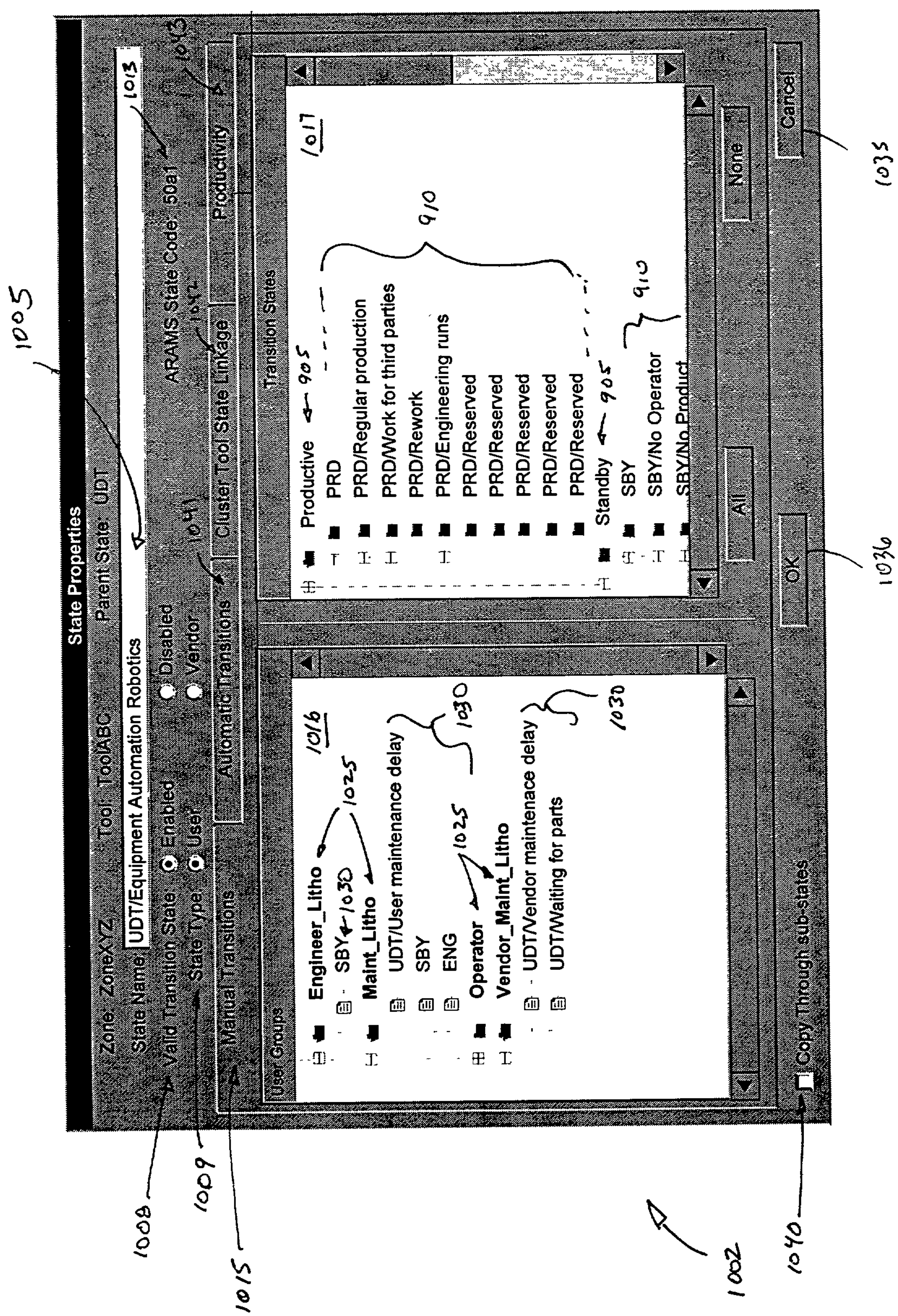

State Properties
Zone: ZoneXYZ
Tool: ToolABC
Parent State: UDT
State Name: UDT/Equipment Automation Robotics
ARAMS State Code: 50a1
Valid Transition State: Enabled Disabled
State Type: User Vendor
Manual Transitions
Automatic Transitions
Cluster Tool State Linkage
Productivity
User Groups
Engineer_Litho
SBY
Maint_Litho
UDT/User maintenance delay
SBY
ENG
Operator
Vendor_Maint_Litho
UDT/Vendor maintenace delay
UDT/Waiting for parts
Transition States
Productive
PRD
PRD/Regular production
PRD/Work for third parties
PRD/Rework
PRD/Engineering runs
PRD/Reserved
PRD/Reserved
PRD/Reserved
PRD/Reserved
PRD/Reserved
Standby
SBY
SBY/No Operator
SBY/No Product
All
None
OK
Cancel
Copy Through sub-states
1002
1005
1008
1009
1013
1015
1016
1017
1025
1030
1035
1036
1040
1041
1042
1043
905
910

FIG. 10A

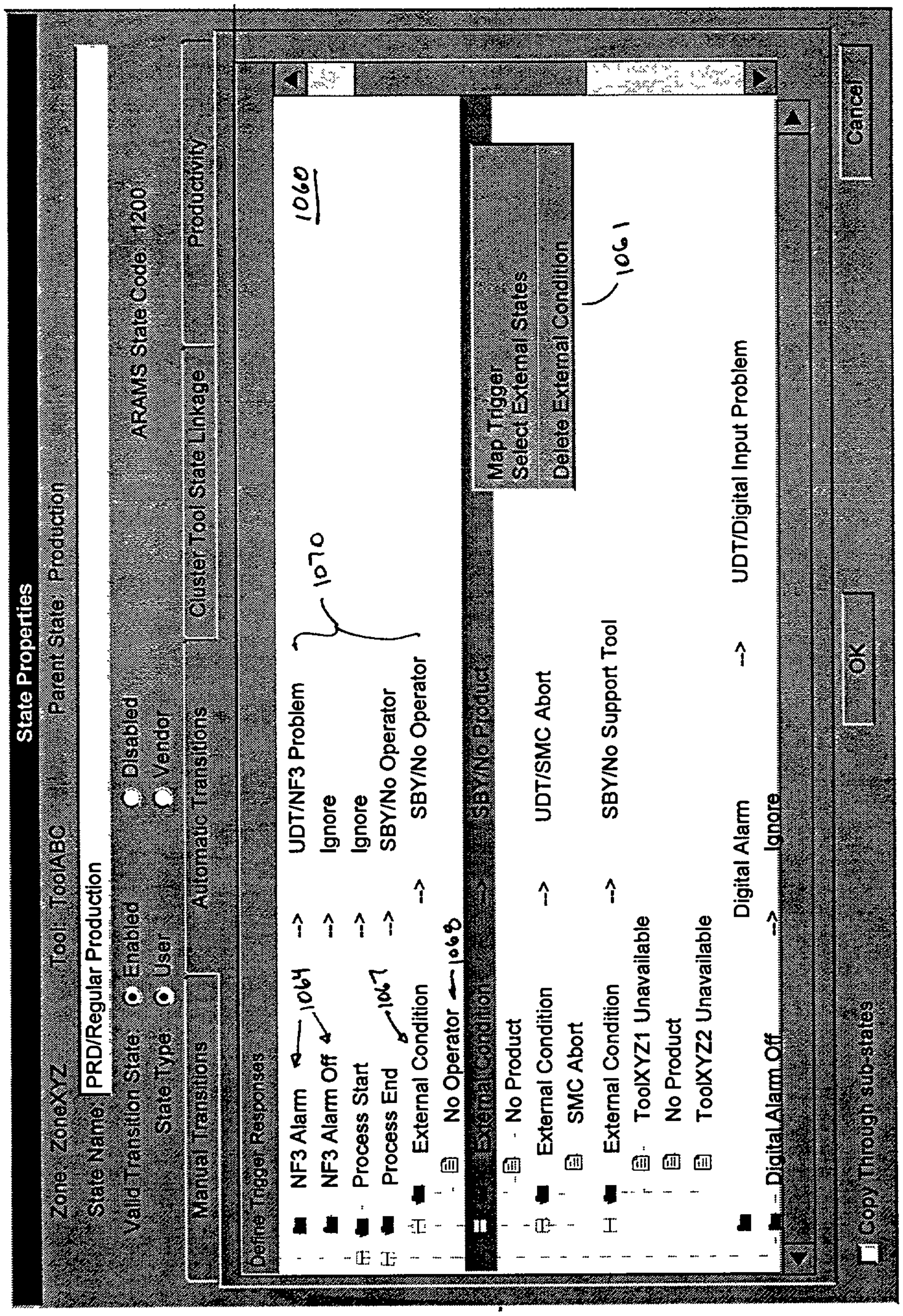

State Properties
Zone: ZoneXYZ
Tool: ToolABC
Parent State: Production
State Name: PRD/Regular Production
Valid Transition State: Enabled Disabled
State Type: User Vendor
ARAMS State Code: 1200
Manual Transitions
Automatic Transitions
Cluster Tool State Linkage
Productivity
Define Trigger Responses
NF3 Alarm --> UDT/NF3 Problem
NF3 Alarm Off --> Ignore
Process Start --> Ignore
Process End --> SBY/No Operator
External Condition --> SBY/No Operator
No Operator
External Condition --> SBY/No Product
No Product
External Condition --> UDT/SMC Abort
SMC Abort
External Condition --> SBY/No Support Tool
ToolXYZ1 Unavailable
No Product
ToolXYZ2 Unavailable
Digital Alarm --> UDT/Digital Input Problem
Digital Alarm Off --> Ignore
Map Trigger
Select External States
Delete External Condition
Copy Through sub-states
OK
Cancel
1060
1061
1064
1067
1068
1070

FIG. 10B

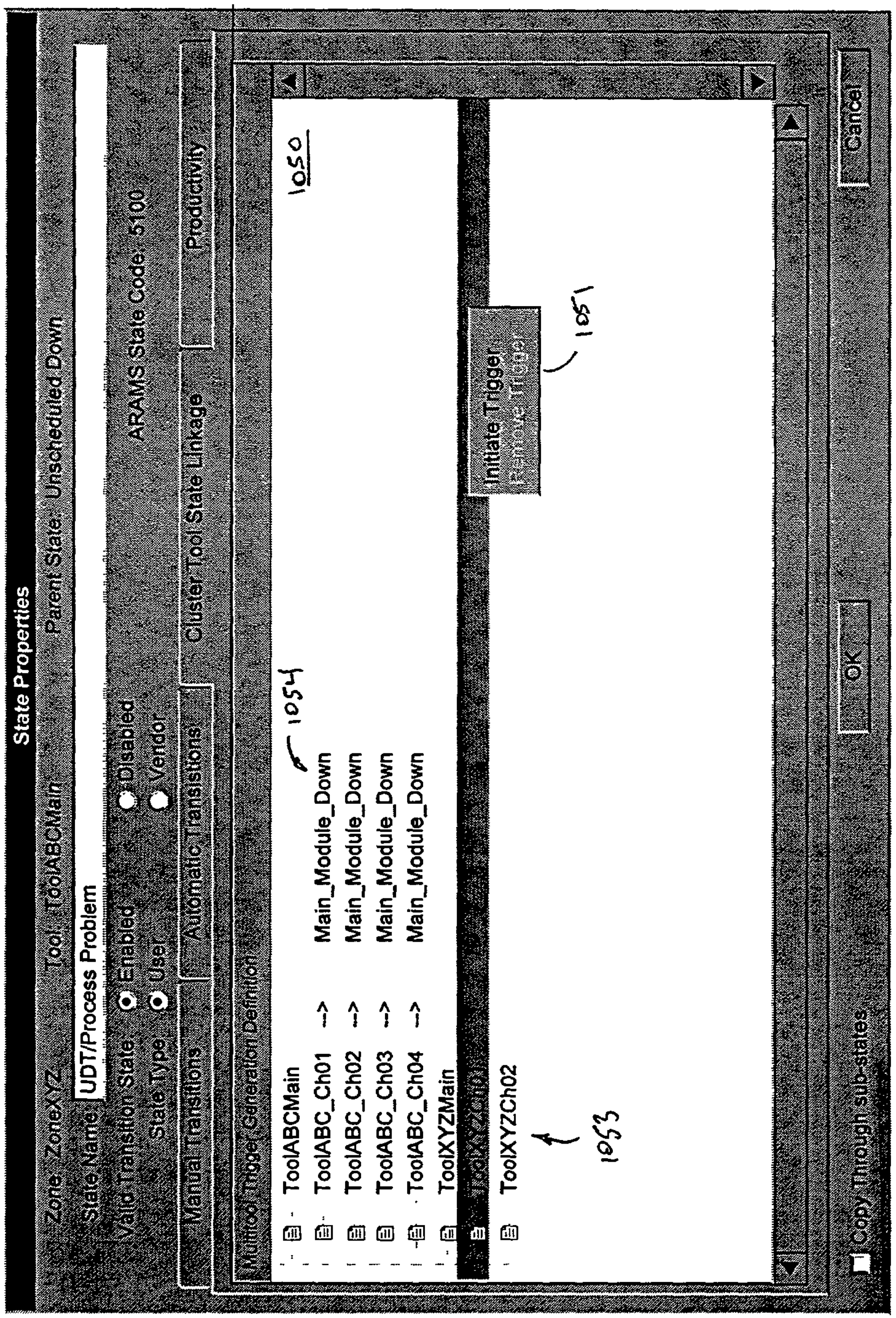

State Properties
Zone: ZoneXYZ
Tool: ToolABCMain
Parent State: Unscheduled Down
State Name: UDT/Process Problem
Valid Transition State
Enabled
Disabled
State Type
User
Vendor
ARAMS State Code: 5100
Manual Transitions
Automatic Transitions
Cluster Tool State Linkage
Productivity
1050
Multitool Trigger Generation Definition
ToolABCMain
ToolABC_Ch01 --> Main_Module_Down
ToolABC_Ch02 --> Main_Module_Down
ToolABC_Ch03 --> Main_Module_Down
ToolABC_Ch04 --> Main_Module_Down
ToolXYZMain
ToolXYZCh02
1054
1053
Initiate Trigger
Remove Trigger
1051
Copy Through sub-states
OK
Cancel

FIG. 10C

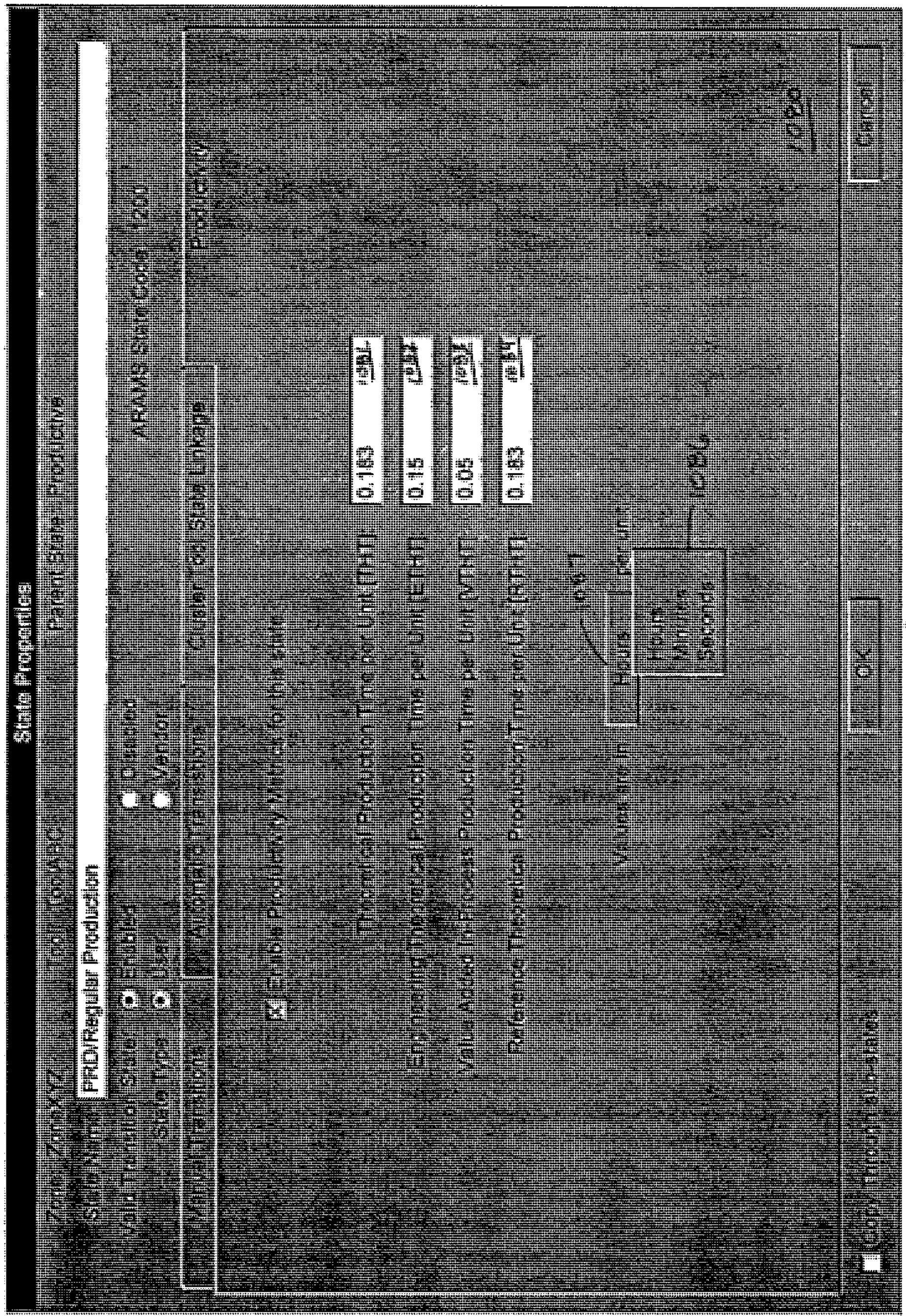

State Properties
Zone: ZoneXYZ
Tool: ToolABC
Parent State: Productive
State Name: PRD/Regular Production
Valid Transition State: Enabled Disabled
State Type: User Vendor
ARAMS State Code: 1200
Manual Transitions
Automatic Transitions
Cluster Tool State Linkage
Productivity
Enable Productivity Metrics for this state
Theoretical Production Time per Unit [THT] 0.183
Engineering Theoretical Production time per Unit [ETHT] 0.15
Value Added In-Process Production Time per Unit [VTHT] 0.05
Reference Theoretical Production Time per Unit [RTHT] 0.183
Volume time in Hours per unit
Hours
Minutes
Seconds
OK
Cancel
Copy through sub-states

FIG. 10D

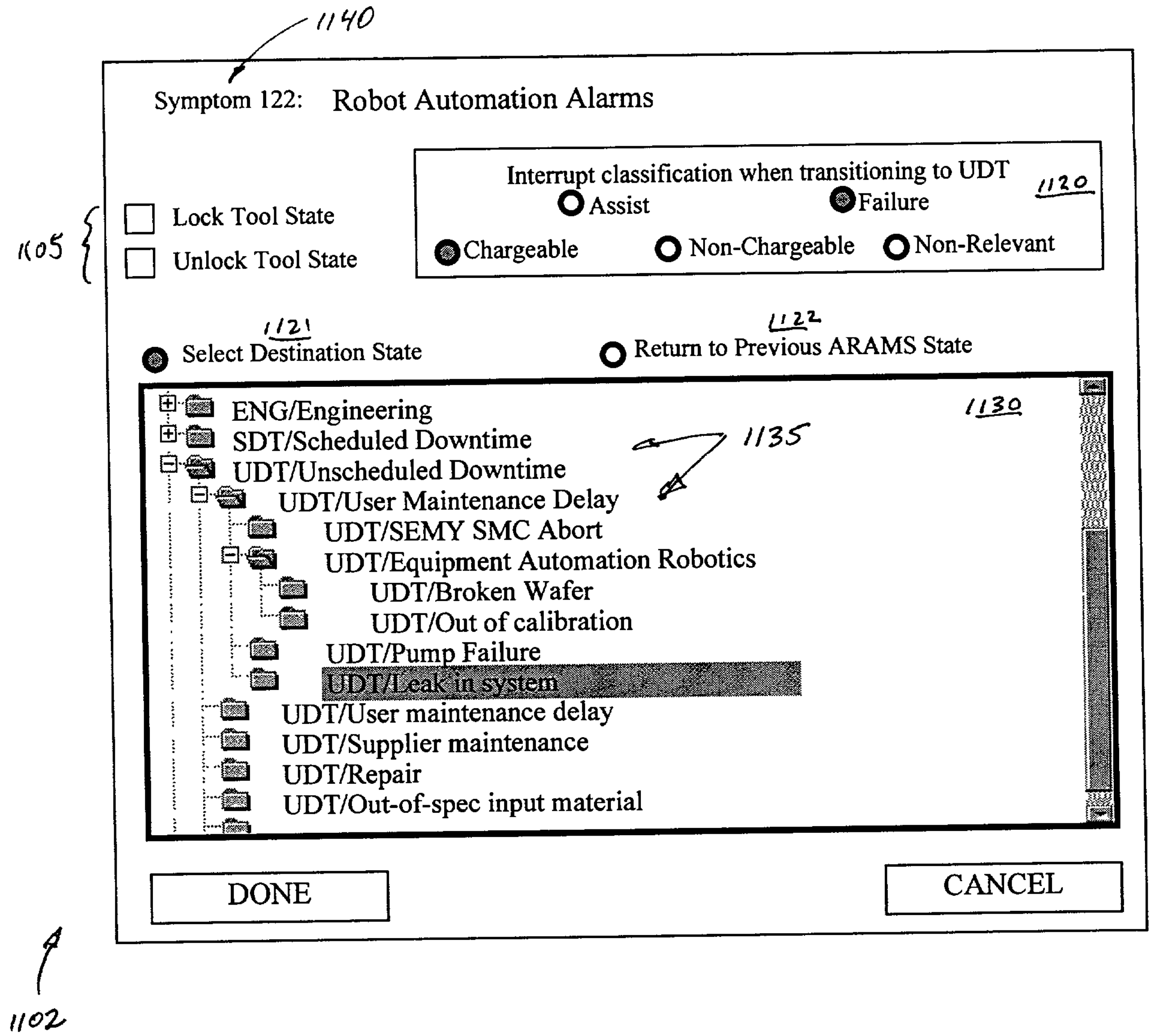

1140
Symptom 122: Robot Automation Alarms
Interrupt classification when transitioning to UDT
Assist
Failure
1120
Lock Tool State
Unlock Tool State
1105
Chargeable
Non-Chargeable
Non-Relevant
1121
Select Destination State
1122
Return to Previous ARAMS State
ENG/Engineering
1130
SDT/Scheduled Downtime
1135
UDT/Unscheduled Downtime
UDT/User Maintenance Delay
UDT/SEMY SMC Abort
UDT/Equipment Automation Robotics
UDT/Broken Wafer
UDT/Out of calibration
UDT/Pump Failure
UDT/Leak in system
UDT/User maintenance delay
UDT/Supplier maintenance
UDT/Repair
UDT/Out-of-spec input material
DONE
CANCEL
1102

FIG. 11

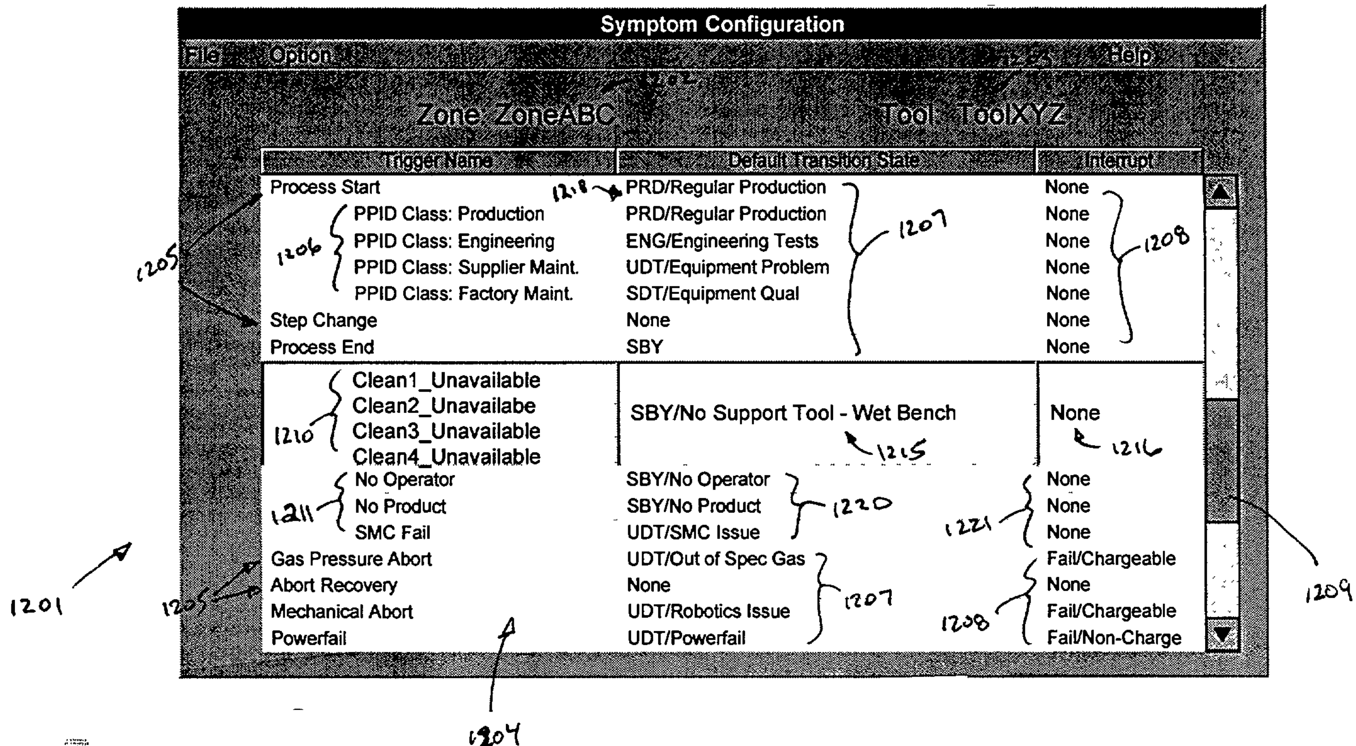


FIG. 12

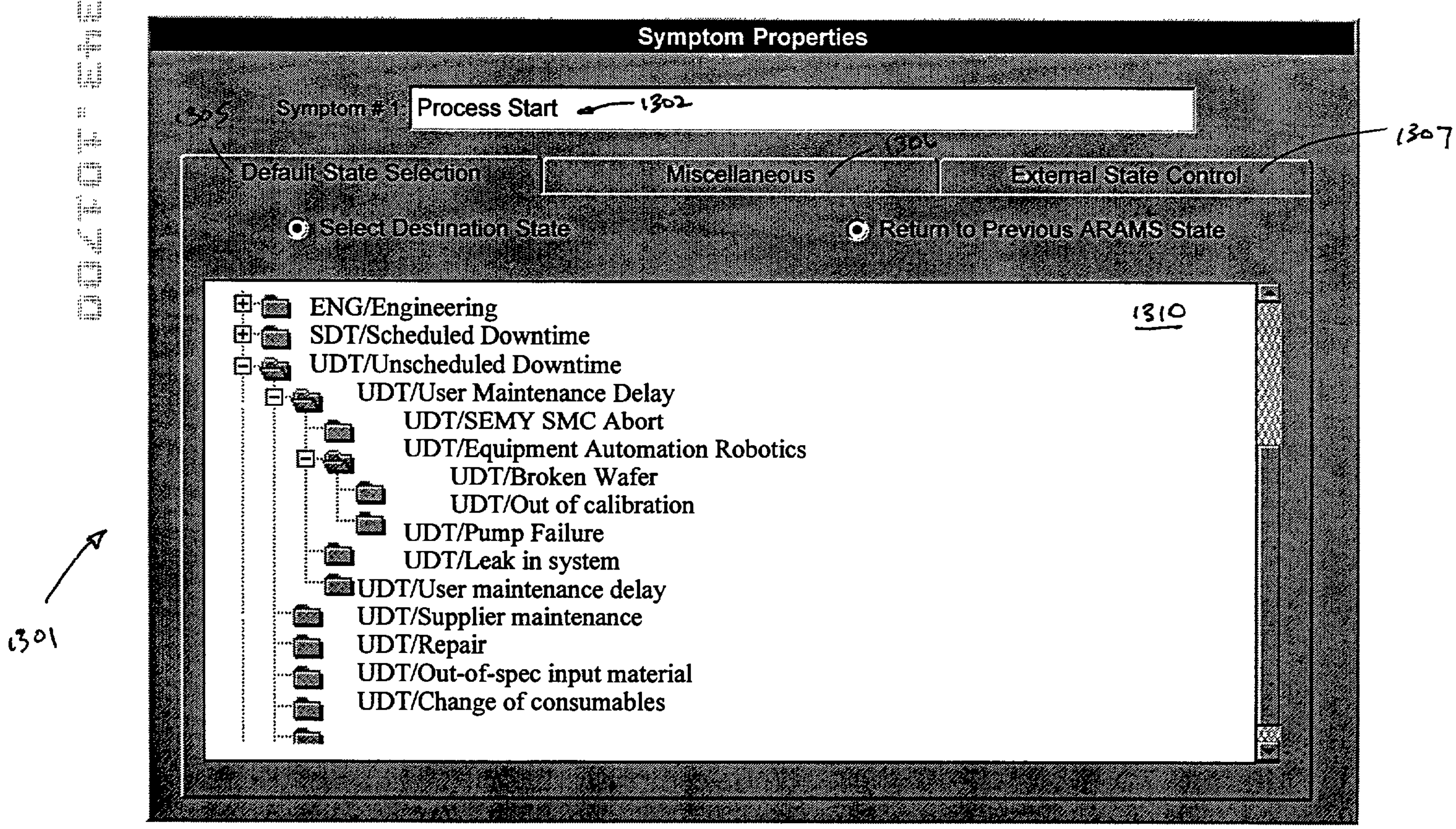


FIG. 13A

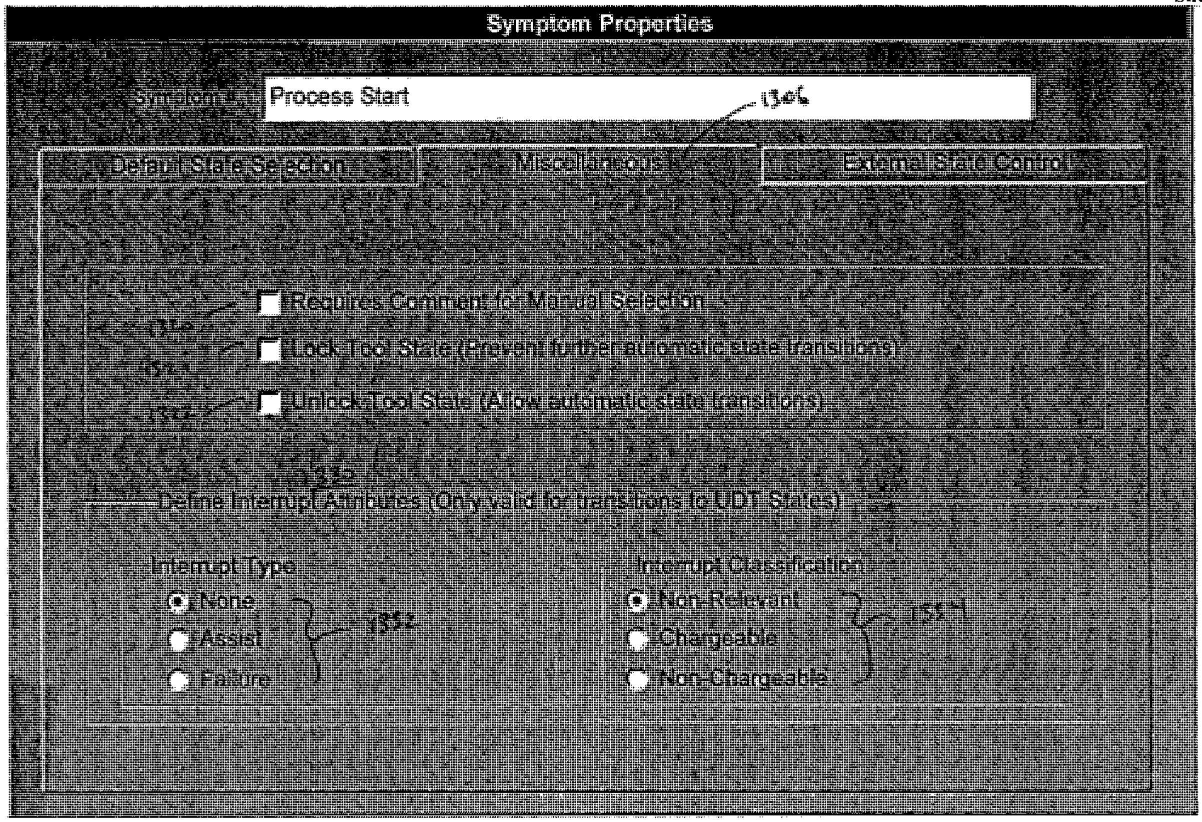


FIG. 13B

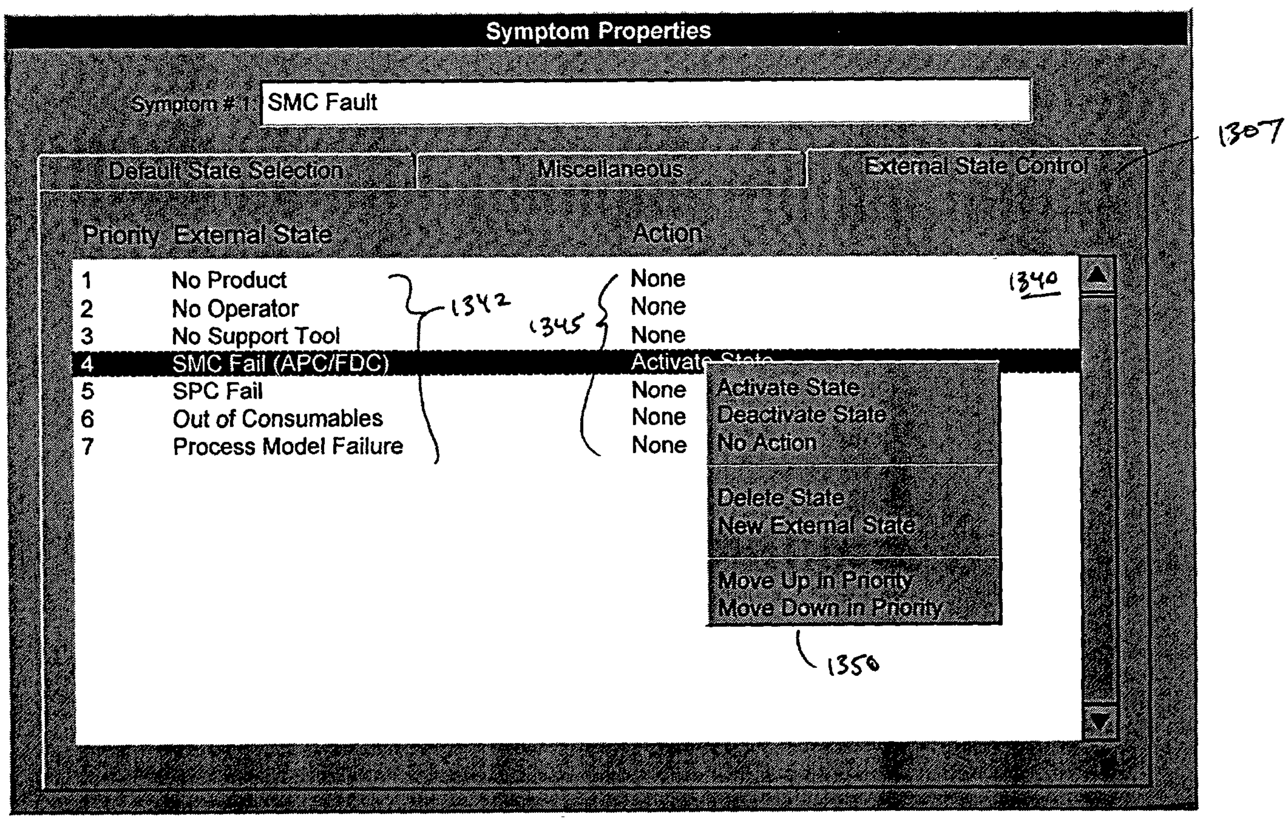


FIG. 13C

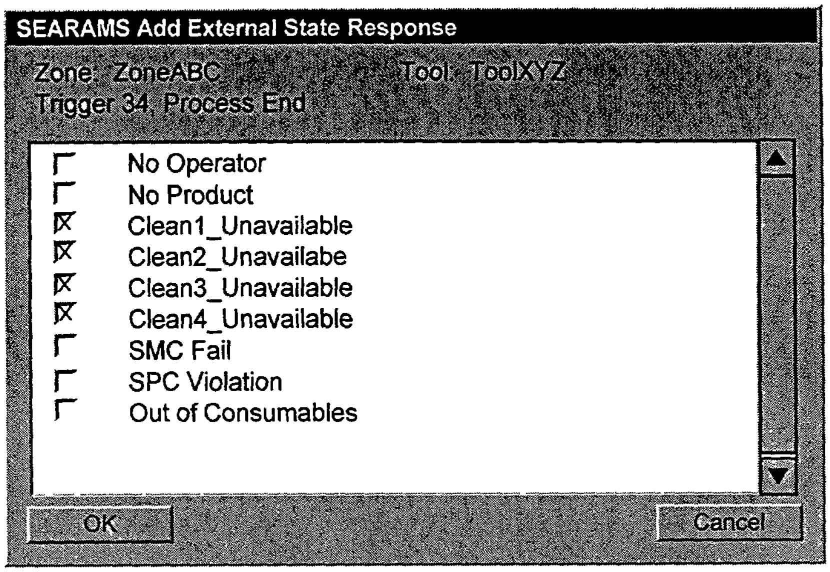


FIG. 14

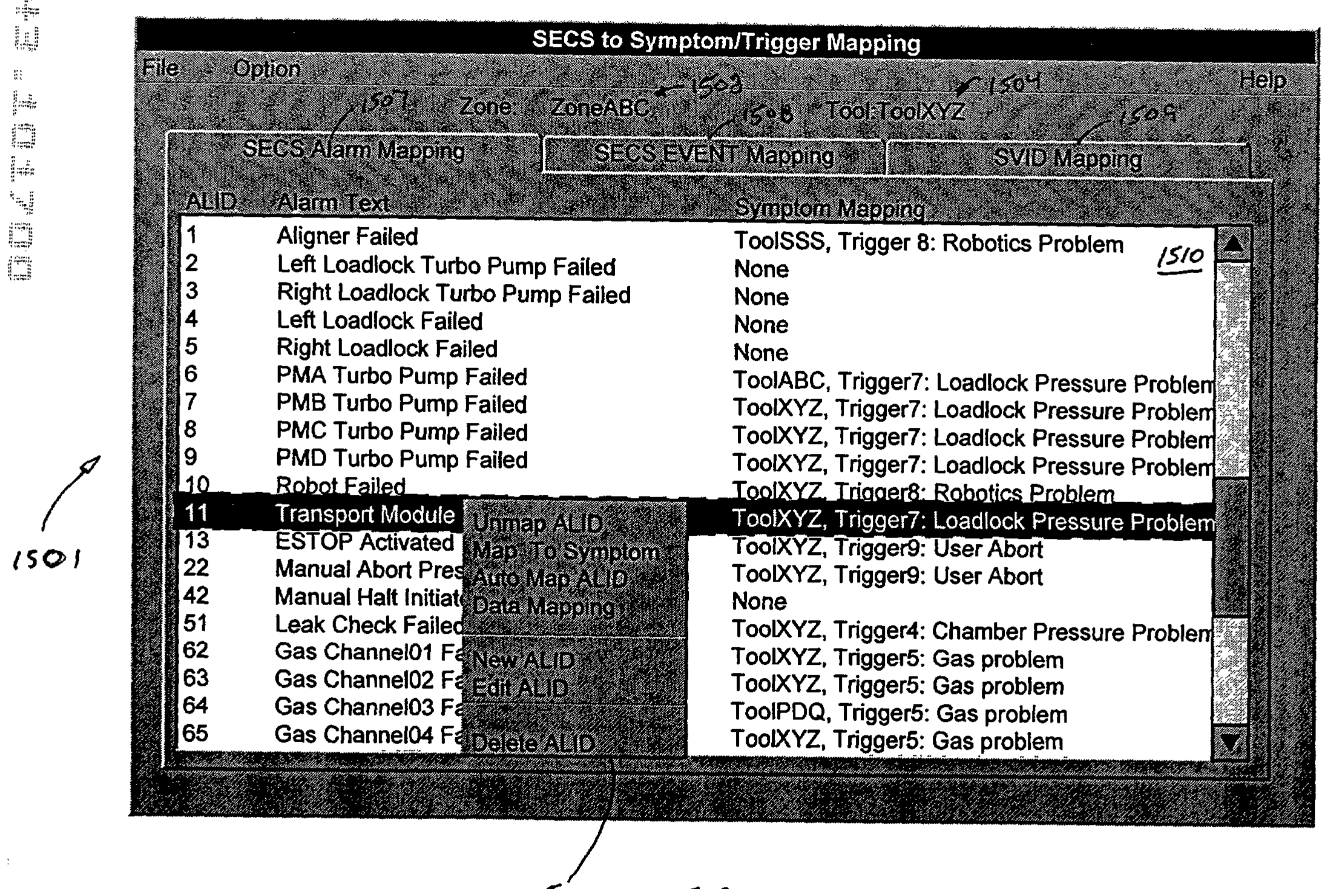


FIG. 15A

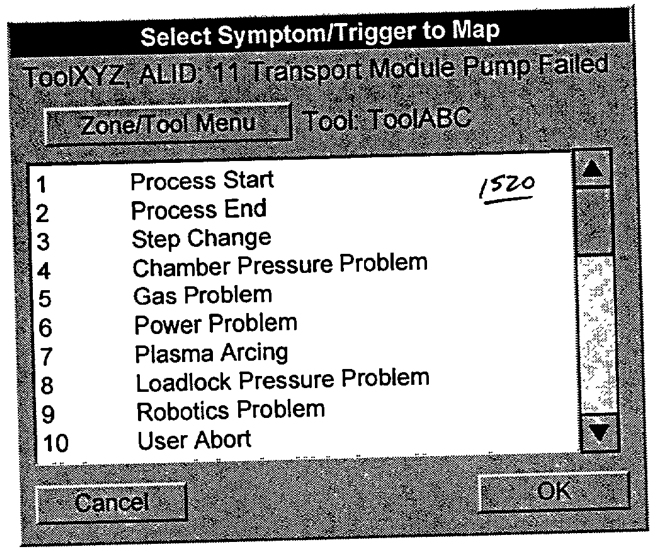


FIG. 15B

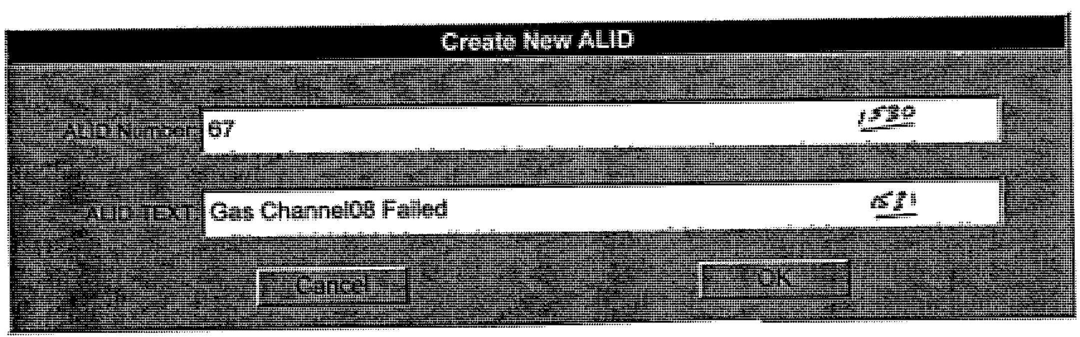


FIG. 15C

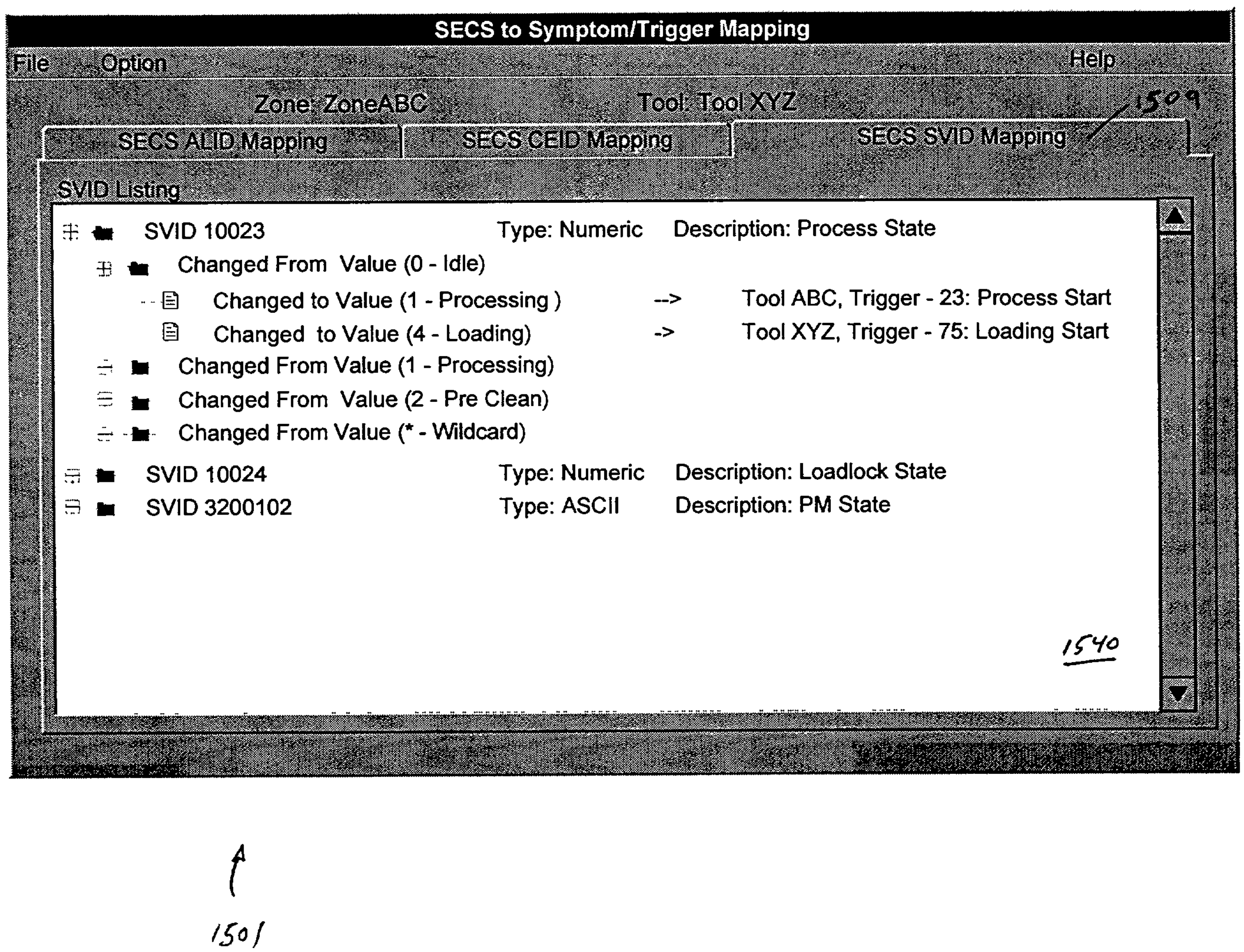

SECS to Symptom/Trigger Mapping
File
Option
Help
Zone: ZoneABC
Tool: Tool XYZ
1509
SECS ALID Mapping
SECS CEID Mapping
SECS SVID Mapping
SVID Listing
SVID 10023
Type: Numeric
Description: Process State
Changed From Value (0 - Idle)
Changed to Value (1 - Processing)
-->
Tool ABC, Trigger - 23: Process Start
Changed to Value (4 - Loading)
->
Tool XYZ, Trigger - 75: Loading Start
Changed From Value (1 - Processing)
Changed From Value (2 - Pre Clean)
Changed From Value (* - Wildcard)
SVID 10024
Type: Numeric
Description: Loadlock State
SVID 3200102
Type: ASCII
Description: PM State
1540
1501

FIG. 15D

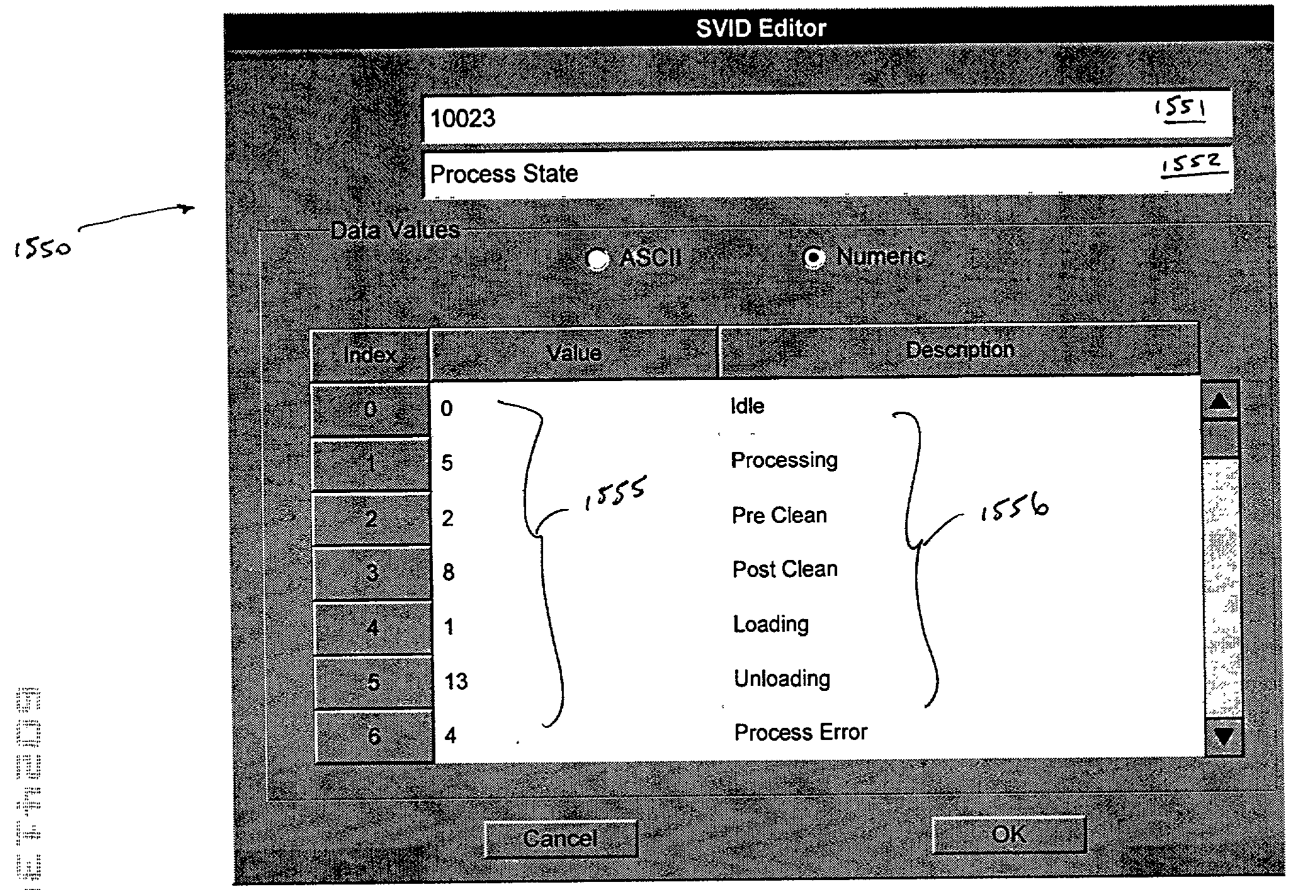


FIG. 15E

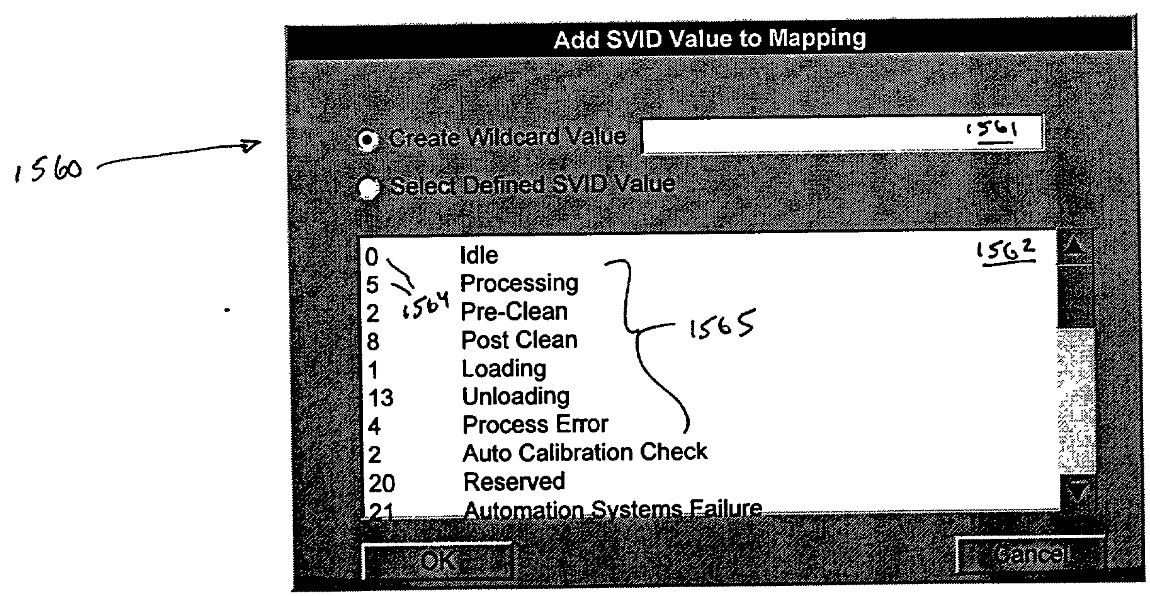


FIG. 15F

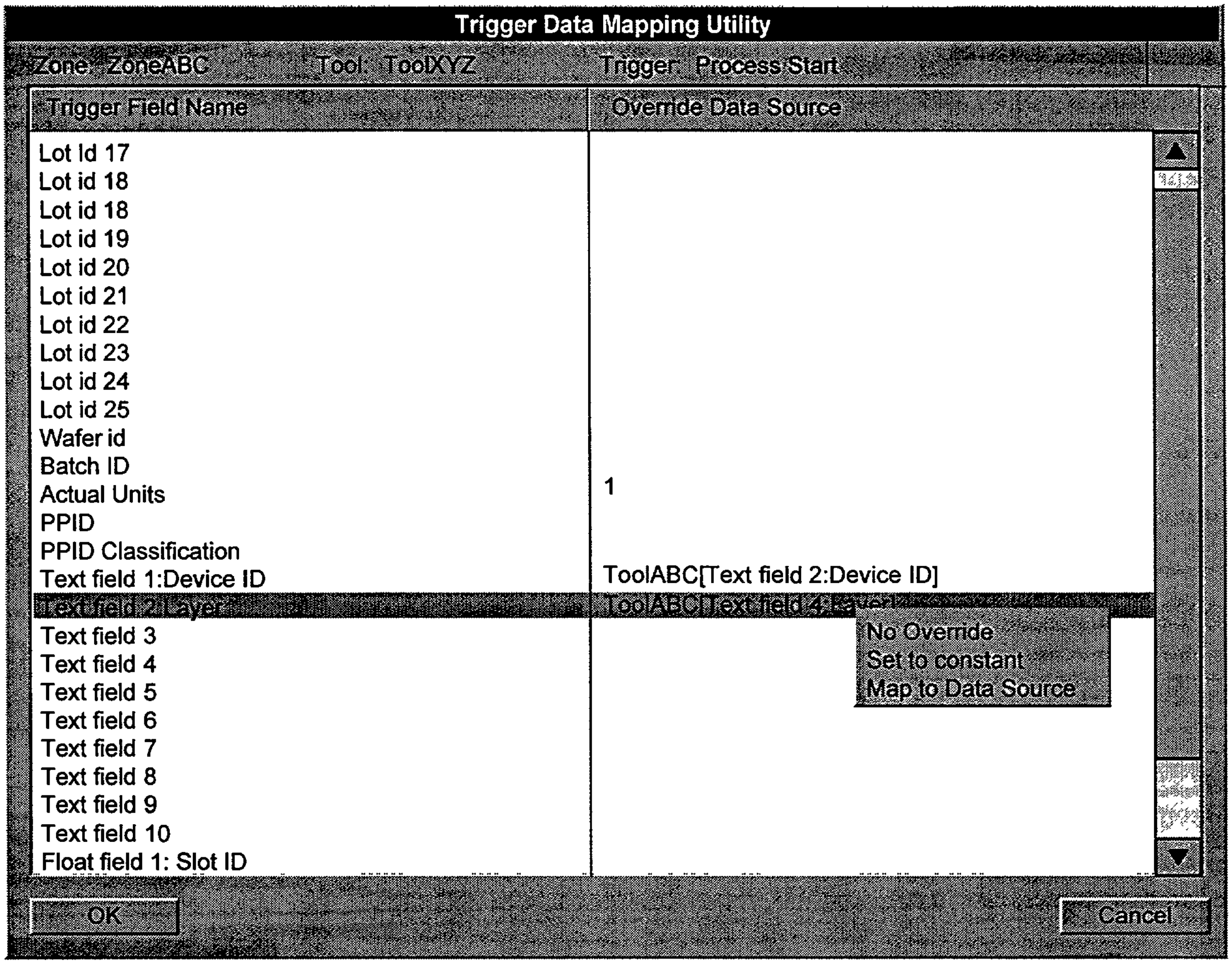

Trigger Data Mapping Utility
Zone: ZoneABC
Tool: ToolXYZ
Trigger: Process Start
Trigger Field Name
Override Data Source
Lot Id 17
Lot id 18
Lot id 18
Lot id 19
Lot id 20
Lot id 21
Lot id 22
Lot id 23
Lot id 24
Lot id 25
Wafer id
Batch ID
Actual Units
1
PPID
PPID Classification
Text field 1:Device ID
ToolABC[Text field 2:Device ID]
Text field 2:Layer
No Override
Set to constant
Map to Data Source
Text field 3
Text field 4
Text field 5
Text field 6
Text field 7
Text field 8
Text field 9
Text field 10
Float field 1: Slot ID
OK
Cancel

FIG. 16

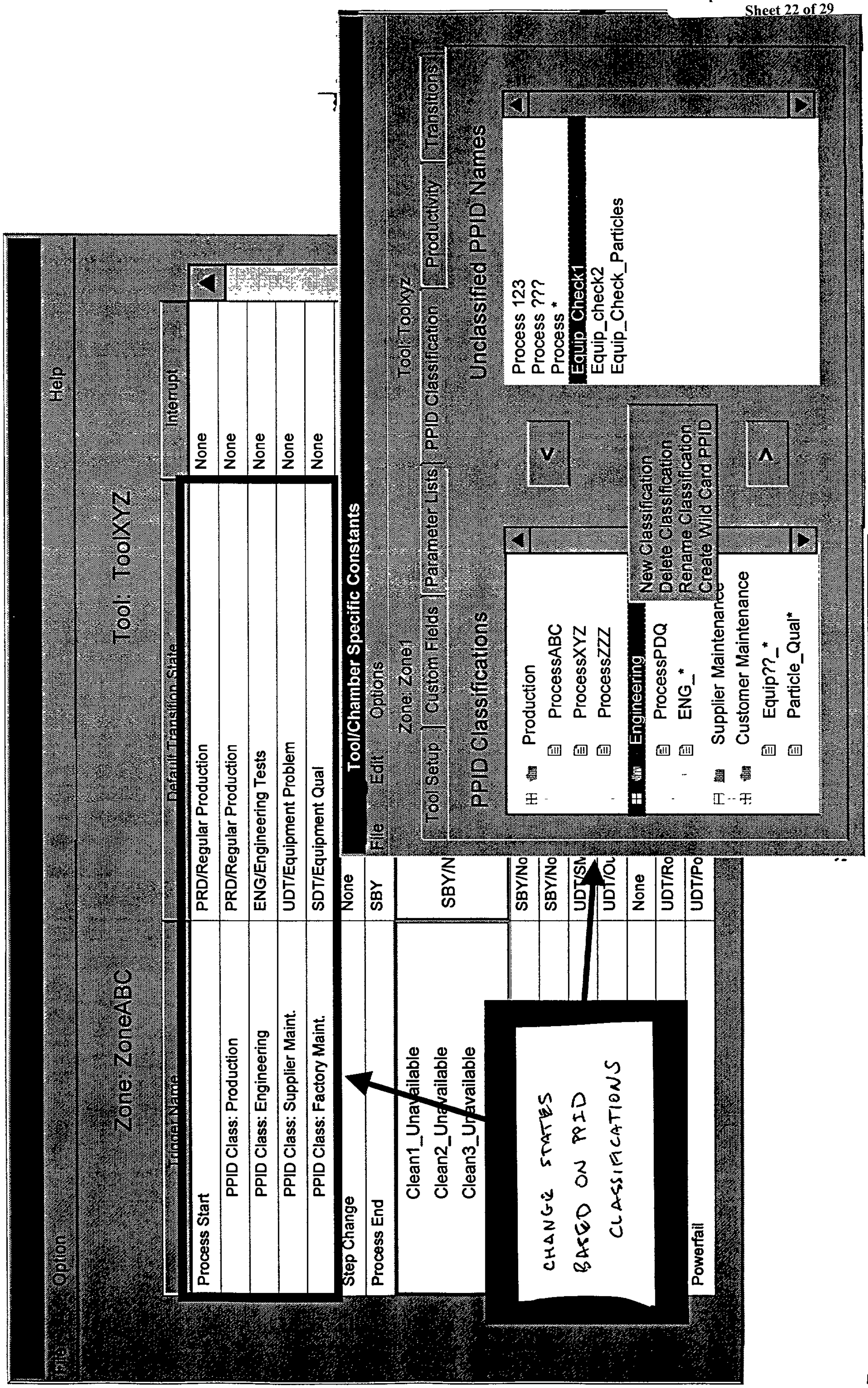

File
Option
Help
Zone: ZoneABC
Tool: ToolXYZ
Trigger Name
Default Transition State
Interrupt
Process Start
PPID Class: Production
PPID Class: Engineering
PPID Class: Supplier Maint.
PPID Class: Factory Maint.
Step Change
Process End
Clean1_Unavailable
Clean2_Unavailable
Clean3_Unavailable
Powerfail
PRD/Regular Production
PRD/Regular Production
ENG/Engineering Tests
UDT/Equipment Problem
SDT/Equipment Qual
None
SBY
SBY/N
None
CHANGE STATES BASED ON PPID CLASSIFICATIONS
Tool/Chamber Specific Constants
File
Edit
Options
Zone: Zone1
Tool: Toolxyz
Tool Setup
Custom Fields
Parameter Lists
PPID Classification
Productivity
Transitions
PPID Classifications
Production
ProcessABC
ProcessXYZ
ProcessZZZ
Engineering
ProcessPDQ
ENG_*
Supplier Maintenance
Customer Maintenance
Equip??_*
Particle_Qual*
New Classification
Delete Classification
Rename Classification
Create Wild Card PPID
Unclassified PPID Names
Process 123
Process ???
Process *
Equip_Check1
Equip_check2
Equip_Check_Particles

FIG. 17

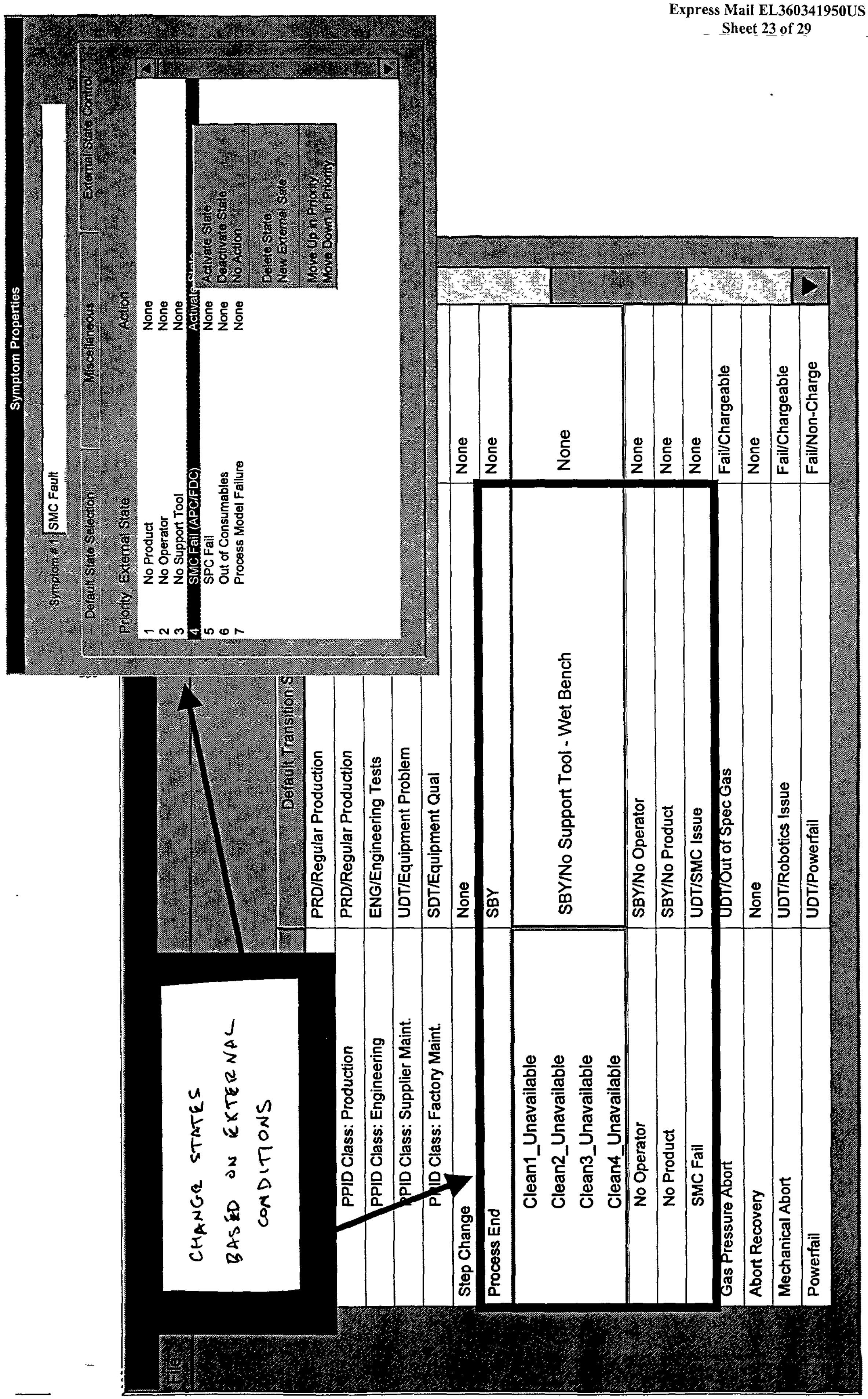

Symptom Properties
Symptom # 1 SMC Fault
Default State Selection
Miscellaneous
External State Control
Priority External State Action
1 No Product None
2 No Operator None
3 No Support Tool None
4 SMC Fail (APC/FDC) Activate State
5 SPC Fail None
6 Out of Consumables None
7 Process Model Failure None
Activate State
Deactivate State
No Action
Delete State
New External State
Move Up in Priority
Move Down in Priority
Default Transition S
PPID Class: Production
PRD/Regular Production
PRD/Regular Production
PPID Class: Engineering
ENG/Engineering Tests
PPID Class: Supplier Maint.
UDT/Equipment Problem
PPID Class: Factory Maint.
SDT/Equipment Qual
Step Change
None
None
Process End
SBY
None
Clean1_Unavailable
Clean2_Unavailable
Clean3_Unavailable
Clean4_Unavailable
SBY/No Support Tool - Wet Bench
None
No Operator
SBY/No Operator
None
No Product
SBY/No Product
None
SMC Fail
UDT/SMC Issue
None
Gas Pressure Abort
UDT/Out of Spec Gas
Fail/Chargeable
Abort Recovery
None
None
Mechanical Abort
UDT/Robotics Issue
Fail/Chargeable
Powerfail
UDT/Powerfail
Fail/Non-Charge
CHANGE STATES BASED ON EXTERNAL CONDITIONS

FIG. 1B

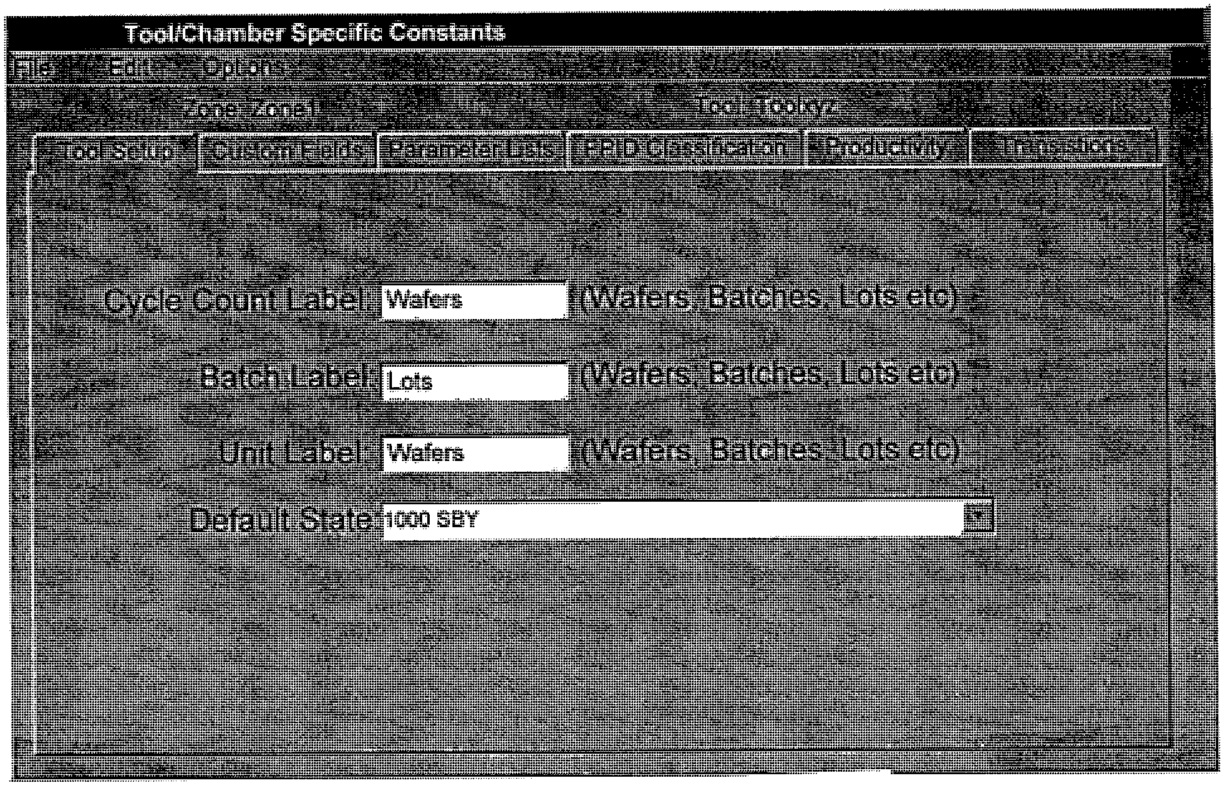


FIG. 19A

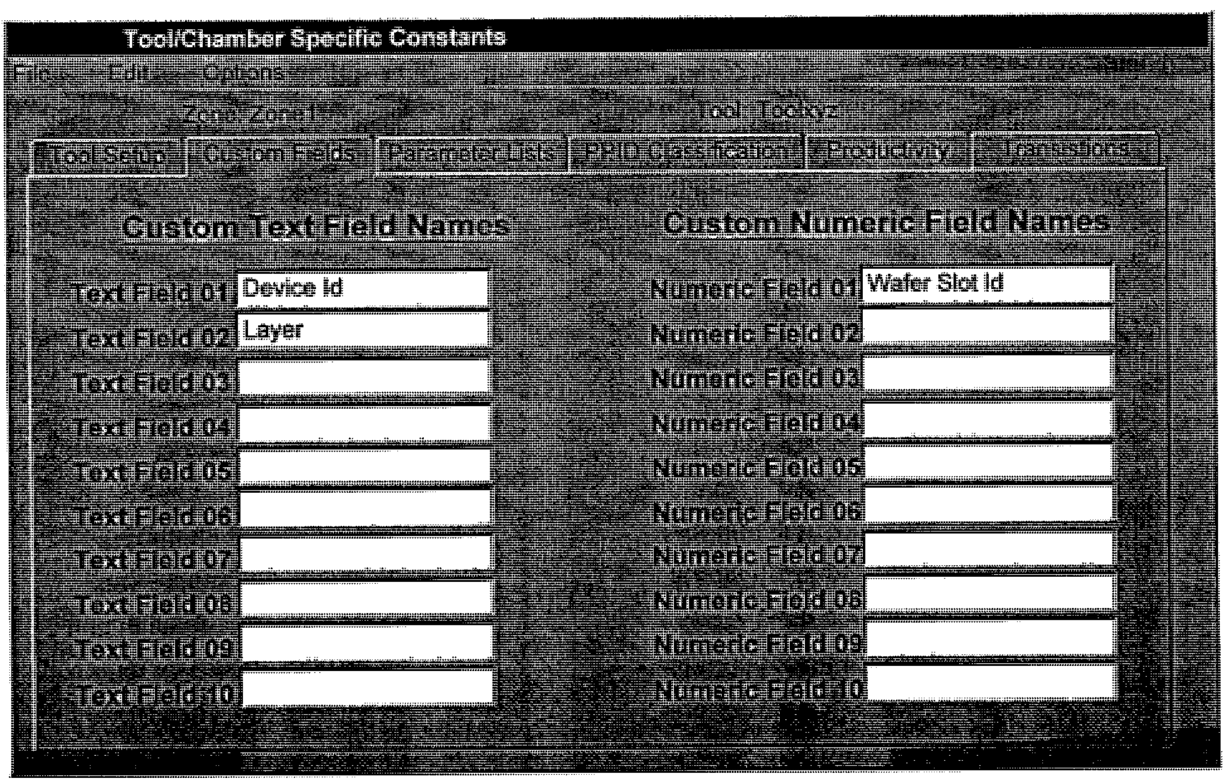


FIG. 19B

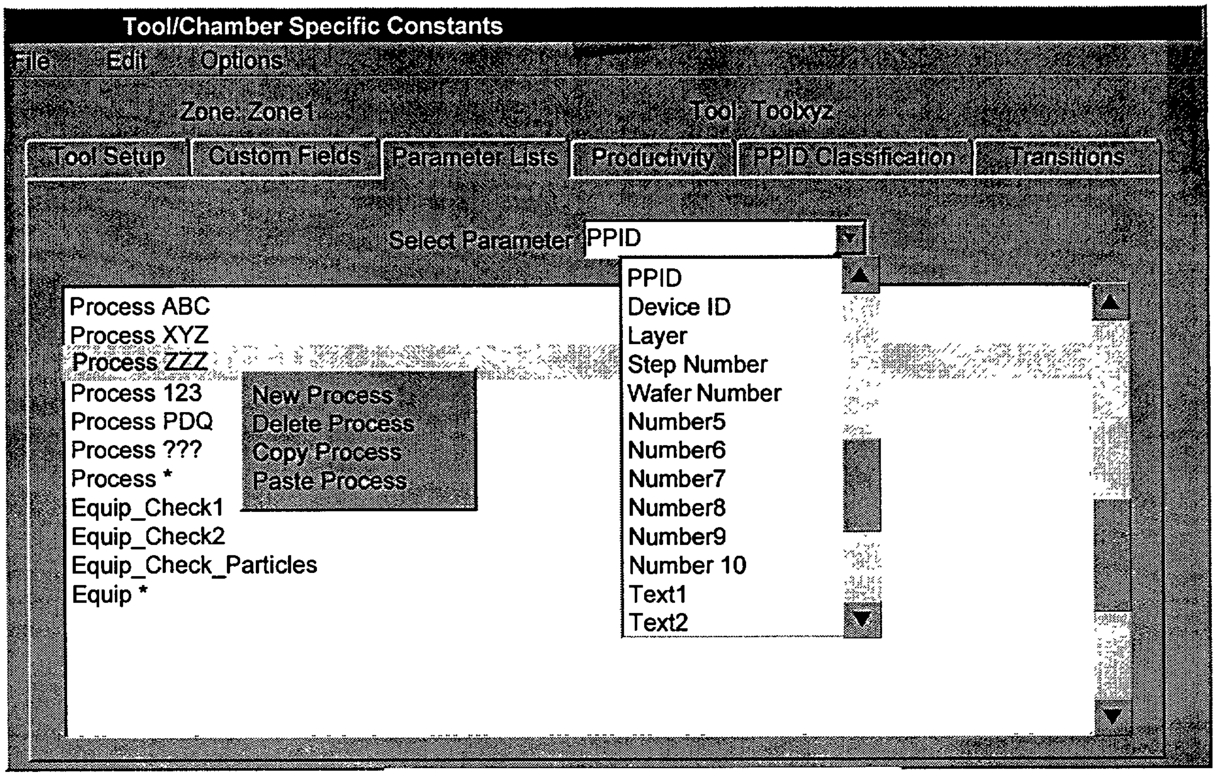


FIG. 19C

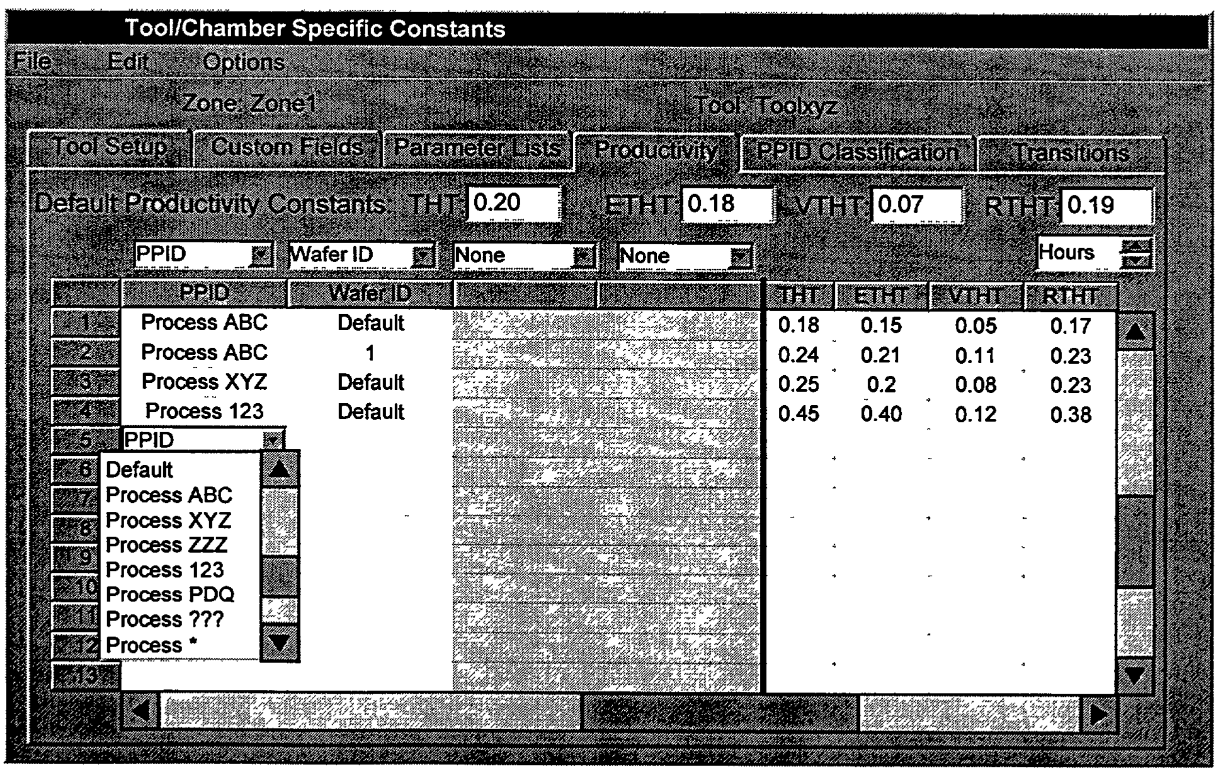


FIG. 19D

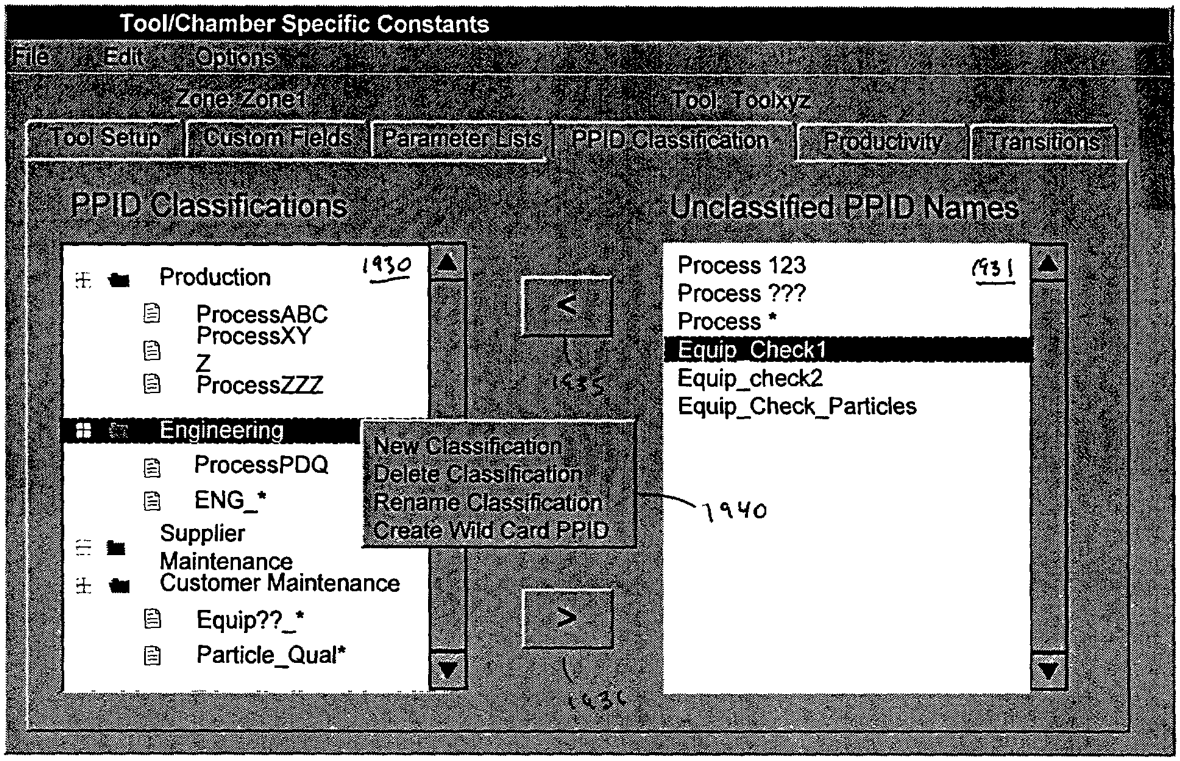


FIG. 19E

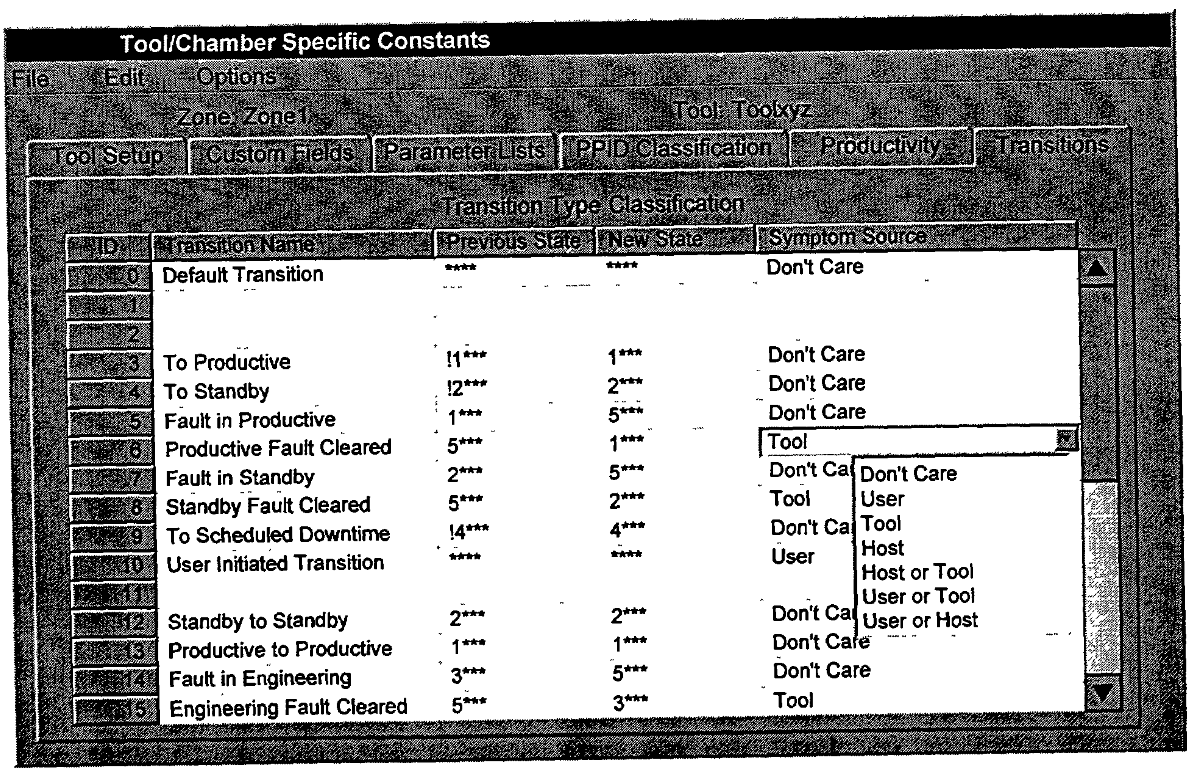


FIG. 19F

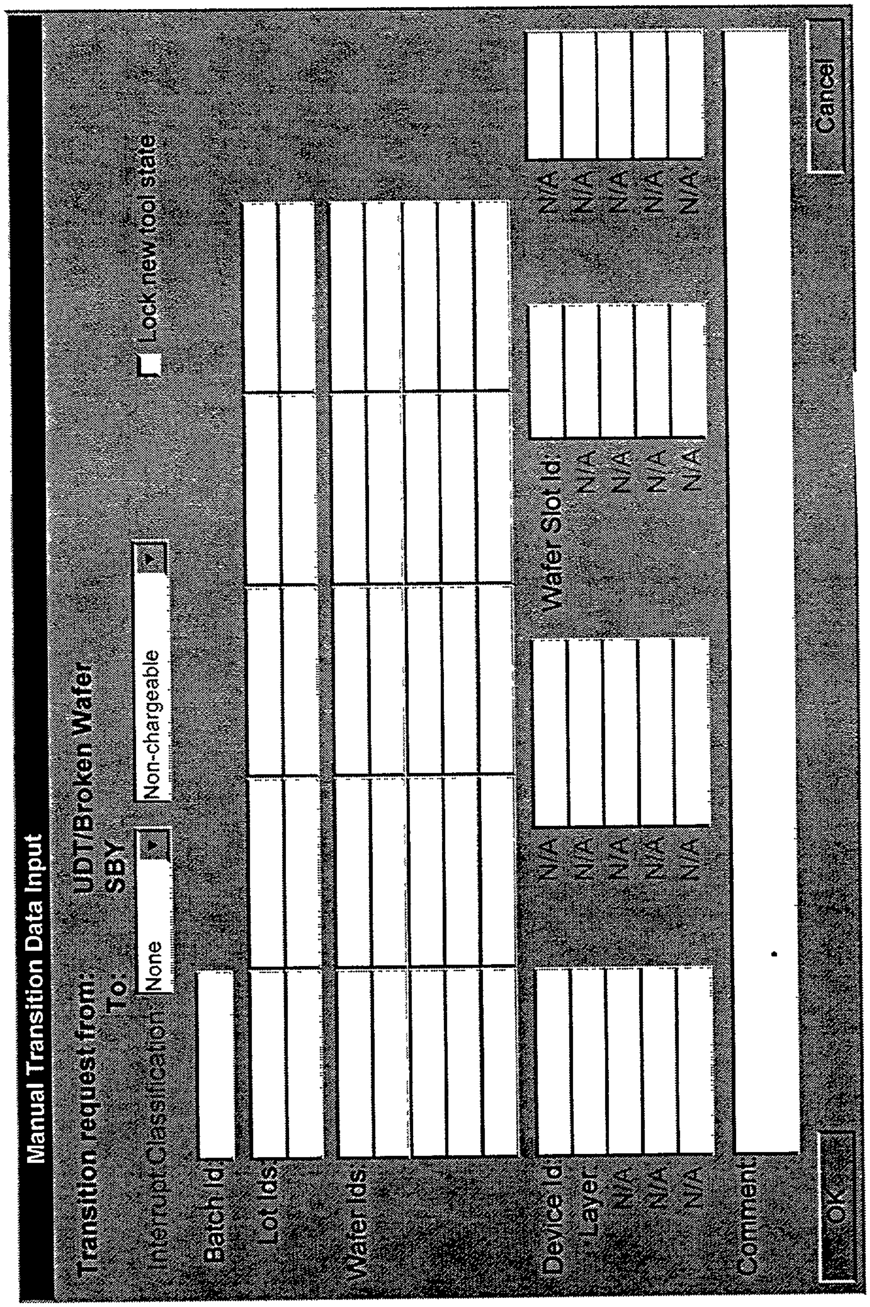

Manual Transition Data Input
Transition request from: UDT/Broken Wafer
To: SBY
Interrupt Classification: None
Non-chargeable
Lock new tool state
Batch Id:
Lot Ids:
Wafer Ids:
Device Id:
Layer
N/A
N/A
N/A
N/A
Wafer Slot Id:
Comment:
OK
Cancel

FIG. 20

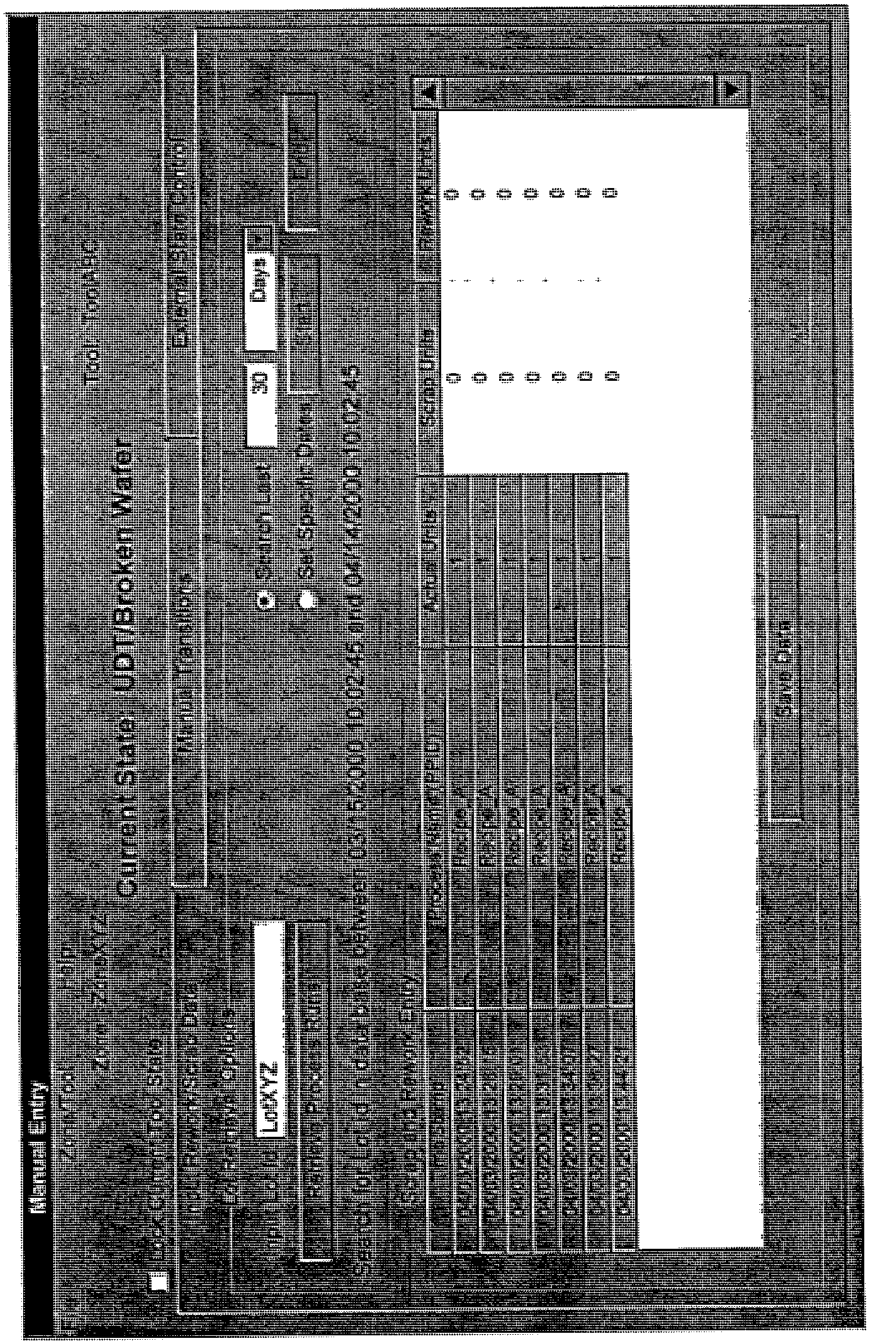

Manual Entry
Zone: ZoneXYZ
Tool: ToolABC
Current State: UDT/Broken Wafer
Manual Transitions
External State Control
Search Last
30
Days
Set Specific Dates
LotXYZ
Save Data

FIG. 21

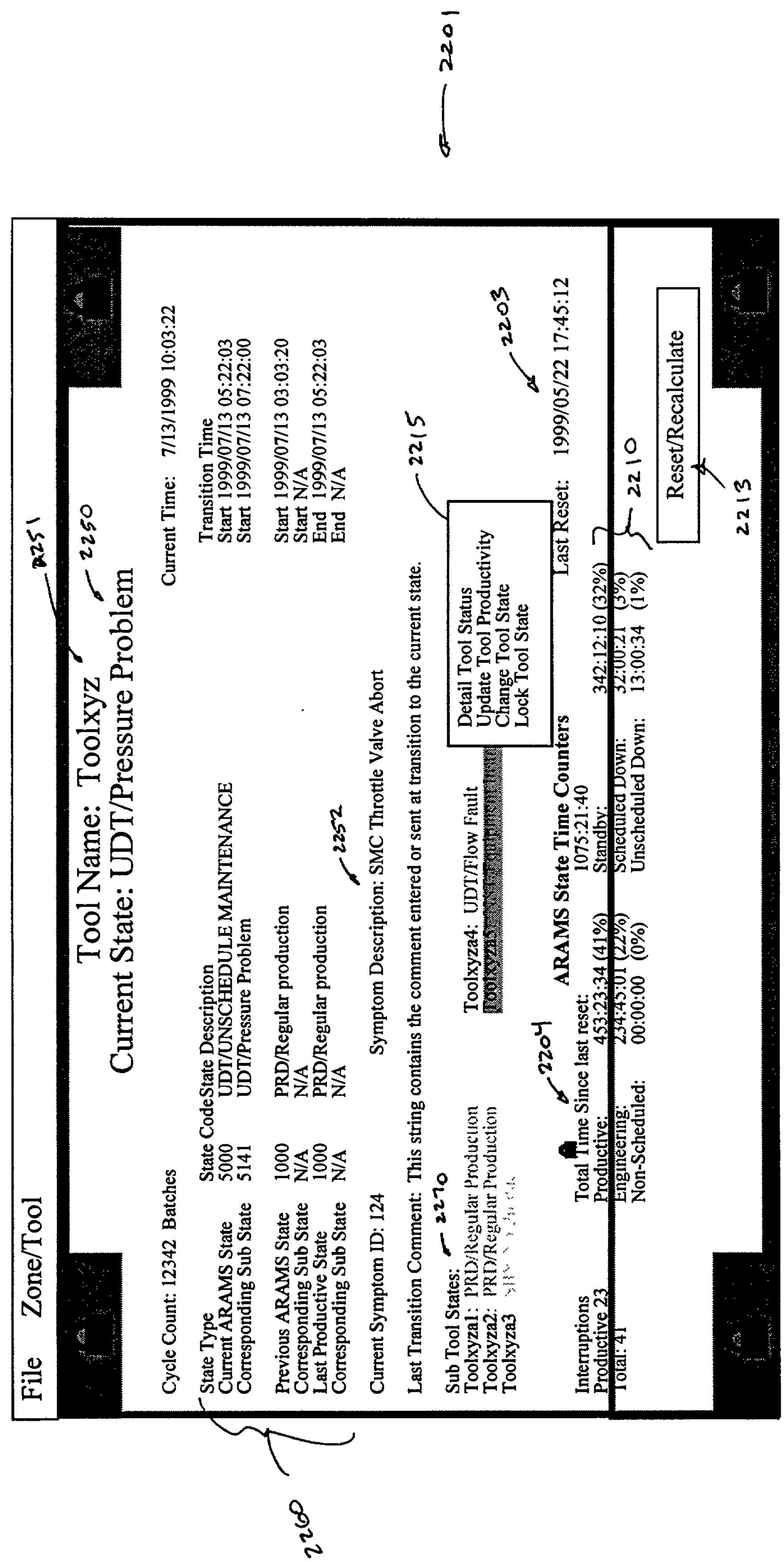

File Zone/Tool
Tool Name: Toolxyz
Current State: UDT/Pressure Problem
Cycle Count: 12342 Batches
Current Time: 7/13/1999 10:03:22
State Type
State Code
State Description
Transition Time
Current ARAMS State 5000 UDT/UNSCHEDULE MAINTENANCE Start 1999/07/13 05:22:03
Corresponding Sub State 5141 UDT/Pressure Problem Start 1999/07/13 07:22:00
Previous ARAMS State 1000 PRD/Regular production Start 1999/07/13 03:03:20
Corresponding Sub State N/A N/A Start N/A
Last Productive State 1000 PRD/Regular production End 1999/07/13 05:22:03
Corresponding Sub State N/A N/A End N/A
Current Symptom ID: 124
Symptom Description: SMC Throttle Valve Abort
Last Transition Comment: This string contains the comment entered or sent at transition to the current state.
Sub Tool States:
Toolxyza1: PRD/Regular Production
Toolxyza2: PRD/Regular Production
Toolxyza3
Toolxyza4: UDT/Flow Fault
Detail Tool Status
Update Tool Productivity
Change Tool State
Lock Tool State
ARAMS State Time Counters
Interruptions
Productive 23
Total: 41
Total Time Since last reset: 1075:21:40
Last Reset: 1999/05/22 17:45:12
Productive: 453:23:34 (41%)
Standby: 342:12:10 (32%)
Engineering: 234:45:01 (22%)
Scheduled Down: 32:00:21 (3%)
Non-Scheduled: 00:00:00 (0%)
Unscheduled Down: 13:00:34 (1%)
Reset/Recalculate
2201
2203
2204
2210
2213
2215
2250
2251
2252
2260
2270

FIG. 22

3 System Requirements

3.1 System Definition

All SEMI E10 states and ARAMS states are supported for state transitions and historical analysis. The customer may define an unlimited amount of sub-states in accordance with section 9 of the ARAMS specification.
ARAMS state changes can be initiated by the MES, the process equipment based on events or the end users through a GUI interface. State changes will conform to the behavioral requirements in section 16 or the ARAMS specification by default but can b modified by the users.
A user interface will be supplied to allow the users to configure sub-states.
A live status screen will be supported for each tool configured in the SEARAMS product. The status screen updates when new information arrives and displays ARAMS status information defined in section 11 of the E58 specification.

SEARAMS will provide a GUI to allow the users to initiate state changes directly and indirectly with the use of symptom selections.
HOST connection will be via framework objects. Initial support is CORBA. DCOM, MBX etc will be supported based on customer need.
SEARAMS supports SEMI E79 production metrics when the following information is provided. Transitions to production states for process start must contain the actual wafer count to be processed. The users must configure the SEARAMS production states and processes with theoretical productivity metrics defined in section 3.3.1.1.

SEARAMS supports SEMI E10 equipment metrics when the following information is provided. Transitions to an unscheduled down state are classified as failure interruptions by default. The users may configure specific cases of assists, or manually classify the failure as an assist using the manual state transition interface or through the HOST interface. SEARAMS provides a graphical configuration setup for interrupt classification.

3.2 Functional Requirements

The following sections define the functional requirements of SEARAMS Product.

3.2.1 User Access Validation

This application's user access will be controlled using the functionality similar to the ComCore Palette and User security features but independently configurable outside the FSW/ESW product line.

3.2.2 Tool Selection

The users will select a tool using a Zone/Tool selection menu.
Each application must have a VERY clear label identifying the currently selected tool or tools.

3.2.3 State Models

The SEARAMS product will support user definable state models building upon the SEMI E10 and SEMI E58 state models. An editor will be provided allowing the users to create new sub-states and assign the sub-states to the SEMI state model hierarchy. In addition, the default transition from one state to another follows the E58 specification section 8.2.

Each state contains a state id and a state description:
State Id:
The state id is a four digit alphanumeric string with format ##xy. The first two digits are numbers and the second two are case sensitive alphanumeric.

The first digit refers to the SEMI E10 state.
1000 – Productive
2000 – Standby
3000 – Engineering
4000 – Scheduled Downtime
5000 – Unscheduled Downtime
6000 – Non-Scheduled time

The second digit is reserved for the SEMI E58 ARAMS sub states defined in SEMI E58 section 9.

The final two digits are use as refinements for the sub states. The users and equipment suppliers may define a sub-state for any ARAMS state. The last two digits increment for each new user defined sub-state. Since there are two digits reserved, two levels of sub-states may be defined. State 5112 is a sub-state of 5110, 5100 and 5000. The state model number convention provides four levels of states and allow the users to define 61 sub-states at the third level for each second level state and 61 fourth level states for each third level sub-state. 61 = 1 to 9 + a to z + A to Z.

The first level state is the default E10 state. The E10 states do not allow user defined sub states as defined in SEMI E58. This rule is carried through all four levels in SEMY SEARAMS. The rule is a '0' can not be to the left of any character excepts another '0'.

Allowed	Not Allowed
1000	1011
1100	1008
1110	2034
1320	1208
3452	3409
1919	9902

Description:
80 character string.
The description may contain alphanumeric and special characters.

State Properties
In addition to the state id and state description, the SEARAMS product will support state properties to enhance the usefulness of the system. The following state properties are supported:

*Enabled/Disabled bit – Allows users to select this state when changing equipment states. An example of disabled states would be the default ARAMS reserved states.

*User/Group access – Defines the group access levels that can transition from this state.

*Valid User State Transitions – Defines the list of valid states the user may transition to from this state. An example use for minimizing the list of valid states to transition to could be the "Down for Repair" state. The users may have to transition to "Process Qualification State" before transitioning to "Up for Production" based on the Fab process qualification needs. This is not part of the SEMI requirements but would be useful in the factories. If the list of Valid Transition states is left empty, then all states will be selectable.

Automatic Transition Triggers – Defines the symptoms that trigger SEARAMS to automatically transition to other states from this state.

Cluster Tool Linkage – Defines the associated state changes to other tools when a state change occurs on the cluster tool. An example would be a state change to unscheduled maintenance of a main tool would automatically change the states of all associated chambers on the cluster tool.

Process Name – The process name is valid for Productive states. It associates productivity statistics with a give productive state. The users may input the theoretical and value added information for any process. This data will be used to compare with actual run time data for SEMI E79 calculations.

* These properties are only used in the SEARAMS user interface to change the current equipment state to some new state. HOST or equipment event initiated state triggers and transitions bypass these properties.

3.2.4 State Transitions

SEMI E58 defines rules for automatic state transitions in section 8, table 1. All automatic state model transitions are supports in the SEARAMS product. The users may define new transition rules. SEARAMS performs automatic state transitions based the user defined transition rules when any event, alarm or symptom is received. The users or the HOST may force a transition to a new state at any time with proper privileges and authorization.

3.2.5 Automatic State Transition Rules

SEMI E58 defines 15 transition rules. The SEARAMS product allows the users to configure the trigger information for each automatic transition state and define new transition rules. The trigger information is typically different from tool model to tool model.

When a transition occurs from one state to another, SEARAMS categorizes and logs the state change as a specific transition type.

Throughout this document, SEARAMS will use the terminology trigger events and symptoms interchangeably. They both define the trigger that will generate a SEARAMS state change. The purpose of the following definitions is to conform to ARAMS for logging in the database. When a transition occurs, SEARAMS will test the following criteria to classify the transition into one of the following default categories. The users may change the transition descriptions or add new transitions. See section 3.4.1.3.6 for configuration description.

Default Transition types.
Transition 1, Power-up/reset
When the power up trigger is received, SEARAMS will transition to the state defined by the symptom. Default destination state is "SBY".

Transition 2, To Manufacturing
Not support in an off tool implementation. SEARAMS does not have access to the production criteria for each tool.

Transition 3, To Productive
Defined as an automatic transition from any non-Productive state to a Productive state.

Transition 4, To Standby
Defined as an automatic transition from any non-Standby state to a Standby state.

Transition 5, Fault Detected in productive
Defined as an automatic transition from Productive to an Unscheduled Down state.

Transition 6, Productive Fault Cleared
When a trigger causes and automatic transition from an Unscheduled Down state to Productive.

Transition 7, Fault Detected in standby
Defined as an automatic transition from Standby to an Unscheduled Down state.

Transition 8, Standby Fault Cleared
When a trigger causes and automatic transition from an Unscheduled Down state to Productive.

Transition 9, Scheduled Downtime
A monitored parameter has reached a pre-defined limit. This may be a Semy PM abort or a tool event. In either case, SEARAMS will transition the tool to the appropriate Scheduled Maintenance sub-state when the appropriate symptom is received.

Transition 10, User initiated transition
The user selected a new state using the SEARAMS user interface or the HOST selected a new state using the object interface.

Transition 11, Power-down
No default set in SEARAMS. Users may classify a specific trigger type as a power down event.

Transition 12, Standby - Standby State Change
Defined as any transition from one Standby sub state to another Standby sub state.

Transition 13, Productive – Productive State Change
Defined as any transition from one Productive sub state to another Productive sub state.

Transition 14, Fault Detected in engineering state
Defined as an automatic transition from Engineering to an Unscheduled Down state.

Transition 15, Engineering Fault Cleared
When a trigger causes and automatic transition from an Unscheduled Down state to Engineering.

3.2.6 State Change Logging

All state transitions will be logged in a database for future review. The data base fields are defined as but not limited to:
Time stamp – Based on local CPU time when the new data arrived.
Transition number – calculated transition type based on SEMI E58 and section 3.2.5.
Unit Ids – List of 25 fields, 20 characters each. (This may be lot ids or wafer ids)
Batch Id – 20 character field. (If Units are wafers, this is the Lot Id otherwise optional batch id)
PPID – 20 character field storing the recipe name if sent with the trigger.
PPID_Class – 20 character field storing the PPID class. Sent with the trigger or from SEARAMS.
Source – Where the transition request originated (user, HOST, tool server).
Symptom – The symptom or trigger number corresponding to the symptom table.
OEE_State_Change – List of four Boolean types, one for each state level. Set to true if the previous state was a different OEE State, otherwise false. (design suggestion)
Cycles – The total number of cycles the equipment has processed since install. (Sent from tool)
Interrupt - Classify a transition to UDT as a equipment Assist or Failure.
Interrupt Classification – Classify the interrupt as Chargeable, Non-Chargeable or Non-Relevant.
ARAMS state number – 4 Digit ARAMS state code identifying the triggered destination state.
External_State – List of 20 Boolean states used to denote when external states changes such as no operator available or SMC violation.
THT – Theoretical Production time per unit. (Only valid in Production States)
ETHT – Engineering Theoretical Production time per unit. (Only valid in Production States)
VTHT – Value Added Theoretical Production time per unit. (Only valid in Production States)
Actual Units – Actual unit processed. (Only valid in Production States)
Scrap Units – Scrapped units in this process. (Only valid in Production States)
Rework Units – Number of Units requiring rework. (Only valid in Production States)
ALID – Record the ALID sent from a SECS compatible driver
ALID Text – Record the alarm text from a SECS compatible driver
CEID – Record the CEID sent from a SECS compatible driver

CEID Text – Record the event text from a SECS compatible driver
SVID – Record the SVID number only when a transition is logged. SVIDs do not get logged except in transition records.
SVID_Number – If the SVID is a number, record the numeric value of the SVID field.
SVID_ASCII – If the SVID is ASCII, record the ASCII value of the SVID field.
ms1, ms2, ms3, ms4 – Number of milliseconds since the last transition for each state level
Text – List of 10 user defined text fields. 20 character fields.
Floats – List of 10 user defined signed float fields.

Design recommendation:
Since many of the reports require intensive time calculations, the SEARAMS database design must be optimized to reduce the report generation time. Add four double fields, ms1, ms2, ms3, ms4, to store the number of milliseconds since the last transition to that level. Field ms1 would contain the number of milliseconds since the last state change that caused the first digit in the state code to change etc. Prior to writing a record in the database, simply read the last record. If the last record contained a state transition, record the number of milliseconds since that record's time stamp and now and store them in the appropriate level. If the previous record did not contain a state transition, read the four ms fields, add the time between that record and now to each and store in the new record.

*Interrupt type is only recorded when a transition to UDT occurs from a non-UDT state. The default Interrupt type is failure but may be over ridden by the symptom definition or user input.

All symptoms submitted to SEARAMS that do not trigger a state change will be logged in the audit trail. The tool name, time stamp, source of the symptom (user, HOST, tool server), symptom, current and ARAMS state number will be recorded, but the database will not be updated.

This information must be stored in such as way as to provide a quick retrieval based on groups of tools, states or transitions or any combination of the stored fields. Support for editing existing data records must be provided. This capability is required due to the possibility that incorrect states were selected based on incorrect input criteria or accidental user selection. The tool uptime performance tracking requires accurate time based data from SEARAMS. Users will be required to edit, delete or insert records when in-accurate information has been supplied causing state transitions.

3.2.7 State Accumulators

All states and sub states will be accumulating time in the SEARAMS product. The unit of measure is milliseconds, although, the SEMI E58 only requires the time in minutes. Several formats will be supported for the status display and the HOST requested information.

SEMI E58 states the accumulators are optional. If they are supported, there is a set of standards in SEMI E58 to define the implementation in section 11.4. Only seven accumulators are defined in SEMI E58. SEARAMS provides a generic approach to the accumulators and supports accumulators for all possible sub states.

The state accumulator reports require four types of information.
1) The timestamp of the last time the state was transitioned into.
2) The number of times any state transitioned to this state.
3) The total amount of time spent in this state in milliseconds since the last user reset.
4) The timestamp of the last user initiated accumulator reset for this state.

The users will be able to reset the total amount of time spent in a state at any time. This action will reset the total count to 0 milliseconds.

Since the actual accumulated time in any state is required in the live ARAMS status screens, a data base search and calculation is impractical. Design suggestion: Keep the current accumulator information in a separate table for easy access providing real time live update.

3.2.8 State Transition Logic

SEARAMS will receive messages from multiple sources. The messages may be transmitted across any BUS but must be converted to a CORBA object prior to being received by SEARAMS. SEARAMS will provide software bridges as needed to convert message to CORBA IDL from DCOM, MBX, etc.

The SEARAMS object may contain conflicting information if the source does not follow the guidelines for object generation described in section 3.2.9. SEARAMS should be robust and handle conflicting information sent in single message. An external source may send a trigger, ALID, CEID and SVID. SEARAMS supports state transitions based on each of these elements but will only support a single transition per message. If the message contains multiple elements that may cause a transition, SEARAMS logic must decide which information will cause the transition to occur and simply record the remaining information in the database.

The users may decide which element in a message will be used to generate the transition in a "Transition Initiation Type" field defined in the IDL. This field is an enumerated field with the following definitions:

0 – "Default" SEARAMS will use it's internal priority to determine which element will cause a transition. The internal priority is 1-Trigger, 2-ALID, 3-CEID, 4-SVID.
1 – "ALID" SEARAMS will only evaluate the ALID to generate a transition, all other elements will be logged in the database. SEARAMS will ignore any value sent in the Trigger field.
2 – "CEID" SEARAMS will only evaluate the CEID to generate a transition, all other elements will be logged in the database. SEARAMS will ignore any value sent in the Trigger field.
3 – "SVID" SEARAMS will only evaluate the SVID to generate a transition, all other elements will be logged in the database. SEARAMS will ignore any value sent in the Trigger field.
X – any other value is treated the same as a 0, "default".

Example: SEARAMS receives a message with the following information:
Tool = 3
Recipe = "Process_abc"
Lotid = "Lot_123"
Text_1 = "IC_36_2003"
Float_1 = 22
Transition Initiation Type = 2
Trigger = 15
ALID = 2312
Alarm Text = "Pressure Alarm"
CEID = 4530045
Event Text = "Pressure Alarm Event"
SVID = 3450220
SVID_Type = 0
SVID_Number = 345.2
SVID_ASCII = ""

SEARAMS will evaluate the value of "Transition Initiation Type". In this example it is "2" which is the CEID Initiation Type. SEARAMS will then look up the CEID in the CEID table. If the CEID is not found, SEARAMS will add the CEID to the CEID table as described in section 3.4.1.2.1. If the CEID does exist in the table, SEARAMS will look up the mapped trigger from the CEID table. If no trigger is found, SEARAMS will log ALL the message parameters in the database without and state change. (Note, the trigger number field will be left blank since no trigger was mapped to the CIED and SEARAMS will ignore the Trigger sent in the object since the Initiation type was CIED.) If a trigger is mapped to the CEID in the CEID table, SEARAMS will use this trigger and send it to the State Transition logic. The state transition logic will then act on the trigger.

As triggers are received by SEARAMS, the state and trigger properties determine the action taken. In many cases, a trigger will cause the state model to transition to a new state. All triggers received will be recorded in the database as well as any action taken for audit trail logging. The state, trigger, and transition rule property configuration editing is defined in section 3.4.

Once a message is received and filtered based on the logic flow described in 3.2.8a, the state model logic is required to transition to the appropriate state. The state and trigger properties define the action taken when a message is received. The following logic flow diagram describes the process.

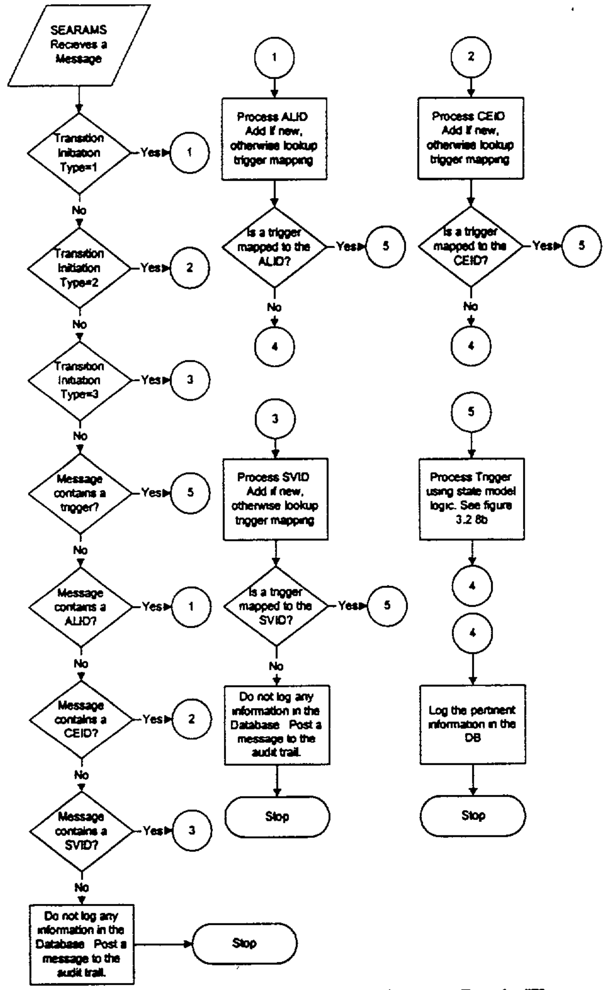
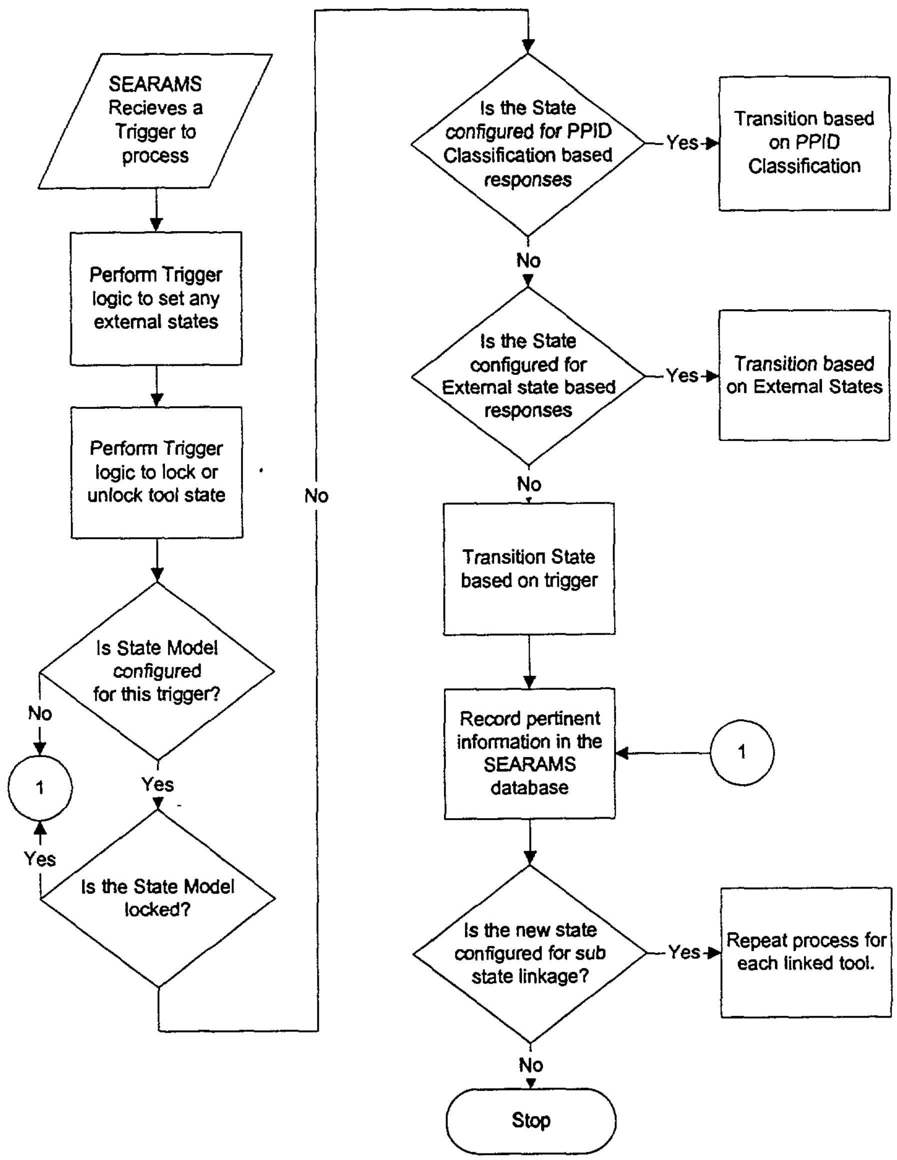


Figure 3.2.8a Process New Message Logic Flow



3.2.8b State Change Logic Flow

Special Case Processing

Special Case 1: Influence from external states
External states affect equipment performance but are not directly related to the equipment actions. Examples of external states are: No Operator, No Product, No Support Tool, No Consumables, Process SPC violation etc. These states typically cause the equipment to record time in a specific Standby sub state. The MES may send a no operator or no product trigger. These triggers may be set up to cause a delayed transition. Example: A tool is processing wafers in the productive state. The MES or HOST system sends a trigger, "No Product". SEARAMS will not transition to a SBY state until the tool has completed processing. When the tool finishes processing at a later time, it will transition to "SBY/No Product" instead of "SBY/Idle". The logic is configurable by the end users using state transition configuration GUIs.

Special Case 2: Return to previous state
A trigger may initiate a transition from an ARAMS sub state causing the state model to return to the previous state. Example: A tool alarm cleared trigger may transition the tool from Unscheduled down back to production, engineering or standby. The new state is dependant on what state the tool was in prior to the trigger causing the state change to unscheduled maintenance. This requirement supports E58 transitions 6,8 and 15.

Special Case 3: Manual Override Trigger Properties
Typically, a transition from any unscheduled down state to standby is a manual action. The user must be allowed to change the "reason" and "classification" recorded when the state model transitioned to "Unscheduled Down". Example: A trigger for "Flow Abort" is classified as an "interrupt" and causes a transition to "UDT/Flow Problem". When the maintenance personnel transition back to "PRD/Normal Production" they may change the classification of the original "Flow Abort" trigger from "interrupt" to "assist".

Special Case 4: Cluster Tool Support
SEARAMS tracks each processing module with an independent state model. Any part of a cluster tool may interact with other tools based on the state model. This is important for cluster tool support. If there is a robot failure on a cluster tool, each chamber should transition to an appropriate, non-productive state until the robot is repaired. SEARAMS supports automatic state interaction based on user defined criteria for tool state linkage.

Special Case 5: Scrap Units and Rework Units
Any tool processing production material is assumed to be producing saleable product wafers when running production states. Some process steps may be reworked when a mistake occurs in the process. This information is available after the actual processing, usually from an inspection step. SEARAMS supports the capability to subtract the production state credit when rework is required or product is scrapped. The MES may send trigger objects with lot ids, wafer ids, wafer count, tool id and recipe name associated with the scrap or rework material. SEARAMS will record the rework or scrap material against the reported tool and save the data with the original run data.
(The tool used to process the rework material the second time will get full production credit based on the assumption that the material will process correctly)
The MES may send rework or scrap material information at any time for any tool. SEARAMS also provides a user interface to input the data as well.

Special Case 6: Lock State
Any state may be locked in the state configuration. A locked state is not affected by triggers. The only way to transitions to a new state is through the user interface. A lock state is useful for unscheduled down states that may receive process start and stop triggers due to maintenance personnel interacting with the equipment. Automatic unlocking of a tool state is support through the trigger properties.

3.3 External Interface Requirements

3.3.1 SCF Tool Support
To be defined in the detailed requirements documentation.

3.3.2 ComCom Tool Support
To be defined in the detailed requirements documentation.

3.3.3 HOST Interface
To be defined in the detailed requirements documentation.

3.3.4 APC Framework Interface

To be defined in the detailed requirements documentation.

3.4 User Interface Requirements

3.4.1 Configuration editors

3.4.1.1 ARAMS State Model Configuration

This GUI interface allows the users to view the existing state models for any supported tool. They can also define new states within the ARAMS specification bounds.

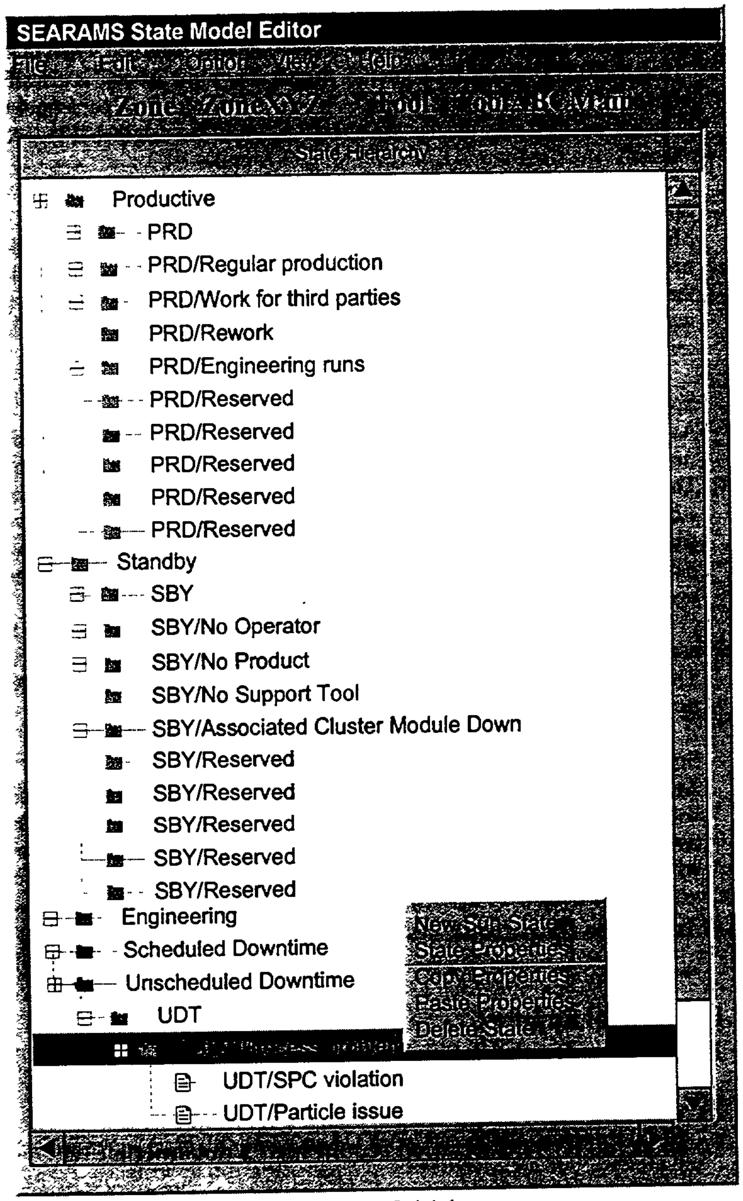


Figure 3.4.1.1a

The user is presented with a list of the default ARAMS states. They may select any of these states by left clicking the mouse on the state of interest.

The state selection list is a hierarchical listing with specialized user operations. If the user clicks the plus sign, the sub states are listed under the current state. The plus will change to a minus. If the click the minus sign, the sub states will roll up and disappear. Any state that contains sub states will have a plus or minus sign next to it. States without sub states do not have a plus or minus icon per example.

File menu:

Open Presents the user with a tool selection list dialog. The user selects a tool and clicks Open.

Save . Allows the users to save their changes so far.

Save As Allows the users to save the current tool's state model to another tool. Should open to a tool selection list

Reload: Reads the configuration from disk. Updates this editor with changes that may have occurred in other editors while working in this editor. Will not save or alter the current changes in this editor unless required due to deleted information from disk.

Print Prints text based list of all defined states and the corresponding properties.

Exit Prompts the user to save changes if needed. Exits the application.

The default OEE and ARAMS sub states are the highest level states and pre-defined in SEMI E58 section 9. These states are not editable by the customers. Delete State should not be accessible. Many of the default states are reserved and could be changed in the future. Therefore, an application specific bit should be used to allow the users to edit the default OEE and ARAMS state names.

If the user right clicks on a state, they are presented with a pop up menu of options as shown in figure 3.4.1.1a.

New Sub State Menu Selection

Opens a dialog to allow the users to define the SEARAMS information for a new sub state. The parent state will be the currently selected state. The user selection will open a new dialog window to define the new state. Third level states do not allow sub states to be declared. When third level states are selected, the New Sub State menu item should be disabled.

State Properties Menu Selection

User select this menu item to edit the name of an existing state or update any of the state property information used to describe the SEARAMS support for the state.

Both the New Sub State selection and the State Properties Selection open the same dialog figure 3.4.1.1b. State properties may not be set for any of the 6 OEE states. The OEE states themselves do not exist as entities, they only serve as a convenient grouping mechanism.

Copy Properties Selection

This function places a copy of the properties from the currently selected state into the clip board. This selection is only available if a single state is selected. When the user has multiple states selected, this function is dimmed.

Paste Properties Selection

This function will overwrite the properties of the currently selected state or states with the contents of the properties clip board. If the user has not made a copy of the properties using "Copy Properties" the paste properties function selection is dimmed. The state name is part of the state properties BUT IS NOT part of the paste properties functionality. All properties except the state name are overwritten in the selected state or states.

State Properties Dialog

The first editable field is the name of the state. Users may name the states but the xxx/ prefix is automatically added to the front of the name. The length is restricted to 80 characters and it supports all special characters with the exception of any reserved GEM characters.

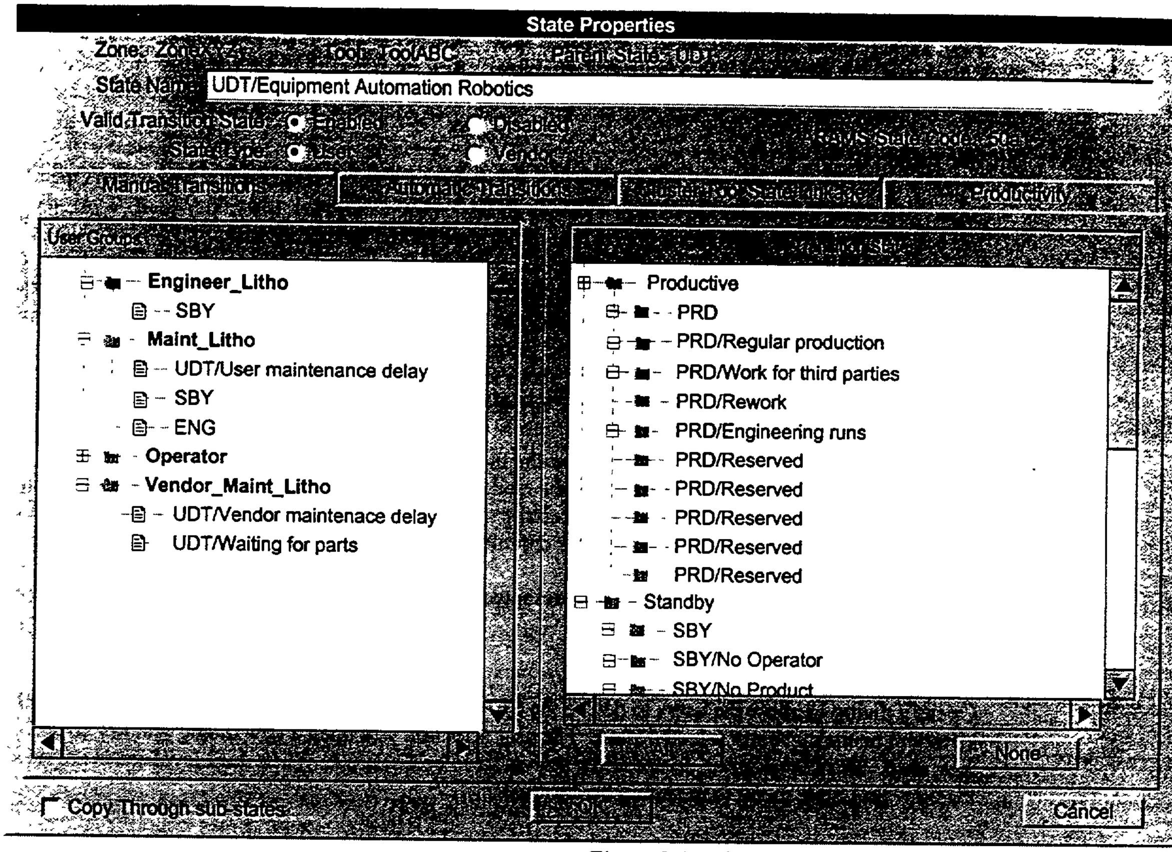


Figure 3.4.1.1b

The capability to rename the state selection is not available for protected states. All states defined in SEMI E58 section 9 are protected states. An application specific bit will over ride the protection of these state names.
The "Valid Transition State" radio button allows the users to remove a sub state from the state model without deleting the state. If a state is invalid for some time, the user may disable it here. The E58 reserved states are examples of states that should be disabled. Disabled states will not show up in the user selection lists with one exception. Disable states will always show up in the ARAMS state configuration window, figure 3.3.1.1a to allow the users access to enable the state.
The "State Type" property allows the users to define the state as a vendor state or a customer state. The SEMI E58 specification defines all states where the third digit ##x# is a number between 1 and 9 to be customer defined states. All state where the third digit is a letter a – z or A – Z, is defined as a vendor sub state. SEARAMS will automatically create the numbering for each state as defined by SEMI E58 and the user's choice of vendor or customer. The user is limited to 9 third level sub states defined as customer states since the third digit is limited to 1 to 9. The user selection of customer state type should be dimmed if there are no more sub states left for that category.
The "Manual Transitions" tab allows the users to enable some security and control features useful when manually changing the tool ARAMS states. The "User Access Level" defines the Group Access levels that will be allowed to manually transition FROM this state. The "Transition States" is the list of states not currently selected for an access group. Users may select an access group. The current transition states allowed for a group are listed below the group. The user may double click a state to move the state from the User Access selection list to the Valid Manual Transition States selection list and vise versa. A group must be selected at all times. The top group will be selected by default. Only groups defined with access for the specific tool will be displayed.

The state selection list is a hierarchical listing with specialized user operations. If the user clicks the plus sign, the sub states are listed under the current state. The plus will change to a minus. If the click the minus sign, the sub states will roll up and disappear. Any state that contains sub states will have a plus or minus sign next to it. States without sub states do not have an icon per example.
Additional group selection capabilities are provided to allow the users to quickly select many states. If the user clicks on a state, it is highlighted and all other states are not highlighted. If a user shift clicks a state, all states between the old highlighted state and the current state will highlight. Control click will select the current state without deselecting any existing highlighted states. The user may drag the list of highlighted states between the user access list and the state list.

Right click on a User group field will provide a pop up menu to allow the users to copy and paste the list of valid states between the user groups.

Copy States Selection
This function places a copy of the state list from the currently selected user group into the clip board. This selection is only available if a single user group is selected. When the user has multiple groups selected, this function is dimmed.

Paste States Selection
This function will overwrite the state list of the currently selected user group or groups with the contents of the state list clip board. If the user has not made a copy of the state list using "Copy States" the paste states function selection is dimmed.

Add New Access Level
Opens the access level editor: Access level editor is not defined in the scope of this specification.

The "Automatic Transitions" tab shown in figure 3.4.1.1b, allows the users to override the default automatic transitions based on the trigger/symptom. A symptom may be defined as an automatic trigger forcing SEARAMS to transition to a destination state. Each state may also override the action SEARAMS will take when a specific symptom occurs. The user may double click inside an over ride transition to open the state selection dialog 3.4.1.1d.

Additional group selection capabilities are provided in the symptom list to allow the users to quickly select many symptoms. If the user clicks on a symptom, it is highlighted and all other symptoms are not highlighted. If a user shift clicks a symptom, all symptoms between the old highlighted symptom and the current symptom will highlight. Control click will select the current symptom and all existing highlighted symptoms are still selected.

If the user right clicks on the "Over Ride Transition label at the top of the scroll list, they may chose the over ride action for all triggers at one time.

Right click on any highlighted Symptom will open a popup menu.
Enable PPID Class Responses and Enable Operator/Product Available options are mutually exclusive.

Enable PPID Class Responses:	Expands the trigger responses to include one additional destination state selection for each defined PPID Classification. Only valid when highlighting a trigger row. PPID Class rows do not have this menu item available.
Add External State Responses	Opens dialog 3.4.1.2e to include a combination of defined external states. The user may select this multiple times to add more conditional transitions. This item is only available on trigger rows. See section 3.4.1.2 for more details on External States.
Override Default Transition:	Opens the "Over Ride Transition" dialog, 3.4.1.1d, allowing the users to select a new destination state when this trigger occurs in the current ARAMS state.

Important – Enabling PPID Class Responses is Mutually Exclusive of Adding External State Responses. The user may set up one or the other or none, but not both.

Right click on an External State Response:

Modify External State Selection: Opens dialog 3.4.1.2e allowing the user to change list of external states for the line item.

Remove External State Response: Removes the Selected External State combination response. Does not update the State Model.

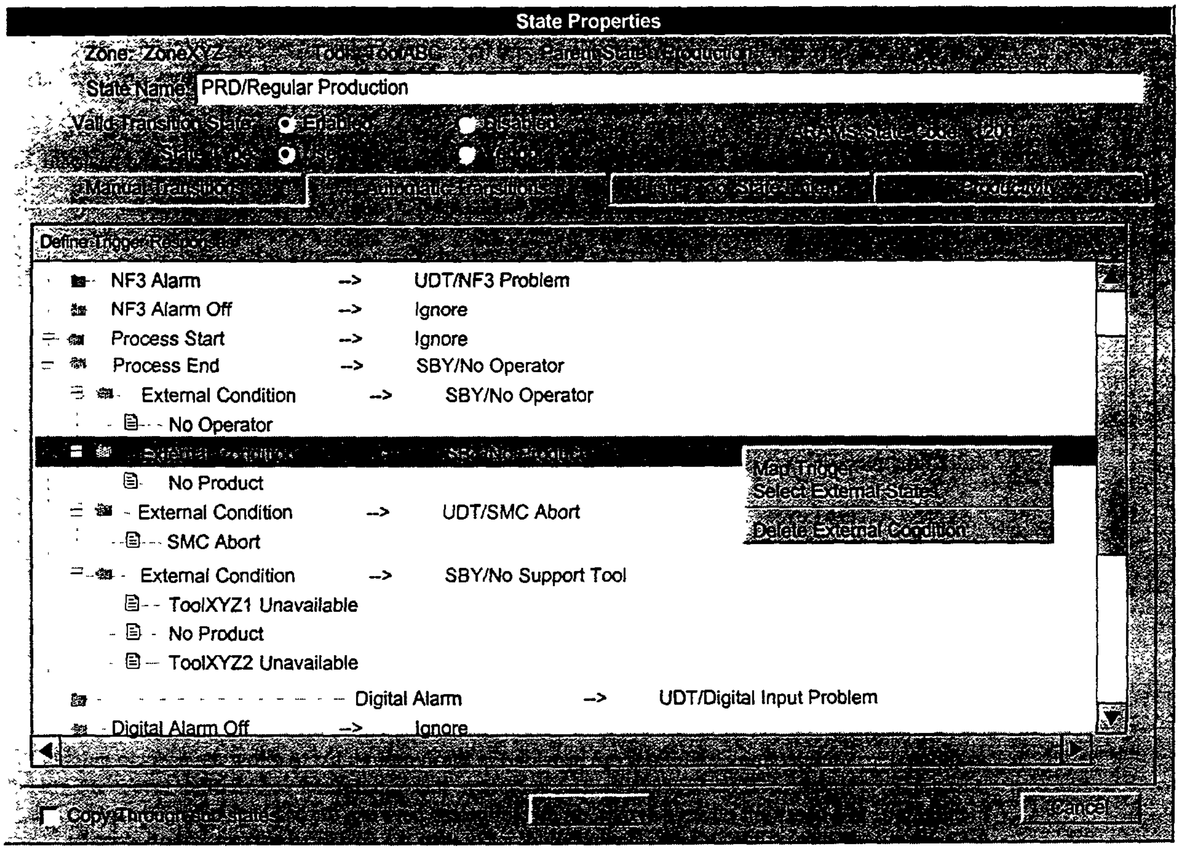
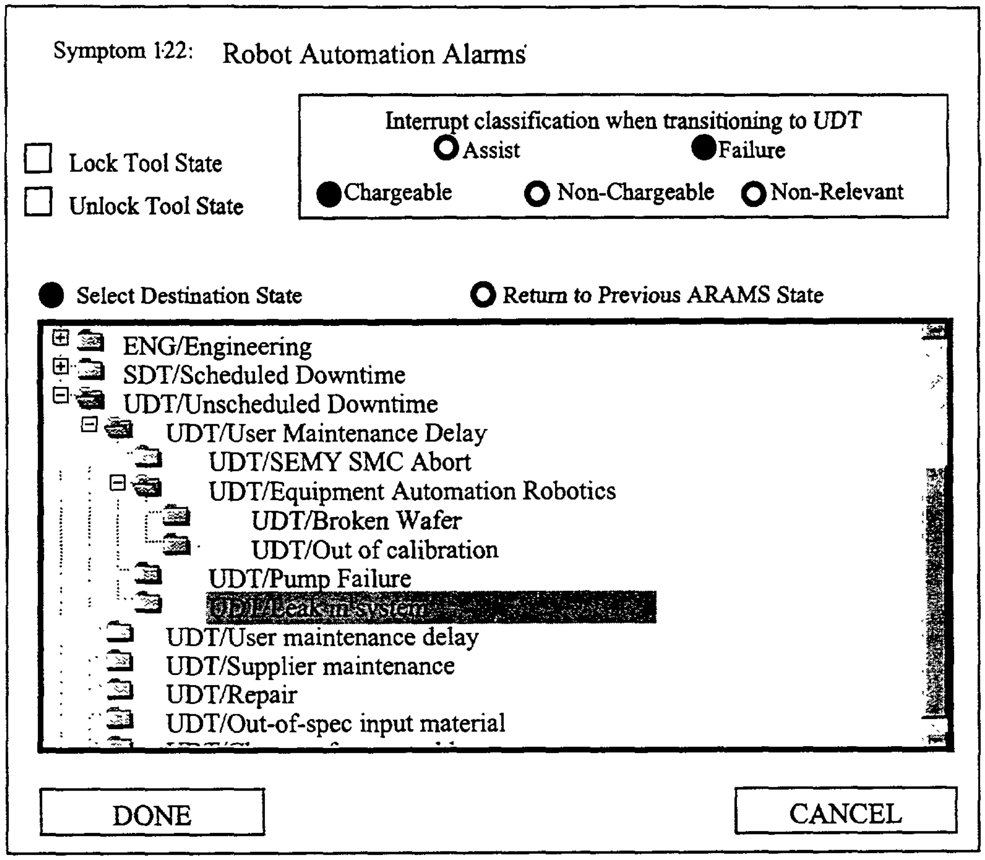


Figure 3.4.1.1b

Right click on a PPID Class will provide a popup menu:

PPID Class Transition Properties: Opens the "Over Ride Transition" dialog 3.4.11d.

The user may choose one destination state or "Return to Previous ARAMS State". "Return to previous state selection will cause SEARAMS to transition to the previous ARAMS state, standby, production or engineering, to meet the requirements of SEMI E58 transitions 6, 8 and 15. If they select "Return to Previous ARAMS State", the selection list of states will be dimmed. Shift click and control click have no meaning since 3.4.1.1d is a single selection list dialog. The first entry should be NONE so the user may disable specific symptoms.


Symptom 1·22: Robot Automation Alarms
Interrupt classification when transitioning to UDT
Assist
Failure
Lock Tool State
Unlock Tool State
Chargeable
Non-Chargeable
Non-Relevant
Select Destination State
Return to Previous ARAMS State
ENG/Engineering
SDT/Scheduled Downtime
UDT/Unscheduled Downtime
UDT/User Maintenance Delay
UDT/SEMY SMC Abort
UDT/Equipment Automation Robotics
UDT/Broken Wafer
UDT/Out of calibration
UDT/Pump Failure
UDT/Leak in system
UDT/User maintenance delay
UDT/Supplier maintenance
UDT/Repair
UDT/Out-of-spec input material
DONE
CANCEL

3.4.1.1d

Cluster Tool State Linkage Tab, figure 3.4.1.1e

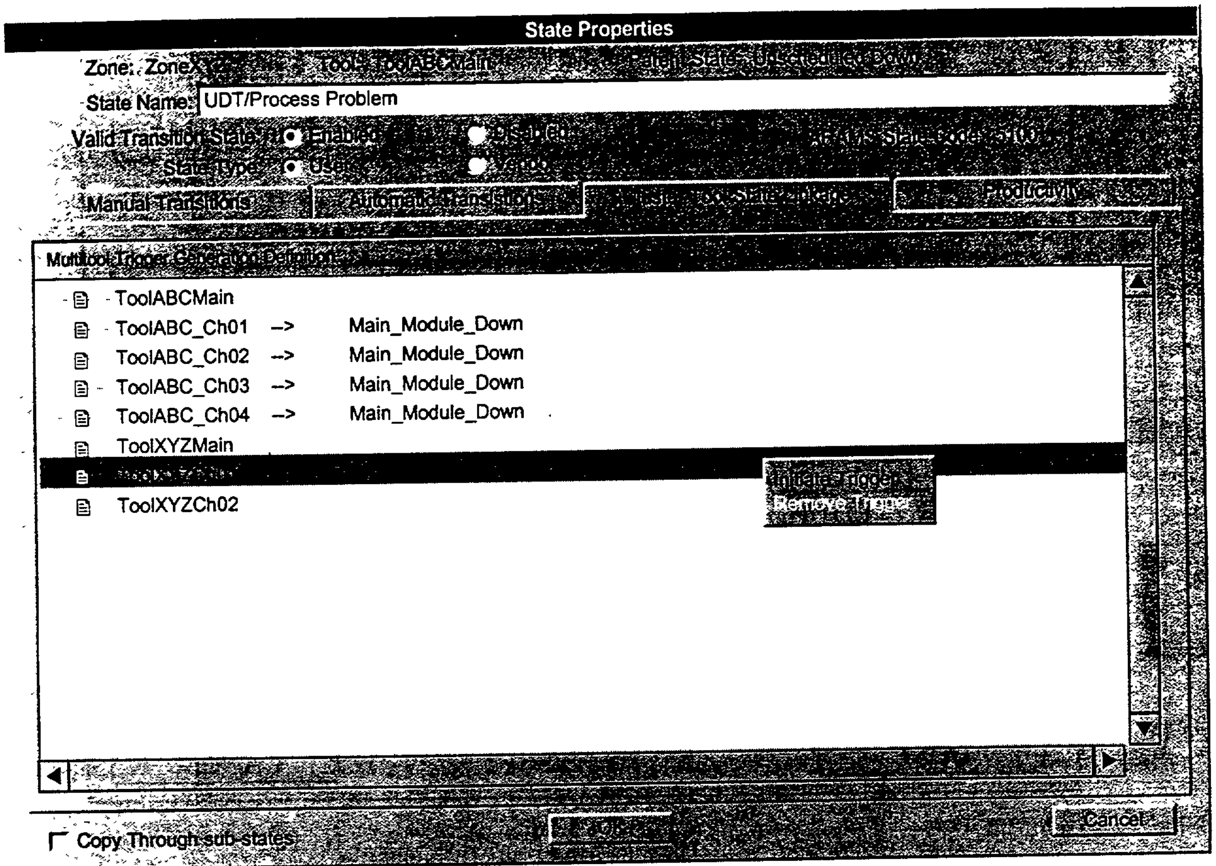


Figure 3.4.1.1e

This section of the state properties allows the change of a state for one tool to initiate a trigger for a different tool. The users will get a display of all tools. They can select the trigger that will be initiated for each tool. SEARAMS will automatically generate the selected trigger for each tool. Each tool's state model will control what transitions will occur, if any.

An example of the usage of this functionality would be if a main tool has an fault that causes process interruptions to the robotics module, the sub tools attached to the main tool should also transition to a fault state of some kind.

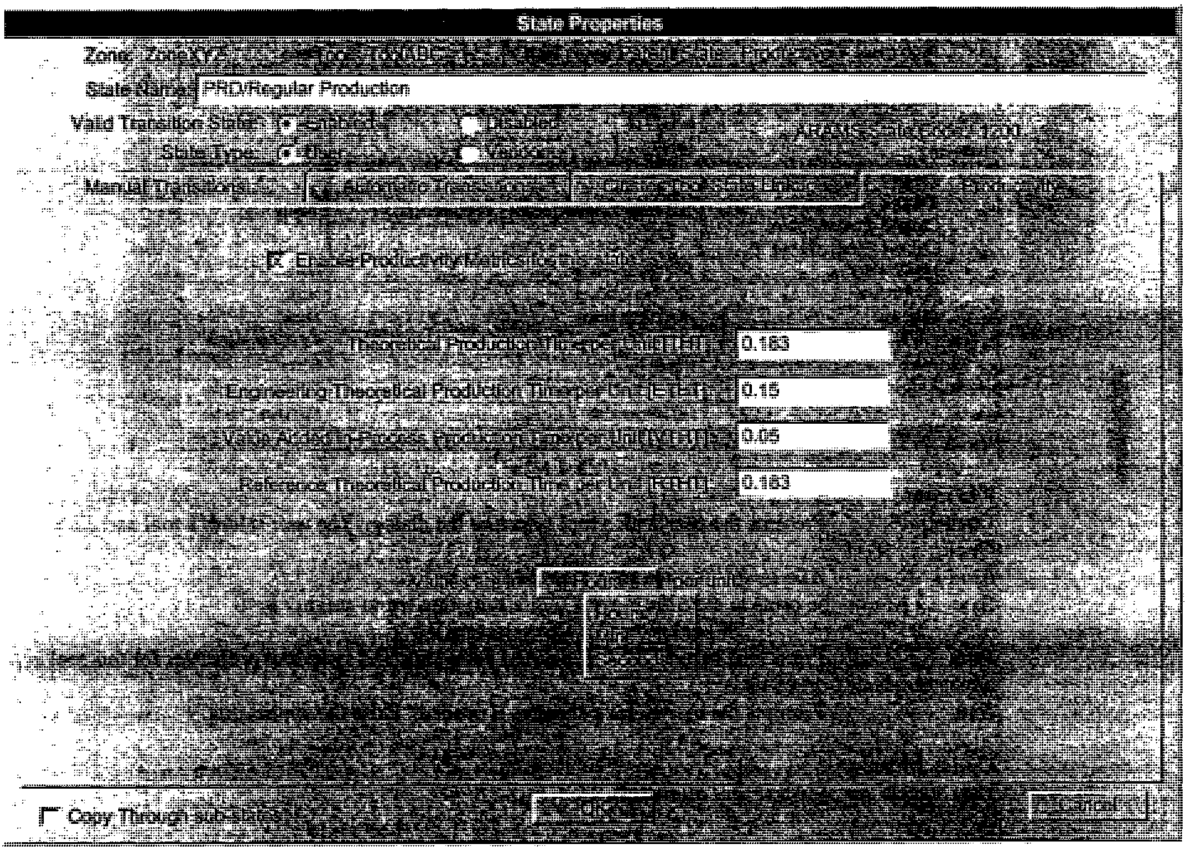
Figure 3.4.1.1e shows a prototype for the tool state linkage tab.
The users may double click in the Corresponding State Transition field to change the destination state for the tool of interest. The user is presented with figure 3.4.1.1d to select a single state.

The "Copy Through Sub States" option works for all properties except state name. When the option is enabled, any action the user takes will update the sub states belonging to the current state. The actual update of the sub states takes place in "real time". The user may turn on the option make a change or two and turn it off to complete additional changes to this state without effecting the sub states. This will be very useful when a new group (Palette) is added and the state models already exist. The user may add changes to all sub states of this state at one time for some properties but not others. This functionality must appear real time to allow this.

Clicking the "Cancel button will cancel all changes including any changes made to the sub states with the "Copy Through Sub States" functionality.

Productivity Settings Screen

All Productive states provide access to the productivity tab. The tab is dimmed or unavailable for any non-productive states. This is an optional screen for the users. All the data in this screen may be over written based on process specific data shown in section 3.4.1.7.



3.4.1.1f

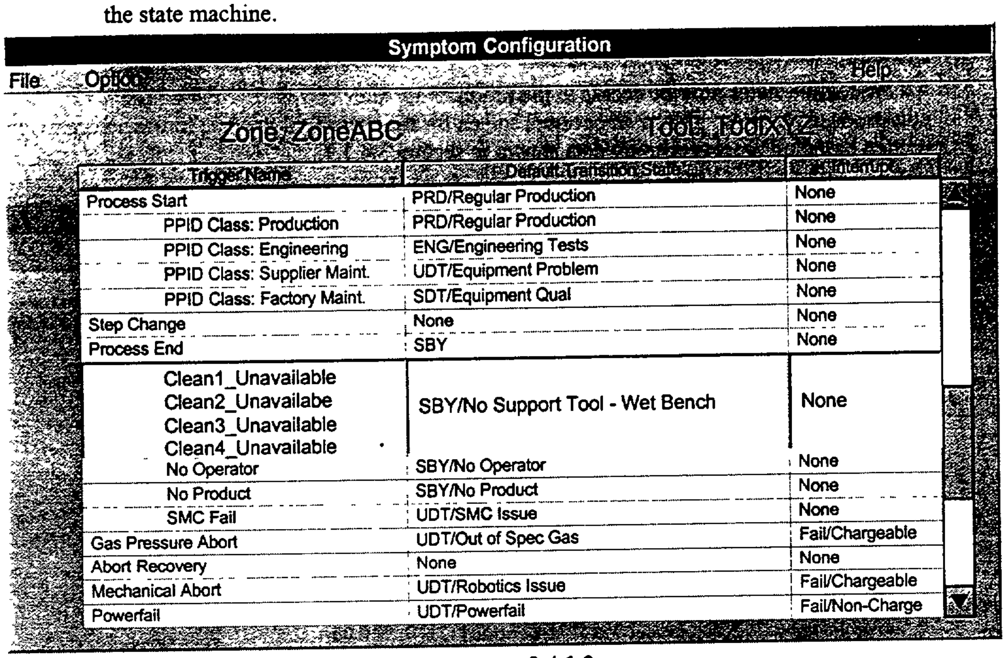
Optional Data
The user may enter the values for THT, ETHT, RTHT and VTHT as defined in SEMI E79. They may also select from a selection list a benchmark tool. These fields are active or inactive based on the state of the Enable check box.

A pop up menu will allow the users to input the productivity metrics in hours, minutes or seconds. Additional productivity fields may be defined in the future.

These fields are the default values for a specific process state. If the equipment process productivity is dependant on recipes, device ids, wafer order etc, these productivity metrics may be over-ridden by the definitions in section 3.4.1.3.

3.4.1.2 Symptom/Trigger Configuration.

This application allows the users to create the list of symptoms that will cause automatic transitions to the state machine.



Trigger Name	Default Transition State	Interrupt
Process Start	PRD/Regular Production	None
PPID Class: Production	PRD/Regular Production	None
PPID Class: Engineering	ENG/Engineering Tests	None
PPID Class: Supplier Maint.	UDT/Equipment Problem	None
PPID Class: Factory Maint.	SDT/Equipment Qual	None
Step Change	None	None
Process End	SBY	None
Clean1_Unavailable Clean2_Unavailabe Clean3_Unavailable Clean4_Unavailable	SBY/No Support Tool - Wet Bench	None
No Operator	SBY/No Operator	None
No Product	SBY/No Product	None
SMC Fail	UDT/SMC Issue	None
Gas Pressure Abort	UDT/Out of Spec Gas	Fail/Chargeable
Abort Recovery	None	None
Mechanical Abort	UDT/Robotics Issue	Fail/Chargeable
Powerfail	UDT/Powerfail	Fail/Non-Charge

3.4.1.2a

File menu:

Open Presents the user with a tool selection list dialog. The user selects a tool and clicks Open.

Save Allows the users to save their changes so far.

Save As Allows the users to save the current tool's symptom list to another tool. Should open to a tool selection list

Print Prints text based list of all defined symptoms and symptom properties for this tool or any user selected set of tools.

Exit Prompts the user to save changes if needed. Exits the application.

Option Menu:
User selects the zone and tool of interest.

Right click on a Symptom will provide a popup menu:

New Symptom: Creates a new symptom and opens the symptom properties dialog.

Symptom Properties: Opens the symptom properties dialog 3.4.1.2b, c, d, e.

Enable PPID Class Responses: Expands the trigger responses to include one additional destination state selection for each defined PPID Classification. This item is only valid when highlighting a trigger row. PPID Class rows and External State Rows do not have this menu item available.

Add External State Responses Opens dialog 3.4.1.2e to include a combination of defined external states. The user may select this multiple times to add more conditional transitions. This item is only available on trigger rows.

Delete Symptom – Removes the current symptom.

Important – Enabling PPID Class Responses is Mutually Exclusive of Adding External State Responses. The user may set up one or the other or none, but not both.

Right click on a PPID Class will provide a popup menu:

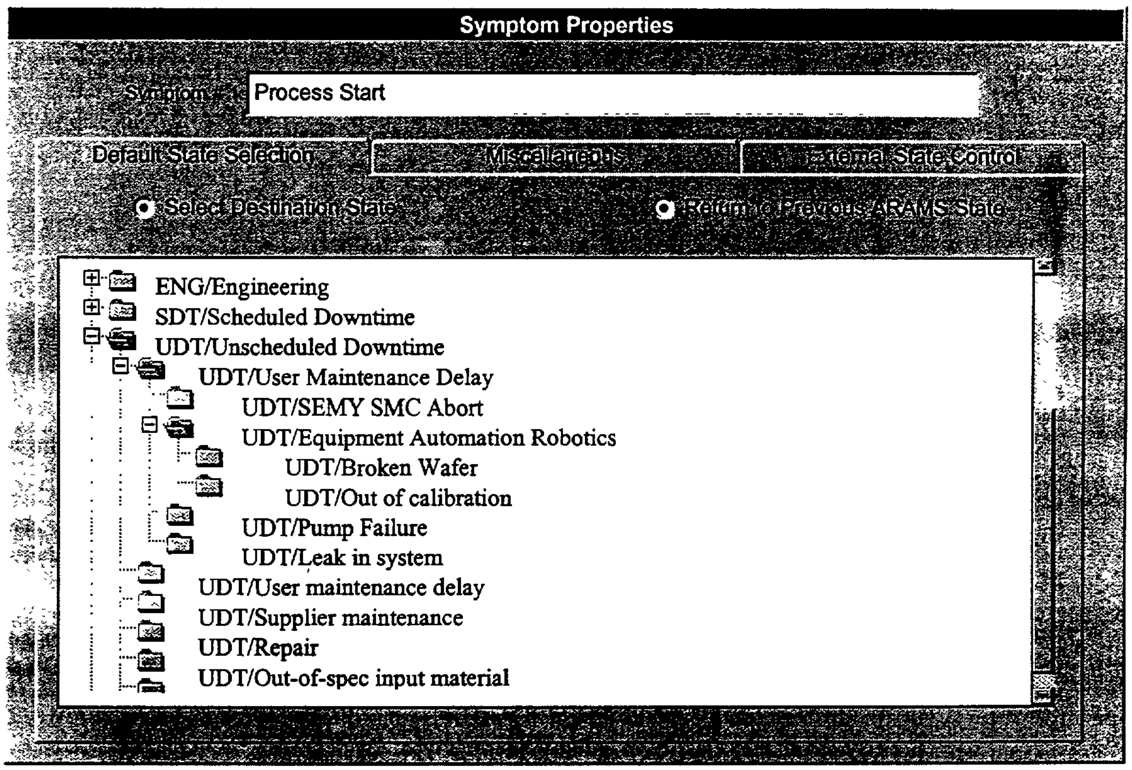
PPID Class Transition Properties: Opens the symptom properties dialog 3.4.1.2b.

Right click on an External State Response:

Modify External State Selection:	Opens dialog 3.4.1.2e allowing the user to change list of external states for the line item.
Remove External State Response:	Removes the Selected External State combination response. Does not update the State Model.

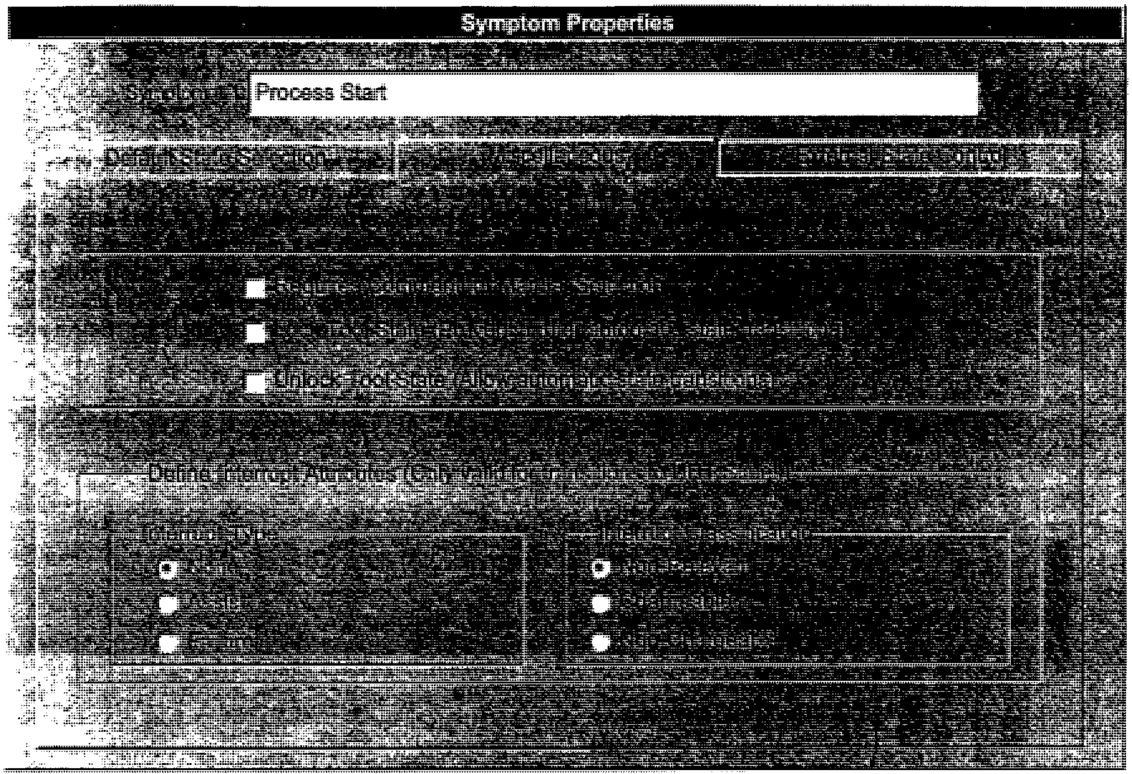
The symptom properties may be overridden in the state model on a state by state basis.

The first tab, shown in 3.4.1.2b, defines the transition action to occur when the trigger is received at runtime. The user may choose one destination state or "Return to Previous ARAMS State". "Return to previous state selection will cause SEARAMS to transition to the previous ARAMS state, standby, production or engineering, to meet the requirements of SEMI E58 transitions 6, 8 and 15. If they select "Return to Previous ARAMS State", the selection list of states will be dimmed. Shift click and control click have no meaning since this is a single selection list dialog. The user can select the currently highlighted selection. This would deselect the row and is analogous to select none. Select none is allowed.



3.4.1.2b

The second tab, shown in 3.4.1.2c, defines some miscellaneous properties associated with the symptom or transition.



3.4.1.2c

"Requires Comment" option forces the user to input a comment when manually selecting this trigger. This is used in the User Transition GUI in section 3.4.1.5.

"Lock Tool State" option transitions to the selected state and disables automatic transitions. This will be useful when the HOST or tool sends a trigger that is known to force some maintenance activity that will generate false triggers.

"Unlock Tool State" option will over ride the user lock on a state. This will be useful when the HOST or Tool sends a trigger to begin automatic state transitions after some maintenance activity. The state will unlock and the trigger transition will occur.

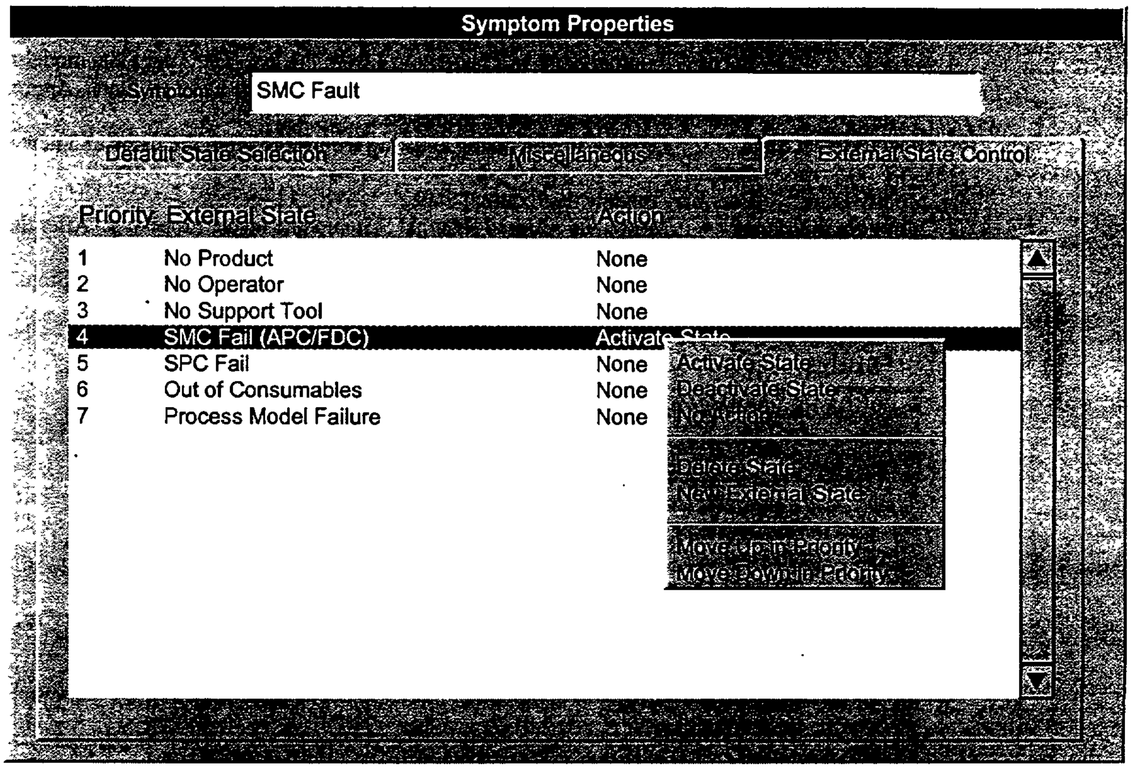
Each Symptom may classify an optional interrupt type. By definition, when the tool state transitions to any UDT state from ENG, PRD or SBY, the equipment has failed. A specific symptom or trigger causing the transition to the UDT state defines the interrupt type and classification. The user chooses between Assist and Failure for the type of interrupt. They choose between Chargeable, Non-chargeable and Non-relevant as the classification.

This section defines the External States. External states are events generated external to the process equipment that have an effect on the tool state model. The states must be defined for each tool or chamber independently

External States are used to conditionally transition the tool state model from one state to another. Example: If the tool is processing wafers and SEARAMS receives a trigger than No Operator is available, it will not have an effect on the tool state until it completes processing. Once the process is complete, the End Event trigger can transition to SBY or SBY No Operator conditionally depending on the external state of "No Operator". This provides a mechanism to accurately track external impacts on tool performance.

Examples of external states defined in the E58 Standard are No Operator, No Product and No Support tool. Each of these external states can have a negative impact on tool performance by stopping the flow of product to the tool thus increasing the tool standby time.

The external state control tab allows the user to define an additional action for SEARAMS to take when the trigger is received. Normally the trigger may cause a state change on the tool, however, the trigger may set an external state such as No Operator or No Product without causing a state transition.
External State Control Tab:



3.4.1.2d

The External State Control Tab is used for two purposes. The first functionality allows the users to define up to 20 External States for each tool. The second functionality allows a trigger or symptom to set an external state to active or de-active. The Tool State Model can examine the state of each External State and conditionally transition to new tool states based on the External States.

External states must be defined in a priority structure. If multiple External States can cause the State Model to transition to different states, the highest priority External State that is active will be the one used at runtime for the transition.

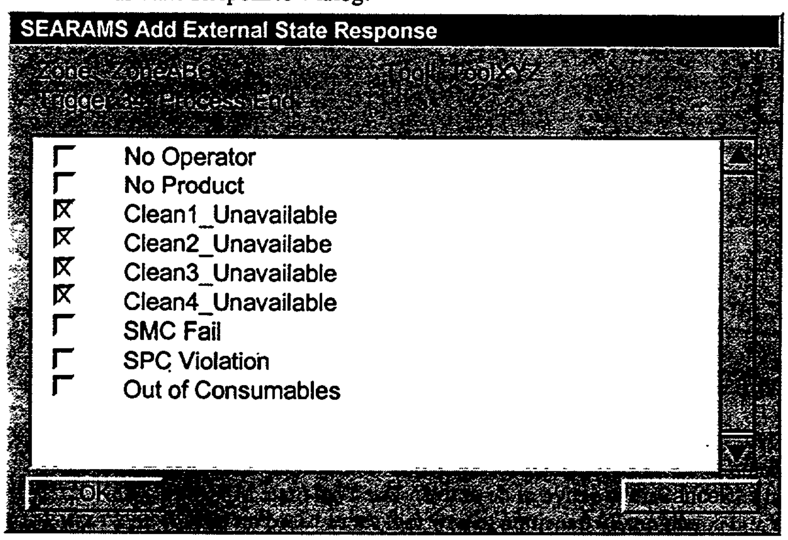
Design Consideration: Keep a fixed list of 20 External State records per tool. Allow the user to set the priority and name. Once an External State has been defined, do not change it's place in the fixed list no matter what priority gets assigned or how many other External States get defined, changed or deleted. Store the state, (0 or 1) of each of the 20 External States by index number, not priority number. This will keep the data consistent over time when the users modify the External States.

It is possible that a Trigger will set the values of one or more External States and also cause tool state transitions. If the user defines both actions, SEARAMS will set the External States appropriately, then perform the tool state change logic.

Right Click Popup menu items:
Right click anywhere within the text field will open a popup menu.
New External State   Opens a simple dialog allowing the user to input the name of a new external state.

Right Click on a defined External State:
Activate State   This trigger will set the selected External State to active.
De-active State   This trigger will set the selected External State to inactive.
No Action   This trigger will not impact the settings of the selected External State.
Delete External State   If an External State is selected, this menu item is available. When chosen the selected External State will be removed from the list. The Tool State model will be modified by SEARAMS to remove all instances of the External State. Appropriate warning messages should be displayed.
New External State   Opens a simple dialog allowing the user to input the name of a new external state.
Modify State   User may rename the External State.
Move Up in Priority   Moves the selected External State up one level. Stops at 1. After the move, the selected External State is still selected.
Move Down in Priority   Moves the selected External State down one level in priority. Stops at bottom of list. After the move, the selected External State is still selected.

Add External State Responses Dialog:



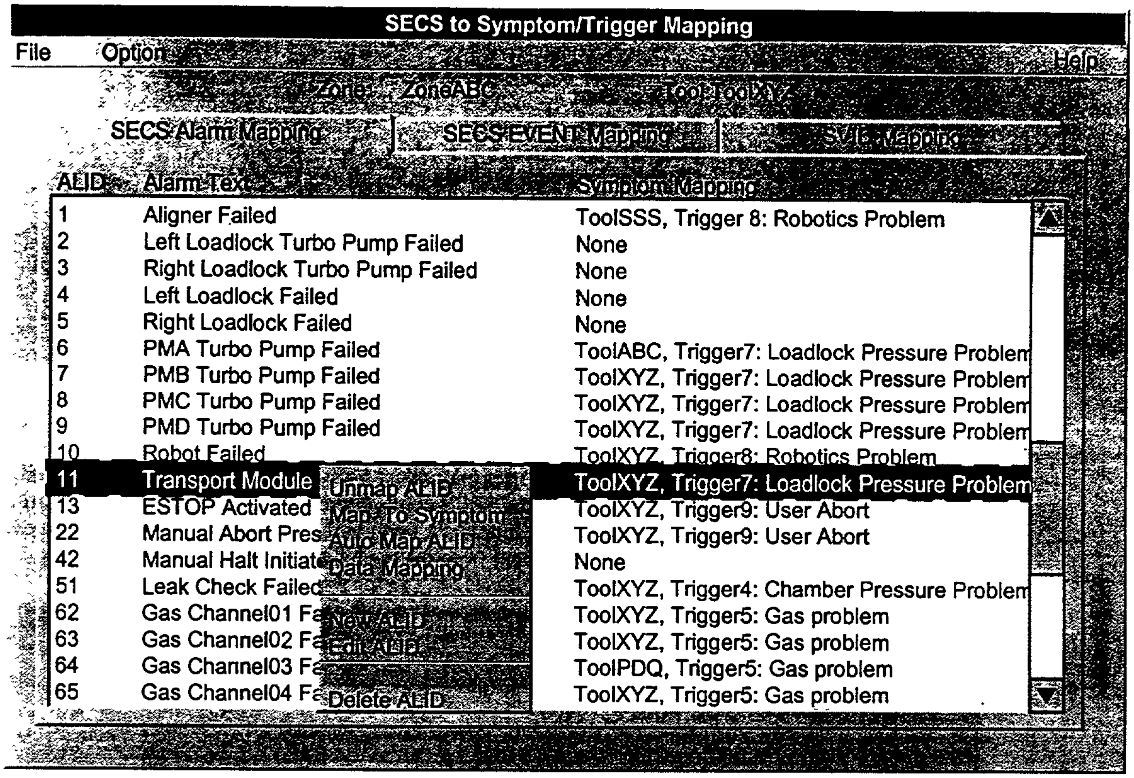
3.4.1.2e

The user may select any number of External State Responses in this dialog, supporting virtual and statements. When the user selects more than one External State Response, the condition is that all selected states must be true to cause this transition to occur.

3.4.1.2.1 SECS message mapping support

This section defines a standalone application to define SECS SVID, alarm (ALID) and event (CEID) mapping to a SEARAMS symptoms. When a SECS message is received by SEARAMS, the trigger mapping can be defined in this application. This functionality reduces the integration costs for the factory. SECS message mapping to trigger a state change on the same tool or another tool is supported.

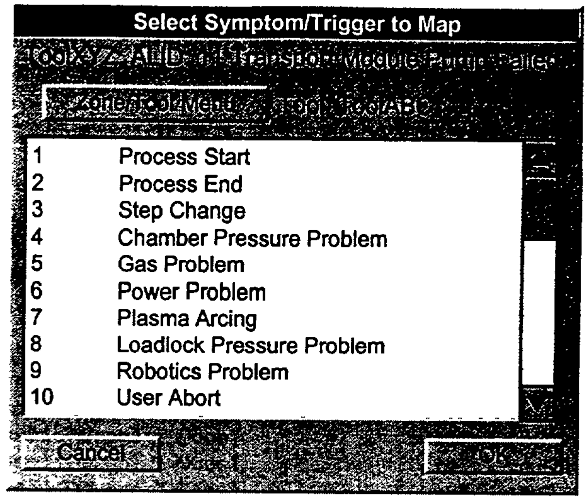
The Alarm properties are shown in 3.4.1.2.1a, b and c. The Event mapping functionality is identical. The SVID properties are shown in 3.4.1.2.1d, e and f.



3.4.1.2.1a

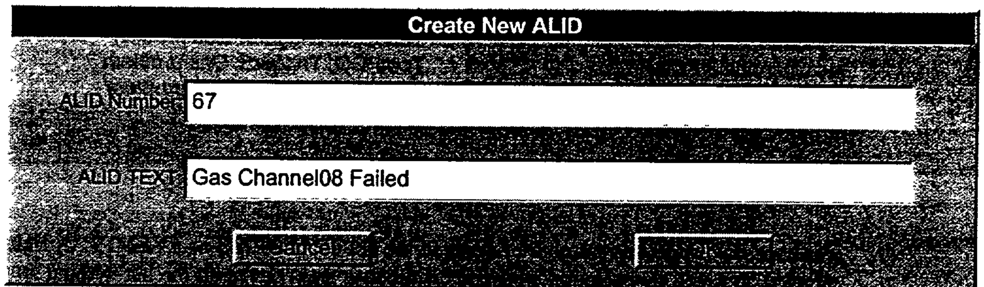
The user may select any number of items in the list of ALARMS or EVENTS. A right click on any selected item will reveal a pop up menu. If the user right clicks on the list without any previously selected items, the item closest to the pointer will be selected prior to opening the pop up menu.

Pop up menu items	
Un-map ALID	Changes the selected items mapped symptom to "None"
Map To Symptom	Opens the symptom selection dialog shown in 3.4.1.2.1b.
Auto Map ALID	Maps the ALID or CEID to a symptom with identical text. If a symptom with identical text does not exist, auto generate a new symptom. This feature is useful to auto generate multiple symptoms based on a selected list of ALIDs or CEIDs.
Data Mapping	Data mapping is only available if an ALID is mapped to a trigger. Selecting the data mapping option opens dialog 3.4.1.2.1g.
Edit ALID	Opens the ALID or CEID dialog shown in 3.4.1.2.1c.
New ALID	Opens the ALID or CEID creation dialog shown in 3.4.1.2.1c.
Delete ALID	Delete the selected ALIDs or CEIDs from the tool specific list.



3.4.1.2.1b

In the select Symptom/Trigger dialog box, the user may select a tool and a single trigger only. The default is the current tool being configured in the SECS configuration editor. A SECS message from one tool may generate a trigger on another tool. Example: A main tool may generate a different start event for each chamber. SEARAMS will may the event from the main tool to a trigger on a chamber.

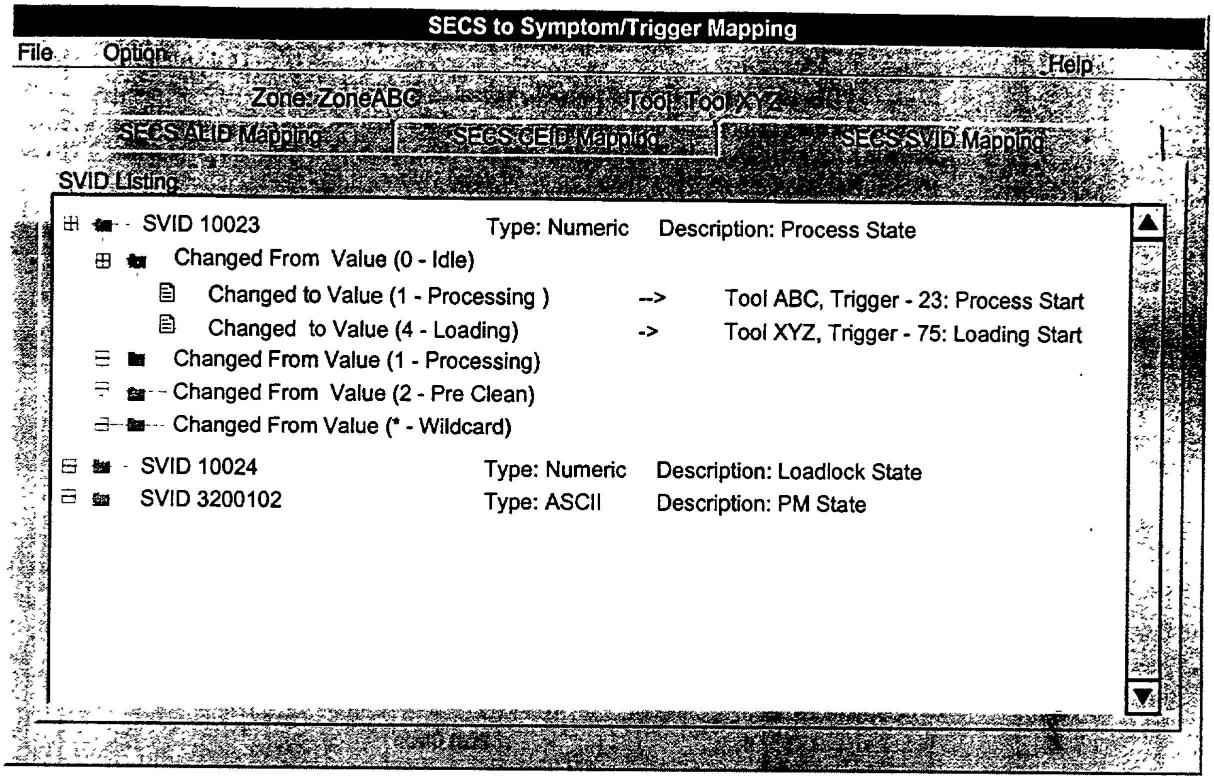


3.4.1.2.1c

The create new ALID dialog is identical to the create new CEID dialog. The user may define an ALID and alarm text. Both ,must be defined before the user may select the OK button. If the user has input a number that already exists, prompt them to confirm if they wish to overwrite the existing ALID text for that number.

Figure 3.4.1.2.1d shows the SVID to Trigger mapping tab.

The SVID support is slightly different than the ALID and CEID support. SEARAMS can be configured to generate a trigger when an SVID changes from one value to another. This is particularly useful when an SVID is used to monitor and equipment process state. For example, there may be a process state SVID that is used to denote when the equipment is processing, idle, cleaning, loading etc.



3.4.1.2.1d

The user may select any number of items in the list of SVIDs. A right click on any selected item will reveal a pop up menu. If the user right clicks on the list without any previously selected items, the item closest to the pointer will be selected prior to opening the pop up menu.

Pop up menus.
Right Click on an SVID item:

Add Changed From Value	Opens a selection list 3.4.1.2.1f of all remaining defined VID values that are not already listed under the currently selected SVID as Changed From values.
Un-map SVID	Changes all the SVID's transitions mapped symptom to "None"
Edit SVID	Opens the SVID Editor dialog shown in 3.4.1.2.1e.
New SVID	Opens the SVID Editor dialog shown in 3.4.1.2.1e.
Delete SVID	Delete the selected SVID and all it's transitions from the list.

Right Click on a SVID "Changed From Value" item:

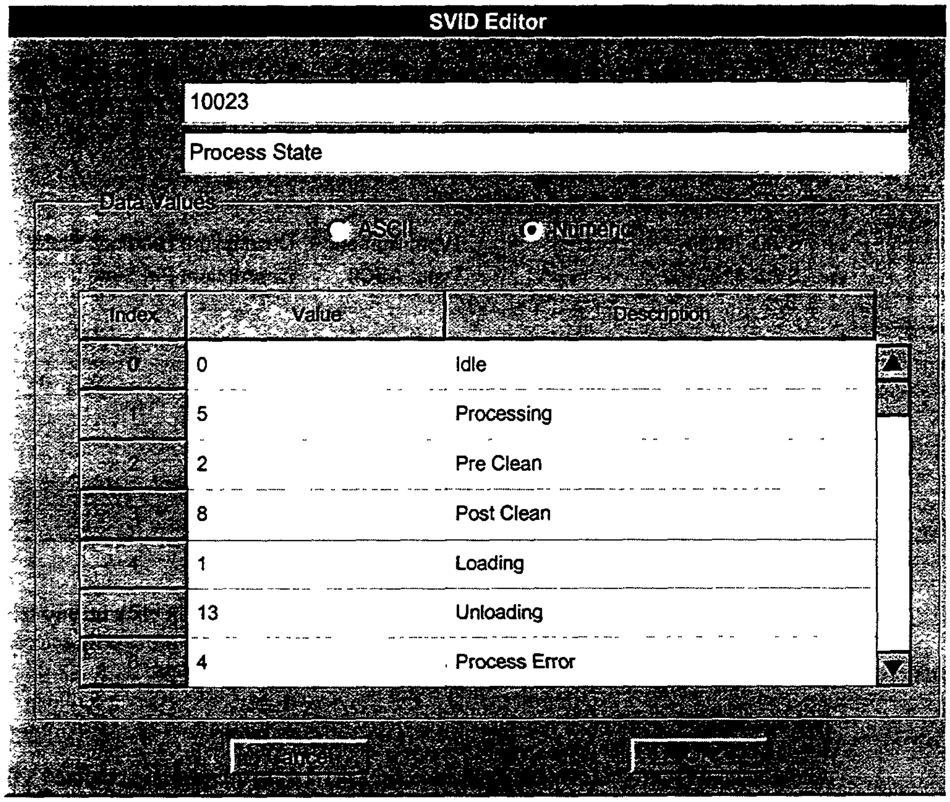
Add Changed To Value	Opens a selection list 3.4.1.2.1f of all remaining defined VID values that are not already listed under the currently selected "Changed From Value".
Remove all Changed To Values	Removes all "Changed To" items from the selected "Changed From Value".
Un map all Changed To Values	Un maps all "Changed To" triggers for the currently selected Changed From value.

Right Click on a SVID "Changed To Value" item:

Map To Symptom	Opens the symptom selection dialog shown in 3.4.1.2.1b. Maps item to the selected Symptom.
Data Mapping	Data mapping is only available if the SVID "Changed To Value" is mapped to a trigger. Selecting the data mapping option opens dialog 3.4.1.2.1g.
Remove "Changed To Value"	Removes the line from the list.

Un map Symptom — If the currently selected "Changed To Value" item is mapped, this option is available and will un map the item when selected.

The user must define the possible values of the SVID to use the SVID transition editor. SVID transitions may be mapped to a symptom, the user must list all the valid SVID values that may be used to initiate a trigger. This editor allows the user to define the SVID number, SVID name, SVID type (only ASCII and Float are supported) and up to 50 valid values.



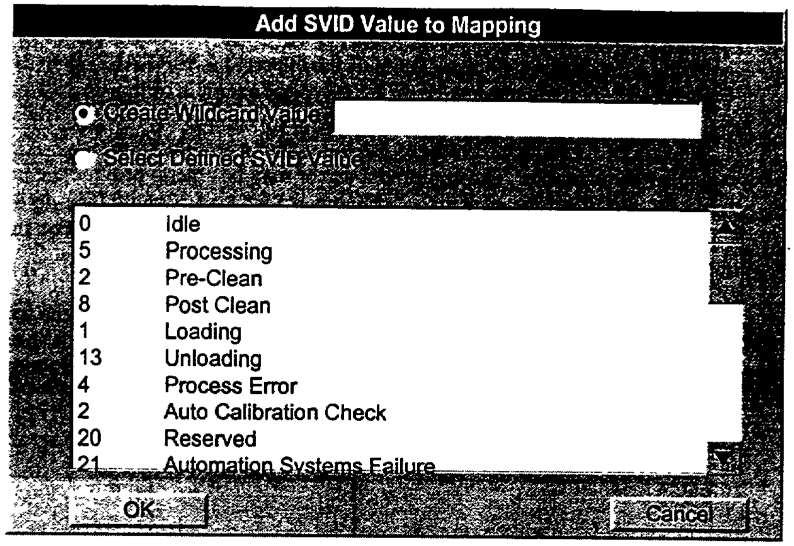
3.4.1.2.1e

The user is present with a scroll list of 50 lines. They may input or overwrite a value and a description in any of the 50 slots. The Description field is optional.

The new and old values are lists of the data values defined in 3.1.4.2.1e. The user may also select a wildcard "*" for either New Value or Old Value. The wild card will be interpreted as any value. This is useful if the only want to know if the VID changed from any value to the new value. For example, if the SVID changes to a "0" they know the tool just went to idle and don't care what the previous value of the SVID was. Wildcards are used only in the event that the SVID actually changed.

Wildcards are also useful if the SVID is continuous data instead of discrete values. The user may want to generate a trigger when the SVID value is "603.23". They could use the wildcard in the old value field and 603.23 in the new value field.

The user may select the set up the same VID value for both the Changed From and Changed To fields if they want. It is probably not too interesting but they may have some custom equipment software that sends the same value periodically when something occurs. They should use the CEID for that case but there are a lot of different SECS implementations in the factories.



3.4.1.2.1f

If the user selects wildcard for both the new and the old values, this is valid and could be mapped to a trigger. It would then initiate the trigger anytime the SVID changed.

Finally, if the user sets up a wildcard it can conflict with other SVID transitions. Any fixed SVID transition will override the wild card transition. For example, if the customer has set up two triggers as shown below, and the SVID changed from 3 to 4, trigger 76 will be generated, not trigger 102. The most concise description will initiate the trigger.

SVID	Old Value	New Value	Trigger mapping
100	*	4	102
100	3	4	76

Trigger Data Mapping Dialog

When a message is received, some of the interesting SEARAMS data variables may not be available in the object. The trigger data could be A typical example of this case is for multi chamber tools. The object received from an equipment driver may contain the recipe ID, device id and layer when the lot is placed. In subsequent messages for wafer start event on multiple chambers, the lot information may no longer be available. The equipment driver may be able to provide the port used for the lot within each wafer start event for each process chamber. SEARAMS could look up the lot information from within the SEARAMS database to set the lot id, device id and layer based on the information that was received when the lot was placed on a specific port.

Trigger Data Mapping allows the users to specify certain fields in the trigger to be set at runtime based on existing SEARAMS database fields from any tool. The dialog is shown in figure 3.4.1.2.1g.

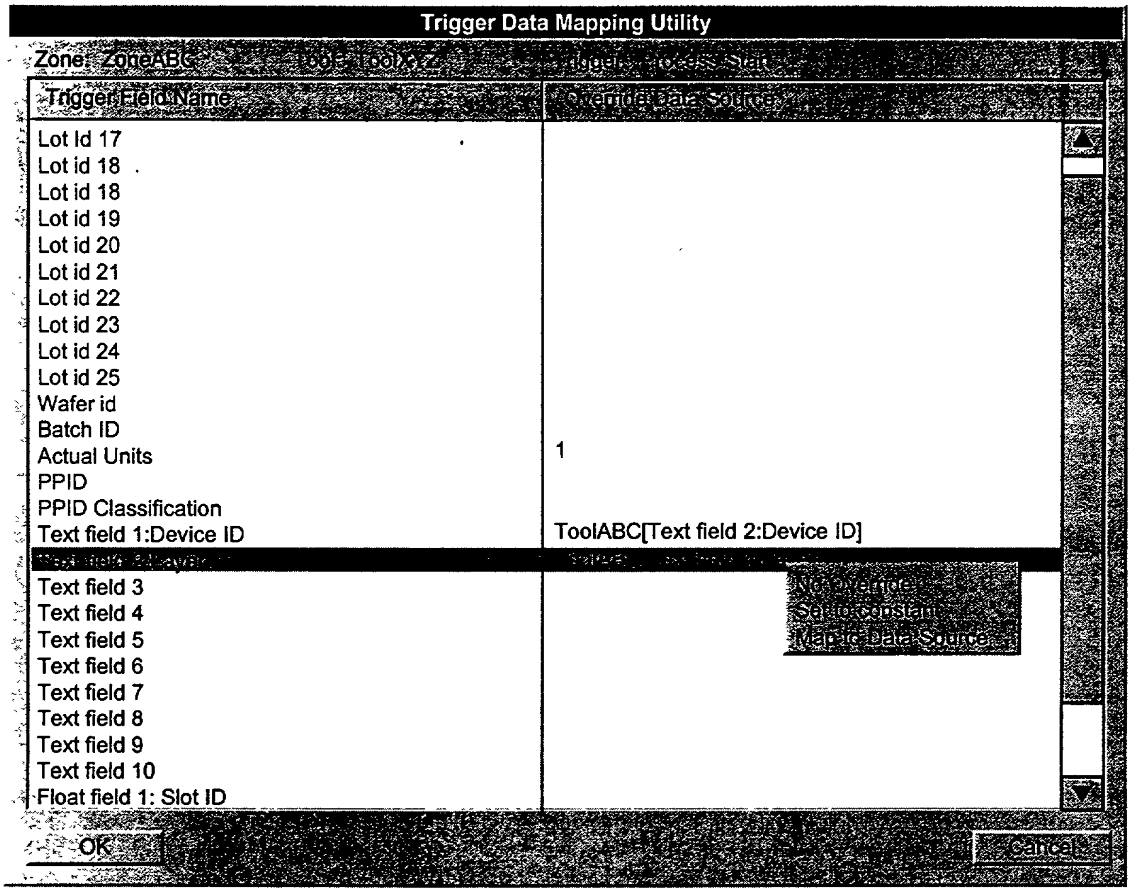


Figure 3.4.1.2.1g

If the Override Data Source is blank, SEARAMS will use the data contained in the incoming object, otherwise, SEARAMS will over write the field with the mapped data.

Each field may be overwritten with a constant or any field from the database from any tool.
Right click on a field will open a pop up menu:

No Override	Removes any override criteria
Set to constant	Opens a dialog allowing the user to input a constant. Data type is based on the field data type.
Map to Data Source	Opens a dialog allowing the user to select any SEARAMS defined tool and a database field of the same type of the object field.

3.4.1.3 ARAMS Tool Setup Options

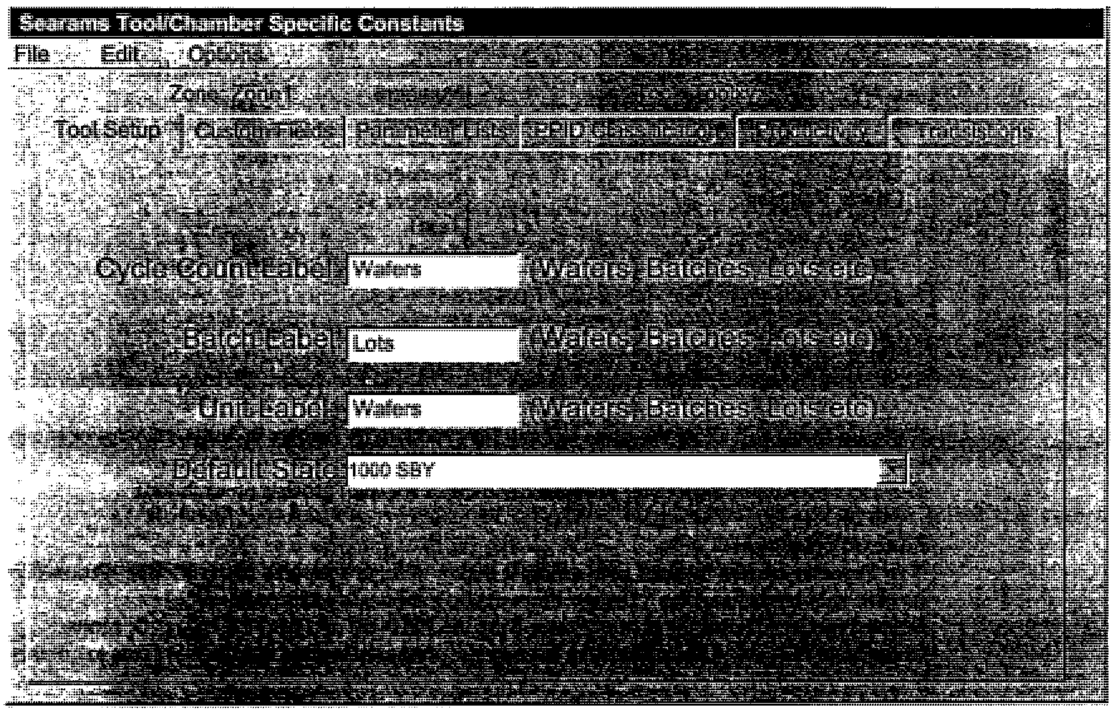
This application provides access to the tool specific options for automatic transitions, recipe name definition (PPID) and recipe name classification.

File menu:

Open	Presents the user with a tool selection list dialog. The user selects a tool and clicks Open.
Save	Allows the users to save their changes so far.
Save As	Allows the users to save the current tool's symptom list to another tool. Should open to a tool selection list
Print	Prints text based list of ARAMs options for all tools.
Exit	Prompts the user to save changes if needed. Exits the application.

3.4.1.3.1 Tool Setup Tab

This application is used to set up the tool specific options and constants.

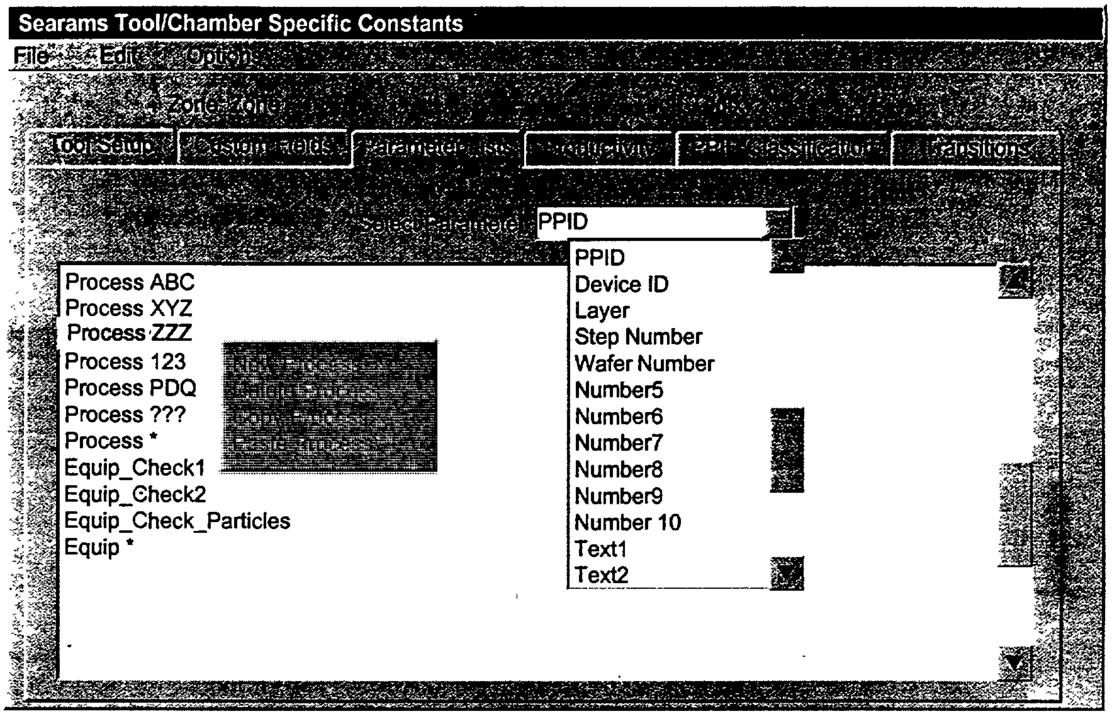


3.4.1.3.1a

The option of cycle counter enables the storage and status display of the number of cycles the tool has processed since installation and also enables the text field so the users may add the units. Single wafer tools will probably use wafers as the unit where furnaces may use batches. The units field is limited to 12 characters.

3.4.1.3.2 Process Specific Productivity Parameter Set Up

Users may set up list if recipe names to apply recipe specific productivity data. Each production tool state may have it's own default productivity data as defined in figure 3.4.1.1f. If a PPID is passed with the trigger, any defined productivity data will over ride the state default productivity data.



3.4.1.3.2a

A pop up menu will allow the users to input the productivity metrics in hours, minutes or seconds.

The users may input theoretical productivity metrics for each process on each tool.

Process Popup Menu:
New Process: Prompt the user with a simple dialog to input a process name (PPID). Process names may contain wild card characters. Do not allow explicit duplicate recipe names.
Delete Process: Deletes the process name from the PPID list and the PPID Classifications
Copy/Paste Process: Allows the users to copy the productivity data from one process to another.

Wild Card Characters:
"*" May contain no characters or any number of characters.
"?" Must contain one character, may be any single character.

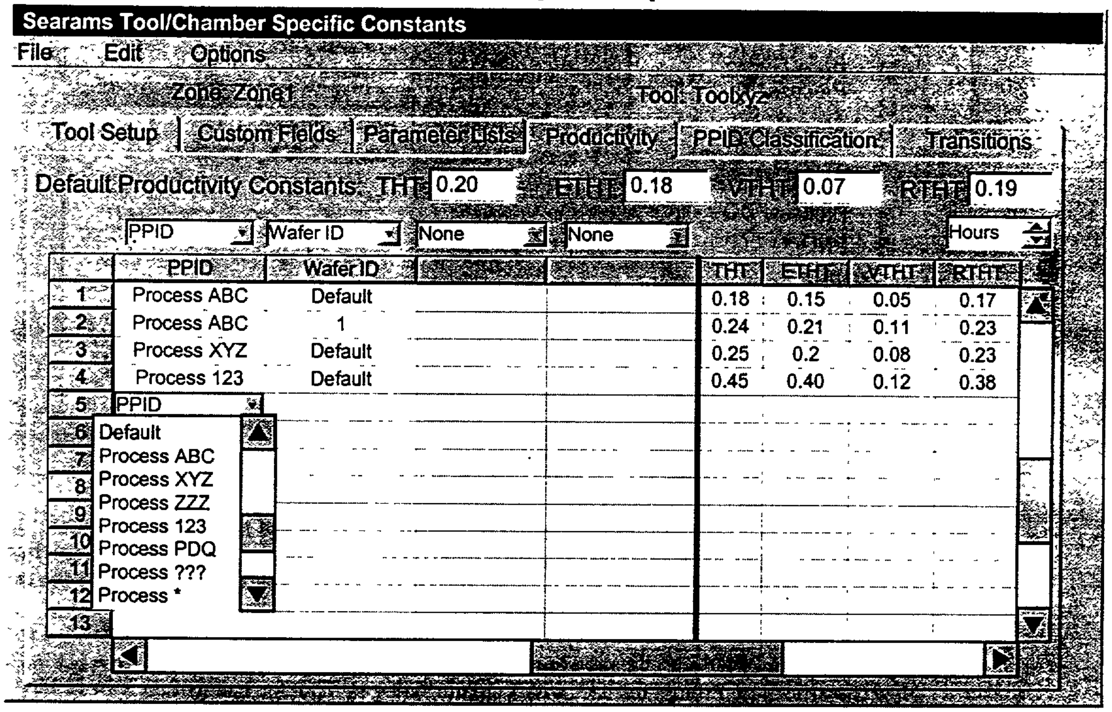
An example process name of "?roc?ss*" would match processABC, PROCESSXYZ and PrOcEsS. It would not match PPROCESS since there are two characters before the "roc" text. A match for PPROCESS could be defined as "??rocess" or "*rocess" or "?*rocess" etc.

3.4.1.3.3 Productivity Set Up

Equipment productivity may be affected by many factors. For example, each recipe may require a different amount of time to process. Also, a specific device type may take longer than another device type in a lithography or CMP operation using the same recipe.

The following editor shown in 3.4.1.3.3a, provides the user with a method to generate the theoretical production time per wafer based on the desired combination of inputs such as device id, wafer id, PPID and layer.

· The productivity constants, THT, ETHT, VTHT and RTHT as defined in SEMI E79. The productivity constants are handled as a hierarchical set of defaults. In general, each tool or chamber has one set of constants. The user may configure constants for a state that would over ride the tool default constants using the State Model Editor. If a specific recipe or device requires a different set of constants, they would override the state specific constants. The Productivity set up tab allows the user to configure the productivity constants for the tool and at parameter specific levels.



3.4.1..3.3a

The user may input the tool/chamber default productivity constants and select Hours, Seconds or Minutes as the time scale. They may also input parameter specific productivity constants in the tab's spreadsheet.

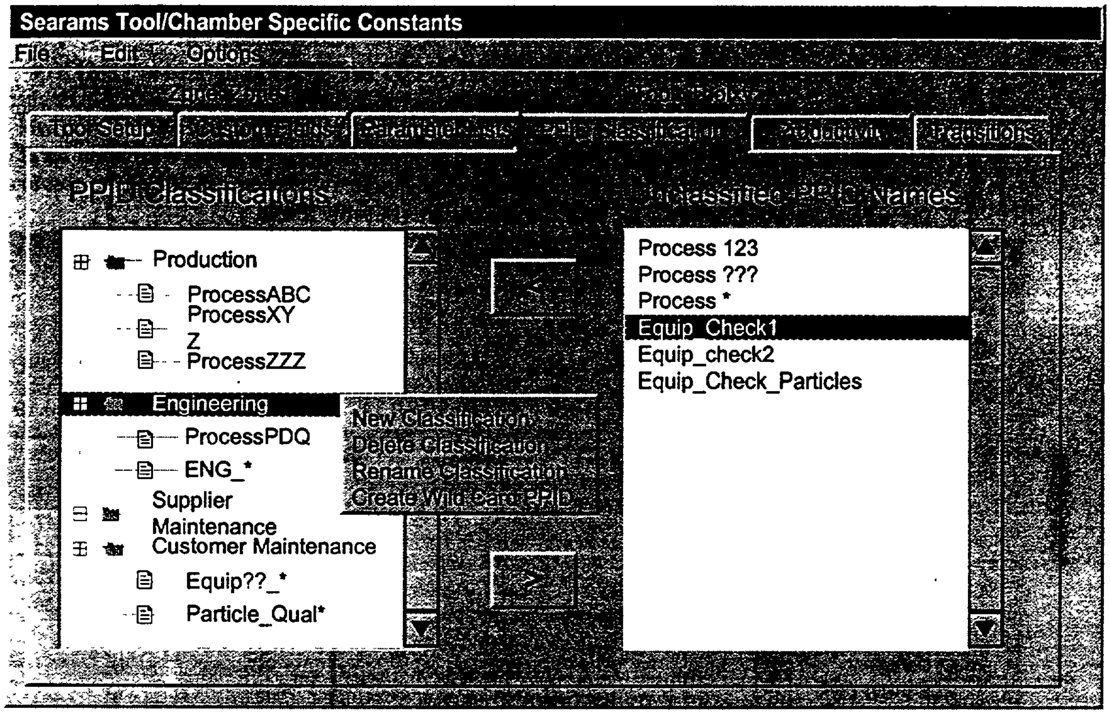
The user may select up to four of the 21 independent parameters from (PPID, 10 user defined numbers and 10 user defined labels). The four combo boxes will display the names of the parameters as set up in the Custom Fields tab.

Once the column name has been chosen, each cell in the column becomes a selection of names as defined in the Parameter Lists tab. The columns are resizable. Each cell will allow only one entry from the selection list. The selection choice termed "default" is used if the value for that field is not to be used in the run time selection of the productivity constants. In figure 3.4.1.3.3, anytime Process XYZ is run, the productivity constants will be (.25,.2,.08 and .23) independent of the wafer id. Process ABC, on the other hand, does require different productivity constants for wafer 1 than the rest of the wafers.

Each column supports sorting. Use user simply clicks the column label and the spreadsheet will sort on that column. A second click will cause the spreadsheet to sort in reverse order.

3.4.1.3.4 PPID Classification Set Up

Some recipes are designed for non productive runs. These recipes may be used for Engineering tests, maintenance activity, equipment qualifications etc. This editor allows the users to classify recipes into categories. When a recipe based trigger is received, SEARAMS will automatically transition to the correct state based on the recipe classification.



3.4.1.3.4a

The GUI contains two scroll lists and two buttons. The left scroll list shows how recipe, (PPIDs) are classified into PPID Classification categories. The right list displays all PPIDs that were defined in the Parameter Lists tab and are not explicitly classified in the PPID Classifications list. Use the two buttons to move a highlighted PPID from one list to the other.

Right click on a PPID Classification to display the Classification Popup Menu:

New Classification: Prompt the user with a simple dialog to input the name of the new PPID classification. The new classification would appear in the left scroll list.

Delete Classification: Remove the classification from the left side scroll list. Any PPIDs contained in the list are moved back to the right side scroll list. All state transitions in the state model dependant on this classification are removed. Prompt the user with the appropriate information.

Rename Classification: User is presented with a simple dialog to rename the PPID classification. All state transitions dependent on this classification are still valid. Only the name is changed.

Create Wild Card PPID: Present the user with a simple dialog to input text that will be used to map PPIDs to this currently selected classification.

Right click on a PPID in the PPID Classification list to display a Popup Menu:

Remove PPID from Classification: Moves the PPID from the classification and adds it back to the right side list. If the PPID is a Wild Card PPID that was not defined in the PPID parameter list (was defined using the "Create Wild Card PPID" option) then it will NOT appear in the right side scroll list.

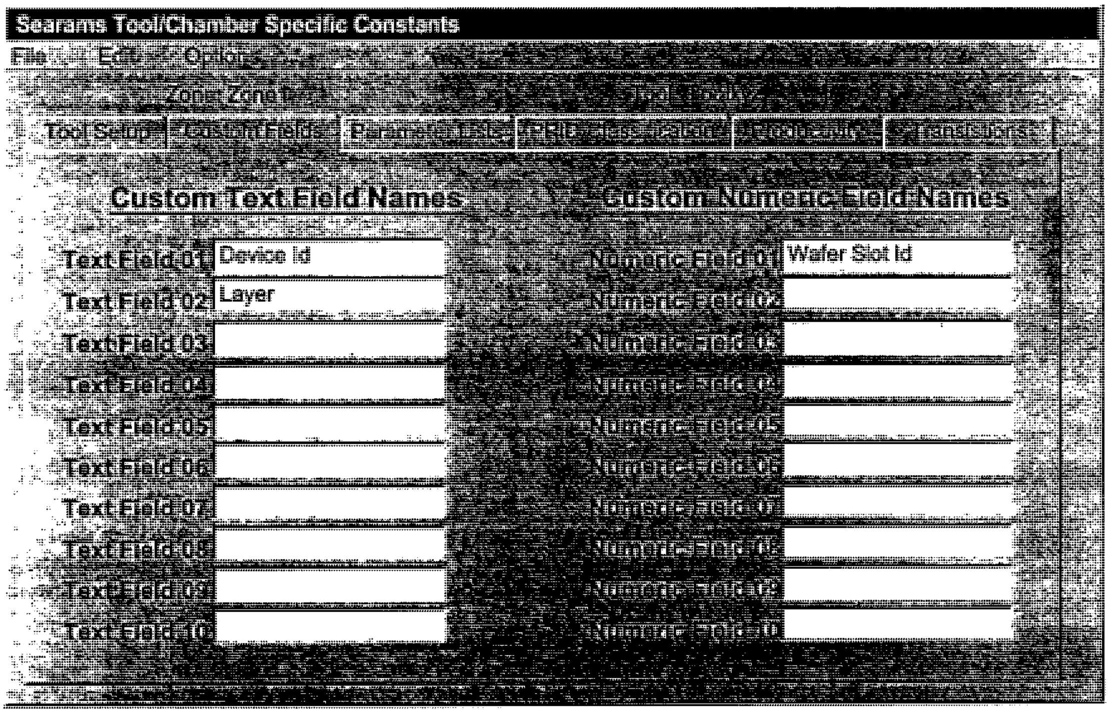
Right Click on a PPID in the "Unclassified PPID Names" list has no effect.

Wild Card Characters:
"*" May contain no characters or any number of characters.
"?" Must contain one character, may be any single character.

An example process name of "?roc?ss*" would match processABC, PROCESSXYZ and PrOcEsS. It would not match PPROCESS since there are two characters before the "roc" text. A match for PPROCESS could be defined as "??rocess" or "*rocess" or "?*rocess" etc.

3.4.1.3.5 User Defined Database Field names

The SEARAMS database provides 20 additional fields per record that are configurable by the user. These fields will typically be used to store additional database partitioning information. The example in figure 3.4.1.3.5a names Text01 field as "DeviceId". The intent would be for the users to send us the device id in the trigger IDL. We would store it in the Text01 field. Later, the users may extract data in the formulas with the criteria such as "Device Id" = "Pentium III".

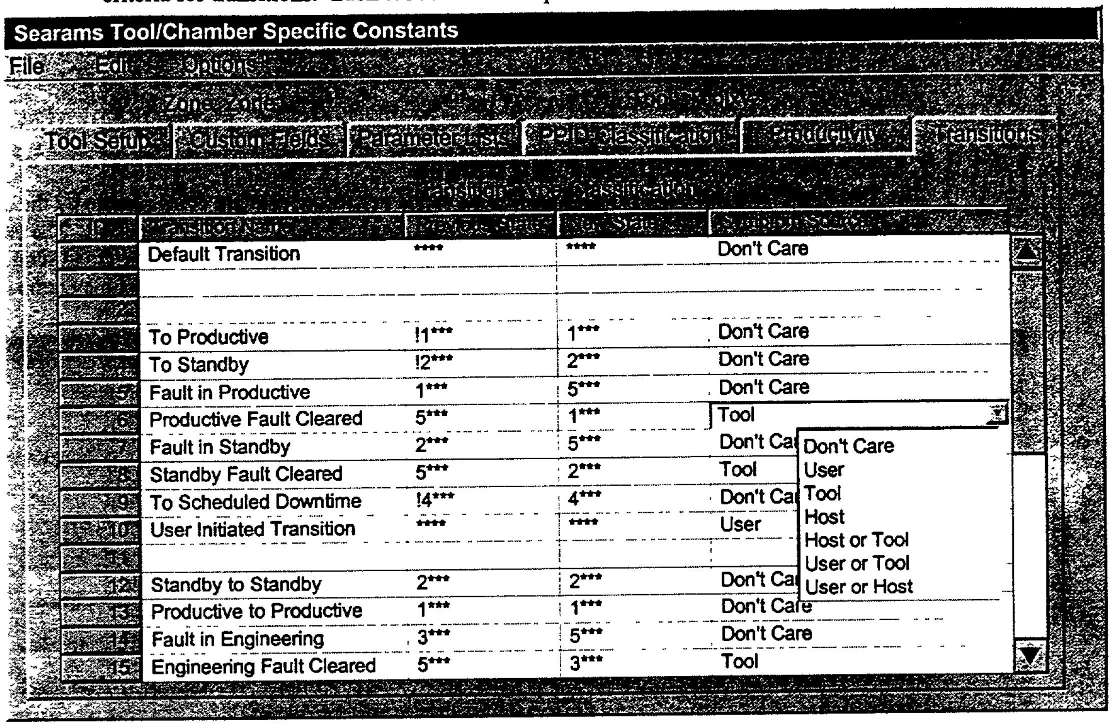


3.4.1.3.5a

The users may input a field name for each of the ten string and ten float fields. This name will only be used in the report generation and display. If the name exists in this tool configuration, the reports should all reflect the name of the field. The users are not required to name these fields. If they do not name a field, but use it in a report, the default names "Text##" or "Number##" will be used.

3.4.1.3.6 Transition Classification Configuration

SEMI E58 supports 15 Transition classifications. This editor allows the users define classification criteria for transitions. Each tool/chamber requires it's own classification criteria.



3.4.1.3.6a

The user may name up to 30 Transition Classifications. SEARAMS pre defines 12 of the 15 E58 classifications. The users may define the other 3 based on their tool specific setup. The users may define new classifications or modify the default classifications. These classifications are used each time a state change occurs and will be written to the database to categorize each specific state transition. The criteria are previous state, new state and symptom source.

Special cases:
Transition '0' is not modifiable by the user. Transition'0' is the catch all when no other transition classification matches the specific state change.
Transition '30' is not modifiable by the user. Transition type '30' used to store when a state change from SBY to PRD has occurred and acts as a flag for start of a production run. Symptom source is "don't care".

User definable fields:
Transition Name – Up to 28 alphanumeric characters may be used in the transition name field.
Previous State – Users may enter numbers, '*' wildcards, '!' inverse, space and ',' commas. They may input multiple 4 character fields of numbers and '*' wildcards separated by ',' commas.
Next State – Users may enter numbers, '*' wildcards, '!' inverse, space and ',' commas. They may input multiple 4 character fields of numbers and '*' wildcards separated by ',' commas.
Symptom Source – Pop up menu selection list to define when the symptom source is part of the classification criteria.

Runtime consideration:
At runtime, SEARAMS will search the list of transition classifications each time a state change occurs. It will find a match for the three criteria and store the transition number in the database. Since the previous and next states contain wild card characters, SEARAMS may find more than one classification that meets the criteria. SEARAMS will sort the list of transition classification by order or "conciseness". The most concise classification that meets the specific transition will be recorded. When more than one classification can be applied to a transition, the classification with the least amount of wild card settings will be logged in the database.

3.4.1.4 Operational User Interfaces

3.4.1.4.1 User Initiated State Changes

This application allows the users to select a new state. It follows the state models directed by the symptom and state definitions in section 3.4.1.1 and 3.4.1.2. The user may change the state by selecting a symptom or directly selecting a valid state. Several application specific bits control what actions the users have access to.

Application Bit A: The user may transition to any enabled state independent to the manual state transition definitions. "Enable the All States radio button"
Application Bit B: By default, the users may always select symptoms. This bit allows the choice of symptoms or a list of states. "Enable the State List radio button".
Application Bit C: Force a comment when selecting a new state. Symptom comment enforcement is defined in the symptom definition GUI.
Application Bit D: Enables or disables the interrupt classification information pane.
Application Bit E: Enables the user to lock the state and prohibit any automated transitions.
Application Bit F: Enables access to enter Scrap and Rework tab.
Application Bit G: Enables access to the External State Control tab.

Figure 3.4.1.4.1a

If the user selects Symptom list, the scroll list changes to the symptoms for the currently selected tool. The button changes from "Log State Change" to "Log Symptom". If the user selects State List or All States, the scroll list changes from the list of symptoms to the list of states and the button text changes to "Log State Change". The radio button should default to Symptom list.

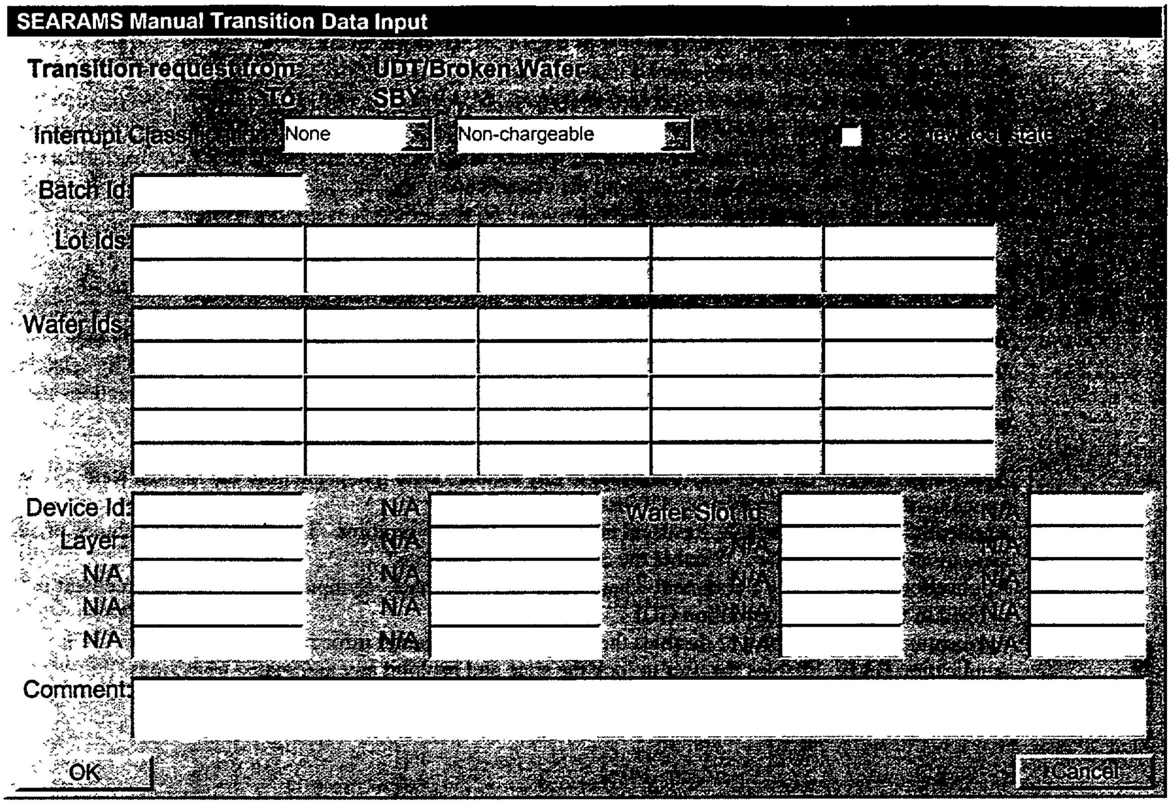
When the user selects the State List choice, they should see a list of valid states. The valid states are only the states that are listed in the manual transition attribute for the current state and this user access level and are currently enabled.

When the user selects the All States choice, they will get a list of all enabled states independent of the manual transition attribute and the user access level.

The state selection list is a hierarchical listing with specialized user operations. If the user clicks the plus sign, the sub states are listed under the current state. The plus will change to a minus. If the click the minus sign, the sub states will roll up and disappear. Any state that contains sub states will have a plus or minus sign next to it. States without sub states do not have an icon per example.

Only one state or one symptom may be selected at any time. The currently selected item is displayed under the scroll list. The label should show "Selected State" or "Selected Symptom" accordingly.

When the user clicks the button to log the change, prompt them for a comment based on the symptom property for comments and application bit C for state changes. A minimum of ten characters is required in the comment field when a comment is required.



3.4.1.4.1b

The interrupt classification pane access is control by two mechanisms, application specific bit D and specific types of state transitions.
The user will be prompted to classify the interrupt when transitioning from any state to UDT if application bit D is set. If they selected a symptom, then the interrupt classifications will default to the bits defined by the symptom but can still be over ridden by the user. If they selected the state without selecting the symptom, the default settings are Failure and Chargeable whether the user has access or not.

An optional field is available allowing the users to lock the new state. If the new state is locked, automatic triggers will not transition to a new state. The state will require manual intervention to become unlocked or transition to a new state.

When the user transitions from UDT to another ARAMS state, the field "Interrupt Classification" will display the classification used when originally transitioned to the UDT ARAMS state. This requires a data base search for the instance when the state transitioned to UDT and to read in the interrupt classification data. If the user wants to over ride the interrupt classifications and they have application bit D, they may set the interrupt classification radio buttons. The new values will be stored in place of the value extracted from the database. The only records in the database that may contain interrupt information are records that store a transition to a UDT state from a PRD, SBY, SDT or ENG state. If the user over rides the Interrupt classifications, it must be recorded in the Audit Trail.

If the user selects one of the 6 OEE states, the default ARAMS state will actually be selected. The OEE states themselves do not exist as entities, they only serve as a convenient grouping mechanism.

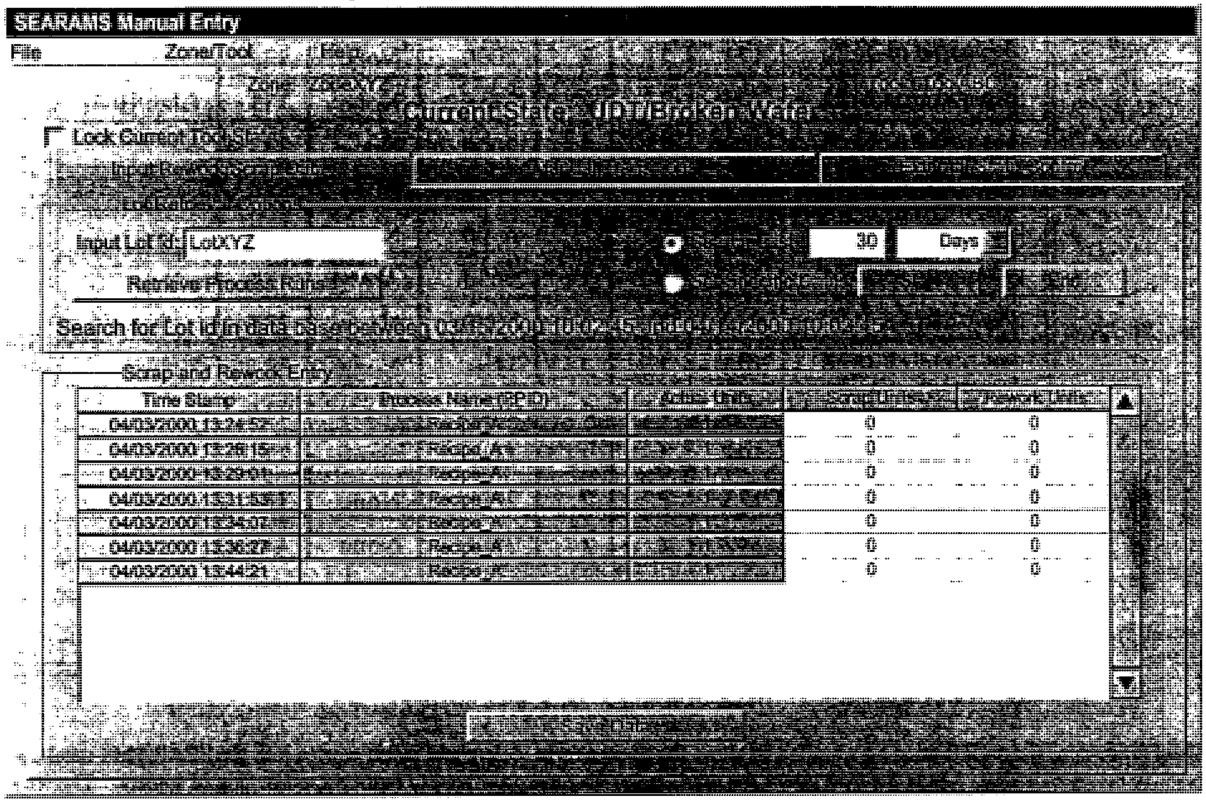
File Menu:
Exit: Close the application. Will leave all other tool specific views open.

Option:

Zone: Select a new zone/tool for the status detail view. Must be a hierarchical menu and the user must select a tool. Simply selecting a new zone will not provide enough info to redraw the screen.

3.4.1.4.2 Update State and Productivity Data

The user may input scrap data and rework data at any time, without changing the current state.



3.4.1.4.2a

The user may enter a Lot Id and specify the amount data base search date range. The "Retrieve Process Runs" button will initiate a data base search for the specific tool and lot id. All entries that match the Lot Id, date range and Transition type 30 will be displayed in the Scrap and Rework Entry matrix.

The user may input scrap and rework data, overwriting the current data base entries. When the user selects "Save Data" SEARAMS will update all the changed records.

When the user selects the Save Data button, verify the sum of rework and scrap counts is less than or equal to the actual count for each record in the database.

3.4.1.2.3 External State Control

The user with proper access may set or clear any defined external state for the specific tool in a similar GUI as described in 3.4.1.2e.

3.4.1.5 Manual Data Base Editing

The tool, users or HOST may report symptoms or triggers in appropriately or triggers may be missed for various reasons. It is extremely important that the information in the SEARAMS database is as accurate as possible. This is the entire premise and motivator for SEMI E58 ARAMS. The users must have the capability to edit the entries in the database when needed.

File Zone/Tool HELP

Tool: Toolxyz 1999/07/16

Time Stamp	Trigger	Origin	Trans.	New State	Interrupt	Cycles	Comment
1999/07/16 03:23:10	123	2	2	2000	None	332	
1999/07/16 03:24:22	124	2	2	11aa	None	333	Blah Blah
1999/07/16 04:23:05	102	3	3	2000	None	333	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1999/07/16 04:51:14	123			00	None	334	
1999/07/16 05:20:03	456	2	2	503d	Assist	334	
1999/07/16 08:45:00	034	2	2	2000	None	334	
1999/07/16 08:48:10	123	2	2	11aa	None	334	Yakkity
1999/07/16 08:23:03	234	2	2	2000	None	334	
1999/07/16 14:03:53	108	2	2	11aa	None	334	
1999/07/16 14:23:10	123	2	2	2000	None	334	
1999/07/16 18:17:37	342	2	2	210f	None	335	

Insert Below
Delete Entry

Deciphered text is automatically placed here when the user clicks a field.

Figure 3.4.1.5a

A GUI must be supplied to allow the users to edit, delete and insert entries into the SEARAMS database log. When the user opens the application they are prompted to input a specific day of interest. The user may change some fields in the database.
The fields for new state may not be edited directly. Instead, the user may double click in the field to get the dialog allowing them to select a new value.

The timestamp may be edited directly. The timestamp must be verified for the proper format.

The Trigger field should allow the user to select from the list of triggers for the tool.

The origin field is an enum field. The users may select from the enum types: User, Tool, or HOST.

The users select from an ARAMS state list to edit the new state field. Use the folder within folder methods described in the previous screens.

The transition type field is automatically calculated based on the last state, new state and origin, see appendix A. The last state field is automatically set equal to the new state from the previous entry and is not editable by the user.

If the record is a transition from a non UDT (non 5000 series) state to a UDT (5000 series) state, then the user may edit the Interrupt field. They are presented with a selection list: None, Failure or Assist.

The comment field will open a window and allow the user to edit the comments for that record.

All other fields including THT, ETHT, VTHT, Actual Units, Scrap Units, and Rework Units may be edited directly but are only allowed in transition to PRD states from non-PRD states.

Pop Up Menu:
Insert Below - Creates a new entry below the highlighted entry by inserting a new row in the database.
Delete Entry - Removes the highlighted entry from the database.

File Menu:
Save – Saves the changes to the database
Change Day – Allows the user to select a different day for the same tool
Print – Prints the currently selected day's database contents
Exit – Prompts the user to save changes if any have been made and exits the app.

Zone/Tool Menu:
Allow the user to select a different tool.

3.4.1 Reports

3.4.2.1 Defining Calculations

Many calculations are defined in SEMI E10 and SEMI E79 specifications. All calculation standards are supported. The users may also edit the standard calculations and create their own. The default calculations are listed in section 3.3.2.2.
An editor is provided to allow the users to define algorithms. The application includes the basic functions, '+', '-', '/' and '*'. It supports parenthesis ')' and '(' with unlimited nesting. The comparison logic symbols, '>,<,!=, ==, <=, >=, and, or', are supported.

3.4.2.1.1 Reserved Functions

TIME(t1, t2, c) calculates the amount of time in seconds that a condition 'c' is true, where 't1' and 't2' are time stamps that define the data base search bounds.
Example: TIME(12/01/1998 00:23:14, 12/13/1998 00:24:05, state = 5 or state =3). This function could translate into:
time stamp > t1 and time stamp < t2 and (state = 5 or state = 3)

SUM(x, t1, t2, c) calculates the sum of the values for x when condition 'c' is met where 't1' and 't2' are time stamps that define the database search bounds.
Example: SUM (gas1 * gas3, 12/01/1998 00:23:14, 12/13/1998 00:24:05, state = 5). This would search the database between the time stamps and accumulate the value of gas1 * gas3 for all records when the state is 5.

COUNT(t1, t2, c) calculates the number of records in the database when condition 'c' is met where 't1' and 't2' are time stamps that define the database search bounds.
Example: COUNT(12/01/1998 00:23:14, 12/13/1998 00:24:05, state = 5). This would search the database between the time stamps and count the number of entries for state = 5.

DELTA(x, t1, t2) calculates the difference between the value of 'x' at t1 and the value of 'x' at t2 where x is a database parameter name. DELTA = $x_{t2} - x_{t1}$. If no record is found at time t1 or t2, the next closest records, greater than t1 and less than t2 are used.

Two reserved words allow the user to dynamically change the function calls at runtime. The reserved names Report_Start and Report_End contain time stamps that the user selects at runtime to define the reporting time range.

AVERAGE(x, t1, t2, c) calculates the average of the values for x when condition 'c' is met where 't1' and 't2' are time stamps that define the database search bounds.
Example: AVERAGE (gas1 * gas3, 12/01/1998 00:23:14, 12/13/1998 00:24:05, state = 5). This would search the database between the time stamps and calculate the average value of gas1 * gas3 for all records when the state is 5.

STDEV(x, t1, t2, c) calculates the standard deviation of the values for x when condition 'c' is met where 't1' and 't2' are time stamps that define the database search bounds.

Q1(x, t1, t2, c) calculates the first quartile of the values for x when condition 'c' is met where 't1' and 't2' are time stamps that define the database search bounds.

MEDIAN(x, t1, t2, c) calculates the MEDIAN of the values for x when condition 'c' is met where 't1' and 't2' are time stamps that define the database search bounds.

Q3(x, t1, t2, c) calculates the third quartile of the values for x when condition 'c' is met where 't1' and 't2' are time stamps that define the database search bounds.

3.4.2.1.2 Formula Calculations

Time based calculations - convert all times in seconds. This should speed processing performance dealing with integers instead of floats.
The 'State' database variable - treat with special consideration. SEMI E58 defines the state to be a four digit number. The user may set criteria such as State = 1. The algorithms should always consider State a four digit number. If the user does not define some of the digits, the algorithms will assume all digits are used. 'State = 1' will use all production states or all states between 1000 and 19ZZ. The condition 'State = 32' will use all engineering equipment experiment state or all states between 3200 and 32ZZ. This functionality is convenient due to the hierarchical nature of the state model.
Multiple tool support – SEMI E79 defines the standards on how to calculate the production metrics across multiple tools. A chamber tool such as Magnum will have production metrics for each processing chamber. The main tool production metrics is defined as the aggregate of the productivity metrics for the chambers. When calculating the metrics for multiple tools together to produce one result, treat the tool's independent databases as one conglomerate database. Also, the time range, Report_End – Report_Start must be multiplied by the number of tools for the calculations to work out correctly. Multi tool support does not require the users to create special formulas, instead, the SEARAMS analysis applications will automatically alter the formulas when needed for multi tool requirements. See SEMI E79 section 6 for more details.
Example 1: Production Time Cluster Tool. The amount of time the tool was in the a productive state. For three chambers, the production time is the sum of the production time for each chamber.
Example 2: %Production Time Cluster Tool. Production Time/ Total Time. Total time is Report_End – Report Start. Actual Multi tool calculation = (production time tool 1 + production time tool 2 + production time tool 3)/ (3 * (Report_End – Report_Start).

3.4.2.1.3 Formula Definition Editor

The user may define the formulas needed to measure productivity and availability. The user may edit and save formulas. The formula editor may be a simple text editor without real time input verification. At save, or save as, the application should perform a syntax check on the text.

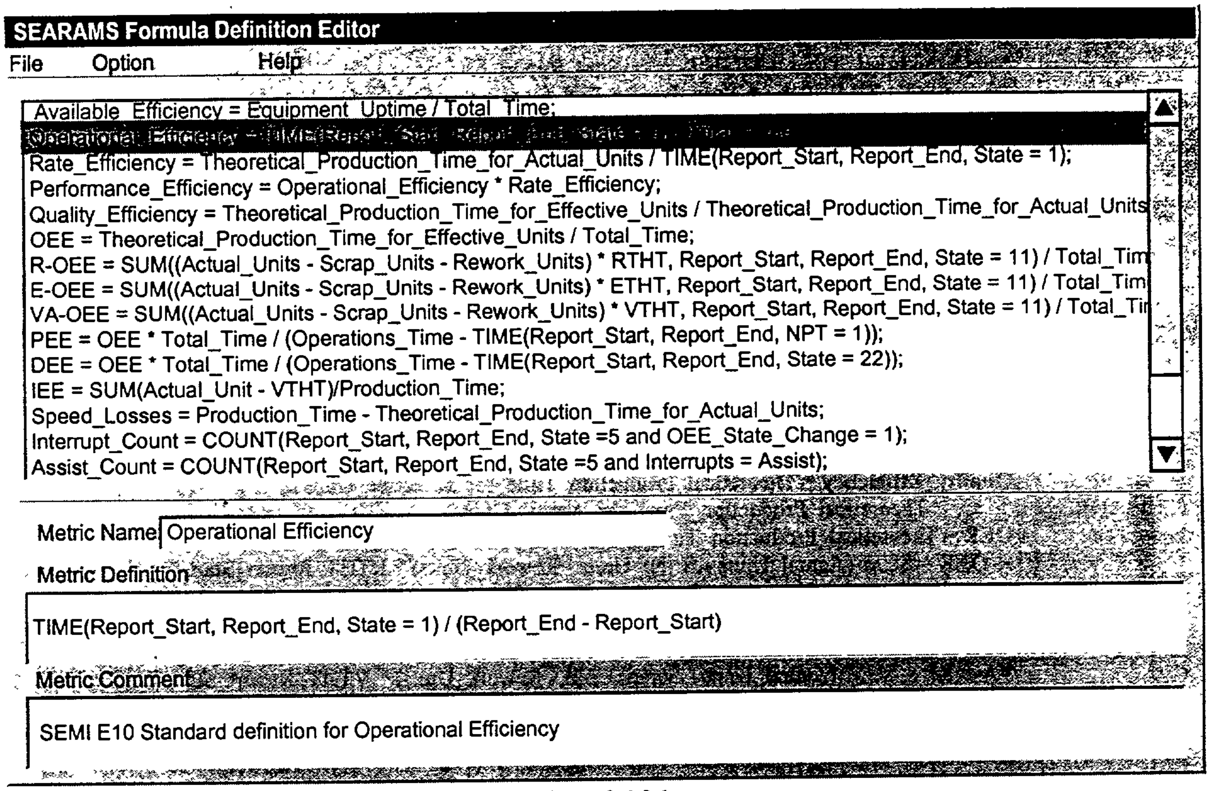


Figure 3.4.2.1a

Menus.
File menu:
Save Allows the users to save their changes so far.
Print Prints text based list of the formulas
Check Syntax The users input is checked for proper syntax. A dialog appears describing any problems or 'Syntax Confirmed' on a per formula basis.
Exit Prompts the user to save changes if needed. Exits the application.

Each formula or parameter name must be defined either by the application or the user.
Verify the correct number of parameters and parameter types are valid for built in function calls described in 3.3.2.1.1.

Metric Name syntax rules:
User must supply a continuos single word containing onlt alpha numeric and '_'.

Metric Definition syntax rules:
';': NOT ALLOWED
'//': NOT ALLOWED
'(': Must have a matching ')'. Unlimited nesting is supported.
'>,<,!=, ==, <=, >=, and , or': must be surrounded by defined parameters names, numbers, strings in quotations, or '),('.

Metric Comment syntax rules:
';': NOT ALLOWED
'//': NOT ALLOWED

3.4.2.2 Pre-defined Calculations (Default Global Formula List)

Total_Time = Report_End – Report_Start;
Production_Time = TIME(Report_Start, Report_End, State = 1);
Non-Scheduled_Time = TIME(Report_Start, Report_End, State = 6);
Downtime = TIME(Report_Start, Report_End, State = 4 or State = 5);
Standby_Time = TIME(Report_Start, Report_End, State=2);
Engineering_Time = TIME(Report_Start, Report_End, 3);
Operations_Time = Total_Time - Non-Scheduled_Time;
Equipment_Uptime = TIME(Report_Start, Report_End, State = 1 or State = 2 or State = 3);
Theoretical_Production_Time_for_Actual_Units = SUM(Actual_Units * THT, Report_Start, Report_End, State = 11 and transition number = 30);
Theoretical_Production_Time_for_Effective_Units = SUM((Actual_Units – Scrap_Units – Rework_Units) * THT, Report_Start, Report_End, State = 11 and transition number = 30);
Available_Efficiency = Equipment_Uptime / Total_Time;
Operational_Efficiency = TIME(Report_Start, Report_End, State = 1) / Total_Time;
Rate_Efficiency = Theoretical_Production_Time_for_Actual_Units / TIME(Report_Start, Report_End, State = 1);
Performance_Efficiency = Operational_Efficiency * Rate_Efficiency;
Quality_Efficiency = Theoretical_Production_Time_for_Effective_Units / Theoretical_Production_Time_for_Actual_Units;
OEE = Theoretical_Production_Time_for_Effective_Units / Total_Time;
R-OEE = SUM((Actual_Units - Scrap_Units - Rework_Units) * RTHT, Report_Start, Report_End, State = 11 and transition number = 30) / Total_Time;
E-OEE = SUM((Actual_Units - Scrap_Units - Rework_Units) * ETHT, Report_Start, Report_End, State = 11 and transition number = 30) / Total_Time;
VA-OEE = SUM((Actual_Units - Scrap_Units - Rework_Units) * VTHT, Report_Start, Report_End, State = 11 and transition number = 30) / Total_Time;
PEE = OEE * Total_Time / (Operations_Time - TIME(Report_Start, Report_End, NPT = 1));
DEE = OEE * Total_Time / (Operations_Time - TIME(Report_Start, Report_End, State = 22));
IEE = SUM(Actual_Unit -* VTHT, Report_Start, Report_End, State = 11 and transition number = 30)/Production_Time;
Speed_Losses = Production_Time - Theoretical_Production_Time_for_Actual_Units;
Interrupt_Count = COUNT(Report_Start, Report_End, State =5 and OEE_State_Change = 1);
Assist_Count = COUNT(Report_Start, Report_End, State =5 and Interrupts = Assist);
Failure_Count = COUNT(Report_Start, Report_End, State =5 and Interrupts = Failure);
MBTI = Production_Time / Interrupt_Count;
MTBF = Production_Time / Failure_Count;
MTBA = Production_Time / Assist_Count;
Total_Cycles = DELTA(Cycles, Report_Start, Report_End);
MCBI = Total_Cycles / Interrupt_Count;
MCBF = Total_Cycles / Failure_Count;
MCBA = Total_Cycles / Assist_Count;
Equipment_Dependant_Uptime(%) = 100 * Equipment_Uptime / (Operations_Time - TIME(Report_Start, Report_End, State = 51 or State = 52 or State = 54 or State = 56));
Supplier_Dependant_Uptime(%) = 100 * Equipment_Uptime / (Operations_Time - TIME(Report_Start, Report_End, State = 51 or State = 54 or State = 56));
Operational_Uptime(%) = 100 * Equipment_Uptime / Operations_Time;
Total_Repair_Time = TIME(Report_Start, Report_End, State = 5) - TIME(Report_Start, Report_End, State = 51 or State = 52);
MTTRf = Total_Repair_Time / Failure_Count;
MTTRi = Total_Repair_Time / Interrupt_Count;
MTOL = Downtime / COUNT(Report_Start, Report_End, (State = 4 or State = 5) and OEE_State_Change = 1);

Equipment_Dependant_Scheduled_Down(%) = 100 * TIME(Report_Start, Report_End, State = 4) / (Operations_Time - TIME(Report_Start, Report_End, State = 41 or State = 42 or State = 44 or State = 46));
Supplier_Dependant_Scheduled_Down(%) = 100 * TIME(Report_Start, Report_End, State = 4) / (Operations_Time - TIME(Report_Start, Report_End, State = 41 or State = 44 or State = 46));
Operational_Utilization(%) = 100 * Production_Time / Operations_Time;
Total_Utilization(%) = 100 * Production_Time / Total_Time;
Other_Loss_Time = TIME(Report_Start, Report_End, State = 12 or State = 13 or State = 14);

3.4.2.3 SEARAMS Analysis Reports

Several analysis reports are supported. Figure 3.4.2.3a lists the report types and shows the analysis icons.

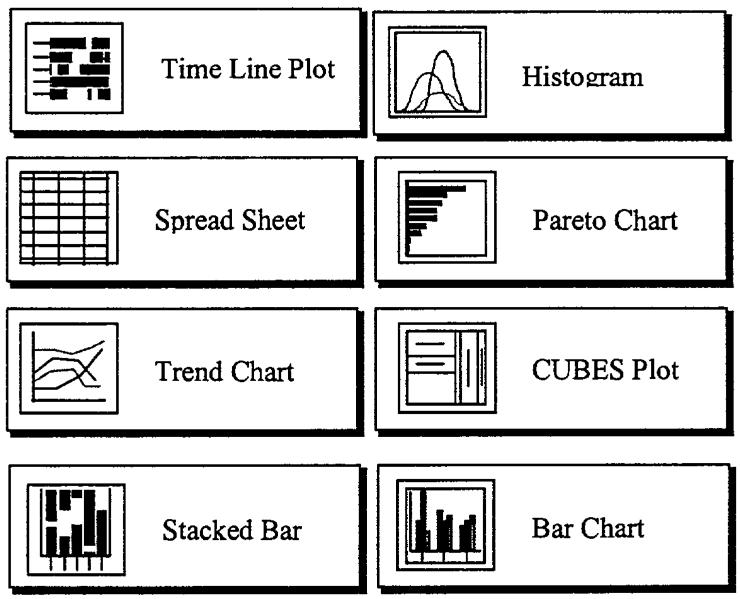


Figure 3.4.2.3a

Each Icon will open an independent application.

Spreadsheet: Displays the results of various productivity calculations in a tabular spreadsheet format.
Pareto Chart: Horizontal bar chart displaying the relative differences between characteristics.
Time Line Plot: Horizontal bar graph color coded to show the historical E10 states.
Trend Chart: Historical trend for any characteristic.
CUBES Plot: Capacity utilization bottleneck efficiency system as defined by SEMATECH.
Histogram: Relative distributions for various characteristics.
Stacked Bar: Relative magnitude of the E10 states vs. tools.
Bar Chart: Relative magnitude of various characteristics vs. various characteristics.

Each application will allow the user to save the complete properties to a file. These properties can then be opened at a later date to regenerate the report.
The report properties can also be saved for use with the Auto Report generator. SEARAMS must provide a directory structure suitable to save properties per application for both auto report and standard user operations.

Design suggestions:

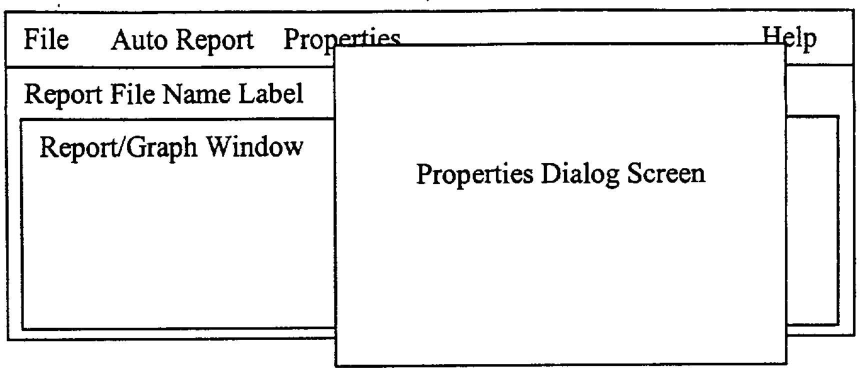
Suggested directory structure. Store the user defined properties files in a global access directory, user specific directory or Auto Report directory on a per application basis.

```
SEARAMS_Reports
        |- Global_Reports
        |        |- Spreadsheet
        |        |        |- fileabc
        |        |        |- filecde
        |        |        :
        |        |        :
        |        |- Trend_Chart
        |        |- Pareto_Chart
        |        |- Time_Line_Plot
        |        |- CUBES_Plot
        |        |- Histogram
        |        |- Stacked_Bar_Chart
        |        |- Bar_Chart
        |- Auto_Reports
        |        |- Spreadsheet
        |        |- Trend_Chart
        |        |- Pareto_Chart
        |        |- Time_Line_Plot
        |        |- CUBES_Plot
        |        |- Histogram
        |        |- Stacked_Bar_Chart
        |        |- Bar_Chart
        |- Userxyz
        |        |- Spreadsheet
        |        |- Trend_Chart
        |        |- Time_Line_Plot
        |        :
        |        :
        |- Userabc
        |        |- Histogram
        |        |- Stacked_Bar_Chart
        :        :
        :        :
        :        :
```

Generate a new directory as needed per user. When a new user tries to save a properties file for a specific report type and the directory does not exist, create it as needed.

No directory clean up is provided by the report applications. If a user is deleted from the system, SEARAMS should remove the user specific directory and all the corresponding files within the directory.

The applications all share a common look and feel for the setup and operation of the application.



Common Report Application Framework

When the report first opens, the user should be presented with an empty report window and the report properties dialog should automatically open for setup.

If the user has saved the report information to file, the name of the report is presented at the top of the window.

File menu:
Open: Opens a selection list dialog to select a previously saved report. The user can select from a global list or the user specific list.
Save: Allows the users to save this analysis as a global file or user specific file. The first time, they should assign a name. Appropriate error checking will be done.
Save As: Save the current report to a new name as a global or user specific file. After the Save As function call, the user will be in the new report, and the new name will be displayed at the top of the window.
Print: Prints a text based description of the analysis configuration.
Exit: Prompts the user to save changes if needed. Exits the application.

Auto Report Menu: (Control access with an application specific bit for each Report app.)
Open: The user is presented with a list of reports previously saved in the Auto Report directory.
Save: Allows the users to save the report properties to the Auto Report directory. The first time, they should assign a name. Appropriate error checking will be done.
Save As: Save the current report properties to a new name in the Auto Report directory. After the Save As function call, the new name will appear at the top of the window.

Properties menu:
Report Properties: Opens the report properties dialog window shown in 3.4.2.3b.

Common Report Properties.

The "Report Time" tab shown in figure 3.4.2.3b, provides a selection for report range. This range is required to set the boundary for the data base extraction. The date range may be selected by defining explicit time stamps or selecting the report duration. The duration, 'X' is defined in terms of time. The user inputs an integer and selects the type, hours, days, months etc. When Report Duration is used, the End time is the current time and the start time is the current time – X.

The End Time Stamp has on additional button above the calendar. The button, "Now", will set the end time stamp information to the current time and date.

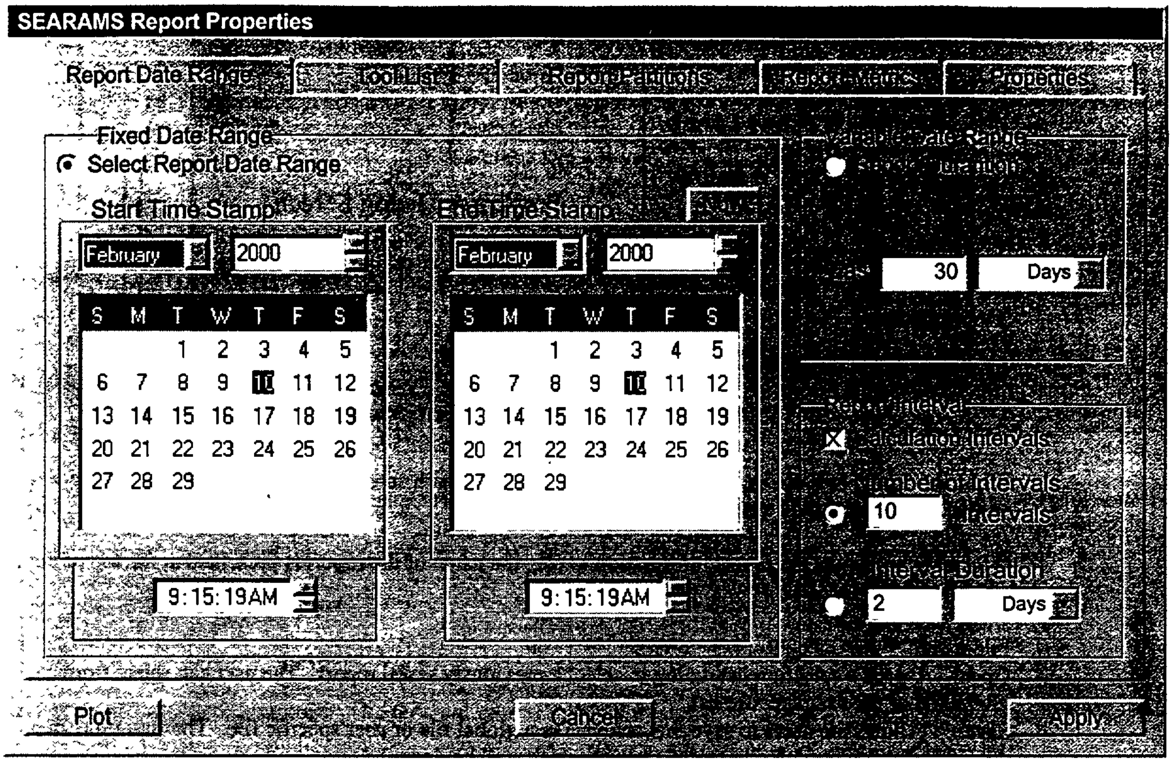


Figure 3.4.2.3b

The section the lower right corner is reserved for defining a calculation interval. The interval is useful to look for trends in the data. When an interval is selected, the calculations will be performed at the specified interval. Example: If the duration is 12 months and the interval is 1 month, 12 sets of calculations will be performed, one for each month within the 12 month range. **IMPORTANT**!! Interval becomes an additional report partition as defined in 3.4.2.3c.

This tab will default to Report Duration and 7 Days. The default range for "Report Date Range" is also set to 7 days between the start and end time stamps. The default start time is 7 days before the current time. The default end time is the current time.

The minimum Report Range or Duration is 1 hour.

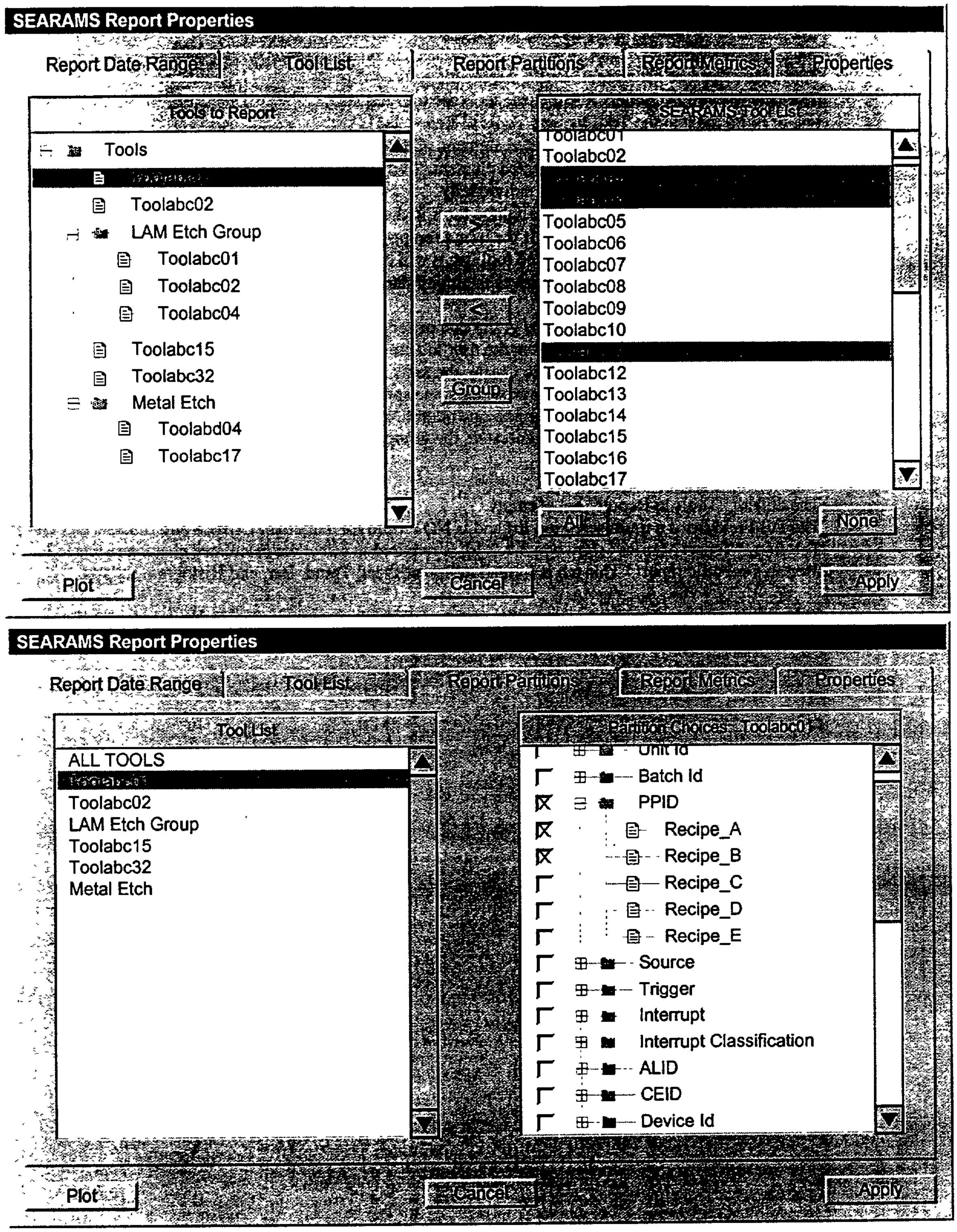


Figure 3.4.2.3c

Tab "Tool List" and tab "Report Partition" shown in figure 3.4.2.3c, are required to select which equipment in the factory to include in the report and what additional partitions to define.

Tool List: The tool list widget should display all tools configured on the system.
The selected tool list widget displays the tools the user has selected for the report. The user may click one or more tools in the Tool list and Tools to Report list. A single click will deselect all highlighted elements and highlight only the selected element. Control click will keep currently highlighted elements and highlight or de-highlight the selected element. Shift click will allow the user to highlight a range of elements without selecting each one individually.

The '>' button adds the highlighted tools in the tool list to the selected tool list. It does not remove any tools from the tool list. If the user attempts to move a tool from the tool list to the selected tool list and it is already in the selected tool list, it will NOT place a second copy of the tool name in the selected tool list. The '<' button removes the highlighted tools from the Tools to Report list.

The 'Group' button creates a database group comprised of the currently selected tools in the Tool list. This button will open a dialog allowing the user to name the group of tools.
If the user names the group and clicks Create, the tools with the group name will be added to the Tools to Report list. This grouping capability provides some specialized calculations that allow a group of tools or chambers to be calculated together into one output. See SEMI E79 section 6 for more details on multi tool calculations. When a report is generated, the group name will be associated with the calculation results for the group.

The default "Tools to Report" list is empty.
The DB Field list is a multi selection list and is NOT valid for Timeline, CUBES and Stacked Bar charts.
Tab four, "Report Metrics" shown in 3.4.2.3d, is required to select the calculated characteristics to be used in a specific report. This tab is limited to Spreadsheet, Trend, Bar, and Histogram reports.

The additional report partitions allows the user to define which recipes, device ids, lot ids, ALIDs etc to calculate metrics on.

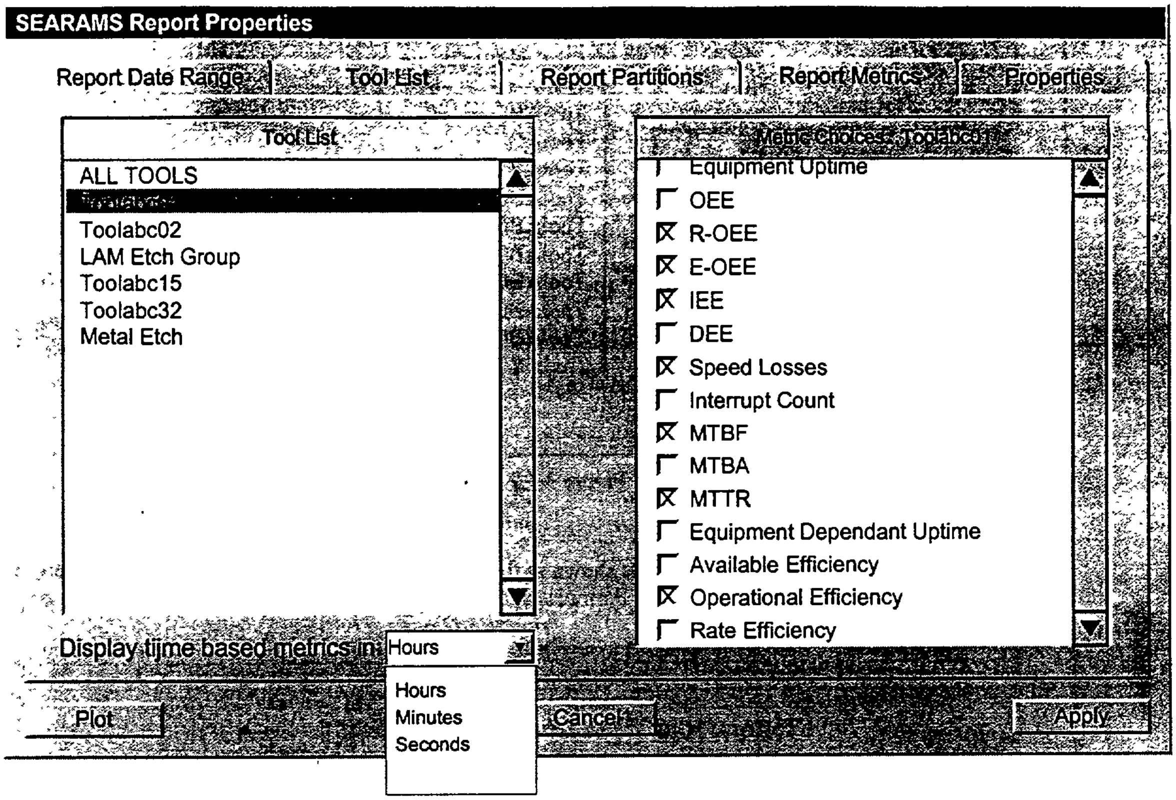


Figure 3.4.2.3d

Formula List Selection lists:
The formula list widget should display all metrics configured on the system.
The selected formula list widget displays the metrics the user has selected for the report. The user may click one or more metrics in the Formula list, and Formulas to Report list. A single click will deselect all highlighted metrics and highlight only the selected metric. Control click will keep currently highlighted metrics and highlight or de-highlight the selected metric. Shift click will allow the user to highlight a range of metrics without selecting each one individually.

Formula list to Formulas to Report list interactions:
The '>' button adds the highlighted metrics in the formula list to the selected formula list. It does not remove any metrics from the formula list. If the user attempts to move a metric from the formula list to the selected formula list and it is already in the selected formula list, it will NOT place a second copy of the metric name in the selected formula list.
The '<' button removes the highlighted metrics from the Formulas to Report list.

The default "Formulas to Report" list is empty.

The "Properties" tab is specific for each formula type. Each report is defined in the next section. As each report is presented in the next section, the ""Properties" tab is also defined.
The Properties tab must only display the properties of the currently selected report

Selecting the "Generate Report" command in the file menu launches a spreadsheet and calculates the report. The spreadsheet supports a comma delimited export facility. The number of tools and formulas can have a dramatic impact on the performance of the calculations. The users should be given a status screen to see the calculation progress, shown in figure 3.4.2.4a.

The user may select the Display Partial button to cancel any additional calculations and view the partial report. All completed calculations will be displayed in a scroll box.

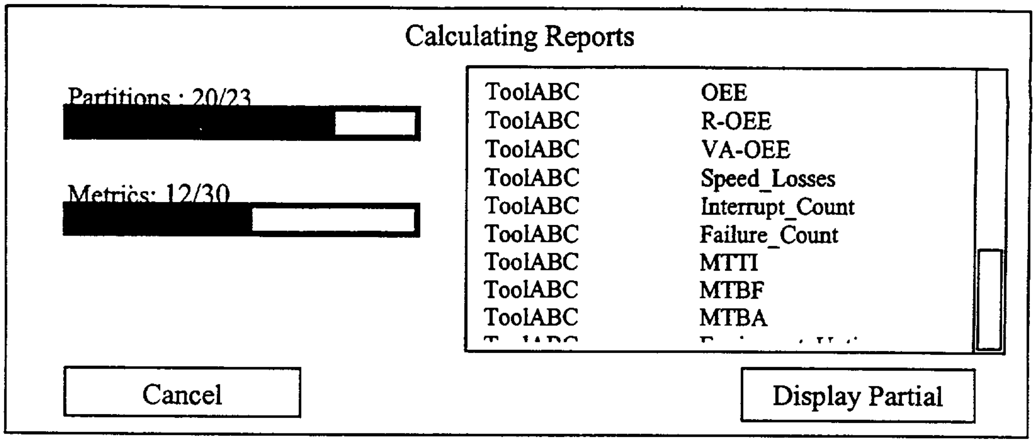


Figure 3.4.2.3e

3.4.2.4 Spreadsheet Report

The spreadsheet report window opens as shown in figure 3.4.2.4a. The optional, "DB Field Partition" would add additional columns between Formulas and Totals. The Column label is the DB Field Name of the first tool in the report.

SEARAMS Spreadsheet Report

File Preferences Help

Report: Idle Time Analysis (All Tools)

Report Start Time: 01/01/2000 Report End Time: 04/01/2000

			Interval (30 Days)		
Tool	Metric	Total	01/01/2000 - 02/01/2000	02/01/2000 - 03/01/2000	03/01/2000 - 04/01/2000
EtchA_01	%Standby_Time	32	26	40	30
EtchA_01	%Standby_Time_No_Oper	10	14	10	6
EtchA_01	%Standby_Time_No_Prod	14	12	13	17
EtchA_02	%Standby_Time	43	46	41	42
EtchA_02	%Standby_Time_No_Oper	8	10	9	5
EtchA_02	%Standby_Time_No_Prod	15	13	14	18
EtchA_03	%Standby_Time	29	30	27	30
EtchA_03	%Standby_Time_No_Oper	3	4	3	3
EtchA_03	%Standby_Time_No_Prod	16	15	17	16
Etch_GroupA	%Standby_Time	35	36	36	33
Etch_GroupA	%Standby_Time_No_Oper	7	9	8	7
Etch_GroupA	%Standby_Time_No_Prod	15	13	14	18
LithoF_01	%Standby_Time	13	11	13	15
LithoF_01	%Standby_Time_No_Oper	2	3	2	1
LithoF_01	%Standby_Time_No_Prod	5	4	5	5
LithoF_04	%Standby_Time	18	18	16	20

Sort Order: Tool, Metric **Time Based Units: Hours**

3.4.2.4a

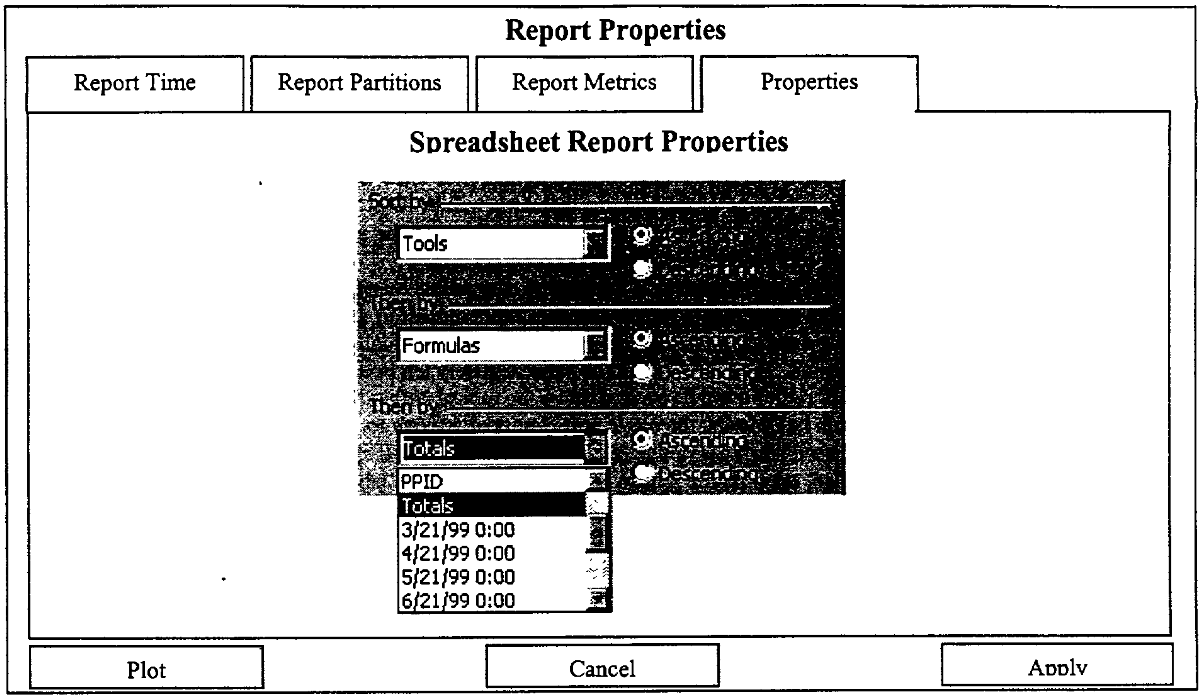


Figure 3.4.2.4c

The spreadsheet application has multiple sorting capabilities. The sort properties allows three levels for sorting. The default sort format is tool, then formula. Each Interval, provides an addition sort possibility.

Example: If the user had set up a report with 4 intervals defined, the possible sort list would contain:
Tools
Formulas
Totals
Interval 1
Interval 2
Interval 3
Interval 4

If a Miscellaneous DB field was used for an additional level of partitioning, the user may select that field to sort on as well.

3.4.2.5 Trend Chart

Plots all the data for a specific report. See figure 3.4.2.5a. This graph plots all report data by default. The users may remove data sets by right clicking on any data point or right clicking on the data set in the legend and selecting the "Hide Data set" option. The users may shift click or control click with the legend and then right click to modify the attributes for a group of data sets simultaneously. Shift click and control click work as previously stated though out this document. The plot supports two Y axis. By default, all data sets containing values between 0 and 1 appear scaled to the right Y axis. The Axis label is (Right Y Axis). All other data sets are scaled to the left Y axis. The Axis label is (Left Y Axis). If no data meets the criteria for one of the Y Axis, that Axis will be turned off by default. The Y Axis labels are vertical labels. Both Y Axis should scale 10% greater than the minimum value and the maximum values from all data sets plotted on that axis.

The users may access a pop up menu at the plotted data points by right clicking the data point. Two features help the user select a data point. The data point closest to the mouse pointer when the mouse pointer is within the drawing panel and the right button is continually depressed will have a flashing circle around the point. The circle should be approximately ten pixels in diameter. The user may continue to hold the right button down and move the mouse within the circle. While moving the mouse, with the right button held down, the circle will continually move to the closest point to the cursor. If the right button is released while inside the circle, a pop up menu will appear with several selections as defined below. Also, anytime the mouse is within the circle, the label bar within the window will identify the data set and the X and Y coordinates similar to the ESW Graphical Analysis application. The Y coordinate will correspond to the left or right axis appropriately. Releasing the right mouse button outside the circle will open a pop up menu for Graph Properties.

Left click and drag within the drawing pane will draw a zoom box similar to Data Plot. A single left click with no drag will zoom out to full scale.

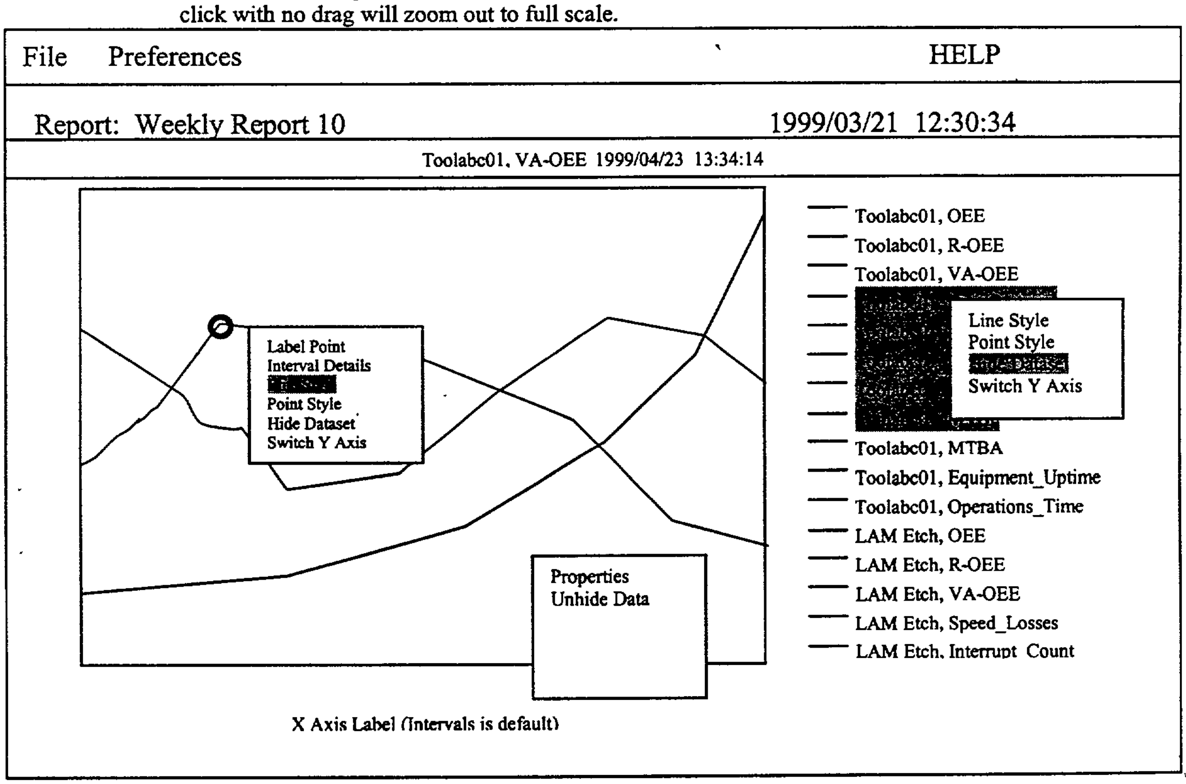


Figure 3.4.2.5a

The default line and point color on a per tool basis and the point style and line style will change from formula to formula. This default schema will provide that all tool's "MTBF" formula will be plotted with the same line and point style, but each tool will be a different color.

Popup Graph Properties Menu
This menu provides the users with some formatting options for the graph properties.
Graph Properties Opens the Properties shown in figure 3.4.2.5b.
Unhide Data Opens a scroll list displaying the list of data sets that have been hidden. This is a multi-selection list. Selected data sets will be re-drawn on the Graph. This option is disabled if no data sets are hidden.

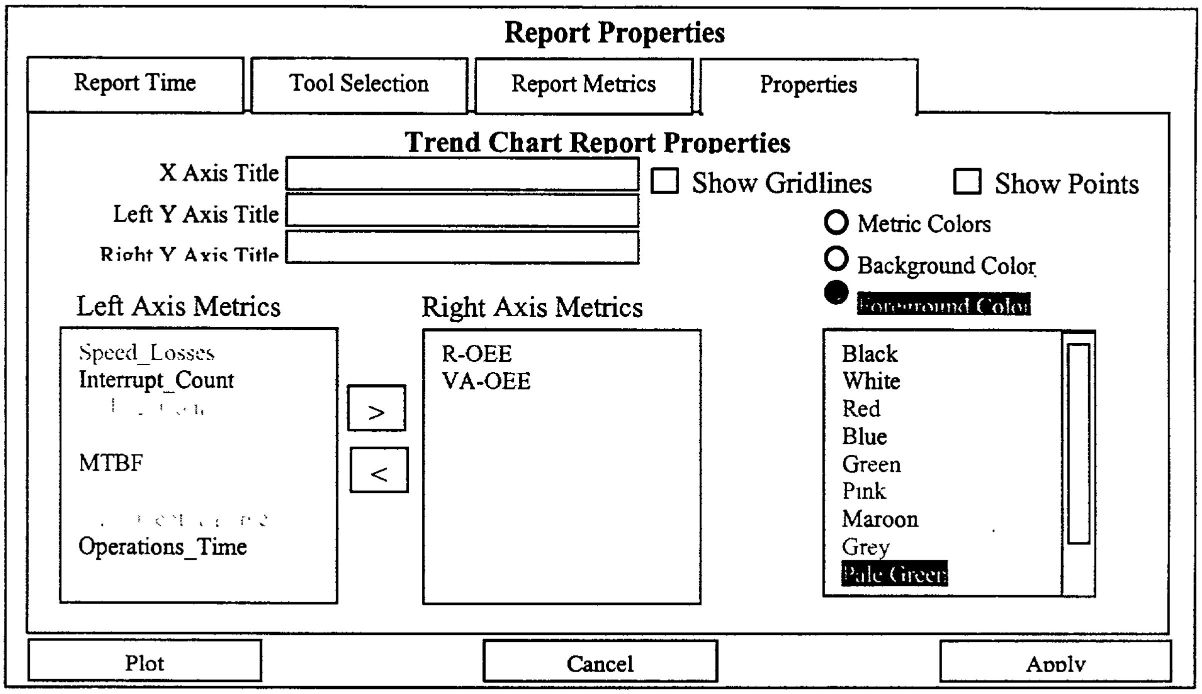


Figure 3.4.2.5b

Popup Point Properties Menu
This menu provides the users with some formatting options for the selected point and data set properties.
Label Data Point Opens a dialog allowing the users name the data point similar to ESW Graphical Analysis data point labels.
Interval Details Displays a selection dialog prompting the users to select a date range and displays the data within the range. The default date range is data point time stamp +/- the report interval time.
Line Style Open a dialog allowing the user to specify the line color and style for the data set.
Point Style Open a dialog allowing the user to specify a point color and style for the data set.
Hide Data set Removes the data set from the graph.
Switch Y Axis Re-scales both Y Axis and plots the currently selected data set on the other Y Axis. This option may force the right hand Y Axis to be greater than 1. Auto scale both Y Axis to show all the data as "best fit" plus ~10%.

Popup Legend Properties Menu
This menu provides the users with some formatting options for the selected data set properties.
Line Style Open a dialog allowing the user to specify the line color and style for the data set.
Point Style Open a dialog allowing the user to specify a point color and style for the data set.
Hide Data set Removes the data set from the graph.
Switch Y Axis Re-scales both Y Axis and plots the currently selected data set on the other Y Axis. This option may force the right hand Y Axis to be greater than 1. Auto scale both Y Axis to show all the data as "best fit" plus 10%.

Unhide Data Opens a scroll list displaying the list of data sets that have been hidden. This is a multi-selection list. Selected data sets will be re-drawn on the Graph. This option is disabled if no data sets are hidden.

3.4.2.6 Pareto Chart

The goal of this application is to allow the users to quickly determine the amount of time the equipment is in the states and sub states as well as counting triggers. The various options associated with this graphing application allow the users to change the level of resolution of the report. The users may choose to view the amount of time the tools or tool groups spent in any of the 60 ARAMS states. They may optionally select to view the sub states of UDT to determine what categories of failure cause the most downtime on the tool.

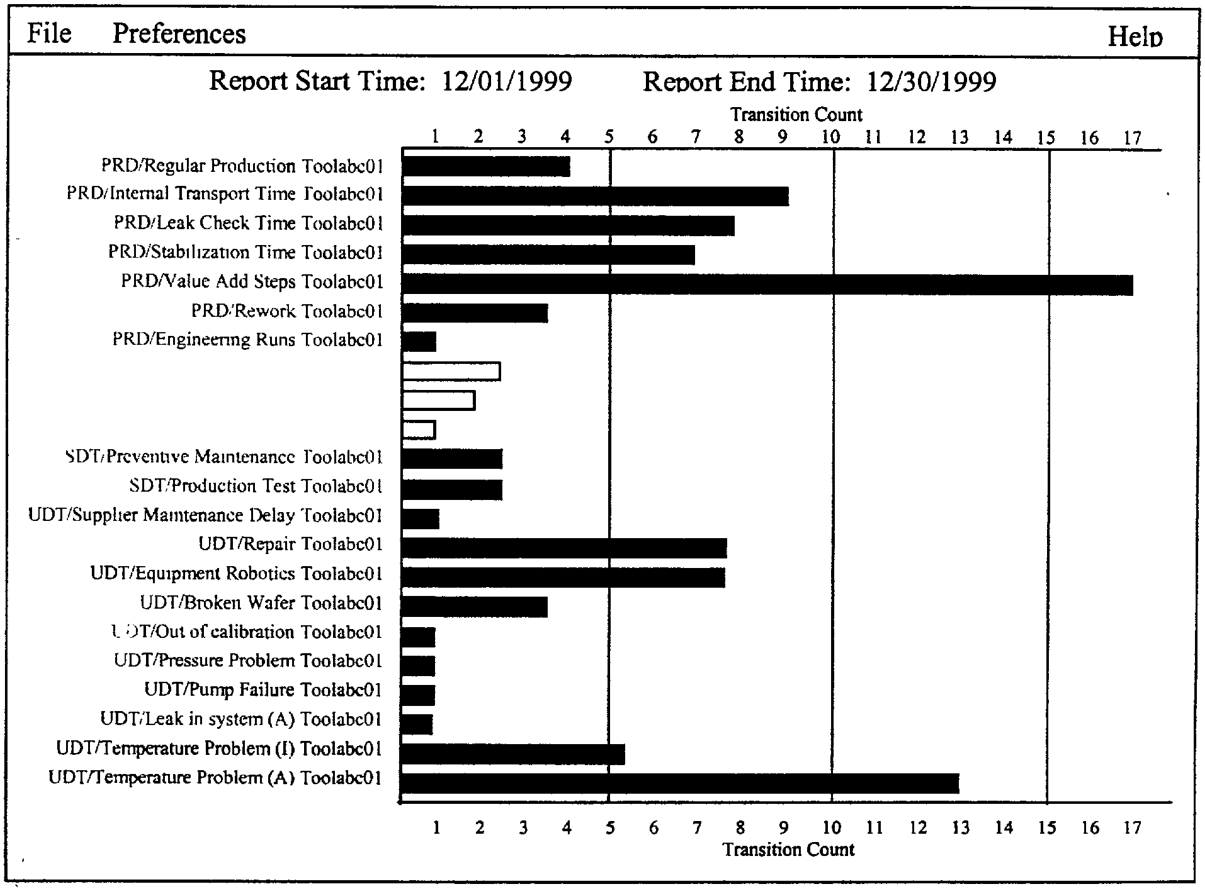


Figure 3.4.2.6a

This plot has two distinct modes of display. The default mode displays the number of times the equipment transitioned into a state as shown in figure 3.4.2.6a. The second mode displays the amount of time the equipment or equipment group spent in each state. The upper and lower x-axis label would change from "Transition Count" to "State Time" and would scale appropriately.

The reporting preferences allow the users to select several tools for analysis. The tool name or group name is appended to the state names for user differentiation.

If the user has selected more tools/states than will fit on the screen, add a scroll bar to the right side of the graph.

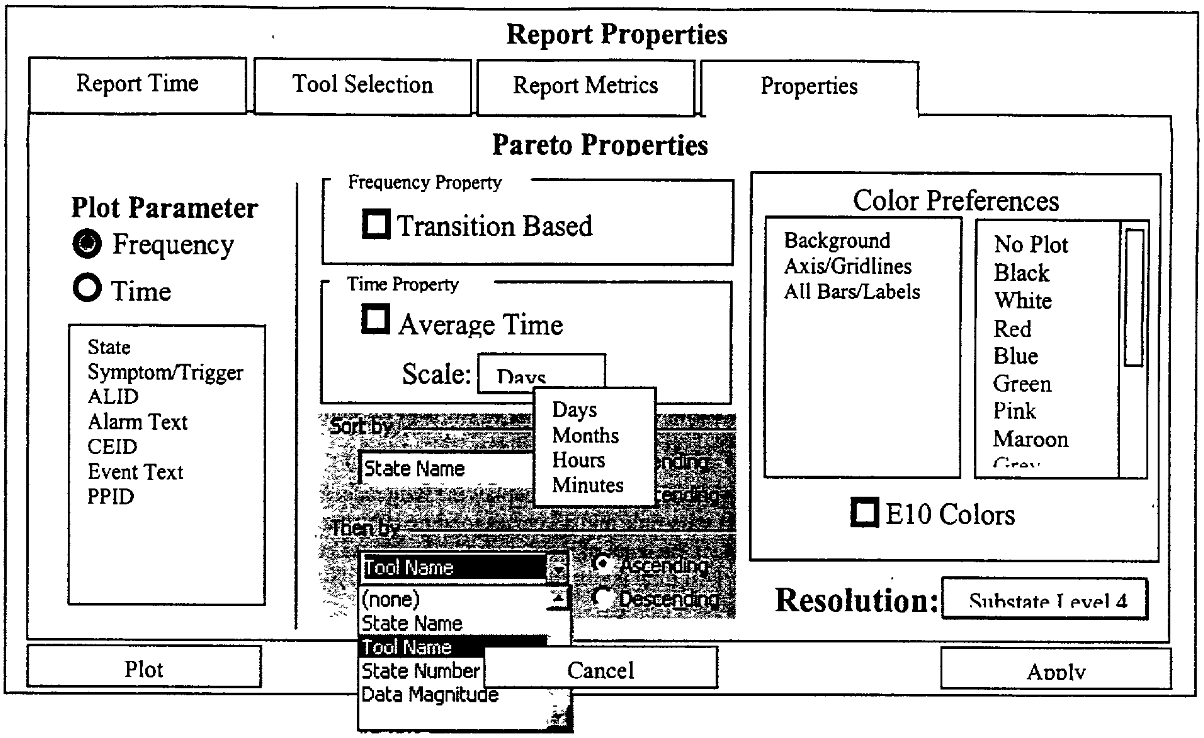


Figure 3.4.2.6b

The Pareto properties allows the user to plot the number of transitions to a state, the amount of time accumulated in a state, the number of occurrences of each parameter or the amount of time accumulated in a destination state for each specific parameter.

The user must select a Plot Parameter. A selection list is presented containing State and Symptom/Trigger by default. Any additional parameters the user selected in the "Tool Selection" tab are also presented.

"Frequency" option:
When plotting the frequency, plot the number of times the parameter was recorded in the database. Selecting this option enables the frequency property box allowing additional options.

"Time" option:
When plotting the times, plot the amount of time that was accumulated in the database when the parameter was at any specific value. Selecting this option enables the time property box allowing additional options.

The "Average Time In State" option is only available when plotting a parameter based on time. When using this option, the amount of time in the state plotted equals the total amount of time in the state divided by the number of times the state occurred. Example: Symptom 34 caused 16 transitions. The total amount of time the tool spent in a destination state was 120 minutes. The bar should have a magnitude of 120/16 = 7.5. This option is specifically useful to plot the average time spent in an USD state based on the kind of alarm, event or symptom/trigger.

The "Scale" option is only available when plotting a parameter based on time. The user may force the units of time on the axis to "Days", "Months", "Hours" or "Minutes".

The "Transition Based" option is only available when plotting based on frequency. This option is a filter and will only increment the count for database records where a transition occurred. This is useful to compare the number of alarms received vs. the number of alarms that caused a state transition to occur.

The "SORT" option allows two levels of sorting. The selection list options are customized depending on the Pareto properties selected as follows:

Plot State	Plot Symptom/Trigger	Plot Other Parameter
Tool Number State Name State Number Magnitude	Tool Number Symptom/Trigger Name Symptom/Trigger Number Magnitude	Tool Number Parameter Value Magnitude

A color preferences is provided. The user may select the color for the background, foreground and bars/labels. A checkbox at the bottom will enable the E10 colors for the bars and labels. SEARAMS will change the color of the bar to the E10 color if all the data for that bar was derived from within one of the 6 high level E10 states.

The Pareto application must allow the users to display the time recorded in a state as the actual time from that state or the SUM of that state time and all corresponding sub state times. A Pareto Resolution popup menu allows the users to select the level of resolution for the Pareto report.
Level 1 is the 6 E10 states. (All time is summarized into the 6 E10 States and plotted)
Level 2 is the 60 ARAMS states.
Level 3 is the first level of user defined sub states.
Level 4 is the second level of user defined sub states.
The Resolution level is treated as a filter. Resolution level two only looks at the first two digits of the state numbers. The remaining two digits are ignored for reporting purposes. This has the effect of adding all time in the 3rd and 4th level states into the second level state.

3.4.2.7 Cubes Plot

See SEMATECH document 95032745A-GEN for full description of CUBES model.

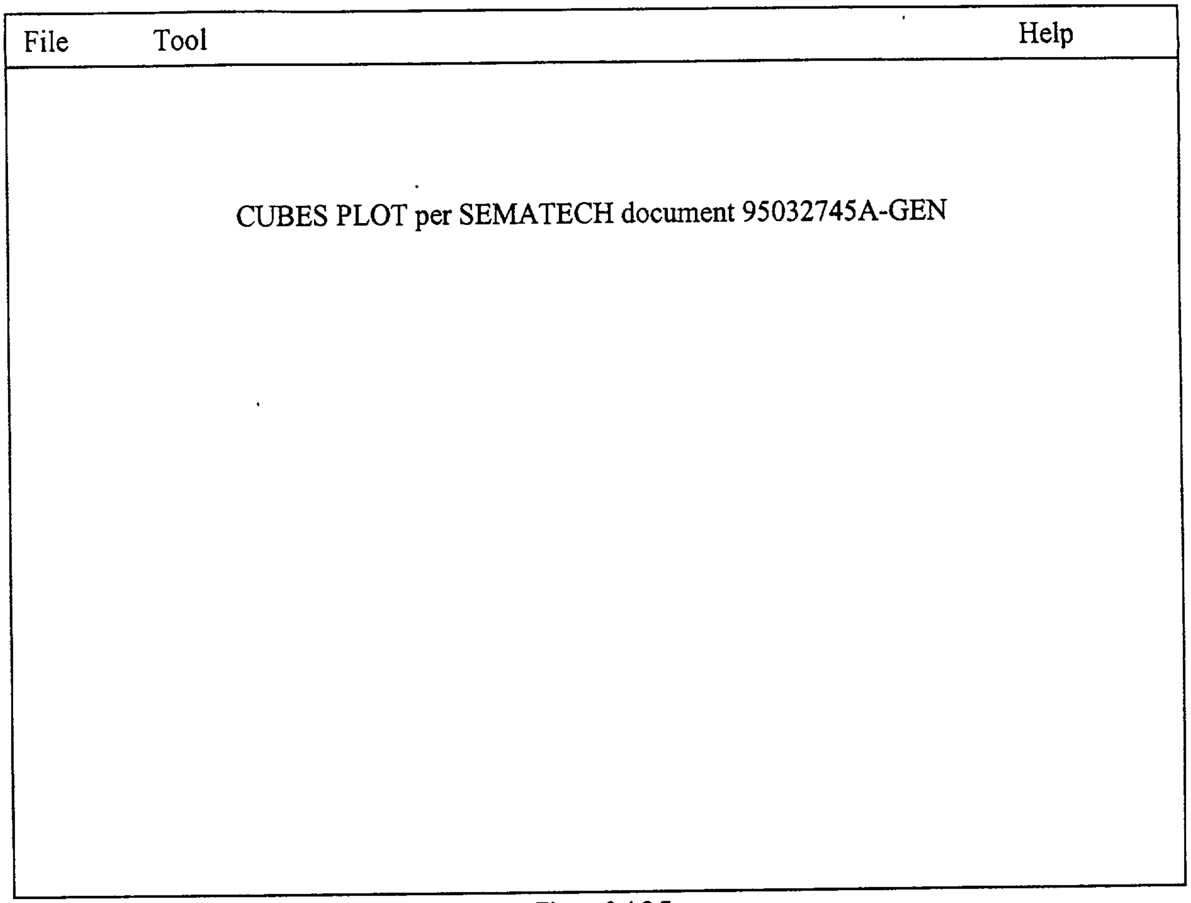


Figure 3.4.2.7a

A right click in the graph will open a pop up menu identical to the preference menu defined below.

Tool Menu

List all tools and tool groups defined in the report. User may select any tool for viewing. CUBES only displays one tool or tool group at a time.

CUBES Properties dialog contains five tabs. Each tab allows the user to select the calculations to be included in the CUBES report.

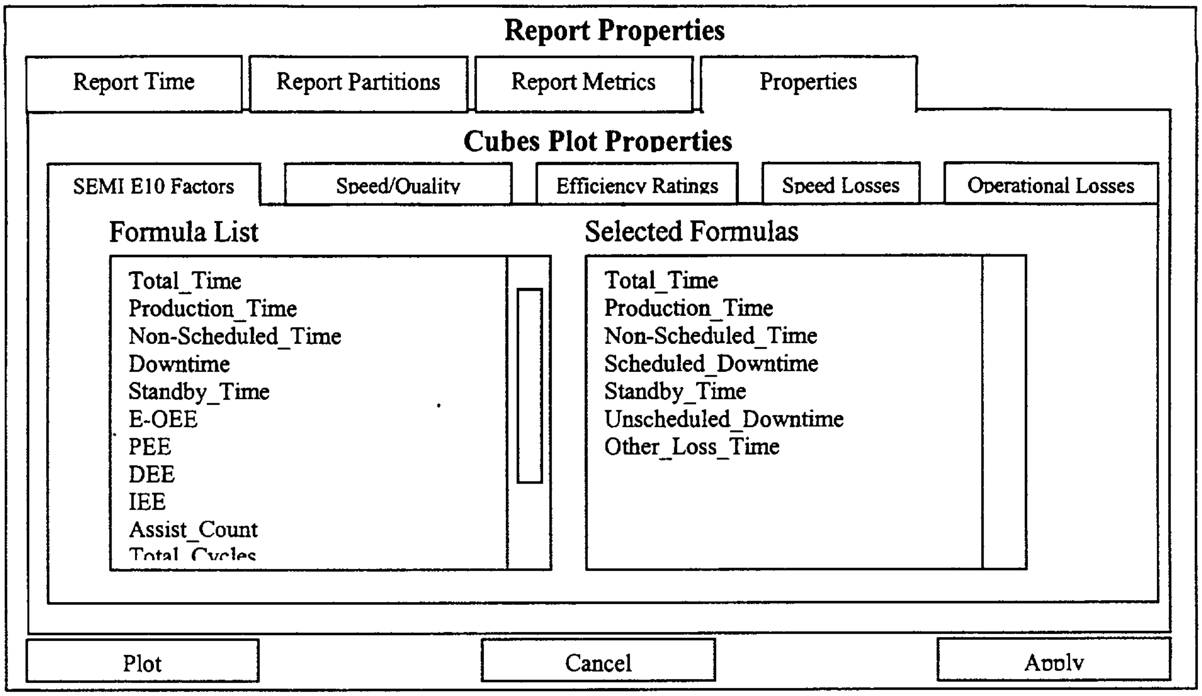


Figure 3.4.2.7

Each tab represents a report section from the top of the CUBES plot. The fourth and fifth tab combine into the "LOSSES DUE TO:" section. They are separated into two independent tabs so SEARAMS can properly plot the CUBES analysis graph. Speed losses are plotted as horizontal sections above the OEE section and operational losses are plotted as vertical sections to the right of the OEE section in the graph.

The labels in the CUBES plot correspond to the formula names instead of the labels specified in 9503745-GEN.

3.4.2.8 Time line plot

The time line plot displays the state each tool was in over a period of time by displaying the E10 color code. Only E10 states are shown without any sub state connotation. The Time Line plot is not valid for grouped tools. If the report contains any grouped tools, they will be ignored.

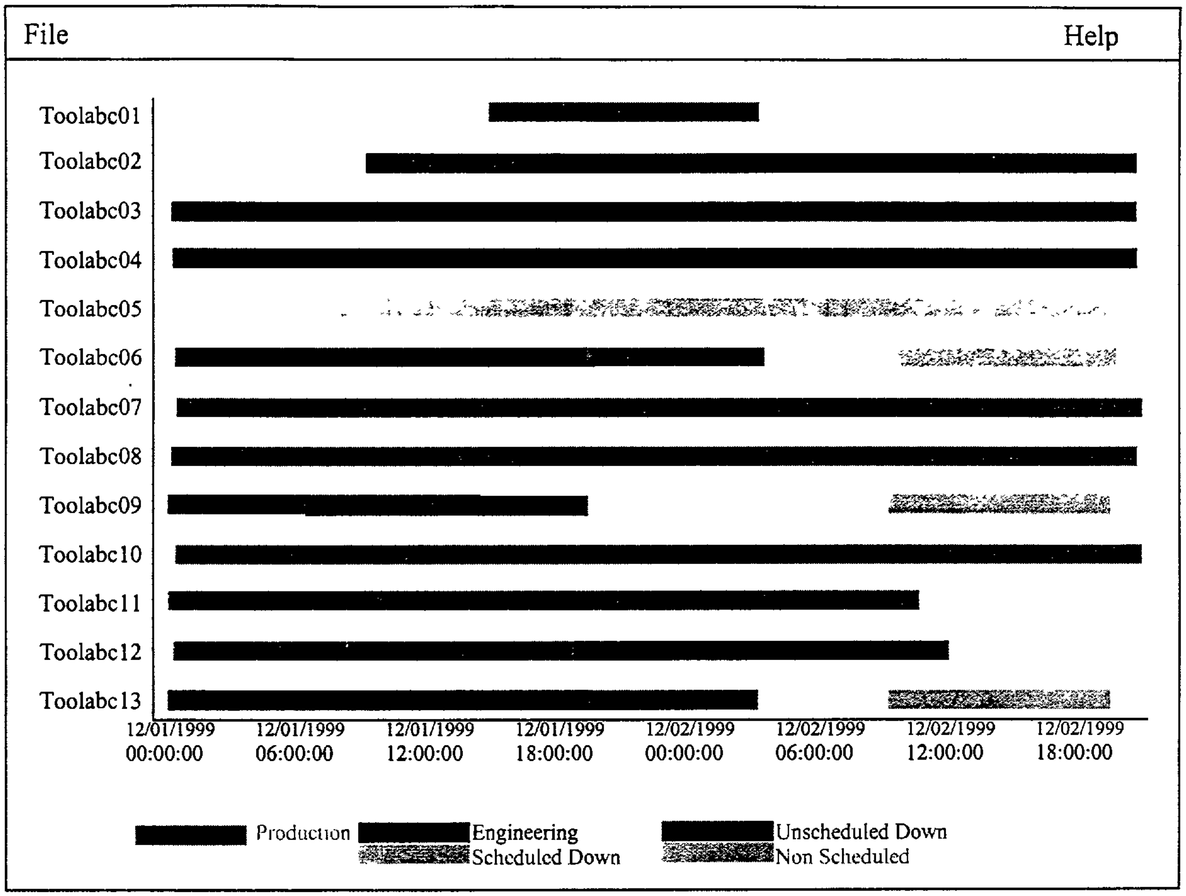


Figure 3.4.2.8a

Left click and drag within the timeline will zoom to the selected date range. The maximum zoom is one minute. A single click in the plot area will zoom out to the maximum size.

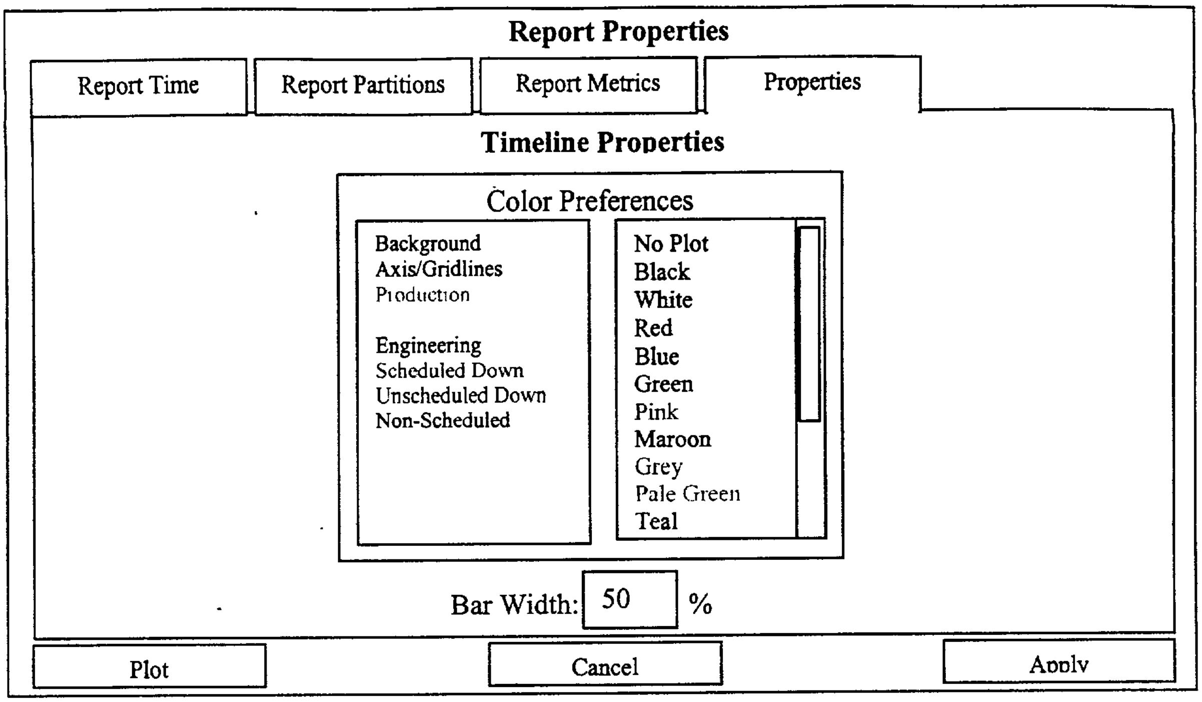


Figure 3.4.2.8b

The users may configure the colors for each of the high level OEE states.

The bar width may be set from 10 to 100%. Changes the "height" bars drawn on the graph. A value of 100% would display a chart where all the bars would touch the bars above and below.

3.4.2.9 Stacked Bar Chart

Similar to time line plot, the stacked bar chart only displays the E10 states based on the E10 color coding. The difference between the time line chart and the stacked bar chart is how the data is summarized. The time line chart shows the states as they occurred in time per tool. The stacked bar chart shows the percentage of time each tool was in the E10 state over the report period

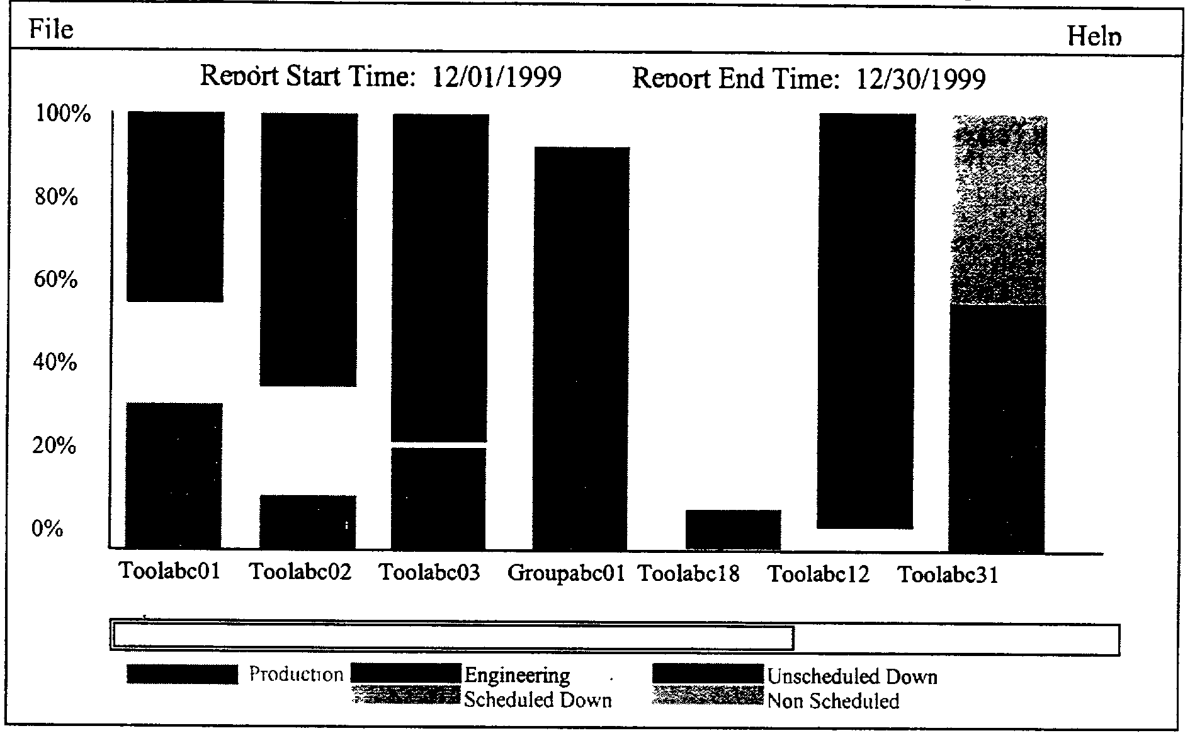


Figure 3.4.2.9a

The stacked bar preferences provide sorting capability. The user may sort by tool name (default) or the magnitude of each one of the E10 states. Example: Sort Descending on Scheduled Down would place the tool with the highest percentage of Scheduled Downtime at the left of the plot.

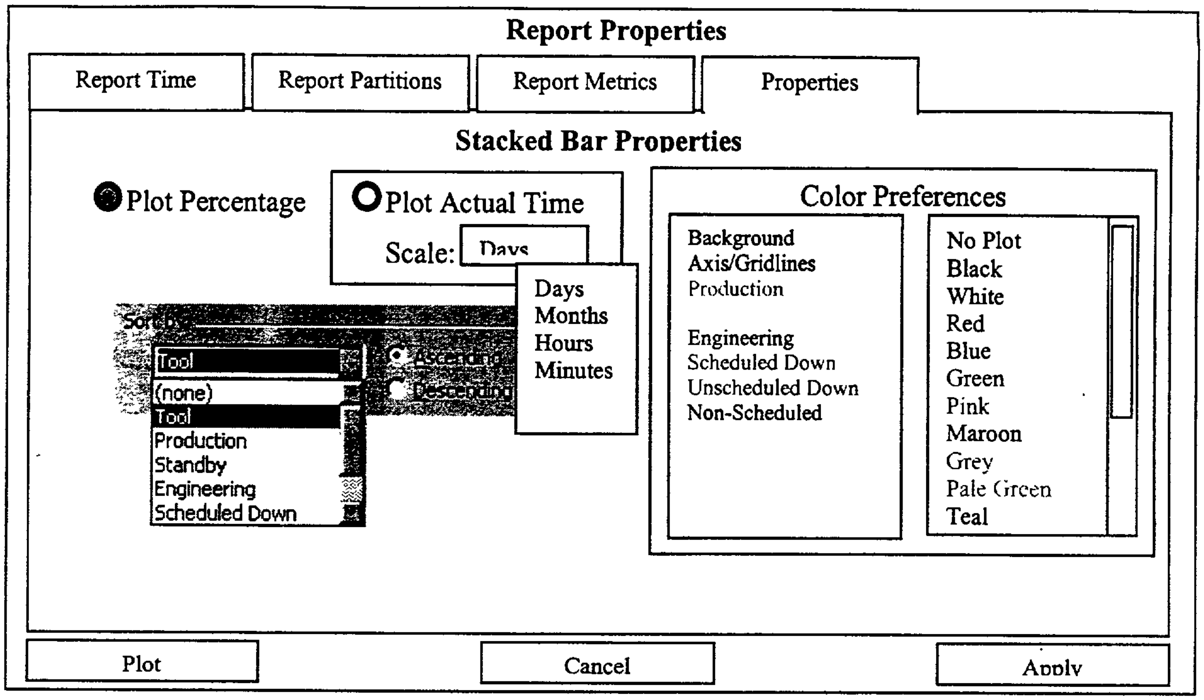


Figure 3.4.2.9b

The user may also change the default color scheme for each of the E10 states.

If the user selects to plot by actual value, the plot will look the same, but the Y axis labels will change. The user may select the time scale to use on the Y axis when in this mode. Otherwise, disable the Scale option.

3.4.2.10 Bar Chart

This plot is useful to see the relative differences between metrics and tools. The user selects a single partition parameter for the X Axis. The example 3.4.2.10 has tools and groups as the X axis partition. The user may then plot any number of metrics for each partition. This example has four custom metrics to show the average number of wafers processed per day by quarter.

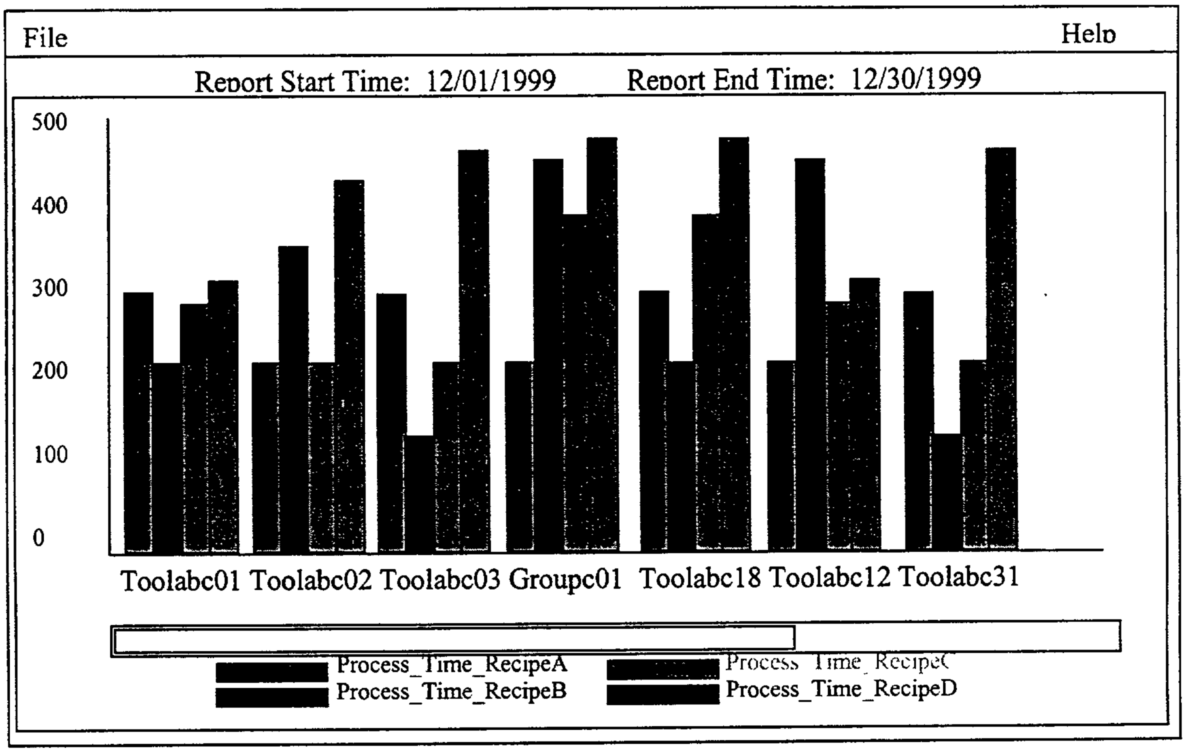


Figure 3.4.2.10a

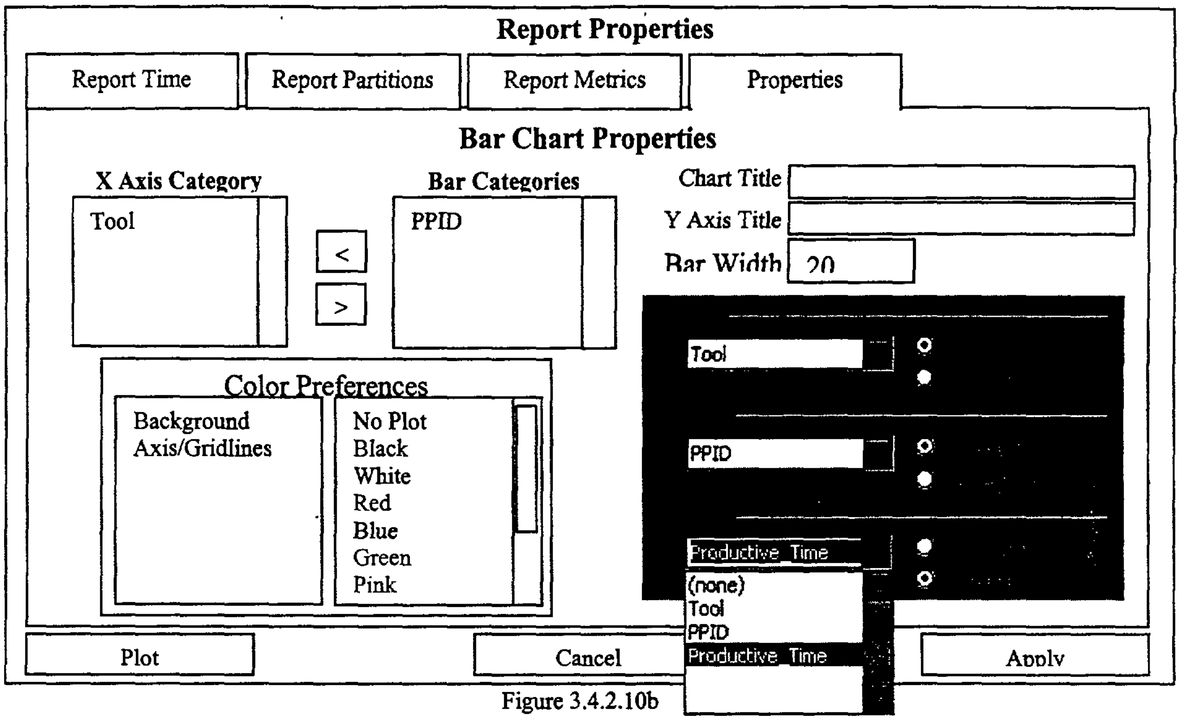


Figure 3.4.2.10b

The Bar Chart Properties allows the users to allocate the partitioning parameters onto the X-axis or the individual bars. All discrete parameters selected in the Report Partition tab are used. The default is to show the tool in the X-axis category and all other selected partitions in the bar categories list. The user may select items in either list and move them to the other scroll list using the arrow buttons. There is no upper limit to the number of parameters in the X axis category or the Bar Categories scroll list. There must be at least one entry in the X axis category list.

The user may label the Chart and the Y Axis and the Chart Title.

Three levels of sorting is supported. The user may sort by any partition parameter or metric that was selected in the Report Partitions tab and the Report Metrics tab.

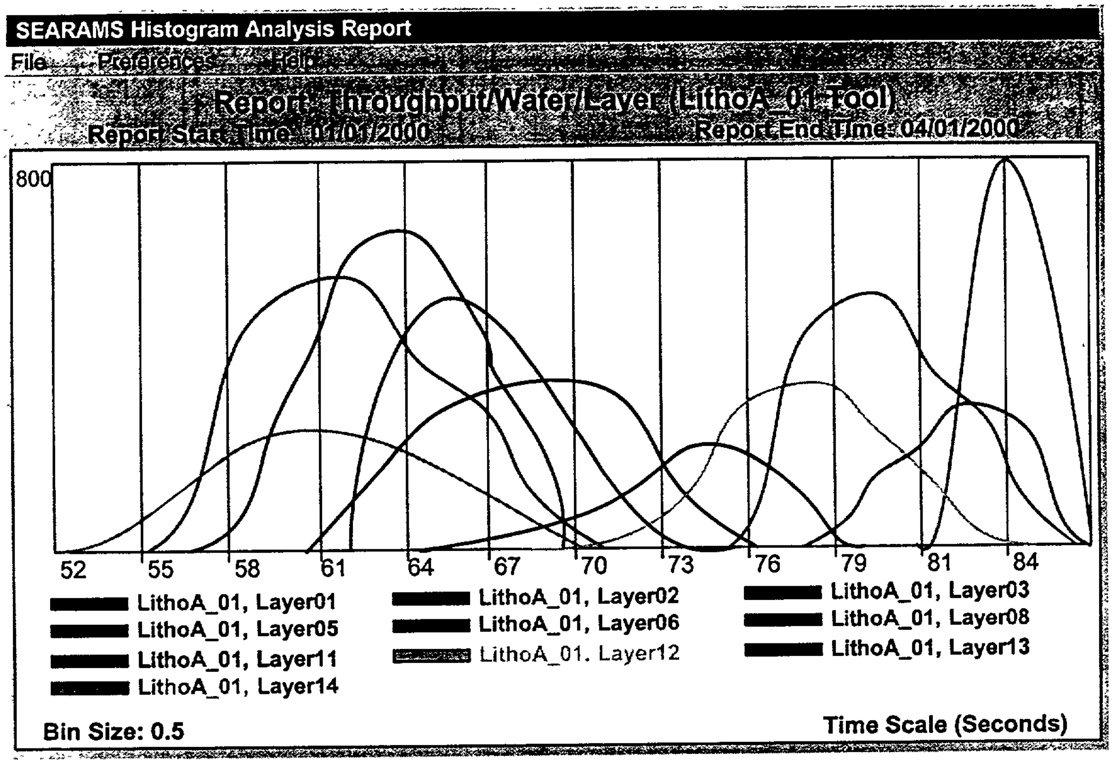
The user may change the color of the background and foreground of the graph.

The width of the bars is configurable by the users. This Bar Width field must be between 5 and 30 units.

The plot will display a bar for each metric/partition combination. The bars will be grouped by the X axis partition and sorted according to either partition name or metric magnitude depending on what the user selected. Sorting occurs from left to right.

3.4.2.11 Histogram Report

The Histogram report shows the distribution of metrics over a give partitioning parameter. The example show in figure 3.4.2.11a displays the distribution of wafers per hour for "RecipeA" on three different tools.



3 .4.2.11a

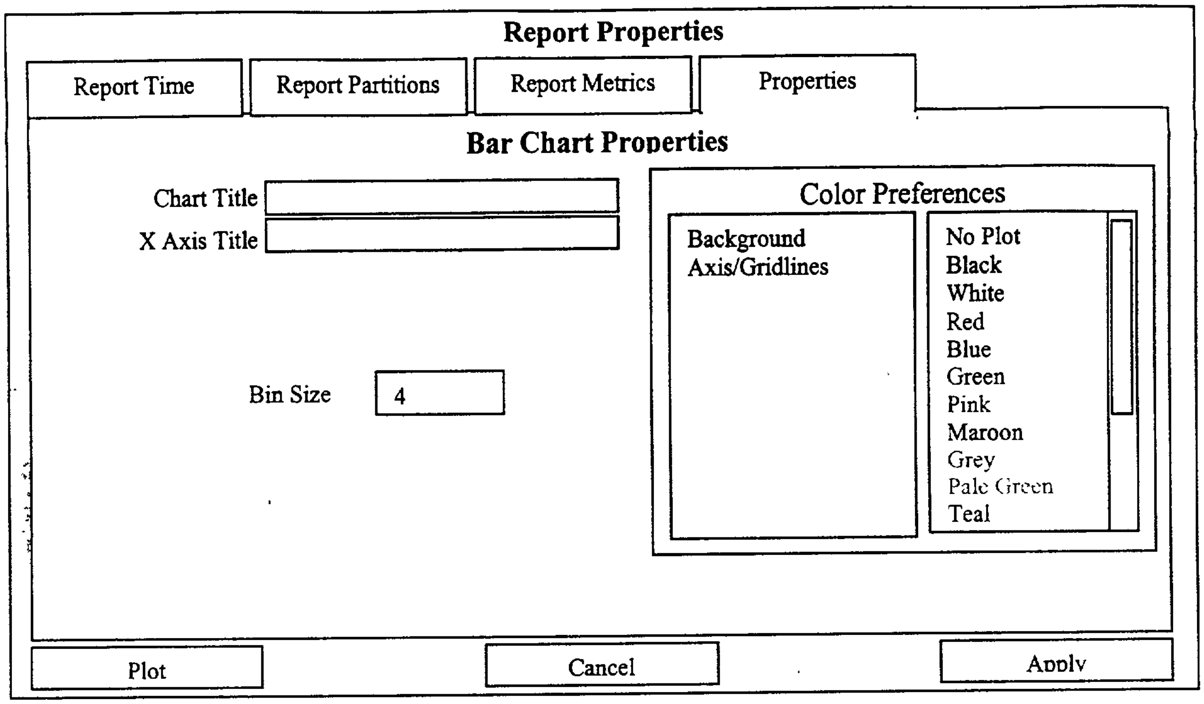


Figure 3.4.2.11b

The user may label the Chart and the X Axis.

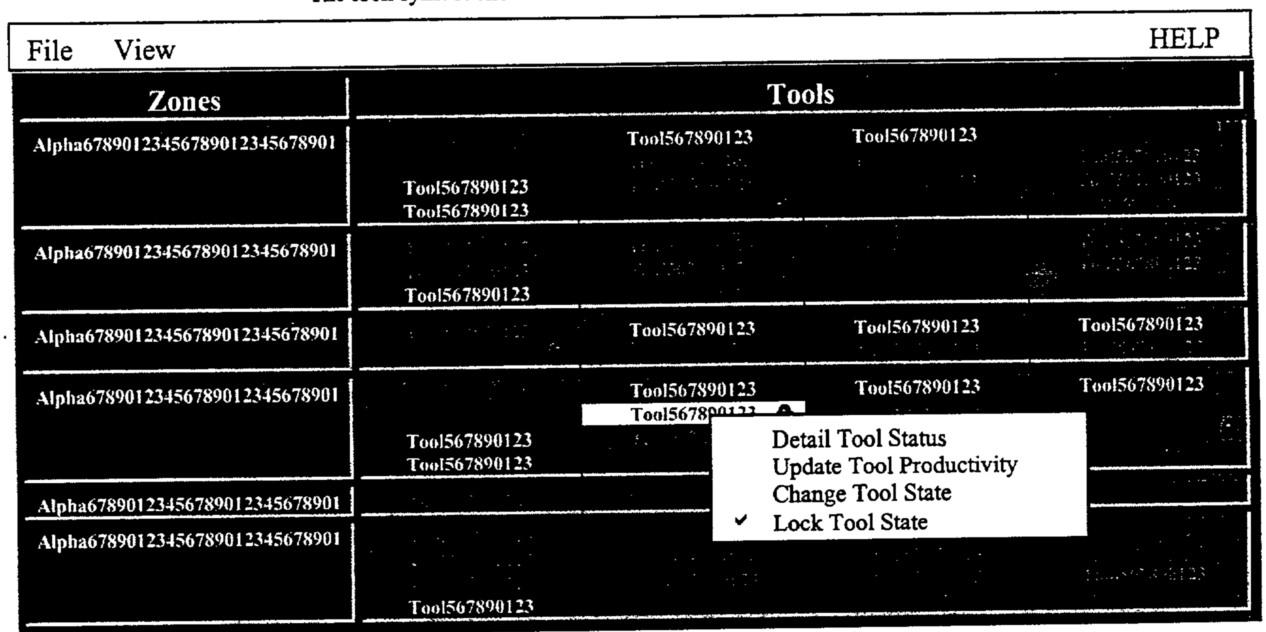
The user may change the color of graph background and foreground.

3.4.3 Live Status Screens

3.4.3.1 Live Factory Status

The status application provides the users with different views of the equipment productivity status. The default screen is a list of all tools defined in the system by zone. The tools are color coordinated to match the 6 primary SEMI E10 states. This screen updates in pseudo real time. Every one minute the states will update based on the latest information.
This is a resizable window with capabilities to reduce to icon and expand to full screen using the windowing widgets in the upper left corner. Scroll bars appear horizontally and vertically when necessary.

🔒 The lock symbol shows the tools that have the automatic transition lock enabled.



3.4.1.4a Example Screen with all tools selected.

File Menu:
Open Tool State Detail: Display a list of all tools. User may select one to open tool specific view figure 3.4.1.4.2a or cancel to return.
Open Zone Status Detail: Displays a recent historical view of the tools in the zone and updates every minute as shown in 3.4.1.4.1a. The user may also double click on the zone name to open the Zone Status Detail.
Print: Prints the currently selected view in color or black and white.
Exit: Close the application. Will leave all tool specific views open.

View Menu
Show/Hide Zones: Shows the zone names next to the tools with delimiter borders around all tools in a zone. The title of the selection will toggle between Show Zones and Hide Zones. If Hide zones is selected, the tool list if alphabetical down the column and provides a best fit for the tools selected in 2 or 4 columns depending on the Show/Hide State menu selection. If 80 tools are selected for viewing, there should be 20 rows. If there are 33 tools, there should be 9 rows.
Select tools: Opens a dialog box allowing the users to select any or all tools to be displayed. Select specific tools is allowed in a multi selection list. Select by zone is also allowed. The current OEE application has a good example in the OEE Statistics selection criteria.

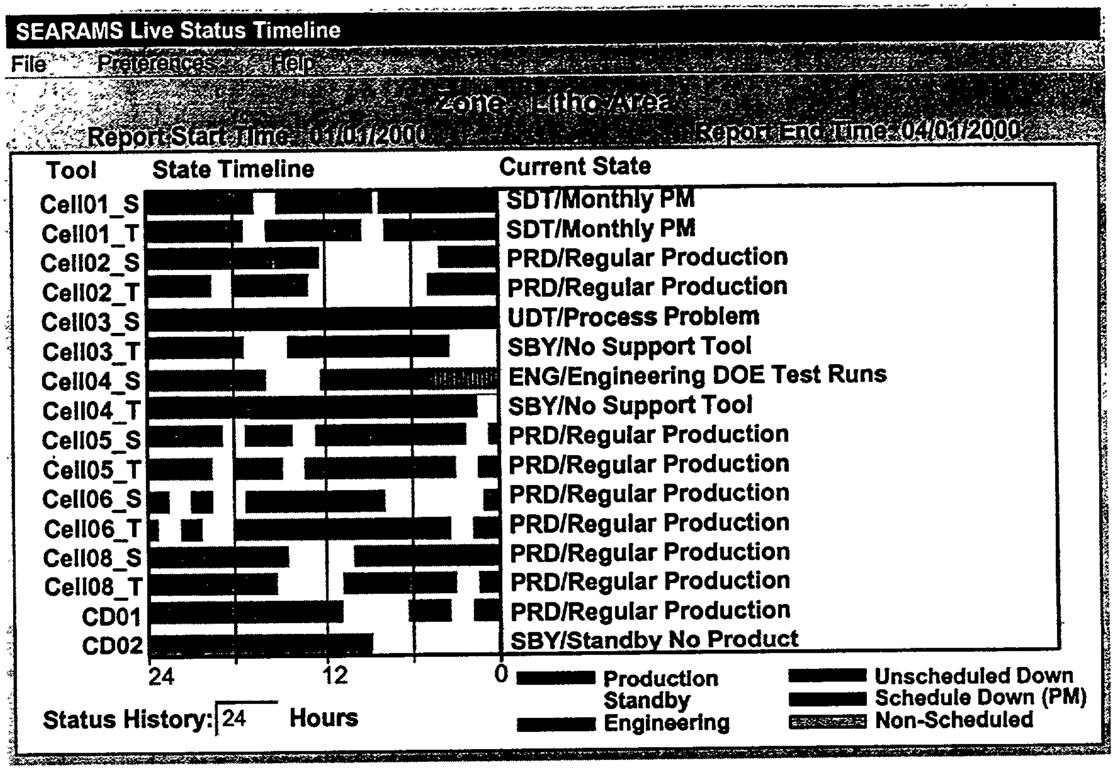
Show/Hide State: The number of columns drops from 4 to 2 when show state is selected. The state name appears next to the tool name. When hide state is selected, the number of columns is four as shown in figure 3.4.1.4a.
Save View as default: Saves the current view selections for the current user. This selection will be used the next time the user opens the status page. Only one preference file is allowed per user. The user may NOT see or edit the names of the preference files.

The user may open a tool specific view by right clicking on a tool name or from the file open menu. The tool specific view displays the SEMI E58 required status information to the users.

Right click on a tool name to veiw the Tool Status popup menu:

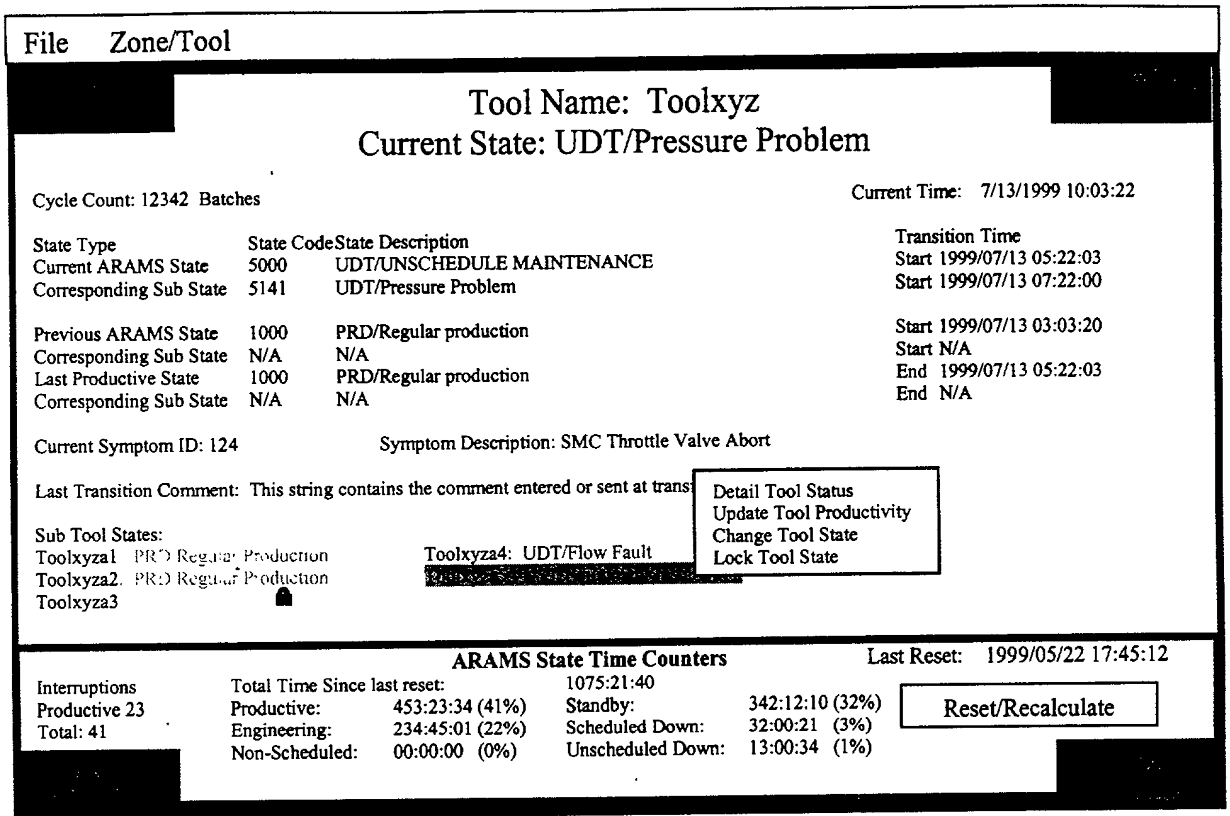
Detail Tool Status:	Opens the Detail Tool status window 3.4.1.4c.
Update Tool Productivity:	Opens the user productivity data screen 3.4.1.5.2a
Change Tool State:	Opens User State Change screen 3.4.1.5.1a
Lock Tool State:	User may lock or unlock the tool state based on App Specific Bit A.

3.4.3.2 Zone Status Detail Screen



3.4.3.2a

3.4.3.3 Tool Status Detail Screen



3 4 1 4 2a

This window is not re-sizeable and is a stand alone application. This is NOT a sub window of the general status screen figure 3.4.1.4a. The application displays the E58 status of one tool at a time. The border is color coordinated to match one of the 6 E10 states based on the current equipment state.

Tool name and state are displayed in a larger font (2 pts larger than the rest of the application) at the top of the screen. This is a pseudo live update screen. The contents update every minute with the latest information.

The current ARAMS state and corresponding sub state display the current equipment state. The ARAMS state is one of the 6 highest, or level one, states. The displayed transition time shows when the tool transitioned to the ARAMS state. The tool may also transition to different sub states with the same ARAMS state. It is likely the transition time for the current sub state is different than the transition time for the ARAMS state.

Previous ARAMS state displays the last high level E10 state prior to the current E10 state. The last sub state the tool was in while in the previous ARAMS state is also displayed.

E58 defines the status of the last productive state be listed as well. If the tool is currently in a productive state (1000 range), then the last productive state and sub state will be N/A.

Display the symptom used to trigger the transition to the current sub state. If the sub state did not have a symptom, display N/A, otherwise display the symptom ID and description.

If a comment was entered at the last transition, display the comment.

If the tool is a main tool, display the sub tool names and current state for each sub tool. Color code the state names to match the SEMI E10 color spec. The user may double click the name of the sub tool to open another instance of the detail status screen for the sub tool of interest. If the tool does not have chambers, auto-shrink the window to remove the extra space.

SEMI E10 defines accumulation procedures for specific state transitions and the time in a state. The 8 counters are displayed at the bottom, displaying the accumulated time and percent of the total time. The reset time displays the last time someone reset the counters. A reset counters button will clear all 8

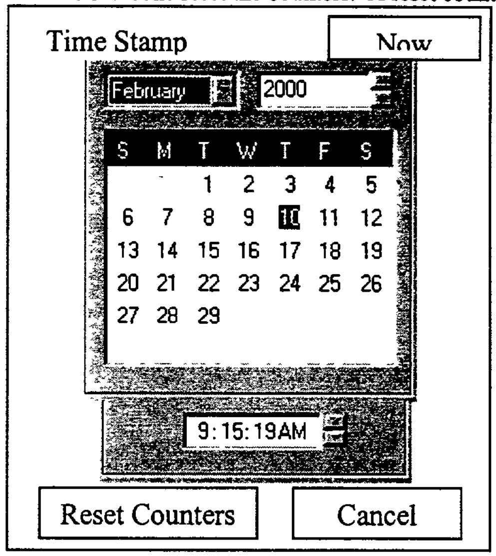


Figure 3.4.1.4d

accumulators and change the reset time stamp to the current time stamp. An application specific bit is required to enable the user to access the reset and recalculate the accumulators button. See SEMI E58 section 11.4 for details of the accumulators. When the user clicks the reset/recalculate button, they are presented with a dialog to reset the accumulator start date, figure 3.4.1.4d.

File Menu:
Print: Prints the currently selected view in color or black and white.
Update Tool Productivity: Opens the user productivity data screen 3.4.1.5.2a
Change Tool State: Opens User State Change screen 3.4.1.5.1a
Lock Tool State: User may lock or unlock the tool state based on App Specific Bit A.
Exit: Close the application. Will leave all other tool specific views open.

Zone/Tool:
Select a new zone/tool for the status detail view. Must be a hierarchical menu and the user must select a tool. Simply selecting a new zone will not provide enough info to redraw the screen.

Right click on a chamber tool name to veiw the Tool Status popup menu:
Detail Tool Status: Switches the Detail Tool status window 3.4.1.4c to the chamber.
Update Tool Productivity: Opens the user productivity data screen 3.4.1.5.2a for the chamber.
Change Tool State: Opens User State Change screen 3.4.1.5.1a for the chamber.
Lock Tool State: User may lock or unlock the chamber tool state based on App Specific Bit A.

3.4.4 Display Audit Trail like history.

Provide capability for filtering by transition type, states, lot ids, recipe names, dates, user defined strings etc..

3.4.5 Warranty Tracking – Future capability may be added to provide Warranty tracking.

3.4.6 Cost of Ownership – Future capability may be added to provide Cost of Ownership reporting.

3.4.7 Automatic Report Generation Wizard

Provide automatic printed or email reports.

The report generation wizard allows the user to select the different reports and set the preferences for each. The periodic time interval and list of email addresses is also configured in this interface.

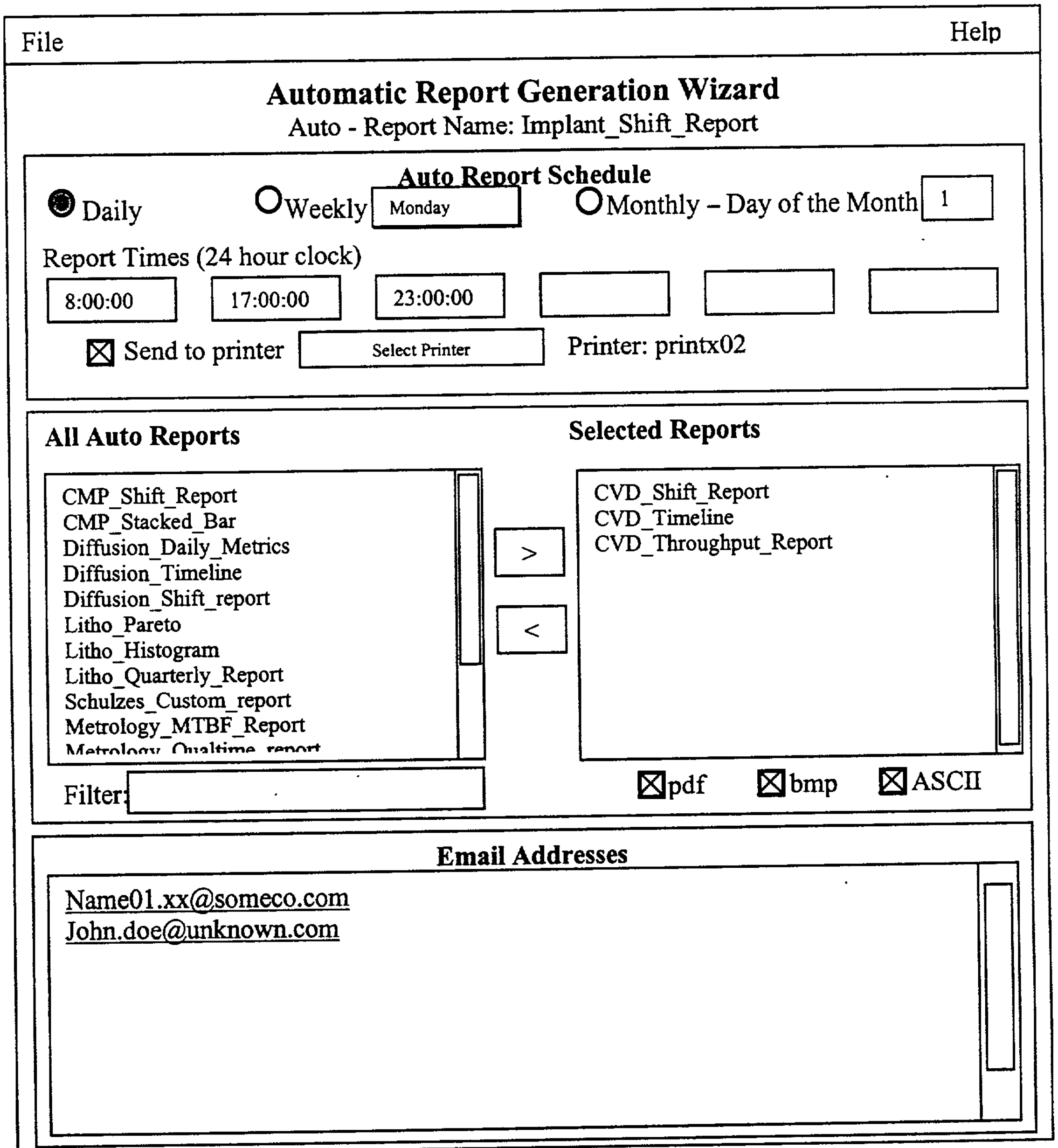


Figure 3.4.7a

The users may create as many auto report files as needed. SEARAMS will run the auto reports based on the user defined criteria.

Menus.
File menu:.
Open Opens a auto report file selection list dialog. Prompt the user to save before opening a new auto report if changes have been made.
Save Allows the users to save this auto report fil. The first time they save, they should assign a file name.
Save As Allows the users to another name.
Print Prints the current auto report set up information.
Exit Prompts the user to save the report file if needed. Exits the application.

Auto Report Schedule
The auto report may be configured to print daily, weekly or monthly. The user may select which days of the week ort month to generate the auto reports.
The user may configure up to 12 report times per file. The time is based on the 24 clock.
The user may want a hardcopy of the reports printed automatically. The "Send to Printer" check box will enable the select printer button. The user can select one destination printer.

Select Reports
The user may check which reports to generate. Once a report type is selected, the preferences button will be enabled. The user may select the preferences for the report type. Most reports have two preference files, one to select the tools and calculations, and one to select the output attributes such as color. The user may set both types of preferences for each report and save this information in the auto report. The
Email Addresses
The users may input email addresses. Each email address will receive an message containing an enclosure file of the specified type.

3.3 Physical Requirements

There are no physical requirements.

3.4 Performance Requirements

SEARAMS must support 2000 configured tools or chambers per server. The system must continue to function normally while running 50 SEARAMS reports simultaneously.

3.5 Software Defect Resolutions

SEARAMS is a new application.

3.6 Human Engineering Requirements

3.7 Expansion Requirements

No special hardware requirements are needed for future expansion.

3.8 Documentation Requirements

The documents listed in Table 3.9-1 shall be prepared and made available on or before the specified delivery dates.

Document	Delivery
Initial Requirements Specification Development Plan Design Documents Test Plan User Documentation	

Table 3.9-1 Document Deliverables

3.9 Training Requirements

There are no training requirements. A user's guide outlining the functions of the system shall substitute for training.

3.10 System Verification and Validation

The application shall be validated in a System Test conducted at SEMY Engineering. The System Test shall verify system requirements and will be specified in the Test Plan. The Test Plan shall be prepared by the Engineering Department and be 10 days prior to Final Test.

The Test Plan shall include functional tests and will be specified in the Test Plan and Procedures.

Glossary of Terms

The following terms are used within this document, and are defined as:

ComCore The set of common libraries and servers the define the base of the Semy Supervisor products (ESW and FSW).
Equipment The user defined name of a selected process equipment. The equipment must be connect to a Semy ESW to be available as a tool.
ESW Semy Equipment Supervisor Workstation.
GUI Graphical user interface
system a collection of components organized to accomplish a specific function or set of functions.
Tool The user defined name of a selected process equipment. The equipment must be connect to a Semy ESW to be available as a tool.
Validation Validation is defined as the process of evaluating a system or component during or at the end of the development process to determine whether it satisfies specified requirements.
Verification Verification is defined as the process of evaluating a system or component to determine whether the products of a given development phase satisfy the conditions imposed at the start of that phase.