Power Boiler Tutor (PBT) simulates boiler operation

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At most pulp and paper mills, the steam required for many operations is generated in hog fuel or coal-fired boilers. Operator training plays a key role in achieving safe and efficient operation of these boilers.

A computer-based training program called the Recovery Boiler Tutor (RBT) was developed for the American Paper Institute, Inc. by the J.H. Jansen Co., Inc.[1] This program for recovery boiler operators has been instituted in over 70 mills in its original and updated forms. The updated version is a Microsoft Windows-based program that allows interactive graphics to be used.[2] The demand for RBT has led to the development of the Power Boiler Tutor (PBT), which simulates normal operation, startup, shutdown, and common problems encountered during boiler operation.

A benefit of a simulator such as PBT is that it exposes novice operators to boiler operations before they are put in control of actual boilers. Also, PBT can help experienced operators refine their skills. This approach also avoids the production losses and risks involved when operators are trained on actual mill boilers.

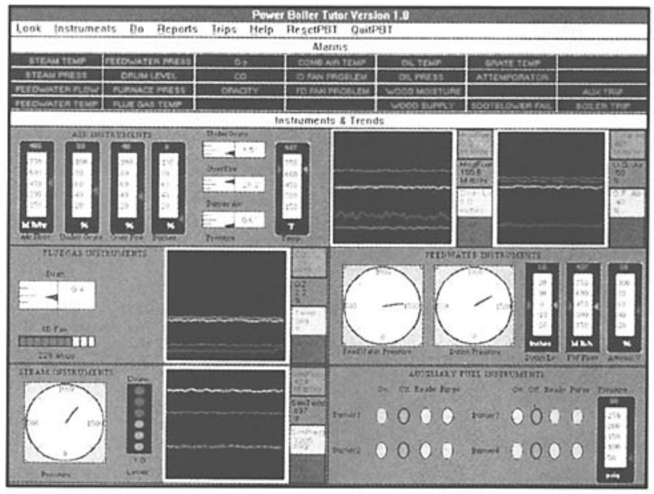
Basics of PBT

PBT relies heavily on computer modeling and high-resolution graphic displays to simulate power boiler operation. Problems can either be user-selected, or selected randomly by the computer. PBT has a tutoring function to provide on-line help in solving problems.

The operator interacts with PBT by changing several normal operating parameters (i.e., the flow of fuel, combustion air, and feedwater) and requesting the tutor to take corrective action for several types of problems. A simulation module that determines the output parameters for the current boiler conditions displays typical outputs on a schematic of a control panel. **Figure 1** shows a typical display screen.

The PBT is designed to run on an 80386-based computer. These machines provide high performance at a relatively low cost and include large, high-resolution monitors that display all of the control panel functions.

1. Main PBT operating screen



Simulation of operating conditions

PBT is based on a mass and energy balance model for the boiler, according to the American Society of Mechanical Engineers (ASME) Power Test Code.[3] The input streams to the boiler are the solid fuel (wood or coal), auxiliary fuel, combustion air, and feedwater. The output streams are flue gas, ash, steam, and a small amount of radiated heat.

The fuel components are specified in terms of an elemental composition and moisture content. Based on the combustion conditions in the boiler, these elements are apportioned according to the appropriate output compounds and streams. At substoichiometric amounts of combustion air, the model generates carbon monoxide (CO) from the fuel carbon, with a corresponding decrease in thermal efficiency. The losses from the stack due to the sensible heat in the flue gases, water evaporated in the boiler, unburned fuel, and radiation losses are also taken into account when calculating thermal efficiency.

The amount of steam generation is based on the heat input to the boiler and the boiler's thermal efficiency. The enthalpy and pressure of the superheated steam are known, which fixes the steam temperature.

The time dependent behavior is simulated by changing the

[1]Jansen, J. H., Verloop, A., and Blegen, D., "Recovery Boiler Tutor (RBT): an interactive simulation and training aid," Kraft Recovery Operations Seminar, Orlando, FL, 1989.

[2]Strandell, O., "The Recovery Boiler Tutor, Version 2 (RBT2)," Kraft Recovery Operations Seminar, Helsinki, Finland, 1990.

[3]AMSE Test Form for Abbreviated Efficiency Test, PTC 4.1, 1964.

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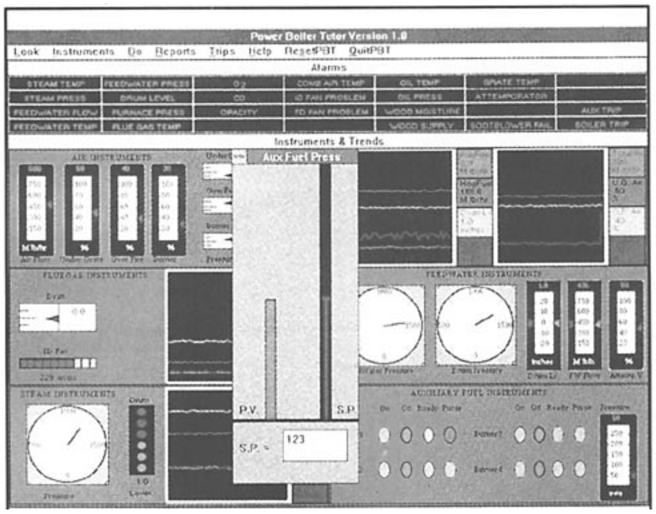
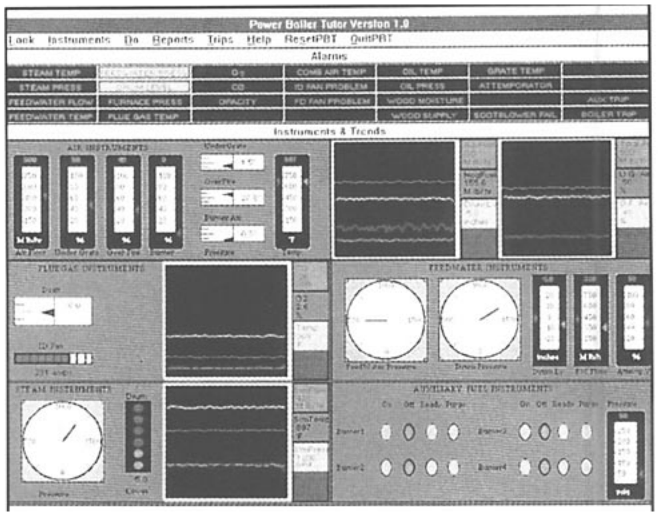
2. Fuel setpoint controller displayed on main screen



3. Low drum level indicators



model inputs to generate the new output parameters.

Operation

PBT is based on Microsoft Windows 3.0, which is the most widely used graphics interface for personal computers. Windowing allows the various layers or levels to be simultaneously displayed on the screen. This system is popular because the required computer operations can be learned quickly. A person who is not familiar with computers can typically learn to use PBT in about 30 min.

The user interacts with the PBT program with an easy-to-use mouse, which eliminates the need to memorize and type long commands. For example, air or fuel flows can be changed with a few clicks of the mouse button. This interface does not put a barrier between the user and the program.

Program contents

To simulate the mill environment, the PBT provides graphical displays of the grate area, smoke stack, and wood feed system. The boiler control panel displays instrumentation for all input and output streams including combustion air, flue gas, steam and feedwater, drum level, auxiliary fuel, and hog fuel (or coal). Trend chart displays are provided for airflows, undergrate and overfire air splits, flue gas components (excess oxygen, CO, pollutant species), flue gas temperatures, steam flow and temperature, and feedwater flow rates.

The program provides a "do list" of actions (i.e., calibrating instruments, checking burners) that the operator can perform to solve common problems. Remedial actions such as boiler trips and auxiliary fuel trips can be performed from a separate menu. PBT also can give the operator access to several reports, including the design boiler inputs and outputs and a fuel analysis.

Customizing PBT

The PBT's usefulness is enhanced if the boiler operation parameters generated by the simulation agree with the actual parameters. To do this, the model uses design and operating data obtained from a mill questionnaire as input parameters. This establishes all flows, temperatures, and pressures for normal operation, and the PBT model calculates new values as the boiler is operated at other conditions.

Modes of operation

PBT has five modes of operation: normal, select problem, problem solver, startup, and shutdown. In the normal mode, the PBT operator can explore the effect of changing several process streams on boiler operation.

The select problem mode allows the user to initiate one of about 20 built-in problems, including boiler tube leaks, loss of power, problems with hog fuel supply, and problems with drum level control.

In the problem solver mode, the computer makes a random selection from the list. This requires the operator to watch the instrument control panel in order to determine the proper solution to the problem.

The startup mode requires the user to start up the boiler from scratch. Items such as opening vents and starting fans are chosen from a list of required operations.

The shutdown mode requires the user to take the boiler off-line in an orderly fashion. The supply of hog fuel and auxiliary fuel to the boiler must be shut off and all auxiliary equipment shut down.

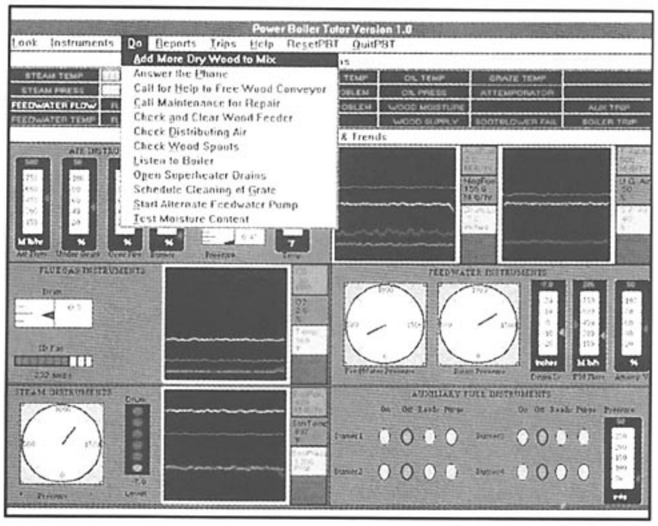
Help functions

The utility of PBT as a training aid is enhanced by an on-line help function. In the problem solving modes, the tutor makes suggestions for remedial action if the user is too slow in taking the proper corrective action. The user can also ask the PBT for help in specific problem situations. Once a problem has been solved, the tutor provides the operator with an analysis of the problem.

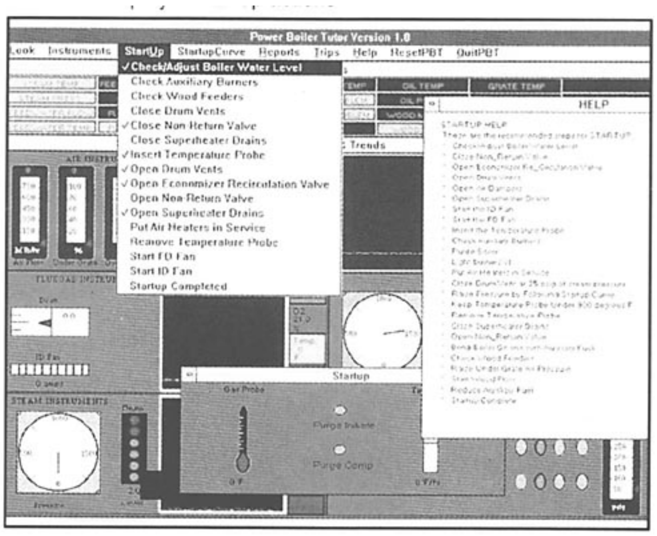
Examples of PBT operation

The use of PBT is illustrated by three examples: an increase in steam demand under normal operating conditions, failure of a feedwater pump, and startup of a cold boiler. These examples

4. "Do list" of problem-solving actions



5. Screen display of startup actions



demonstrate how PBT can be used to train new operators and hone the skills of experienced ones.

Change in steam demand under normal operation

In this example, another batch digester has come on-line and the boiler operator is asked for more steam. Since the boiler is being operated with no auxiliary fuel, the decision is to light an auxiliary burner.

The operator proceeds through the steps of opening a damper for the burner air, and then purging and lighting the burner. Each step is displayed on the operator's screen.

After the burner has been lit, the oil pressure can be increased by using the auxiliary fuel controller, as shown in **Fig. 2**. The controller is changed to increase the oil pressure to 123 psig.

Lighting up the burner causes the excess O_2 levels to decrease, with a concurrent increase in the CO and opacity levels. The amount of combustion air is increased to bring the excess O_2 level to 2% and the boiler is returned to a new operating level. A check of the trending instruments shows that steam flow has increased, along with an increase in the auxiliary oil flow and combustion airflow rates.

Failure of feedwater pump

This example shows how a problem is selected from the list and then solved. In the select scenario mode, PBT displays a list of problem scenarios on the screen. The operator selects the Failure of Feedwater Pump scenario and PBT develops the problem.

On the main operating screen display, the number of green balls on the drum level indicator, the drum level trend line, and the illumination of drum level and feedwater alarms indicate a falling drum level. (See **Fig. 3**.)

The first response is to select the feedwater controller and manually increase the feedwater flow, but as the drum level continues to drop it becomes apparent that opening the feedwater valve will not solve the problem. The message "Have you noticed that the drum level is still falling?" pops up on the screen. The boiler has not yet tripped out due to the low drum level, but the situation has begun to get more serious. In response, the list of action items is displayed by selecting the "Do list" menu (**Fig. 4**). If the action "Start alternate feedwater pump" is selected, then the message "Now you are back on track" will be displayed. The trend lines will show the feedwater increasing to the desired level, and the drum level increasing back to the normal level. When all parameters have returned to normal levels, PBT automatically ends the scenario by displaying an analysis of the problem and the actions taken. The problem is listed at the top of the screen followed by the recommended actions and a critique of the actions taken. The correct actions are listed in black text; any omitted actions are displayed in red type as a reminder to the user.

Startup

The startup mode objective is to familiarize the trainee with bringing a cold boiler on-line. In startup mode, PBT displays the main operating screen, which now includes a menu of startup items (**Fig. 5**). These items are intended to be representative of all boilers and may not include some mill-specific requirements.

The items are listed in alphabetical order, and the actions must be selected in the proper order to progress with the startup. If required, help for startup can be obtained by selecting "startup" under the help menu. (See Fig. 5.) This will display the correct sequence of steps required to bring the boiler on-line.

Selecting the items on the list will accomplish most of the simulated startup actions that must be taken on an actual boiler, such as opening or closing steam drum vents. With some items, the user must determine parameters. For example, purging the boiler requires that the user set the desired airflow to 30% of normal airflow, which will initiate the purge cycle.

Auxiliary burners can be lit once the preliminary steps have been completed. The startup, including measurements of flue gas and steam temperatures, can be monitored with the startup instruments.

The steam drum pressure is trended for comparison to the recommended startup curve (**Fig. 6**). Under ideal conditions, the boiler would be brought on-line in accordance with the startup curve.

When the boiler reaches the normal operating pressure, the operator opens the nonreturn valve and steam begins to flow from the boiler. The gas temperature probe can be removed and wood flow initiated to the boiler. Hog fuel will be used to raise steam flow to the desired level. The auxiliary fuel burners can be taken out once the boiler operation has been stabilized with wood firing.

Summary

A simulation of power boiler operation that allows a user to easily interact with the program produces a powerful training tool for operators. A similar training tool for recovery boiler operators has been very well accepted by the pulp and paper industry. A computer-based training aid has been shown to be more efficient than traditional study sessions using a manual. □

6. Screen display of startup curve