# Picles™ - A Simulator for "Virtual World" Education and Training in Process Dynamics and Control

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Practice in applying textbook theory is motivating, promotes critical thinking, facilitates understanding of the use and limitations of the theory, and helps prepare students for the challenges of the professional world. For process dynamics and control, Picles™, the Process Identification and Control Loop Explorer System, is a cost effective way to provide this practice.

Picles is PC/DOS compatible software now being used in process dynamics and control courses around the world for the education of students and training of practitioners. Picles is easy-to-use, visually appealing and provides the capability to explore a wide range of process dynamics and control concepts. Thus, students can quickly and inexpensively gain experience which benefits their education.

Picles contains a series of case studies, animated in color-graphic display, for self-paced or instructor guided learning. Users can manipulate process variables in open loop to obtain pulse, step, sinusoidal or ramped test data. The data can be recorded as printer plots or disk files for process identification and controller design. Digest™, companion software to Picles, is one package well suited for this identification and design task. After designing a controller, students then return to Picles and immediately evaluate and improve upon the design for both set point tracking and disturbance rejection.

The processes and controllers available in Picles enable the exploration and study of increasingly challenging concepts in an orderly fashion. Early concepts to explore include the basics of process dynamic behavior such as process gain, time constant and dead time. Intermediate concepts include the tuning and performance capabilities of all modes of the PID controller. Advanced concepts include cascade, decoupling, feed forward, dead time compensation and digital control.

After a review of Picles processes and controllers, brief summaries of two case studies are presented which illustrate how Picles can be used to obtain virtual world experience in the theoretical concepts of process dynamics and control. To obtain a copy of the software and a host of basic, intermediate and advanced case studies, please contact the author.

## The Picles Processes

The Picles processes and data trends are animated on the screen in color-graphic display to facilitate an illusion of real world process operation. The processes available for study are reasonably straightforward to conceptualize so students can readily understand the dynamic behavior of the process and thus grasp the control challenge at hand. The current list of Picles processes include:

***One-Input One-Output Case Studies;***

Gravity Drained Tanks, Heat Exchanger, Pumped Tank, Mystery Processes

***Ideal Transfer Function Case Study***:

Design a Process

***Multiple Steady State Case Study:***
Jacketed Reactor Process

***Two-Input One-Output Cascade Case Study:***
Jacketed Reactor Process

***Two-Input Two-Output Multivariable Case Study:***
Distillation Column Process

**The Picles Controllers**

The Picles control algorithms can be implemented and custom tuned in only a few key strokes. The PID controllers can be implemented in any combination of P-Only through full PID. The digital controller permits study of discrete time algorithms such as the deadbeat and Dahlin algorithm:

Manual Control
Velocity PID Control with Derivative on Measurement
Velocity PID Control with Derivative on Error
Position PID Control (no windup protection)
Velocity PID with Smith Predictor
Velocity PID with Feed Forward
Velocity PID with Decouples
Velocity PID Cascade
Digital Sampled Data Controller

**Case Study 1: P-Only Control and Offset**

Proportional (P-Only) control is easy to implement because there is only one tuning parameter. The price for this simplicity is offset, which arises when the set point is moved away from the nominal operating point associated with the controller bias or null value. P-Only control is explored in this case study using the Gravity Drained Tanks process, shown in Fig 1.

As shown, the Gravity Drained Tanks process consists of two non-interacting gravity drained tanks in series. The manipulated variable is the flow rate of liquid entering the top tank. The measured variable is liquid level in the lower tank. The disturbance variable is a secondary flow out of the lower tank due to a positive displacement pump. Thus, the disturbance flow is independent of liquid level except when the tank is empty. This process is modestly nonlinear because the drain rate from each tank is proportional to the square root of the hydrostatic head (liquid level in the tank).

Figure 1 shows the Gravity Drained Tanks under P-Only control. The lower strip chart shows two set point square waves as a solid line and the measured level in the lower tank tracking the set point as a dotted line. Random error is added to the measured variable to simulate measurement noise. The bold arrow between the set point square waves marks where the gain of the P-Only controller is increased by a factor of five. The upper strip chart shows the controller signals to the inlet flow rate valve regulating flow into the first tank.

As shown in lower strip chart of Fig. 1, the set point is initially at 49 cm. The measured variable shows zero offset at this initial set point because 49 cm was the design level of operation used to determine the controller bias. At the first set point step, the measured level responds rather weakly as the controller attempts to track the change. The result of this weak control effort is the large offset shown in Fig. 1 after the first set point step.

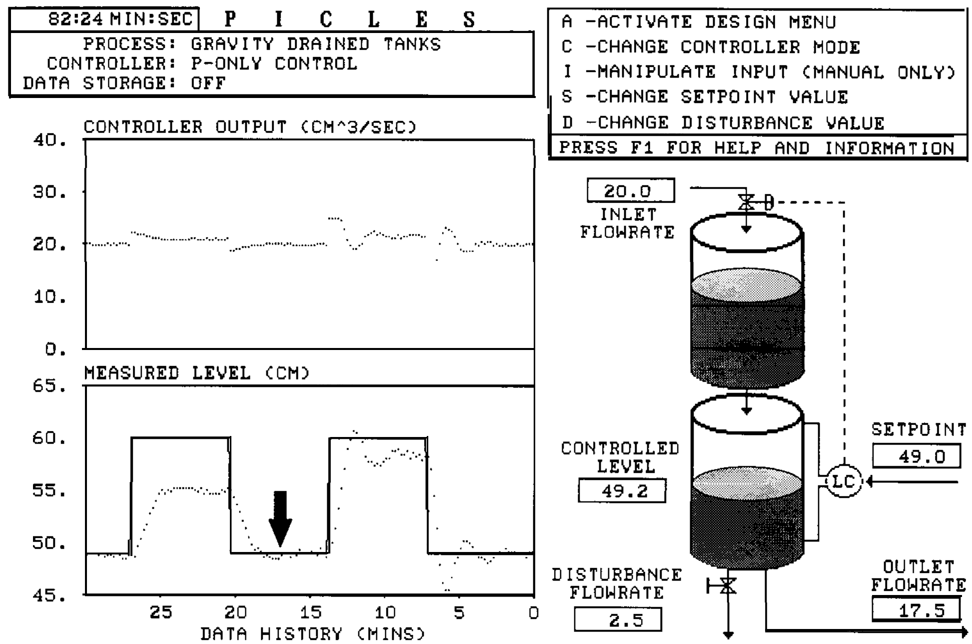


*Figure 1 - Gravity Drained Tanks under P-Only Control with controller gain increase occurring at arrow.*

The set point is then returned to the initial value of 49 cm and controller gain is dramatically increased as indicated by the bold arrow in Fig. 1. The performance of the P-Only controller is shown as it tracks the second set point steps. Although offset still persists, the change in set point tracking performance is apparent. Specifically, for a P-Only controller, an increase in controller gain decreases offset and increases the oscillatory nature of the response.

As this case study illustrates, text book ideas become hands-on experiences with Picles. And these real world experiences increase understanding and expand appreciation for the subject of process dynamics and control.

**Case Study 2: Controller Performance and Nonlinear Processes**

Fig. 2 shows the Heat Exchanger process under PI control (the derivative time has been set to zero using the Picles controller design menu). The Heat Exchanger process is a counter-current lube oil cooler. The manipulated variable is the cooling liquid flow rate on the shell side. The measured variable is lube oil temperature exiting the exchanger on the tube side. This nonlinear process has a negative steady state process gain. That is, as the manipulated cooling flow rate increases, the measured exit temperature decreases. Also for this processes, load disturbances produce an inverse (also called nonminimum phase) open loop response in the measured exit temperature.

The lower strip chart in Fig. 2 shows two increasing set point steps as a solid line and the measured exit temperature tracking the set point as a dotted line. The upper strip chart in Fig. 2 shows the controller signals to the valve regulating cooling flow rate on the shell side of the exchanger.

Controller tuning is fixed throughout this case study. In spite of this, controller performance is shown to vary significantly as the set point changes move this nonlinear process across operating regimes. Hence, this case study provides hands-on experience with the implications of controlling a process with a nonlinear character. One important real world lesson from this case study is that the tuning of linear controllers such as PID can be very specific to operating regime.

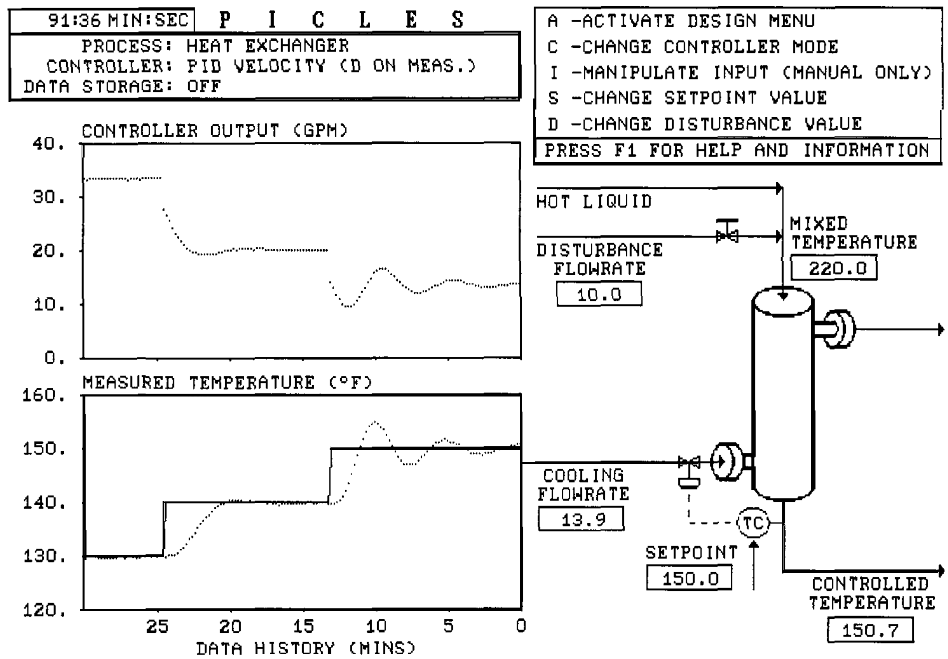


*Figure 2- Heat Exchanger under PI Control shows that control performance changes with operating regime for nonlinear processes.*

**Final Notes**

There are literally hundreds of case studies possible with the Picles processes and controllers. A very large portion of the topics discussed in the popular texts can be explored in a hands-on manner using Picles. Picles and Digest cost less then $150 per year when used for teaching undergraduate and graduate students who are receiving regular course credits. For more information about the software and available teaching materials, please contact:


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