Robert A. Mollenkamp

Introduction to AUTOMATIC PROCESS CONTROL

IRP *Instructional Resource Package*

STUDENT TEXT

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INSTRUMENT SOCIETY OF AMERICA

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PREFACE

I hope that this study will be only a small part of your training and experience in process control, a rapidly changing field due to recent advances in computer technology. Our current bottleneck in performing many worthwhile and profitable industrial projects is simply a lack of trained people at all levels. I hope that your studies provide you with the same challenges and enjoyment that I continue to find in each day of my work.

I would welcome any questions or comments that you might have about this textbook and your experiences in applying the ideas you have studied. I encourage you to write to me at:

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June 9, 1983

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SECTION 1

INTRODUCTION TO THE STUDENT

1-1 COURSE CONTENTS

The purpose of this course is to demonstrate the fundamental engineering methods of designing and improving process control systems at the first level of control. The method used is to avoid as much as possible the highly mathematical approach used in most formal textbooks. The emphasis is on a rather practical, application-oriented approach, although some would argue that any course that doesn't use a screwdriver, an ohmmeter, or a wrench is too theoretical.

The subject coverage of the text includes a wide range of topics including:

- The objectives of process control
- Process dynamics
- The feedback controller
- Cascade, ratio, and feedforward control
- Interacting control systems

Little time is spent on the extremely important subjects of measurement techniques, control valve characteristics and selection, or the electronic or pneumatic hardware for signal transmission and calculation in the control system. These topics are covered in detail by other *Instructional Resource Packages*.

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1-2 COURSE OBJECTIVES AND AUDIENCE

The primary objectives in this text are to examine the characteristics of various industrial processes and to see how these characteristics influence or determine the choice of the control strategy. Although some of the material does require some mathematics that is normally in the realm of the engineer, others (technicians, sales personnel, managers, etc.) may find that perhaps eighty percent of the material is not only understandable but also informative and useful. However, the text is designed primarily for use by those engineers and technicians actively engaged in design or operation of process control systems.

The style of this text is at best informal, but it is the author's sincere belief that technical education does not have to be a dreary experience. Those who feel that true education at higher levels must include some suffering may wish to skip many of the parenthetical comments throughout the text.

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SECTION 2

THE PROCESS CONTROL SYSTEM

2-1 PROCESS CONTROL OBJECTIVES

What is the meaning of "process control"? Among the several explanations are:

- Keeping industrial processes at their most efficient operating points
- Preventing runaway conditions in the process that might endanger people or equipment
- Displaying information for plant operators so they can keep the process running safely and efficiently.

Process control is all of these things and more. One could go on and on trying to come up with one short definition of process control but would probably not be very successful. The reason is that process control is concerned with many aspects of plant design and operation. Control specialists are concerned with the instrumentation or hardware for measurement and control, design techniques for control systems, basic strategies of control, digital data communications, digital computations, computer programming, maintenance of control systems, and so on.

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The overall objectives of process control systems depend on one's position in a company. The plant manager is most interested in "the bottom line", i.e., profit and cost, as well as more intangible items such as company image. The production superintendent is most concerned with meeting production schedules and maintaining a competent work force. The head of the engineering design group wants to efficiently produce process designs that are cost effective and require a minimum of field modification. The process engineer would like to find ways to improve the productivity of the process equipment. The plant operator likes a process that is understandable and "stable as a rock". The instrument mechanic would like instrumentation that is reliable and easy to service. All of these objectives are dependent upon process control systems.

The organization in most companies resembles a pyramid with many levels — each with its own responsibilities and concerns. A pyramid of process control objectives could be developed that would be quite similar to the company organization chart. In fact, this is one of the objectives of some rather advanced distributed control concepts.

At each level the process control concerns can be classified into four different categories of control:

- Feedback regulation
- Feedback improvement or stabilization
- Control of events
- Optimization of operations

The first of these categories deals with the control of some variable, either measured or calculated, at a set point. The second is designed to improve the operation of basic feedback control using techniques such as feedforward, cascade, ratio, multivariable decoupling, and adaptive control. The third type of control includes the handling of emergency situations, startup, shutdown, and batch process sequencing. Optimization calculates the plant operating conditions that will result in the highest profit, lowest cost, or minimum energy consumption, as just a few examples, and takes into account the limitations and operating constraints for the plant.

Of these four categories of control the primary interest here is in the first two — feedback regulation and feedback improvement. While these topics are of importance at all levels of the company pyramid, their design, application, and operation occur at the first level of process control. Therefore, examples will be presented of control of temperatures, pressures, flow rates, chemical composition, and so on.

At the first level of control there are many variables that might require control. Although it is not possible to list all the variables used in the thousands of industrial processes, the controlled variables can be classified into five categories (Ref. 1):

(1) Production rate

(2) Product quality

(3) Inventory

(4) Processing environment

(5) Economics

The meanings of these terms are best explained by an example from Reference 1.

Example 2-1 Control of a Superheated Steam Boiler

Classify the controlled variables represented by the transmitted signals from a boiler (Figure 2-1).

Solution

1. Production rate through the boiler is steam flow, usually set by downstream process demand.

2. Inventory is the accumulation of either mass or energy. In this process, liquid level in the drum is an inventory variable. Also, the steam pressure is an inventory variable because pressure is a measure of the mass in a gas system.

3. The processing environment includes those operating conditions that, while not really important in and of themselves, have an important effect on the process performance and product quality. In this example the furnace pressure or draft is an environmental variable.

4. Product quality is the chemical composition, purity, thickness, color, or whatever else determines the value of the product to customers. In this example the steam temperature is the product quality.

5. Economic variables are either directly or indirectly related to profits, or costs. In the boiler, the cost of processing is related to the composition of the flue gas.

Each type of variable has its own requirements and objectives. Inventory variables may require only loose control while product quality variables deserve very close, tight control. Economic variables are controlled in such a way as to maximize or minimize some profit or cost. Production rate constraints depend on the current market situation for the plant, i.e., production limited, market

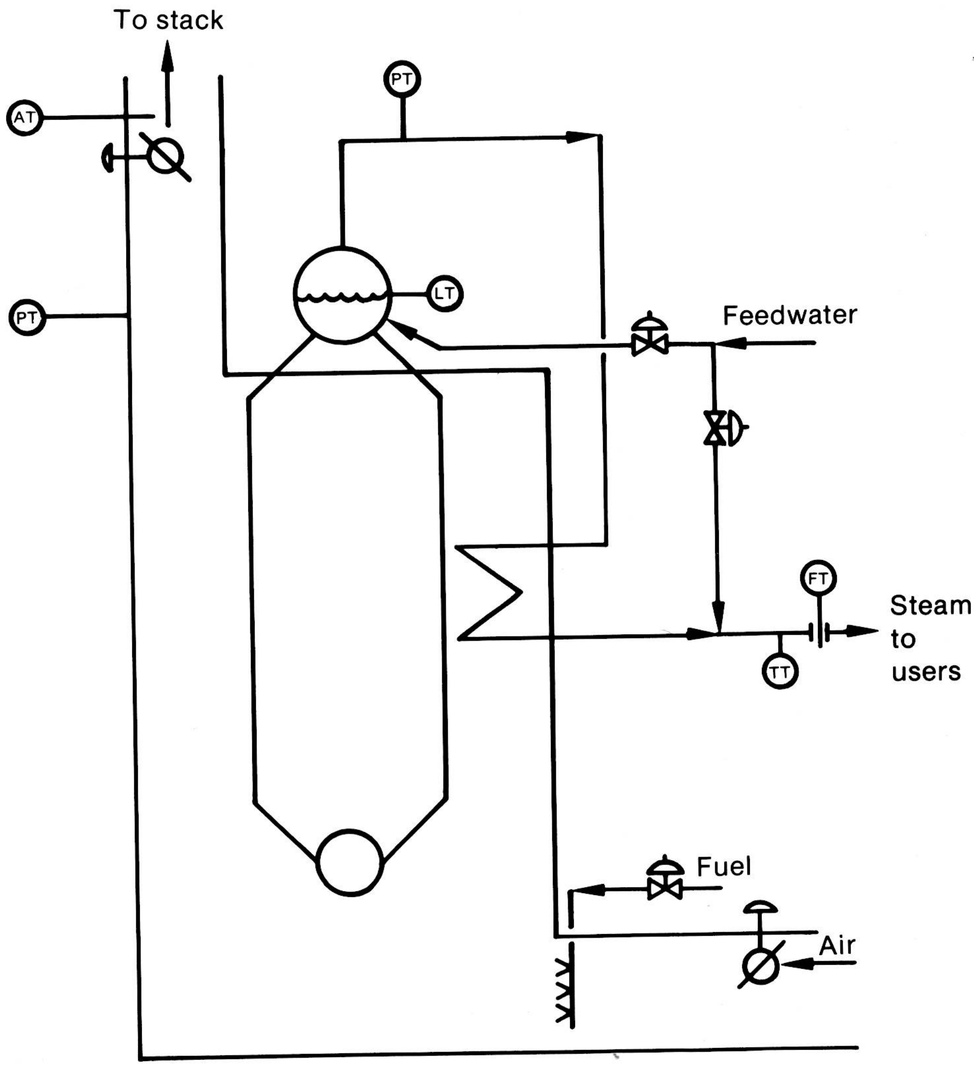

Figure 2-1. Superheated Steam Boiler (Ref. 1)
(Courtesy ISA)

limited, or resource limited. For any particular variable, one or more of the techniques described earlier may be applied to regulate, stabilize, control events, or optimize. The first of these techniques is feedback regulation.

2-2 THE FEEDBACK CONCEPT

How many types of control are there? ONLY TWO! What about feedback, feedforward, cascade, ratio, adaptive, supervisory, direct digital, distributed, learning, and decoupling control? Only the first two in the list are basic control strategies. The rest are modifications and variations of the basic strategies — *feedback* and *feedforward.* Of the two strategies, feedback control is the technique used in the vast majority of industrial applications at the first level of control. Because of the importance of the feedback concept the idea is introduced