Instrumentation

Franklyn W. Kirk

Nicholas R. Rimboi

Third Edition

an atp publication

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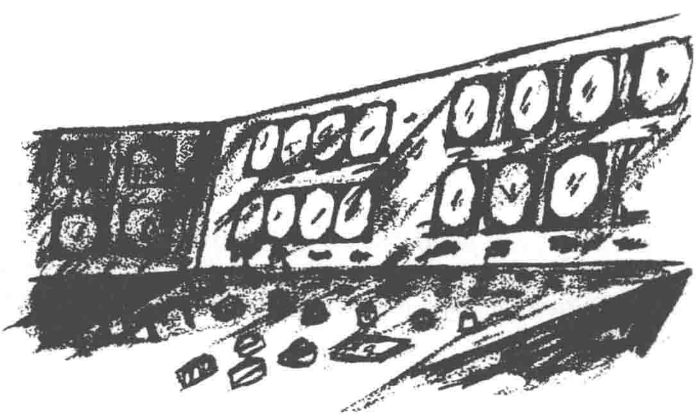

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Preface to the Third Edition

Instrumentation has served as a practical introductory text for over ten years. Its three-part program of *introduction, comprehension,* and practical *application* has proven itself as a valuable learning tool.

Part One introduces the student to the basic principles of instrumentation. It includes a discussion of the various instruments employed in industrial applications. *Part Two* deals with operating principles. Instruments are discussed in greater detail to provide fuller understanding. *Part Three* gives the student examples of the actual application of instruments used in process control.

This enlarged 3rd Edition of *Instrumentation* has been recast in a new, easy-to-read format. New illustrations have been generously included to familiarize the student with current equipment and developments. All of the chapters have been expanded to present the advances in instrumentation. *Review Questions* and a *Words to Know* section appear at the end of each chapter to aid the student.

Appendices have been completely revised. *Appendix A,* entitled *Instrumentation Symbols,* provides the latest symbols available from the Instrument Society of America. *Appendix B* shows the most commonly used electrical symbols. *Appendix C* consists of tables which give useful information to the inquiring student. The *Glossary* has also been expanded to include new and changed terminology.

FRANKLYN W. KIRK
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Contents

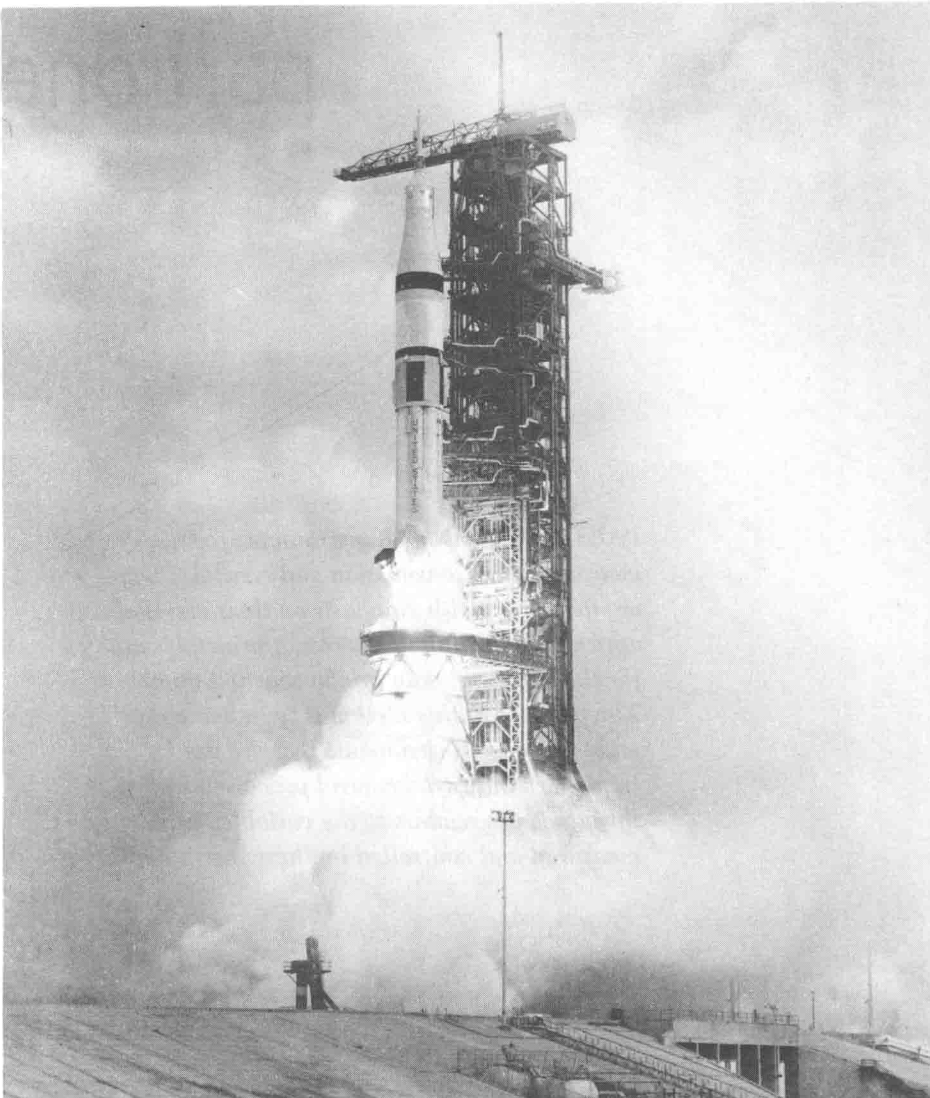
Page

Part Two

Part Three

part one

PART ONE deals with instruments for measurement, transmission and control. They are described with emphasis on their external appearance, and their operating principles are for the most part only briefly touched upon. The purpose of this section is to indicate the wide variety of instruments that are used in modern industrial control processes, and to introduce the readers to the variables which are measured and controlled by these instruments.



Lift-off of the Saturn IB rocket which carried three astronauts (Charles Conrad, Jr., Dr. Joseph P. Kerwin, and Paul J. Weitz) to the skylab. Skylab is the orbital workshop which was designed to enable scientists to gain new knowledge for improving the quality of life on the earth. Complex and advanced instruments played a key role in the success of this and several succeeding skylab missions. (NASA)

Introduction

Chapter

1

Measuring and process control instruments are essential parts of any industry, from the manufacture of breakfast cereal to the building of huge jet airliners. Improvement in measuring and process control devices has provided essential improvements in the quality and quantity of services and goods necessary in society today.

Instrumentation also provides a means for environmental control, disposing of wastes and by-products of industry to avoid pollution of our cities and to protect precious natural resources. It has also been used to help correct pollution problems stemming from earlier abuses. Thousands of intricate computers and controlling and measuring devices were prime reasons men were able to travel to the moon.

Because of the great strides in science and technology in the modern world, we frequently overlook the instruments which play important roles in our daily lives. The use of instruments in satellites and various installations provides us with weather and other important information. Most homes and apartments are equipped with thermostats which control the temperature and maintain comfort, regardless of the season. The thermostat shown in Fig. 1-1 provides a fuel saving device. This device enables a person to preset the thermostat, which automatically lowers the temperature during sleeping hours and raises the temperature to the original setting at a fixed time. Automotive instrument panels can be equipped to provide a wide range of important information to the motorist. The panel, shown in Fig. 1-2, can measure vehicle speed, motor speed, and provide information on the charging rate of the battery, the level of fuel, and the temperature of the engine. Instruments control the temperature of food. As a safety measure, instruments can be used to control lighting in various parts of a house or other building. Hand calculators are now common in homes and offices. This list, of course, is by no means complete.

This text concentrates on the instruments used in modern industry and process control. These precise, effec-

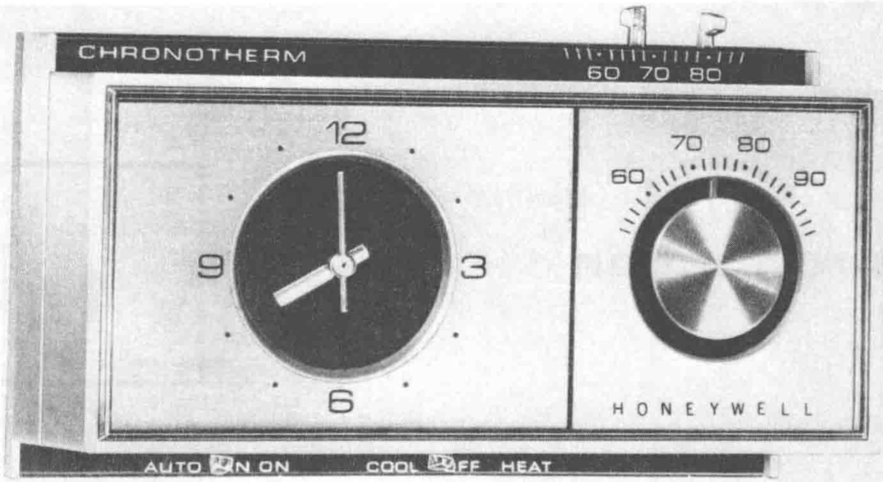


Fig. 1-1. This thermostat has a built-in timer which allows for automatic temperature adjustments at predetermined intervals. (Honeywell Process Control Div./Fort Washington, Pa.)

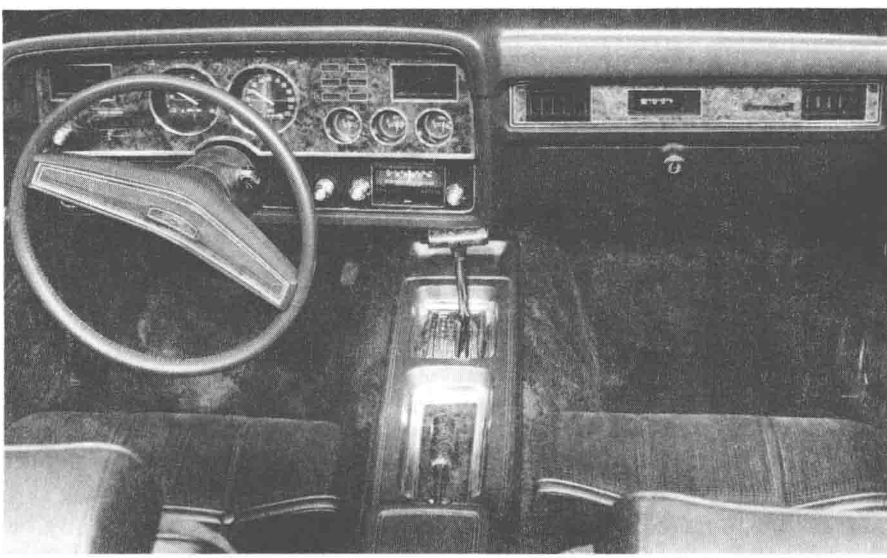


Fig. 1-2. This automotive instrument panel provides the motorist with vital information. (Ford Motor Co.)

tive, and diversified instruments make possible the massive production feats essential to today's society. It should be noted immediately that the principles of measurement and control do not vary, whether the particular application is in modern industry or a part of a monumental undertaking, such as a moon landing. Improvements in measuring and control aid progress in both industry and science.

Industrial Instrumentation

Instrumentation is the technology of using instruments to measure and control the physical and chemical properties of materials. The term *process instrumentation* refers to instruments used to measure and control manufacturing, conversion, or treating processes. Fig. 1-3 shows an operator monitoring the processing of oily waste water. A *control system* combines measuring and control instruments to provide automatic remote action. The resulting process is termed a *controlled process.*

Measured and Manipulated Variables. Instruments can not always directly measure and control the properties of a process material. Variables, such as temperature, pressure, flow, level, humidity, density, viscosity, etc. frequently affect the process. A variable that must be measured or controlled is called the *measured* or *controlled* variable. A variable which is used to affect the value of the mea-

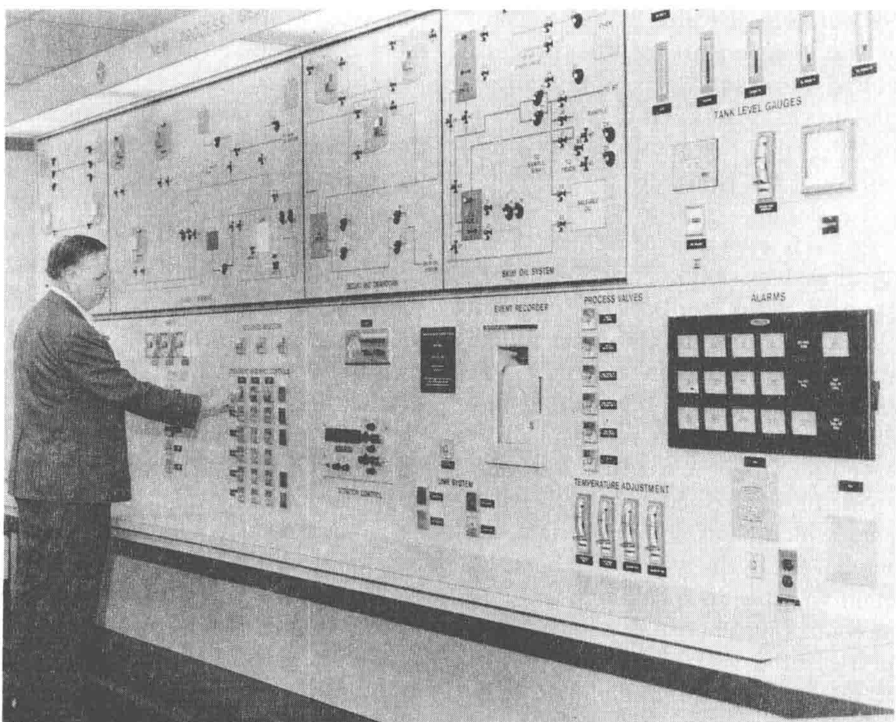


Fig. 1-3. The control center enables a single operator to monitor the entire process system. (Honeywell Process Control Div./Fort Washington, Pa.)

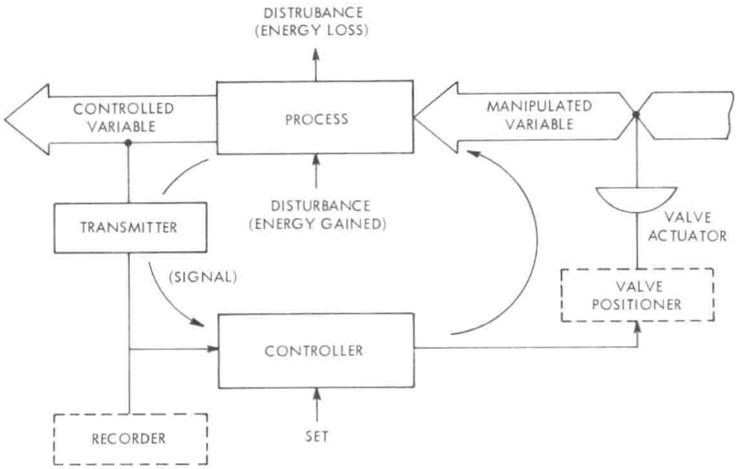


Fig. 1-4. A closed-loop control system. (The Foxboro Co.)

sured variable is called the *manipulated variable*. If water is used to control the temperature of the process material, for example, the temperature of the process material is the controlled variable, and the temperature and quantity of the water are the manipulated variables.

Fig. 1-4 is a diagram of a closed-loop control system. A closed-loop control system provides feedback to the controller about the value of the controlled (measured) variable. An open-loop system, such as an automatic washing machine, does not provide feedback. The transmitter in the closed-loop system provides a signal (feedback) to the controller which takes an appropriate action to return the value of the controlled variable to set point.

A control system can have more than one measured variable. It can be important, for example, to maintain temperature, flow, and level in a given process. Some of the measured variables, however, are not measurements of physical or chemical properties of the process material. Flow measurement can be taken from the example just used.

Often the flow rate of a substance depends on the temperature, density, or viscosity of the substance. Oil, for example, has a higher flow rate at higher temperatures, hence it flows faster in an operating engine than when poured out of a can. Frequently in industrial processes, however, the measurement and control of flow rate establishes the rate at which a substance is subjected to various process changes. Often it is not the flow rate of the process material itself that is of prime importance, but the flow rate of a second substance which is supplying or removing energy. If water is used as the cooling or heating medium in a process, it is the flow rate of the water and not the process material that is of prime importance.

The measurement of level in process control is another example. Level can indicate the size of granular material in a container. But the measure and control of level are most often required to maintain the continuation of the process. Likewise, it can be important to measure and control the level of a second substance rather than the process material itself, like available fuel oil or cooling water.

It can be seen that a control system requires more than measuring and controlling the physical and chemical characteristics of the process material. The various conditions involved in the process itself must be measured and controlled. This information must be continuously available, and the performance of the control units continuously monitored. Measurements can be observed directly on indicating instruments, or recorded continuously on charts, depending on the nature of the process application. Control devices are monitored through the use of visual or audible alarm signals.

Indicating Instruments. Indicating instruments are generally equipped with scales graduated in units of the measured variable. An instrument indicating level would be graduated in feet or inches, or in metric units. The shape and size of the scale vary, depending on the needs of the specific application. In some applications, the scale might be linear, in others, circular. Regardless of these physical characteristics, however, the scale must be capable of correctly indicating the value of the measured variable. The indicating instrument shown in Fig. 1-5 is a typical circular indicator and is graduated in inches of water for the measurement of pressure. Usually, the scale is made so that the value of the

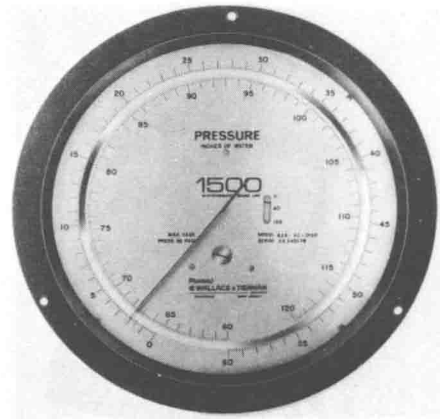


Fig. 1-5. A typical indicating instrument. (Wallace & Tiernan Div., Pennwalt Corp.)

measured variable is read by estimating the position of the indicator between two successive divisions.

Digital Meters. Digital panel meters are being used with great frequency in industrial processes because of their accuracy, response, speed, and readability. They can be used to measure or control any of the measured variables. They generally feature a liquid crystal display of the type shown in Fig. 1-6. A chip contains the entire digital circuitry which is hermetically sealed to prevent burnout and hence an inaccurate reading. Other types of displays are available for process environments in which liquid crystal displays might be unsuitable. Digital meters are available in various sizes, ranging from the meter shown in Fig. 1-7A to the large multirange precision indicator shown in Fig. 1-7B. Fig. 1-7A shows a digital thermocouple indicator. The indicator in Fig. 1-7B, designed to readout temperature, is available in dual or triple ranges. Fig. 1-8

Fig. 1-6. A portable digital multimeter with LED (light emitting diode) readouts. It is used to troubleshoot electronic instruments. (Data Technology Corp. / Santa Ana, Calif.)

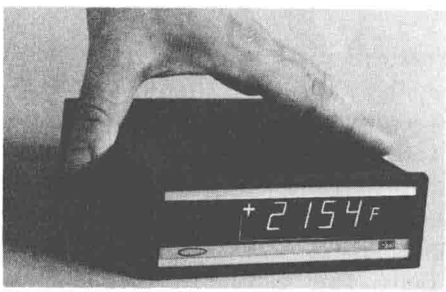


Fig. 1-7A. A digital thermocouple indicator for indicating temperature. (Ircon Inc.)

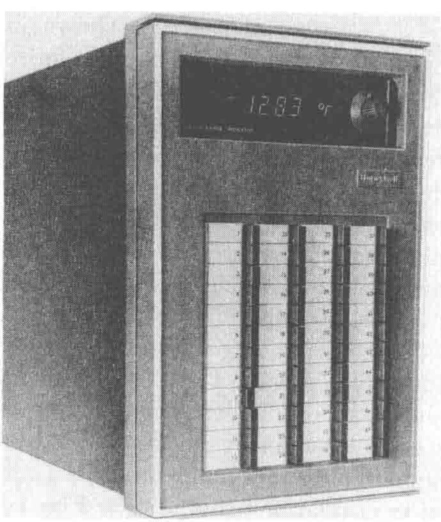


Fig. 1-7B. A digital multirange indicator. (Honeywell Process Control Div./Fort Washington, Pa.)