Instrumentation for Thermoplastics Processing

Edited by James M. Margolis

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Edited by James M. Margolis

Dedicated to my wife,
RENA

PREFACE

The plastics industry has entered the world of automated processing (Figure 1), and it is now sorting out available options in order to be competitive. The purpose of this book is to provide technical information on instrumentation for thermoplastics processing. Instrumentation is at the nerve center of automation, because without instrumentation, there is no control of a process.

In order to provide the reader with a "plate size" meal, rather than a bewildering menu, the book uses injection molding as the model for thermoplastic melt processing. The instrumentation is applicable to all other thermoplastic melt processes such as extrusion and blow molding; and even to thermosetting resin processes that are being applied to thermoplastics, such filament winding and pultrusion.

There is a misconception within the plastics industry that automation is only for the multibillion dollar, multinational companies. Another notion is that instrumentation and automation require extensive training and sophisticated engineers, in order to be implemented. These ideas are not entirely unfounded. There are certain aspects of instrumentation/automation (I/A) that are confined to the multibillion dollar companies and to the brilliant engineers.

But there is a world of instrumentation for processing and related activities, such as quality assurance and auxiliary equipment, that is within grasp of any molder or machine operator. The smallest custom molder with only a few machines, not only can afford instrumentation/automation, these companies cannot compete effectively without I/A.

An essential ingredient to successful use of I/A is careful selection of instrumentation. The user must be wary of being oversold controls that do not pay back, do not operate properly for the process and require too much training. The user must also be careful not to establish a system that is too confining, and soon outgrown by the success of the I/A system itself.

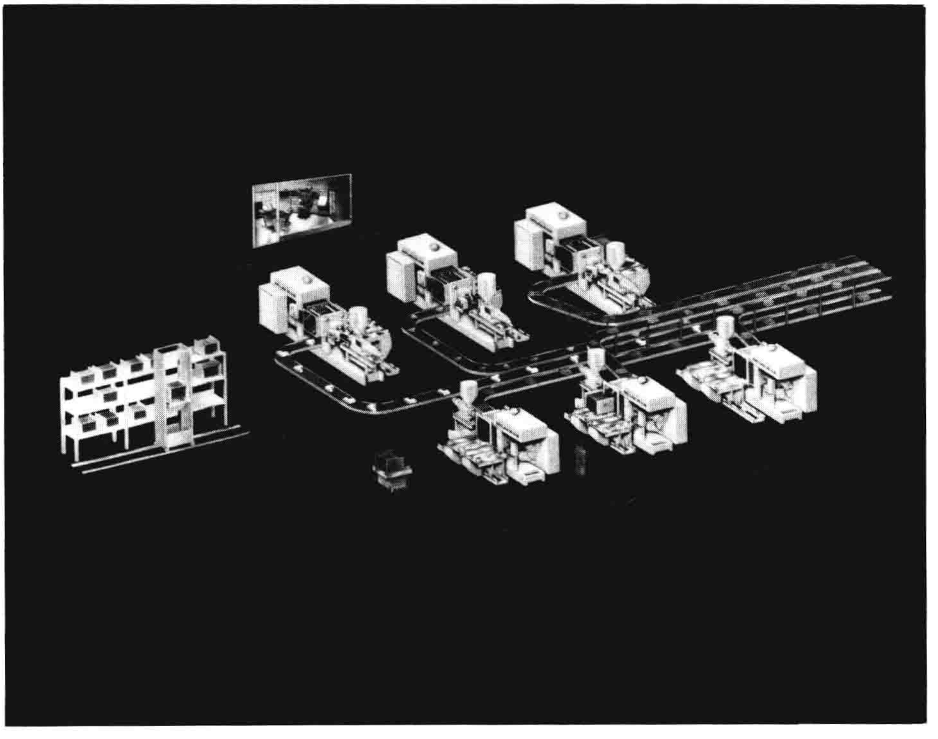
This book will help both large and small processors to understand principles and practices for I/A, in order to make a careful selection of controls. There is an abundant amount of hardware available, from computers, programmable controllers and microprocessors (and software); to control systems. Minisize and giant size systems leading to local area networks (LAN) and computer integrated manufacturing (CIM) are available from companies specializing in these systems. The chapters in this book are designed to provide technical and practical information on instrumentation for melt processing and auxiliary operations such as materials handling, and quality assurance testing.

The reader will gain insight into the significance of control systems for temperatures, pressures and viscosities; and machinery mechanisms (e.g., hydraulic drives and feedback devices).

This book has limitations as well as benefits for individuals working for materials suppliers, processors and machinery/equipment companies. The book is not intended to make anyone an instant expert. Many subjects covered here are brief descriptions. The reader should supplement the information here with supplier company literature and direct inquiries to the chapter authors. The authors are all experts in their field, working for companies with years of experience in their subjects.

Instrumentation For Thermoplastics Processing serves three valuable purposes to the reader: 1.) an awareness of the capabilities of I/A, 2.) a foundation in I/A to build upon, and 3.) assistance in sorting and selecting cost effective instrumentation.

New York, New York — James M. Margolis
June, 1988



Courtesy of Cincinnati Milacron, Inc.
Plastics Machinery Division, Batavia, Ohio

INTRODUCTION

This book describes the four essential segments of instrumentation for thermoplastic melt processing: controls for primary machinery (e.g., injection molding machinery), instrumentation for melt control, quality assurance instrumentation, and controls for auxiliary equipment.

Control Systems for Injection Molding describes the types of controls required for melt processing, using injection molding as the process example. The author, from Allen-Bradley describes six essential subjects to understand control systems for injection molding: 1.) the types of control functions required for the process; 2.) the theory of control mechanisms for positioning mechanical components (e.g., screw, clamps, carriage, hydraulic and electric drives); 3.) position feedback devices; 4.) demand for responsive controls, 5.) controller capabilities and 6.) communication networks.

A key point to understand in the theory of controls is the distinction between open and closed loop, and discrete digital and analog controls. A position feedback device (the third essential subject) is an element of closed-loop positioning. It is illustrated with a linear potentiometer, the oldest type used for injection molding. A more recent example is the pulse-echo type of absolute-linear-position transducer. The demand for responsive controls is increasing in the plastic industry, as the demand for "first-time" quality products increases. Responsive control, as the name implies, is a step toward intelligent automation, where the controls respond to a specific molding condition. A responsive function for a parts-ejector allows the part to be ejected fast without being damaged. Another example described in this chapter is using responsive control to provide a consistent melt when the back pressure varies from too low or too high during plastication.

Controller capabilities are divided into three subjects: 1.) positioning and pressure control, 2.) temperature control and 3.) discrete on/off controls. Temperature controls are covered in Chapter 2. Communication networking is a "teaser" technology: it offers a processor new dimensions of automation usage, both within the plant and with outside facilities. However, communication networking requires more investment in capital and training than other modes of instrumentation/automation (I/A). This subject is also covered in Auxiliary Equipment II.

Melt Control, authored by an expert from Syscon International, is required reading for anyone involved with thermoplastic resins and melt processes. An understanding of melt behavior and melt temperature control is necessary for optimum product quality and process economics. The author uses conventional engineering thermoplastics, ABS, impact acrylics and nylon, to illustrate temperature profiles and controls. This chapter also covers the important subjects, control loops and proportional controls. These subjects are covered from another point of view than chapter 1., providing the reader with further insight into melt process controls.

"Increasingly powerful control strategies replace on-off control with various forms of proportional control. The most advanced analog controllers offer proportional plus integral and derivative (PID) control," according to the author. The integral control compensates for a mismatch between the heater and the actual load by measuring the difference between the setpoint and the actual melt process value. Similar to the initial cost/ultimate benefit ratio for communication networking, PID controls require higher initial costs than other modes of I/A. The potential user should discuss the trade-offs with vendors and qualified consultants.

The two paramount objectives of I/A are to achieve optimum product quality and process economics. Controls provide the user the opportunity to achieve these objectives, but another segment is needed to complete the picture: namely, a method to observe the results. The third chapter, Thermal Analysis, from the E.I. du Pont de Nemours & Company, covers this third segment. The chapter describes the capabilities of the four techniques most commonly used for characterizing thermoplastics: 1.) Differential Scanning Calorimetry (DSC), 2.) Thermal Gravimetric Analysis (TGA), 3.) Moisture Evolution Analysis (MEA) and 4.) Dynamic Mechanical Analysis (DMA), based on the company's instruments and software.

Thermal analysis offers more than routine quality control of materials and products. In addition to quality control, characterization of resins provides data for optimum process conditions. The degree of crystallization determined by DSC is useful for predetermining process parameter setpoints, as well as for monitoring the process and controlling product quality. Measurement of the glass transition temperature (T_g) and melt temperature (T_m) also provide data for process control and monitoring.

Each instrument offers special capabilities. TGA is a simple, fast method to determine several critical properties of materials, including burning characteristics. MEA is used to determine moisture content of both starting resins and compounds, and final product. DMA is especially important for determining viscoelastic properties of resins. These properties are unique to plastics (as opposed to metals which are elastic). Viscoelastic properties have a profound effect on the long term, or service life, of plastic products; and on melt rheology behavior.

The versatility, accuracy and fast operation of thermal analysis is a cost-effective way to improve competitiveness by improving process economics and product quality. The capabilities of thermal analysis modes are succinctly described in this chapter, with accompanying photographs, diagrams and graphs.

The Auxiliary Equipment Chapter by the editor, describes state-of-the-art auxiliary equipment instrumentation. "Big doors swing on little hinges" and new auxiliary equipment is swinging big primary machinery (e.g., molding machines, extruders, etc.). Auxiliary equipment has become a critical link in the process chain due to automation of primary machines. Section I describes the capabilities of instrumentation for the different modes of auxiliary equipment: materials handling equipment, granulators, blenders, recycling systems, dryers, chillers and robots; and miscellaneous equipment such as automated guided vehicles, ultrasonic welders and laser machining equipment, and insert feeders.

Section II gives the reader an early briefing on auxiliary equipment software protocol developed by the Society of the Plastics Industry (SPI), Washington, D.C. U.S.A. The objective of this protocol is to allow different auxiliary equipment manufacturers' models to be co-automated,® by standardizing the software language. Section II outlines the objectives and applications for the SPI protocol, and describes initial progress by auxiliary equipment manufacturers.

Section II contains additional current developments with auxiliary equipment not included in Section I.

New York, New York U.S.A. James M. Margolis
June, 1988

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1

CONTROL SYSTEMS FOR INJECTION MOLDING

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Chapter Objectives

This chapter presents control systems for injection molding by describing:

- the types of control functions needed for injection molding machine mechanisms.
- theory of control mechanisms for positioning and pressure on injection-molding machines.
- position feedback devices for injection molding machines.
- demand for responsive control for injection molding.
- capabilities of controllers for injection molding.
- capabilities of a communication network.

Control Functions

Figure 1 shows the basic actions of the mechanisms within an injection molding machine. Control systems for these machines provide the following control functions:

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