INSTRUMENTATION IN DESIGN

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Introduction

Instrumentation and process control has been a basic ingredient in the growth of most chemical companies. Management has long since recognized that application of advanced instrumentation techniques was essential in insuring strong competitive market positions. The esteemed position instrumentation holds today in most companies has been well earned. Its future holds even greater potential since it represents to management one of the basic keys to meeting competition through production of new and better products, increased plant operating efficiencies and the ability to hold closer (and more exacting) product quality specifications.

Economic Considerations

Today in a typical petrochemical company instrumentation and control represents a substantial portion of the company's effort. According to data on instrument sales compiled by the Department of Commerce, the chemical industry accounted for 16.6% of all the instrument sales in the country. The petroleum industry adds additionally another 12.5%. In total, the petrochemical industry accounted for about 30% of all instrument sales, yet during the same time accounted for slightly less than 10% of all new plant investment. The Department of Commerce figures also reveal the ratio of instrument cost to total plant cost ranges from 3 to 15% for the chemical industry.

A large and constantly growing percentage of the money spent by many petrochemical companies goes for instrumentation. For example, The Dow Chemical Company usually spends between $2 and $6 million annually on instruments of all types. In addition to Dow's outside purchases, we spend a substantial portion of our research dollar on engineering, design, and fabrication of special purpose instruments in addition to a good share of the test and engineering laboratory work done in the company.

DuPont released figures recently that showed an impressive 10% of their total plant investment as being directly attributable to instrumentation, a value of well over $100 million. Truly, the chemical and petrochemical industry is more dependant upon automatic control than perhaps any other industry.

While these figures are impressive, they perhaps fail to indicate clearly the true spread of instrumentation costs on an individual project basis. A breakdown that we at Dow have found useful is shown in Figure 1 and is a correlation of our experience of instrument cost. In this figure, the cost (as a percentage of total direct project cost) is shown vs the total direct project cost. This data, which separates batch and continuous processes shows a spread of 6 - 8% of total cost at an 8 million dollar project level. A spread of 8 - 11% is shown at a $1 million project level for the continuous process. Batch process instrumentation costs are characteristically less, running on the average 4% lower than for continuous processes. Translating these figures into dollars means, for example, that for a 10 million dollar plant the installed instrumentation cost can be expected to run between $400,000 and $600,000.

Design Estimates

Investment figures such as these clearly emphasize the importance of careful economic considerations in the control system proposals. In the engineering design area, the ability to accurately estimate the costs of various equipment configurations and complete projects is of primary importance. In many cases - especially in preliminary proposal stages, the engineering estimates may make or break the complete project; while in other cases, it materially affects selling price, profitability forecasts, and similar areas. Since instruments and controls represent a significate portion of the total investment in process plants, estimates of such costs must be made with increasing accuracy throughout the progress of the engineering project. Data such as shown in Figure 1 can be quite useful in early stages of project study.

An alternate method of showing instrument costs is as a percentage of purchased process equipment as shown in the next figure. Once a project has been studied in enough detail that the major process equipment has been determined, this figure becomes a more realistic base for estimating instrument costs. From the figure, for a continuous process we could expect instrument costs to be between 30 to 45% at a one million dollar project level to a 15 to 20% range at a $10 million project level. Again, batch processing instrumentation costs run less; in this case form 15 to 20%. This seems reasonable in that instrumentation for batch operation is normally not as complex as that required for continuous processes. Also, production size batch equipment usually is quite large in comparison to continuous type equipment and, therefore, represents a larger portion of the plant costs. The data shown in this figure, essentially correlating past experience for The Dow Chemical Company, is useful for two reasons; first, it realistically outlines instrument costs and, second, it becomes quite useful in the preparation of "quicky" estimates and in quick comparison of alternate process layouts.

Once a project has been studied long enough to determine the various control systems required, a preliminary cost estimate based on the installed cost of the necessary instrumentation can be prepared fairly quickly.

Installed costs - at Dow - include such items as labor, painting, wiring, piping, and similar items. Currently at Dow our installed costs for instruments run between 160 and 170% of purchased instrument costs. This factor, of course, varies from year to year and is dependent on local labor conditions and the like.

In our detailed cost estimates, we additionally try to include all costs of an instrumentation system - such as piping requirements, power requirements, air requirements, panel and floor space requirements and the like. For, example, if we install a control valve, we will include in the instrumentation cost, the cost of the conduit run, the by-pass valve and piping and the air or electrical requirements. These so called "extra" costs often represent a sizable part of total. Many companies include such costs in electrical or piping areas and for this reason their instrumentation costs often appear much lower than ours. By contrast, however, our piping and electrical estimates may appear much lower than theirs.

While these figures give an excellent picture of where we have been, they certainly do not indicate where we are going in instrument costs.

INSTRUMENTATION COST VS.
TOTAL DIRECT PROJECT COST

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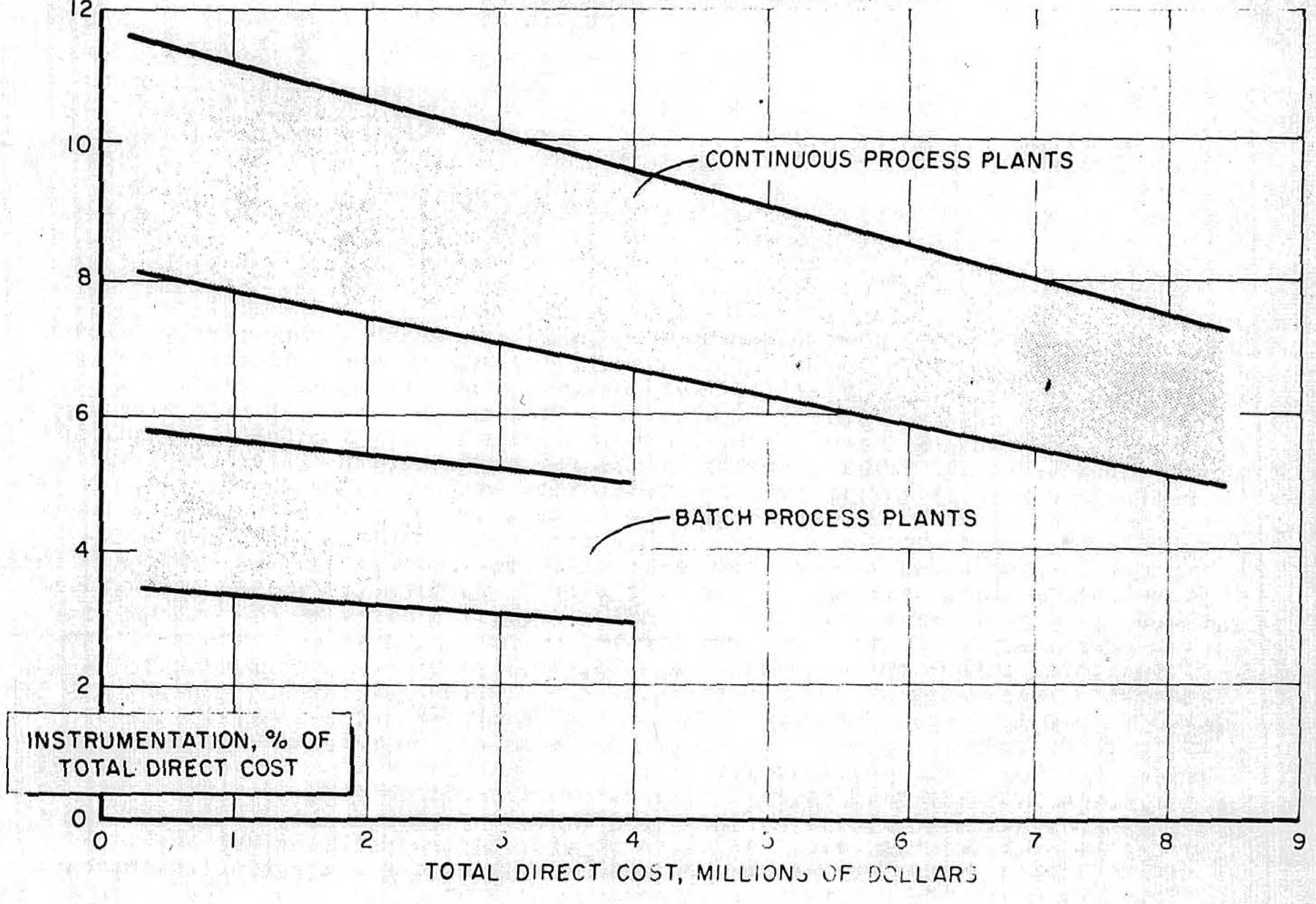

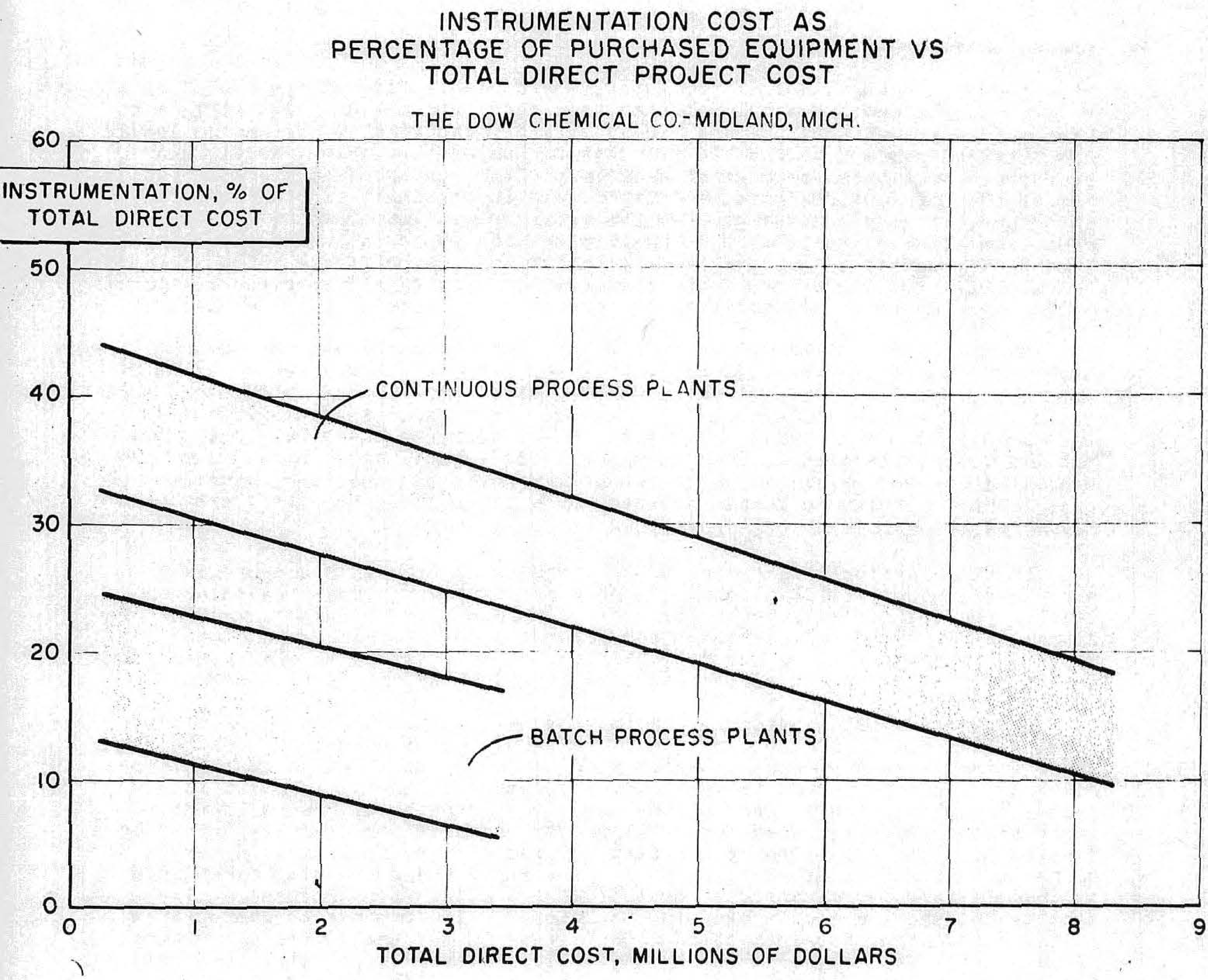

In general, we can expect a continued rise in instrumentation costs with more and more of the project dollar being spent in the control area. For example:

A) For the past five years or so the purchase price of new instruments has been increasing at a faster rate than for other equipment. This price index rise has been in the neighborhood of 7 - 10% per year for instruments as compared to the Marshall Stevens equipment index rise of 4 - 7% per year. While the instrument price rise is today tending to level off, the effects of this difference will be felt for some time in increasing instrumentational costs relative to equipment costs.

B) Much of the present instrument cost data, at least for The Dow Chemical Company, reflects a minimum of analytical type instrumentation in the initial design. Usually the analytical instruments (especially the more sophisticated types) were installed after the plant had been in operation for a time. More and more we find today that many of the analytical instruments are being specified during the initial design of the project. As such, you can expect their influence to add somewhere between 2 to 20% to cost figures in Figure 2.

C) We are starting to reach the point of diminishing returns in the sole use of more instrumentation. We are starting to see where something a little better than more single element or single loop controllers will be required. Today and more so in the future, we will see not only more instruments per plant but more intercoupling of instruments per plant. In essence, we are slowly entering the area of more sophisticated control with both analog and digital control schemes playing an important role. I do not believe there is a one of us that does not feel these schemes will result in increased instrumentation costs.

As way of example, if one takes a $20 million Styrene plant and adds around a $300,000 investment in computer control, the total investment in instrumentation goes from around $800,000 to $1,100,000 - a sharp jump of 37%, yet with other equipment costs remaining substantially the same.

Present Development

Today in our industrial processes, where plant measurements are of vital concern to the economics of operation, engineers are making great strides toward accuracy, reliability, and versatility of measurement. We are no longer completely dependent on the old standbys of temperature, flow, level, and pressure. Analytical measurements of composition and product characteristics, rather than its environmental condition, are increasingly finding their way into the initial plant design. We are seeing rapid improvements in measurement transmission, reliability, sensitivity, and sensor accuracy and stability. Important progress is being made in computation of significate information not directly available from individual primary sensing elements and multiloop performance control, accomplished by computers, is increasingly necessary.

Since most chemical processing is so dependent on proper measurement and control, let us take a quick look at our present design trends. Measurement and control of temperature, pressure, level and flow are without a doubt still the workhorses of chemical process control. With a gradual swing to electronics, and with refinements both in the elements themselves and in application know-how that fully recognizes their capabilities, steady improvement in these key measurements continue. Magnetic and turbine flowmeters, capacitance, ultrasonic , and radiation type level control devices are but a few examples of important improvements in these areas.

In the electronic controls, while there is an improving acceptance in our plants, we are still plagued by the many different signal transmission levels. We are forced somewhat to buy a complete system from one manufacturer rather than picking and choosing from several manufacturers as is common practice in pneumatic. Of course, the lack of an inexpensive electronic valve actuator is at present a severe handicap in wider use of electronics.

Increased consideration is continually being given to the value of continuous analysis equipment during the design stages of new plant construction. Where formerly such equipment was omitted in the initial design due to delays and lack of confidence in reliability, performance, and the like, it is now installed as an integral part of the usual instrumentation. This is not to imply that analyzers are as common as pressure guages for example, but it is routine to inquire into the possibilities presented by their use in design of new plants. Further experience with analyzers and increasing dependance on them is largely responsible for this change along with improved equipment techniques and sample handling techniques. Vapor phase chromatography is the outstanding development of recent years in the analytical measurement field, and is well established in many applications. While still used primarily for measurement today, its demonstrated reliability is leading to increased use in closed-loop control.

Although spectacular developments in VPC have tended to overshadow those on other fields - there has been considerable activity and improvement in infra-red, in micro-wave and mass spectroscopy, and in related areas. Increased usage and application of these wide and diverse analytical techniques will add measurably to the instrument engineers design capability.

Dynamic Considerations

I'd like to switch now to another facet of instrumentation and control that I feel is becoming more and more important in our engineering design. For several years now, the instrumentation and control engineers have been hammering away at the importance of process dynamics in the understanding and application of control systems. Today a good many engineering groups in the chemical industry have fairly well equipped (but poorly staffed) analog simulation facilities. This effort to me symbolizes and characterizes one of the most important advances in the instrumentation and control effort. For the first time the control engineer has the tools and techniques with which to intelligently compare various control schemes, to evaluate the performance and interactions of such control, and to, at long last, come up with rational justification and tangible economic benefits of instrumentation schemes. Dozens of proposed control and design configurations can be quickly and easily evaluated; effects of different startup and shutdown procedures can be determined; operational procedures can be studied; operators and plant personnel trained; emergency procedures can be worked out; all made with the assurance which comes only from the intimate knowledge of both the dynamic and the steady-state operation of the process.

As a result of active use of analog simulation techniques, we find the so called control engineers entering into more and more of the actual process design. In many cases, they are no longer satisfied with the process as envisoned by the chemical engineer, but may find that to properly control the process - radical changes in design or equipment sizing must be made.

By analyzing the proposed process and its control as a system, rather than as separate entities - with dynamic as well as steady-state considerations included - the control and instrumentation engineers are able to make significant contributions not only to the control of the process but to the <u>entire</u> process design.

For example, in an exothermic reaction step, if the reaction temperature starts to rise, the resulting ability of the control system to prevent runaway conditions depends on the relative transient speed of the heat generation mechanism and the speed with which cooling can be supplied to the system. A partial listing of typical determining steady-state and dynamic parameters is:

- Reaction Mechanism
- Degree of Mixing
- Instantaneous Conversion
- Instantaneous Volume
- Instantaneous Thruput
- Instantaneous Cooling Fluid Flow
- Rate of Heat Transfer
- Heat Transfer Surface
- Controllers; Type and Operation
- Valve Type and Speed
- Detector Sensitivity
- Detector Lags
- Heat of Reaction

In the design of a typical process, seldom, if ever, is the dynamic interaction of all these parameters investigated - even though they influence greatly the control of the plant, the operating capability of the plant, the cost of the plant and the choice of design. In the past, it has not been necessary to include such information because it was usually easier and perhaps cheaper to overdesign the process to avoid problems. In this example, an oversized cooler, extra surface areas, diluents and other expedients were satisfactory. Such procedures for insuring controllability, however, are becoming less and less attractive to the chemical industry as our competitive race tightens.

The sum total of this effort - besides resulting in better designed and better controlled plants - has been to bring the process engineers and the instrumentation and control engineers closer together. Today you will find many knowledgible process engineers that can discuss at will such concepts as Bode plots, phase plane plots, and the like; while on the other side of the fence, many more control engineers can now at least hold their own in such fields as heat transfer, fluid flow, reactor design and similar areas. This cross-fertilization of talents has and will continue to result in immeasurable benefits.

<u>Summary</u>

For the past few minutes we have taken a quick look at only a few of the areas of importance in instrumentation and process control. There are others of vital concern that have not been touched on. The steady but rapid growth of engineering technology has brought to industry many new methods, concepts, and tools for instrumentation and process control. The further application of this technology to our day-to-day engineering design problems will continue to bring about the improvements in productivity and cost reduction so prevalent in past applications of instrumentation concepts.

Costs of instrumentation, I feel, are rapidly approaching the point where management can no longer sit idly back and consider instrumentation a necessary burden of being in the chemical business. Economic justifications, so long a part of the chemical engineers way of life, are becoming more and more important to control engineering concepts. With the proper motivation, tools, concepts, and hardware at his disposal however, I think most instrument engineers can rise to the challenge.