COMPRESSED AIR SYSTEMS

A Guidebook on Energy and Cost Savings

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PREFACE

Previous work by United States Department of Energy (DOE) contractors, most especially the authors of this report, while performing another DOE contract, has led to firsthand, factory-level experience with compressed air systems and the energy factors associated with them. These observations of factory operations, and how compressed air is being used, were made by objective engineers having no economic interest either in the factory operation or in the marketing of compressed air equipment. It was noted that:

1. Compressed air is a popular and highly productive utility that is growing in use, and with good reason.

2. In most factories there were many opportunities for energy conservation in the generation, distribution, and use of compressed air.

3. In some factories there was found to be an outrageous waste of energy associated with compressed air systems.

4. Often, compressed air equipment selection, distribution system layout, and final application were made by medium and lower levels of management. Some of these decisions have had major economic consequences without a consideration of lifetime cost factors and, in some cases, without good engineering practice.

In some factories, it was found that the hissing of air leaks was audible even above the din of a manufacturing operation. In others, pressure drops were found to be on the order of 40 percent of the original compressor discharge pressure. Compressors were being added to systems for the reason that "the pressure is too low at the work stations" without even a cursory analysis of the reason for the low pressure.

The cost of this to the nation in lost energy and to the participating factories in lost dollars is significant. Over the lifetime of the compressed air system, energy is the greatest single cost, in most cases exceeding 30 percent of the total cost involved. If, as in some of the worst cases, 40 to 50 percent of this is being wasted, or, even in some of the more favorable cases where only 10 to 20 percent is being wasted, it is easy to see that the penalty for the improper management of compressed air is a high one indeed. Such is the motivation behind this publication.

Industry sources have estimated that the total connected horsepower of our factory compressed air systems exceeds 17 million. This presents a worthy target for the application of energy conservation technologies. Many energy-conscious engineers exposed to factory environments believe that at least 10 percent and perhaps 20 to 35 percent of this could be saved.

This guidebook seeks to increase the awareness of the compressed air equipment designers, system engineers and air users to the opportunities for conserving energy. By suggesting methodology and offering approaches to energy and cost analysis, it is expected to motivate conservation through better system design and management. It was decided that such a guidebook, published by a United States Government agency dedicated to energy conservation, technical objectivity, and commercial impartiality, will make an authoritative and persuasive statement.

It has been the intention of the authors that the book be factual and understandable to working level engineers and supervisors. It is intended that "the results be seen on the factory floor." Therefore, a style somewhat less formal than that of most technical reports has been adopted. And yet, it is believed that the significant data and methodology have been covered.

Special appreciation must be expressed to the many members of the compressed air industry for their generous assistance with this publication. Companies, industrial associations and individuals have contributed thought, suggestions and constructive criticism to the early drafts of this work in an effort to make this a valuable aid to compressed air users.

CONTENTS

COMPRESSED AIR SYSTEMS

A GUIDEBOOK ON ENERGY AND COST SAVINGS

1.0 INTRODUCTION

1.1 Purpose

The purpose of the guidebook is to assist industry in the efficient use of compressed air. Compressed air is one of the most important aids to the manufacturing and process industries of any modern nation. It frequently is known as the fourth utility, and it has proved to be an important tool for increasing productivity when applied properly.

The generation of compressed air can be one of the more energy consumptive activities taking place in an industrial operation. It has been estimated that throughout the United States the energy used, just to compress air in industry (not including small and portable compressors), exceeds one half quadrillion BTU. The use is increasing as our industrial sector grows. Therefore, it is in the national interest that something as important and useful as compressed air be generated and used with efficiency and economy wherever possible. Not only will the result be energy saved, but it also will be dollars saved. It is the intention of this guidebook to outline ways in which compressed air systems can be better designed, laid out, procured, operated and maintained in order to achieve greater energy efficiency and dollar economy.

1.2 Intended Audience

This guidebook is directed to compressed air users, compressed air systems operating and maintenance personnel, compressed air system and equipment engineers, and compressed air equipment manufacturers. The technical level is accessible to most persons in these activities.

1.3 Scope

Specific areas of potential are manufacturing facilities of all sizes and types where compressed air is used on a regular, continuous or near-continuous basis. Compressor systems in industry and manufacturing tend to operate on high duty cycles, service many different types of tools and processes, and have distribution systems covering large areas. Therefore, they offer opportunities for energy loss and hence for energy loss recovery. This report is directed primarily to such installations.

Some of the discussion and suggestions will, of course, be applicable to the process industries and to the less energy intensive and lower duty cycle usages such as service stations and construction. In the case of process industries, compressed air more often is treated as an ingredient of the process rather than as a utility. The energy costs incident to compressed air in these industries is a design parameter which tends to be monitored carefully. Typical construction compressors are portable, operate only a few hundred hours per year and serve local sites. Service stations and other portable compressor applications tend to be small and to operate at low duty cycles. Some of this guidebook, such as the sections on maintenance (4.2.7 and 4.3) will apply to these systems also.

The prime targets for the energy conservation measures contemplated in this report are the wide variety of manufacturing facilities of many sizes and categories. The compressed air systems and equipment to be discussed will be the types most typically found in such installations.

This report is not intended to be a complete engineering guide to air compression; the reader is presumed to have a rudimentary knowledge of air compression systems and equipment, the basic units of power and compressed air flow, and normal factory practices.

Within these boundaries then, the report discusses the configurations and ingredients of compressed air systems as they relate to the energy used by the systems and the possible economic impact of the energy requirements. Various approaches are suggested for reducing the energy used without impairing the utility of the systems. A bibliography is included to assist those who wish to study these systems in greater detail.

1.4 Content

The main body of the report begins with a description of typical compressed air systems which are found in manufacturing operations. This includes some diagrams of such systems. The next section, section 3, describes some of the components and subsystems typically found in industry and some of the engineering practices normal to most compressed air installations. This is to establish the fundamental engineering frame-of-reference for the parts of the report which follow. Readers well versed in compressed air systems may wish to bypass or scan sections 2 and 3.

The main thrust of this report is included in Sections 4 through 6, and the appendices. These describe specific energy conservation practice, recommendations, experience, and economic analyses.

1.5 Other Considerations

Finally, it should be noted that this guidebook addresses part of a large subject. The factory manager must, in the final analysis, be responsible for his choices and operations and thus must consider all aspects of compressed air systems such as acoustic effects, safety, and "bottom line" economics. This report intends to address primarily energy conservation and related technological and economic factors.

1.6 How to Use This Guidebook

The sections of this book which may be of greatest interest to a particular user will be determined by the nature of that reader's concerns with compressed air. Some parts of the book provide an overview of typical industrial systems, others will be of greater assistance to system designers, others to maintenance supervisors, and others to operations and energy management personnel.

Appendix C lists the abbreviations used most frequently in this book.

Table 1-1, following, lists specific areas of application, with recommended sections. Reference to this table can speed answers to specific problems.

TABLE 1-1

GUIDEBOOK APPLICATION

Type of Application	Considerations	Sections of Primary Interest	Sections for Background Information
New System Design	Air demand, pressure, quality; location of work stations; life-time cost; initial cost; growth potential.	3.0, 4.0, 5.0 Appendix A	2.0, Appendix B
System Modification	Same as above plus constraints introduced by existing system.	3.0, 4.0, 5.0 Appendix A	Appendix B
Compressor Replacement or Addition	Increased/decreased capacity; growth potential; distribution system capacity; life-time costs; initial costs.	2.0, 3.0, 4.0, 5.1	Appendix B
Addition to Distribution System	Location of new sections; adequacy of existing headers; pressure drop; installation and ΔP costs.	3.10, 4.1.9, 5.0 Appendix A	3.0, 4.0 Appendix B
System Maintenance	Pressure drop; leakage; corrosion; maintenance costs.	2.0, 4.3, 5.2.3	Appendix B
System Operations	Plant efficiency; air availability; up-time; operating costs; adequate air pressure and quality.	2.0, 3.0, 4.2, 5.2	4.0, 5.0 Appendix B
System Cost Analysis	Operations requirements; equipment costs; all other costs; cost of money.	5.2	3.0, 4.0 Appendix B
Pressure Too Low	Operations requirements; system capacity; system condition.	4.1.2, 4.2, 4.3 5.1 Appendix A	3.0, 4.0, Appendix B
Air Too Wet	Operations requirements; system capability; cost of drying.	3.7, 3.8, 3.9, 4.1.2, 4.1.7, 5.0	Appendix B

2.0 GENERIC SYSTEM DESCRIPTION

Most compressor systems consist of the following three major subsystems:

(A) Compressors, with drives, controls, intercooling, compressor cooling, waste heat recovery, and air inlet filtration.

(B) Compressed air conditioning equipment consisting of aftercoolers, receivers, separators, traps, (also frequently called drain traps or drains), filters, and air dryers.

(C) Air distribution subsystems, consisting of main trunk lines, branch lines, drops to specific usage, valving, additional filters and traps (drains), air hoses, possibly supplementary air conditioning equipment, connectors, and sometimes pressure regulators and lubricators.

Not all compressed air systems include all of the equipment listed above. Furthermore, there are many ways to compress and to condition air and to distribute it to its end use. Therefore, there is no standard system which would be appropriate to every need.

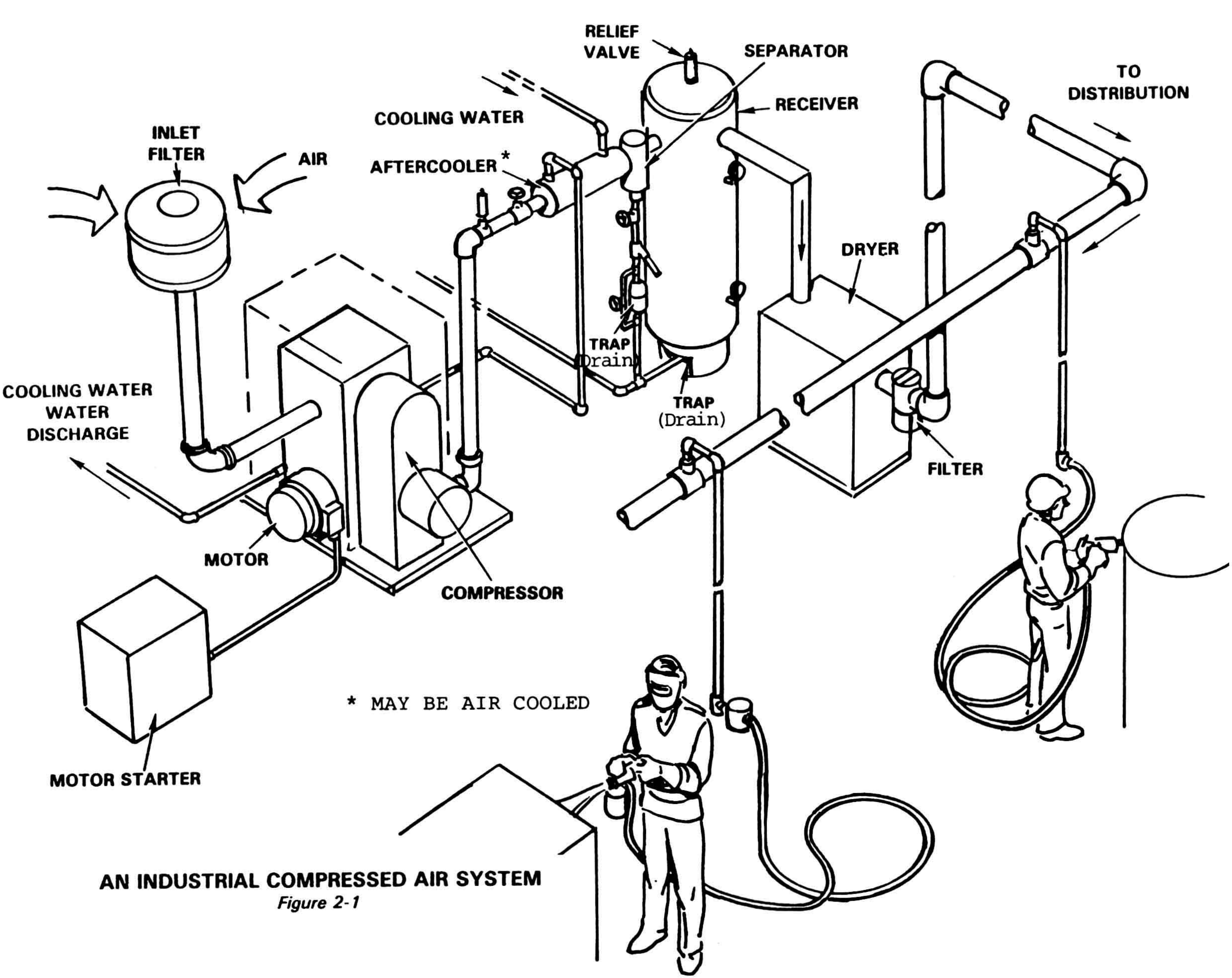
This report will explore the energy factors associated with the most frequently encountered types of compressed air systems. It will explore four compressor types: single acting reciprocating, rotary positive displacement, double acting reciprocating, and centrifugal compressors. There are other types which are not used, or expected to be used, as frequently in industry as those noted above. Similarly, the types of air distribution systems and conditioning equipment discussed are those most likely to be encountered, and there always will be some variation from factory to factory. Sometimes there will be installations where an unusual layout will modify the degree of applicability of the observations and recommendations to be made below.

This report is not meant to be a comprehensive analysis of all types of air compression systems that can be established, but instead concentrates upon those most often found in industry and upon the energy relationships incident thereto. More comprehensive analyses and general discussions of air compression systems can be found by reference to the materials in the enclosed bibliography.

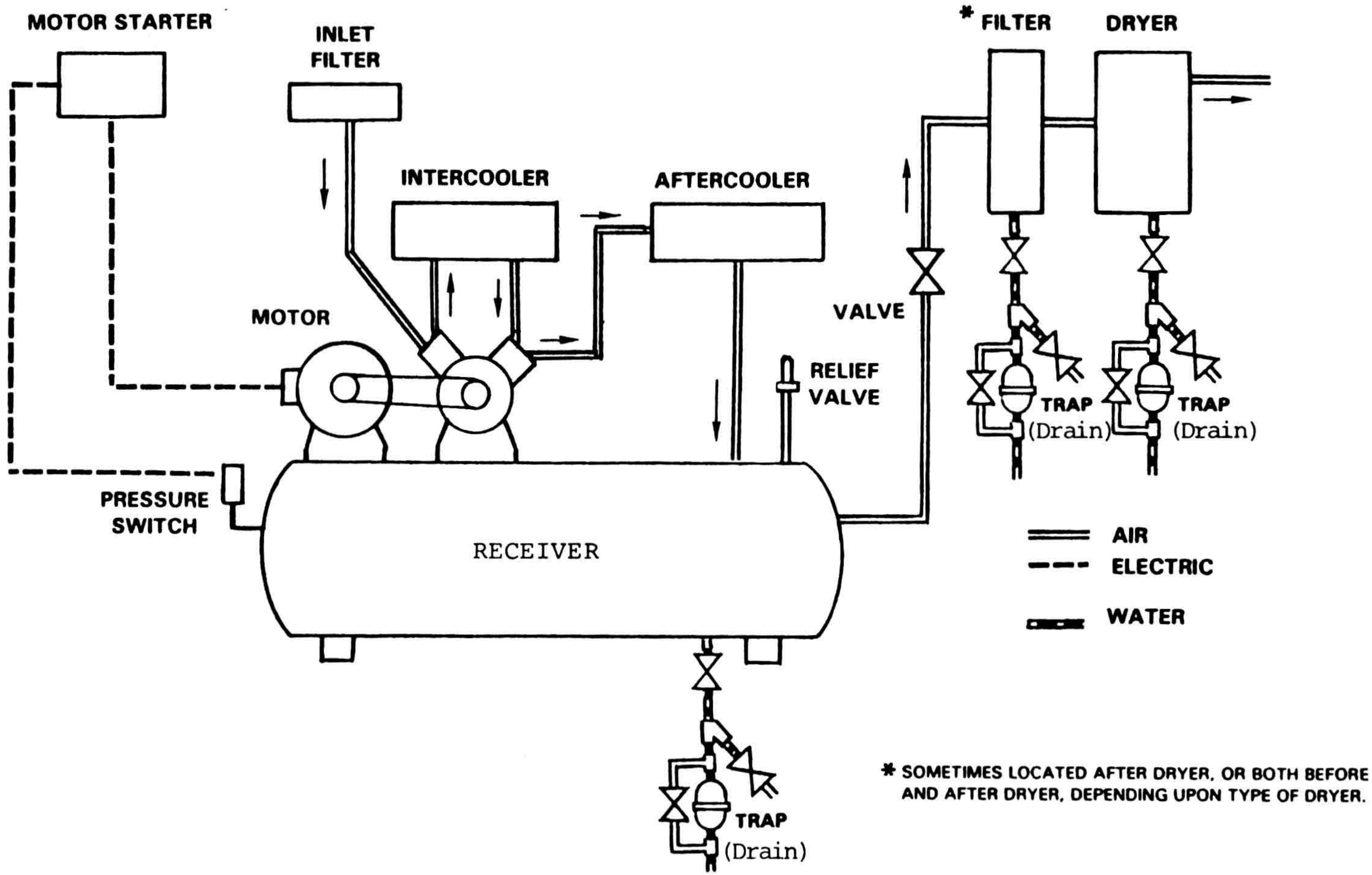
With these observations in mind, then, the typical systems which will be the subject of this discussion can be found in Figures 2-1 through 2-6. References to these figures will be made from time to time throughout the report.

Figure 2-1 illustrates a typical industrial compressed air system. Figure 2-2 shows a representative single acting reciprocating compressor installation. Figures 2-3 and 2-4 illustrate, respectively, oil cooled and dry rotary positive displacement systems. Figure 2-5 typifies a double acting reciprocating compresor and Figure 2-6 shows a similar system incorporating a centrifugal compressor.

Regarding Figure 2-2, and 2-3, the compressors are shown mounted upon the reservoir. This tends to be standard practice only for the smaller systems, i.e., 30 horsepower and under. When the user has control of his reservoir location, he may wish to locate it downstream from separators and dryers, since the latter are more effective and more efficient when flow rates are more uniform.



AN INDUSTRIAL COMPRESSED AIR SYSTEM
Figure 2-1



SINGLE ACTING, TWO STAGE RECIPROCATING COMPRESSOR

Figure 2- 2