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INDUSTRIAL ENERGY MANAGEMENT

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Abstract

Ten years ago we didn't know we had an energy problem. We seemed to have all the resources we needed. This paper delineates some commonsense guidelines on energy management that are necessary to make sure that 10 years from now we will still have the energy that we need to run the Nation.

THE ENERGY PROBLEM

Since the Arab oil embargo in 1973, a lot of information has come to the surface concerning the present energy situation and alternatives for becoming self-sufficient in future years. More recently, the focus of the energy situation has been on President Carter's National Energy Plan, submitted to Congress on April 20, 1977 (ref. 1). A review of the National Energy Plan places in perspective where we were headed before we became enlightened about the energy problem, and where we believe we need to go in order to survive until new, renewable sources of energy can be developed.

Reduce Energy Demand

The annual growth rate in energy demand has been 4 to 5 percent over the past decade, as shown in figure 1. In contrast, the National Energy Plan calls for reducing the growth rate to less than 2 percent. This is a short-term goal, one which could only be achieved through effective energy management, particularly focusing on energy conservation.

Switch to Coal

A further goal of the National Energy Plan is to develop our coal resources and reduce our dependence on oil and natural gas. Note, for example, that the United States was energy self-sufficient as late as 1950. But since that time, energy consumption has increased at a rate faster than our domestic energy production. Natural gas consumption has been exceeding new discoveries since 1968. The production of crude oil has been declining since about 1970, and even with the discoveries in Alaska, domestic oil production is still in a

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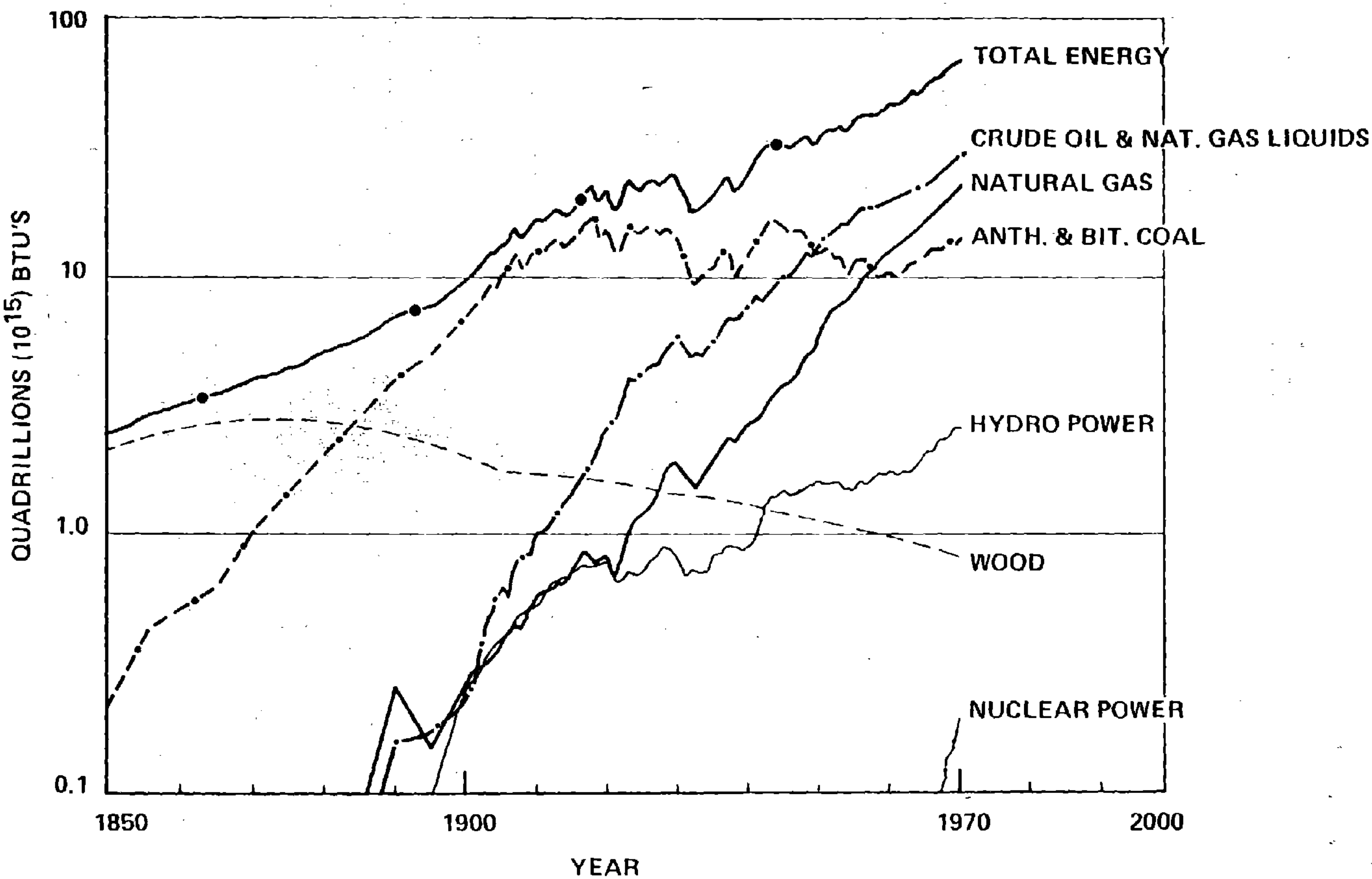


Figure 1. Annual energy consumption in the U.S.A. (ref. 2).

decline. The problem is so acute that the imports of oil amount to 47 percent of the total consumption of petroleum for the last 3 months (ref. 3). Prior to the oil embargo of 1973, our imports were already 30 percent of total consumption. That was over 4 years ago, and the situation is growing steadily worse.
On the other hand, the United States has proven coal reserves estimated to last us as long as 2,000 years. Certainly coal is a much dirtier fuel than petroleum products and represents a significantly worse environmental hazard; but technology is being developed to burn coal in an environmentally acceptable manner.

The relationship between our coal reserves and coal utilization, as compared with petroleum products, is shown in figure 2. The goal of the National Energy Plan to switch from oil to coal is based on the gross imbalance between reserves and production.

THE SOLUTION--ENERGY CONSERVATION

We cannot afford to sit around and wait for new energy resources to be developed. The only immediate alternative facing us today is that of reducing energy consumption through an effective energy conservation program. The recirculation of industrial exhaust air is only one of several ways of conserving energy consumed in the industrial and commercial sectors of the U.S. economy. In this paper, the focus will be on what makes sense in energy conservation, and on placing in perspective the very many alternatives that energy designers are faced with in trying to develop rational energy conservation strategies.

Current Usage

The current demand for energy in the United States stands at 74 quadrillion Btu's per year (quads). This is shown broken down into the five consuming sectors in figure 3. Figure 3a shows total gross energy inputs by major consuming sectors for all types of fuels and includes the fuel requirements of electric utilities. More important to industrial energy conservation, however, is the breakdown into the four consuming sectors, as shown in figure 3b. The difference between these two bases is in the energy loss in generation or distribution of electricity.

The energy savings from recirculation of exhaust air can come only from the energy spent for space heating in the industrial and commercial sectors. This is identified in figure 4 based upon the following:

1. Industrial sector--We have estimated the total space heating requirement in the industrial sector to be only 7 percent of the total energy consumption. Hence, the total space heating demand is 1.54 quads.
2. Commercial sector--Almost 60 percent of the energy consumed in the commercial sector, or 2.40 quads, is for space heating.

Space Heating Target

In space heating applications, energy is lost via the following mechanisms:

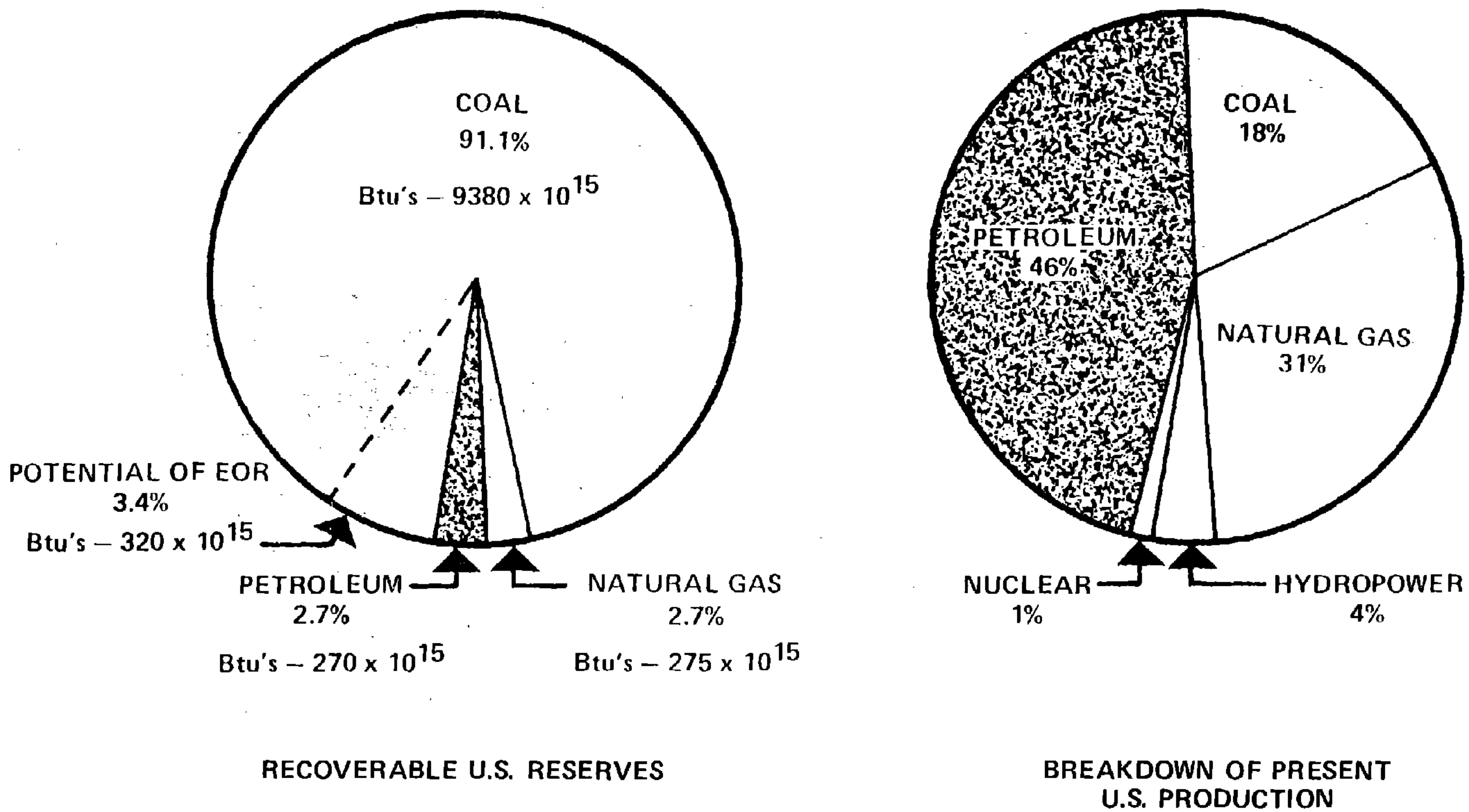
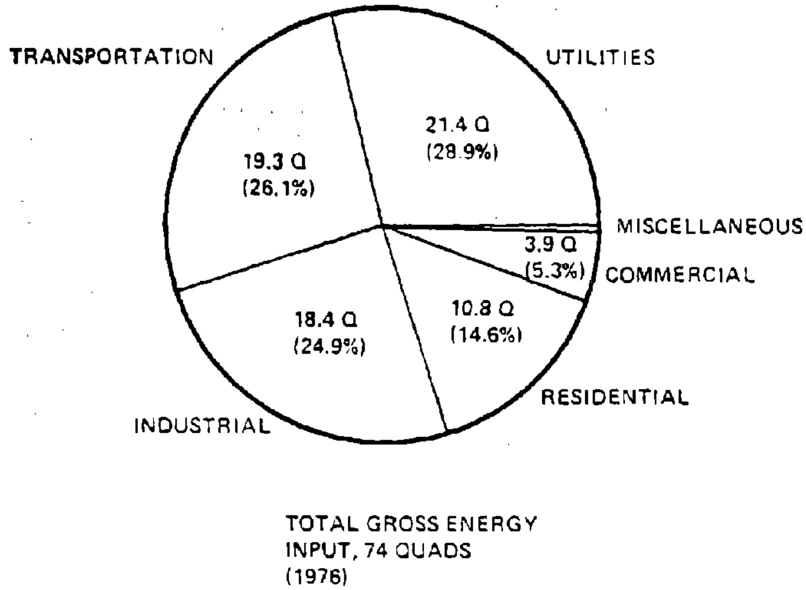
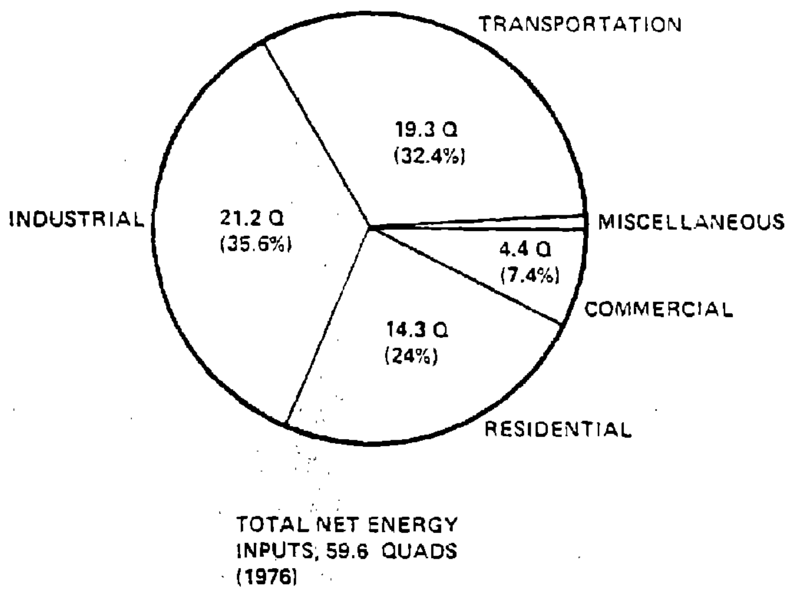


Figure 2. U.S. reserves and production: The crux of the problem, 1975 (ref. 4).



a. Gross energy inputs by major consuming sectors and for all types of fuels.



b. Net energy inputs by major consuming sector.

NOTE: The difference between net and gross energy totals consists of conversion losses in the electric sector.

Figure 3. Energy inputs by major consuming sectors (ref. 5).

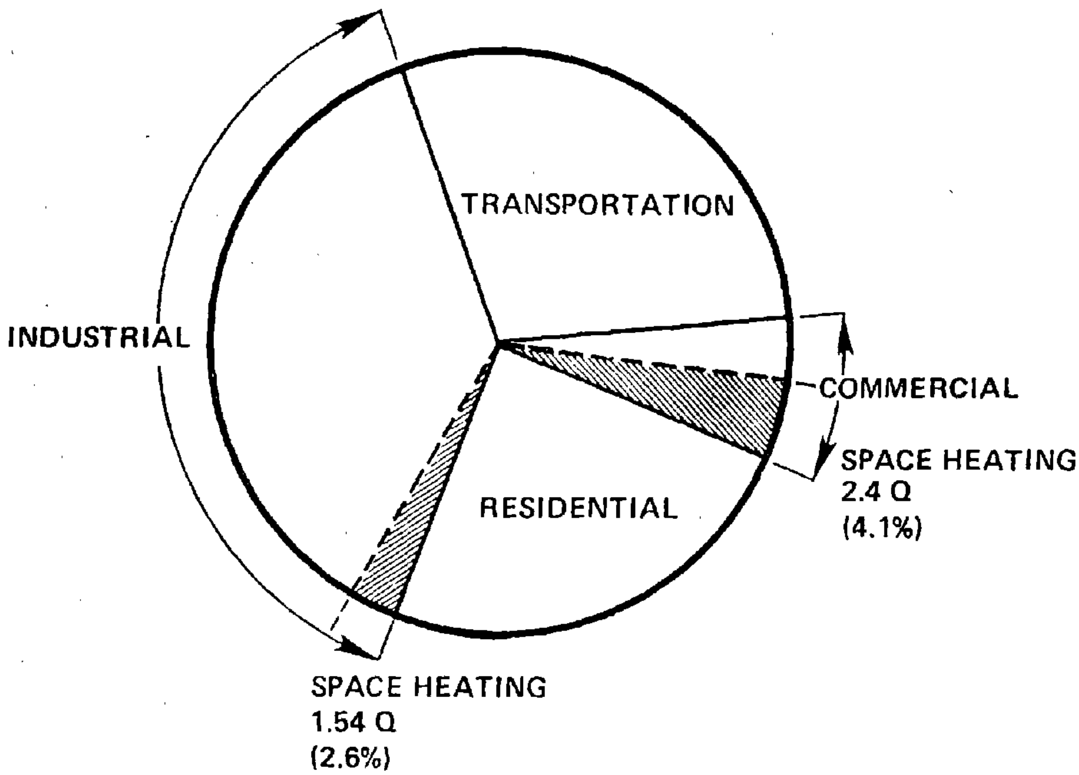


Figure 4. Total net energy inputs (1976) showing fraction used for space heating in the industrial and commercial sectors [5,6,7].

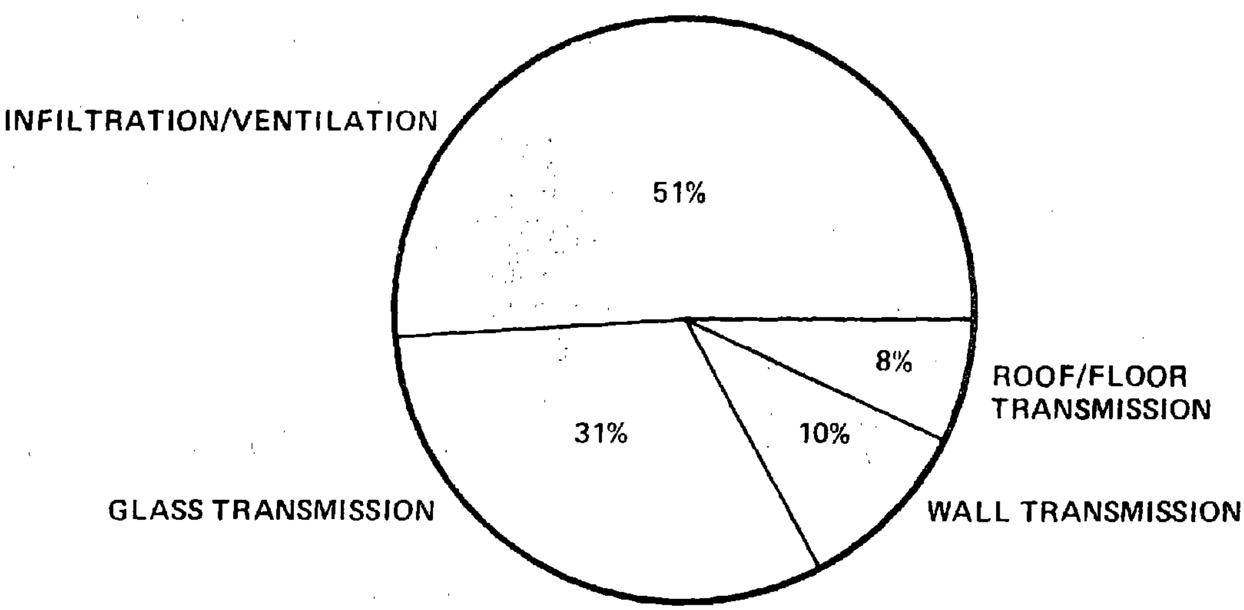


Figure 5. Heat load breakdown for typical 3-story, 400,000 ft^2 office building in typical 5,500° day location [A. D. Little, Inc. estimates, quoted in ref. 7].

1. conduction losses through walls and windows;
2. infiltration losses resulting from the opening and closing of doors, for example; and
3. ventilation losses resulting from fresh-air makeup requirements for buildings.

Calculations based upon the American Society of Heating, Refrigerating, and Airconditioning Engineers (ASHRAE) guidelines for a typical three-story building show that as much as 49 percent of the energy loss occurs by conduction through walls, windows, and doors (ref. 8) (see figure 5). Infiltration from miscellaneous leaks or from opening and closing of doors amounts to another 10 percent of the space heating requirements. Fresh-air makeup accounts for the remaining 39 percent of the space heating requirements.

Note that even at very high recirculation ratios, heat will be required for conduction losses and infiltration losses as well as for a reduced fresh-air makeup. In the author's opinion, it is unlikely that this specific situation will achieve any more than a 30 percent recovery of the space heating requirements. Obviously, the exact amount of energy that could be recovered, either by heat exchange system or by a recirculation system, will vary from situation to situation. As an order of magnitude estimate, we have estimated that approximately 50 percent of the space heating requirements are recoverable.

Industrial vs. Commercial

Even though space heating requirements could be fulfilled through recirculation in either an industrial or commercial situation, there are too many sufficient differences between the two environments to expect that major differences in reaction to the recirculation scheme will be experienced. The problem is in assessing the relative degree of difficulty in achieving recirculation as compared to the relative energy benefits to be attained. The industrial and commercial situations are compared in table 1. Note that in a commercial environment, the air is relatively free of hazardous pollutants, suggesting an uncomplicated recirculation system, whereas in an industrial environment (a foundry, for example) the potential for buildup of highly hazardous materials is much greater than in a commercial sector. Likewise,

Table 1. Comparison of commercial and industrial situations.

Factors	Commercial sector	Industrial sector
Contaminants	Minimal	Potential hazard
Space heating requirements	60 percent of total	7 percent of total
Waste heat sources	Few, if any	Several
Exhaust recirculation	Potentially attractive	Limited use

SOURCE: Energy Resources Company (ERCO) assessment.

space heating energy requirements comprise approximately 60 percent of the total energy needs of the commercial environment, whereas they make up only 7 percent of the total energy needs of the industrial environment.

In most cases, the energy designer will consider all the alternatives that he faces for conserving energy. In the case of the commercial environment, the number of alternatives are limited, in many cases, to a trade-off between heat exchange vs. recirculation of industrial exhaust. In the industrial situation, the energy planner can choose from a number of waste heat recovery options from a number of waste heat sources. In most cases, the energy designer will not be limited to air-to-air heat exchange, but in fact will have a number of low-grade heat sources in the plant from which to capture space heat requirements. After all, his space heat requirements are only a small portion of the total energy usage in the plant, and in most cases only a small portion of the total waste heat in the plant. On the basis of this preliminary review, we would conclude that the major target for recirculation technology is in the commercial sector; that in fact the industrial sector will provide very little of its space heat requirements by recirculation of exhaust air.

Estimated Net Benefit

Based upon a 50 percent recovery efficiency, the total energy recovery by this technique is slightly in excess of 1 quad or slightly more than 1.5 percent of the energy consumed in the United States. That may not sound like a lot of energy, but is, in fact, equivalent to a half million barrels of oil per day, or approximately one-fourth of the maximum capacity of the Alaska pipeline. Industry has gone to great lengths to build the Alaska pipeline to gain the benefits of the energy there; perhaps industry will also be willing to go to great lengths to reap the benefits of energy conservation techniques such as recirculation of exhaust air.

THE PROCEDURE

Up to this point we have discussed energy requirements in the United States in general, and have identified the potential market for industrial exhaust recirculation. We have also suggested, however, that there are several other alternatives that energy planners must consider: heat exchange, recovery from other waste heat sources, and so on. The major questions, then, are: How does one decide? What are the trade-offs between one recovery method and another? Two techniques are vitally important to energy management:

1. energy planning model, which concentrates on energy strategy and focuses primarily on the energy supply situation; and
2. industrial energy activity, which is a tactical recipe for energy conservation focusing on the demand side of the energy equation.

In the paragraphs below, we have described these two down-to-earth methods for assessing the energy supply and energy demand of a given industrial situation. We have also presented a few examples of how these techniques have been put to work in real industrial situations. Together, these two techniques provide a framework from which the energy planner can make rational decisions regarding the recirculation of industrial exhausts by placing them in context with the many other energy conservation opportunities available to the commercial and the industrial sectors.

The Energy Planning Model

At the present time there is a great deal of uncertainty regarding energy planning, particularly in the following areas:

1. Fuel availability--Most industries are facing restricted supplies for fuels such as natural gas, propane, and even fuel oil. While coal is available, delays of one or more years are common for obtaining the proper permits and opening new mines.
2. Price fluctuations--The Arab oil embargo has clearly demonstrated that energy has no intrinsic market value, but rather is worth whatever people are willing to pay. Hence, the price for energy several years from now cannot be predicted today with any reasonable accuracy.
3. Several new technologies are being developed, such as fluidized-bed combustion, coal gasification, solar heating, and several others which are in early stages of demonstration or commercialization. These, of course, introduce technical uncertainties into the planning process.

Before energy became a problem, plant designers had very few alternatives to choose from; nor did they need many. Energy was available, it was cheap, and it rarely had a major impact on the cost of the plant outlet. Things have now drastically changed and the energy planner is faced with providing answers for the following questions:

1. What fuel should be used to minimize energy costs without running significant risks of plant shutdown because of restricted supplies?
2. When should old equipment be phased out and new energy-efficient equipment installed?
3. Are large cogeneration-based utility plants more cost-effective than smaller, dispersed equipment, including solar systems, for example?

The energy planner today has literally hundreds of options--most of them not as attractive as options available 10 years ago. To deal with these options, several computer-based programs have been or are currently being developed for energy-use planning at the corporate level. In figure 6, a schematic is shown of one such computer-aided design program having the following components:

1. Input--the program is an interactive program where the engineer tries different plant configurations while on-line with the computer.
2. Executive program--the program handles the actual calculations, optimization, and so on.
3. Data files--these files contain physical/chemical data, descriptions of equipment within the plant, data on material and energy flows, equipment costs, and so on.

Programs such as these have been used historically in the chemical design business for designing a chemical plant. More recently they have been adapted

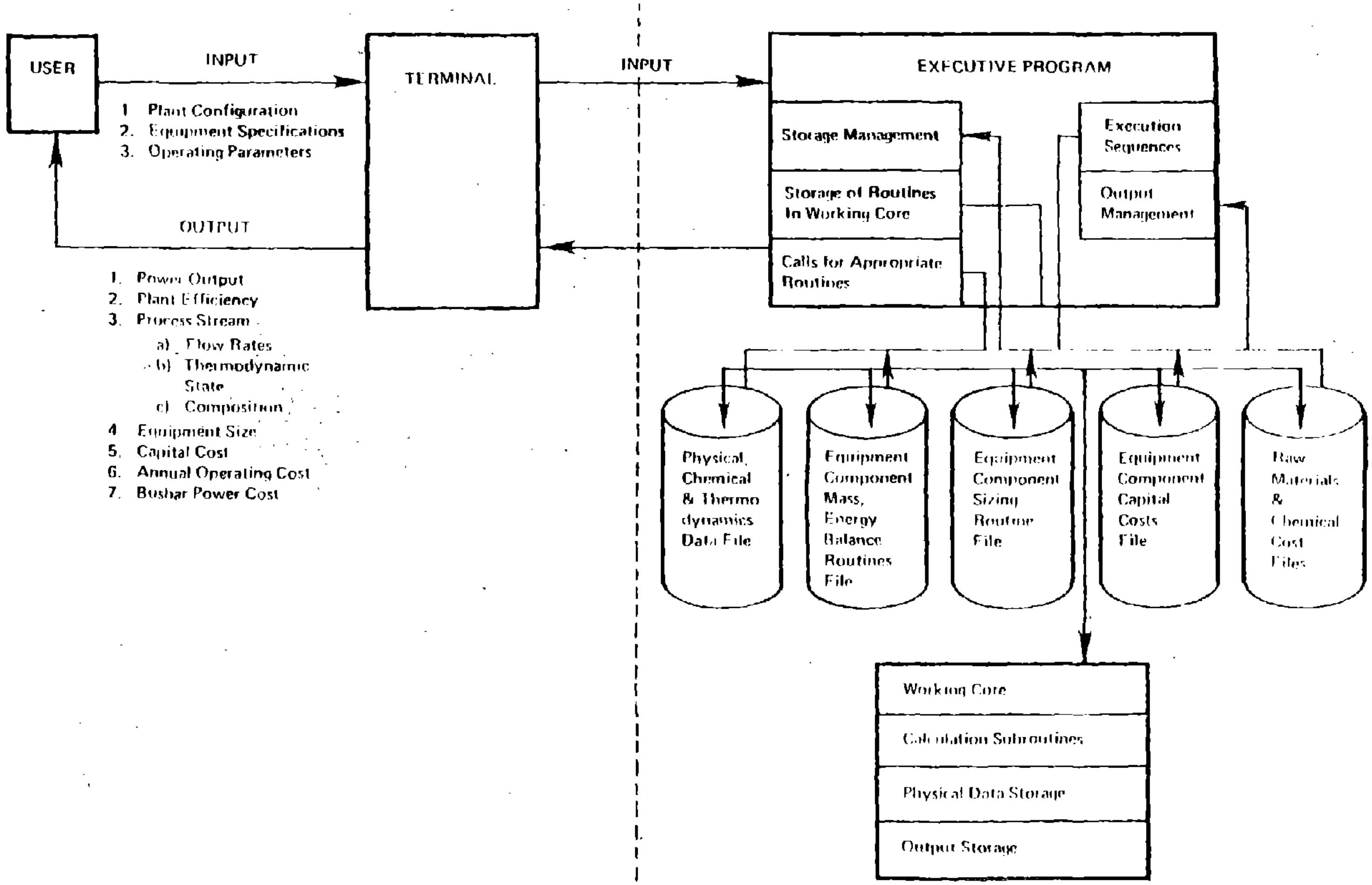


Figure 6. Schematic of computer-aided design.

for providing a cost optimization of energy supply options to suit specific plant situations.

Simplified versions of this type of energy planning model are currently available and in use by a number of companies in the United States, and more advanced, sophisticated versions are currently being developed by industry by EPRI, and within the new Department of Energy.

The Energy Audit

The demand side of the energy use picture for any industrial situation is much more definable. For the last several years, the technique of industrial energy audits has developed to the point of being a well-developed engineering science. Briefly, this technique traces the energy flow through the plant and determines exactly where energy is spent and where it is lost. Once this is identified, it becomes a matter of straightforward analysis to determine the most cost-effective means for eliminating losses or minimizing them. The steps in an industrial energy audit are detailed in the following paragraphs.

Plant Survey--

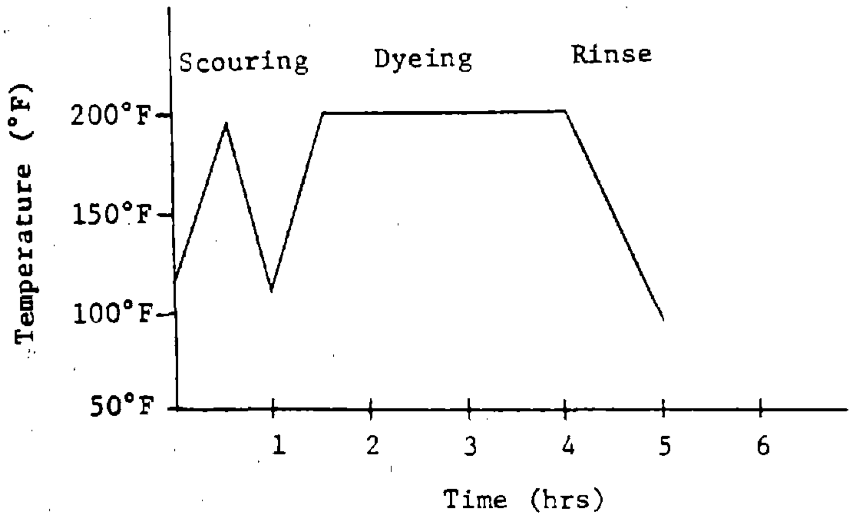
The first step in an energy audit is to conduct a detailed plant survey to determine the flow of energy for each individual building or industrial operation within a plant. As an example, consider an audit recently conducted for a textile manufacturer using a batch system for dyeing a product. The dye operation has three steps--scouring, dyeing, and rinsing. The temperature of the system and the corresponding energy requirements, either for heatup or for holding at temperature, are shown in figure 7. Similar data are developed for each major energy-consuming operation within the plant.

Establish Par Values--

Apart from understanding what each process in a plant consumes in the way of energy, it is also important to establish a par value, i.e., the amount of energy that a reasonably energy-efficient process should be using. As an analogy, consider a golfer who measures his efficiency at the game according to the number of strokes he takes above or below par. The par for each hole is set up according to the number of strokes required by a proficient golfer, if he makes no mistakes and does not rely on luck. The same type of scale can be constructed for each operation in a plant. Note that these are not theoretical limits, but are limits that could be obtained under normal practice.

Determine Total Energy Use Patterns--

Once the energy usage and par value for each process in the plant have been determined, then it is possible to simulate the energy flow for the entire plant. For example, the textile mill described previously has an energy flow shown in the Sankey diagram in figure 8. The plant uses both natural gas and fuel oil shown on the left. The fuel oil is used entirely for steam generation while the gas is used both for steam generation and for direct-fired heaters. The plant has several sources of heat loss, as shown across the top of the diagram. The plant achieves a modest amount of waste-heat recovery in the form of heat exchange with hot water, and condensate returned to the boiler. Major losses occur from the fact that the Becks are open to the atmosphere at near-boiling temperature, and therefore considerable heat is lost due to evaporation. Second, a large amount of hot water is literally



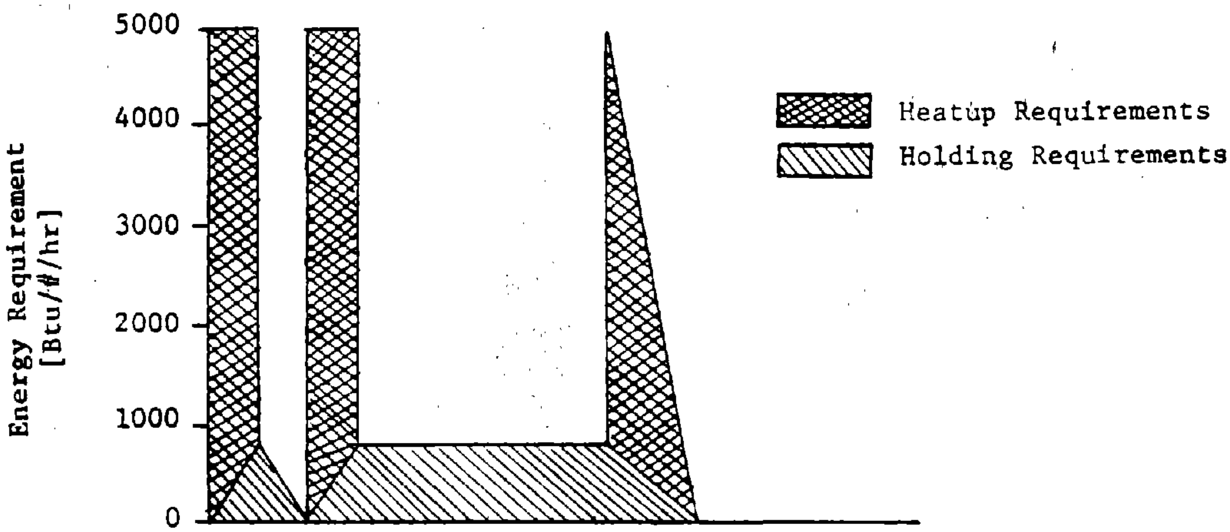


Figure 7. Energy requirements for typical open Beck cycle.

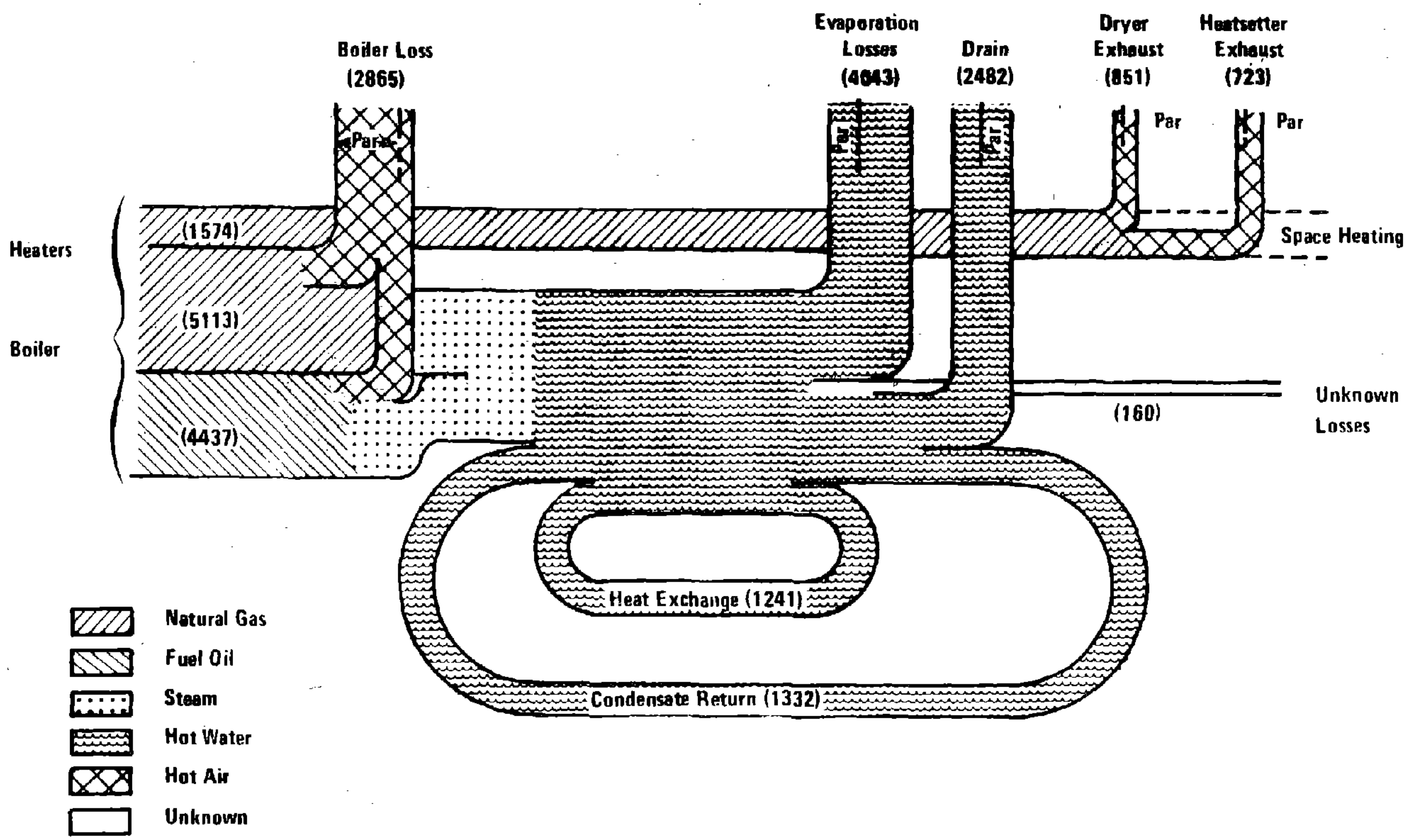


Figure 8. Example energy audit.

down the drain. Finally, note that the space heating requirements on the far right are supplied entirely by exhausting the fabric dryers and heat setters into the building. This is not the most effective system from an occupational safety point of view, but it does show that space heating requirements are much less than the total energy requirements of the plant, and that the amount of waste heat available at the plant is indeed greater than the amount required for providing 100 percent of the space heating requirements.

Evaluate Conservation Alternatives--
Experience in the process industries has shown that the first 10 to 15 percent in energy savings comes fairly easily through minor changes throughout the plant. As the company reaches this point, even more sophisticated ideas will be proposed for eliminating unnecessary fuel uses or increasing process efficiencies. The ideas for energy conservation fall into the following three categories:

1. Waste savers--Waste-saving ideas include relatively low capital expenditure projects aimed at specific waste streams. In practically every establishment, there will be a variety of things that can be done that could improve the energy utilization of various operations. These include additional maintenance, added insulation, and so forth.
2. Capital projects--Capital projects are those that could result in significant energy savings but will require significant investments as well. These types of projects include greater utilization of heat exchangers, more efficient use of steam power, recirculation of exhaust air, and the like.
3. Process modifications--The area in which the most significant energy savings can be accomplished in the long term is in major process modifications. Major process changes can take two forms: (1) adding or replacing equipment that increases the flow of production through the plant or reduces costs; and (2) replacing old process schemes with innovative technology.

With each of the types of conservation projects described above, the energy planner must evaluate the cost and energy savings for the technology and choose those mixes of technology that are most cost-effective.

As a result of the steps outlined above, an energy planner will be able to determine where the energy is coming from, where it is going, and what the most effective means are for reducing energy losses. Certainly, in carrying out this procedure, the recirculation of industrial exhaust will be one of the methods considered in step 3. As can be seen from the examples, the opportunities for recirculation of industrial exhaust are more likely to occur in the commercial sector where less competition with other techniques is expected.

ENERGY MANAGEMENT IS A FULL-TIME JOB

It is not enough to study the energy situation of a given plant or even enough to figure out what the most cost-effective means are for achieving conservation. Energy conservation must be a corporate endeavor that is given a high priority from the company's top management. Support for an energy conservation program includes both manpower and money necessary to carry out energy savings ideas.

The objectives of an energy conservation program are to:

1. set reasonable goals for energy consumption at each plant;
2. monitor and report energy utilization in each plant; and
3. promote communication on energy conservation both vertically and horizontally within the company.

The idea of goal-setting is an important one because it establishes a reference from which to measure progress in energy conservation. The key step in the energy conservation program is to continuously monitor the energy usage at each plant and compare this usage with target values determined during the energy audit. The monitoring should be accomplished by plant operating personnel for two major reasons. First of all, this type of monitoring program increases the operator's awareness of energy waste within the process, and secondly, it allows a company to capitalize on the operator's know-how in being able to improve process efficiencies. In fact, experience in the process industries has shown that one of the most valuable sources of waste-saving ideas is the operating personnel.

Finally, interplant communication is extremely important to an energy conservation program because it maintains a constant awareness of the need for energy conservation throughout the company. Each plant should report its energy consumption monthly as compared to the target of consumption for that plant. A corporate energy coordinator should review these reports and transmit them directly to top management. At the same time, coordinators should develop a means of communications through a newsletter in order to keep all the company informed of the progress in energy conservation, and also to encourage the exchange of technical information between plants. This type of program has proven to be very effective in both process and manufacturing industries in that it provides a forum for explaining various energy-saving techniques used in different plants.

IMPACT OF INDUSTRIAL EXHAUST RECIRCULATION

Over the next several years, particularly in light of the National Energy Plan, energy conservation will become an increasingly more important topic. A new surge in energy planning will come about comparable to the surge experienced shortly after the oil embargo of 1973. It is during the course of this new emphasis and new evaluation work at the plant level that the worth of recirculation of industrial exhausts will be borne out. From the present perspective, however, it is clear that:

1. recirculation can indeed effect significant savings in energy in the coming years;
2. the technique can be quickly implemented on both the industrial and commercial scale; and
3. as a part of a systematic analysis of energy conservation opportunities, recirculation is a welcome addition to the portfolio of techniques currently considered by energy planners across the nation.

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DISCUSSION

MR. ROBERT POTOKAR (General Motors, Warren, Michigan): I wonder where you got your 7 percent energy, industrial heat?

DR. STEPHENS: The 7 percent is an informal estimate attributed to Westinghouse.* The space heating requirement in the commercial sector is reasonably well-defined, but the data for the industrial sector is not broken down by end-use and therefore the space heating requirement is not readily available.

Mr. Potokar: Exxon is involved with a survey, and I believe the figure is going to be closer to 20 percent.

*Personal communication from Mr. Michael Glesk, Arthur D. Little, Inc., Cambridge, Mass., September 1977.

THE RECIRCULATION OF INDUSTRIAL EXHAUST AIR

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NIOSH Project Officer: Alfred A. Amendola
Principal Investigator: Franklin A. Ayer

FOREWORD

These proceedings of the symposium on "The Recirculation of Industrial Exhaust Air" are submitted under Contract No. 210-77-0056 to the National Institute for Occupational Safety and Health of the U.S. Department of Health, Education, and Welfare. The symposium was held in Cincinnati, Ohio, on 6-7 October 1977.

The objective of this symposium was to discuss the development of technical criteria for the recirculation of industrial exhaust air. With emphasis on the protection of the worker's health, technical subject matter discussed included: (1) decision logic for determining recirculation feasibility; (2) design and performance guidelines for recirculation systems; (3) availability of air cleaning and monitoring systems; and (4) maintenance guidelines.

Mr. Robert T. Hughes, Chemical Agents Control Section, Control Technology Research Branch, Division of Physical Sciences and Engineering, National Institute for Occupational Safety and Health, Cincinnati, Ohio, was the Symposium General Chairman.

Mr. Alfred A. Amendola, Control Technology Research Branch, Division of Physical Sciences and Engineering, National Institute for Occupational Safety and Health, Cincinnati, Ohio, was the Symposium Vice-Chairman and Project Officer.

Mr. Franklin A. Ayer, Manager, Technology and Resource Management Department, Center for Technology Applications, Research Triangle Institute, Research Triangle Park, North Carolina, was the Symposium Coordinator and Compiler of the proceedings.