The M/E Engineer's Role on the Building Energy Conservation

HERBERT KUNSTADT, Chief Executive Officer

Working together from the inception of a project, the consulting engineer and architect can achieve substantial reductions in energy consumption. A brief review of the problems and their solutions.

THE TORRENT OF WORDS about the energy crisis appearing these last several months in the daily newspapers and mass circulation magazines lend credence to James Reston's comment that the oil embargo imposed upon us by the Middle Eastern oil producing states has been "a blessing in disguise".

Queuing at gas stations is, in my view, the major single reason which awoke the public to the grim reality that fuels are not available in endless quantities and that squandering our energy resources could lead to grave economic (and political) consequences. Brownouts and localized heating fuel shortages had been placed in the "nuisance" category and so did not trigger the reaction dry gas pumps at neighborhood filling stations provoked.

In October, 1972 *Fortune* astutely titled its lead story "The Energy Joyride Is Over". I wonder, how many architects, developers, building owners and operators or consulting engineers, took the magazine's grim forecast seriously enough to change their way of designing or operating buildings?

Available statistics indicate that about one-third of all the energy we consume is presently used for lighting, heating, air conditioning, ventilating, domestic hot water and power requirements for residential, institutional and commercial buildings. Industrial users, accounting for approximately 30% of the primary energy resources, spend also a great proportion of their energy consumption on HVAC and lighting systems.

Since such a large proportion of present energy usage is attributed to buildings, it follows that we must honestly ask ourselves whether we have not neglected our professional obligation to design the most efficient mechanical and electrical systems, best suited to each of our projects?

Subordination of Energy Criteria

Unfortunately, the consulting engineer has not had the power to significantly influence the energy usage of buildings. He has been generally confronted with a set of decisions taken prior to his involvement, which decisions have had a substantive impact on his projects' future energy budget. Building siting, orientation, shape, fenestration and glazing, exterior design, materials all bear heavily on the requirements for lighting, heating and cooling which continue to influence every structure's energy consumption for many years to come.

The engineer has been asked to accept all these decisions gracefully, to subordinate his system's requirements to the pre-established conditions. This severely limits his ability to select optimum mechanical and electrical systems from an energy efficiency standpoint. Most of the engineer's skills have been devoted to squeeze the various components of the M/E installation into the building's shell. Of course, heating and cooling loads were computed and various HVAC systems analyzed, but always for the building as it has been pre-designed and, what is even more important, under a mandate that the first cost must be kept at the lowest possible level.

When owning and operating cost studies were prepared, the fuel component in the operating cost budget could hardly swing a decision in favor of energy conservation. The average commercial building's energy bill has always been negiligible when compared with such other operating expenses as debt service, maintenance, personnel, and cleaning.

Working against budgets that do not credit future savings in energy consumption restricts the engineer to systems with lowest initial cost and, often, low efficiencies. Furthermore, even with awareness of rising energy costs, lack of adequate compensation for his efforts frequently forces the consultant into routine type solutions. More thorough cost analyses, investigation of alternate solutions and incorporation of energy conservation features into building design require considerable additional time and skilled personnel, not always permitted by the design budget.

The Roles of Owner, Architect and Engineer

Only joint effort by owner, architect and engineer can successfully lead to dramatic reductions in building energy usage. Following is a succinct presentation of the role we envisage to be played by each of these parties:

The owner must recognize the need for a thorough project analysis from an energy usage viewpoint. In this context, he should request his architect/engineer team to prepare a documented study of various M/E systems as they relate to various building configurations, glazing, orientation, skin, insulation, shading, etc. Realistic design criteria for lighting, temperature and humidity levels should be established. Since lighting accounts for about one-quarter of all energy used in this country, any significant reduction of its use will have the most beneficial effect.

There are relatively few hours in the course of a year when outdoor temperature reaches the levels recommended for design. Consequently, the owner should accept deviations from the average desired indoor design conditions for those days with extremely unfavorable weather conditions.

Reduced outdoor ventilation rates, in conjunction with improved filtration, will substantially diminish the building's energy usage.

Last, but not least, the owner must realize that minimizing energy consumption will increase initial project cost, but a life cycle cost study should prove that the additional first cost minimizes long range owning and operating expenses.

The Architect is really in the driver's seat when it comes to energy savings in a building. The conceptual philosophy, reflected in the building's design, determines the energy use pattern for the life of the building. The architectural solution is, however, influenced by the client, economic considerations and legal implications. We wish that the mechanical and electrical consultant would be permitted to play a significant role in those of the architect's design decisions which influence future energy use. Due to building space limitations, for instance, M/E systems are frequently selected on the basis of available shafts or machine room areas. To cite one example, high velocity air systems, with their powerful, high-pressure fans, are an illustration of trading space for energy.

Lighting design, although a specialty in itself, is most often determined by the architect. Local task oriented lighting rather than generalized overhead lighting, could save large energy resources, without diminishing illumination quality. By involving the engineer in the very early stages of design, the architect will be in a position to obtain his advice on how to optimize energy needs without compromising the project's design features.

The Engineer must convince owner and architect that he has the know-how and desire to be a creative member of the design team. Thorough familiarity with the latest technical developments, hardware, system design and operation can equip the consultant to creatively influence the design. Thorough familiarity with the building's program and the architect's design philosophy could greatly help the M/E designer.

The engineer must persuade the architect to permit him to work on the project from its inception in order that he be in a position to participate in the initial fundamental decisions which will affect M/E design later on. It is incumbent upon the M/E consultant to alert the architect to any adverse energy use impact of a non-mechanical design decision. Too often had the engineer acquiesced in design solutions which adversely influenced energy usage.

What the Engineer Must Investigate

Following is a succinct outline of suggested work stages for the engineer:

1. Prepare comments for architect on the building siting, orientation, fenestration, glazing, insulation, configuration, and other primary decisions which will influence the building's energy use. Make analytical comparisons between various schemes proposed, showing the cooling and heating requirements and project their operating cost differentials over the building's life.

2. Alert the architect on new technical developments as they relate to the project requirements, such as new insulating materials, multiple glazing systems, fuel and electric energy rates, solar panels, etc.

3. Delineate to the architect the various system options available and the *pro's* and *con's* of each of them. An owning and operating cost study should be prepared for at least three recommended schemes.

4. As a general guide, the following is a listing of the major HVAC systems which should be reviewed on every project. Some of the systems may be eliminated by a cursory inspection. An economic analysis should be prepared for the selected schemes:

A. All-air systems: — Variable volume (low and high pressure), Reheat, Dual duct, Dual conduit, By-pass, and Multizone.

B. Air-water systems: — Fan coils (with 2, 3 and 4 pipes), Induction units (with 2, 3 and 4 pipes), and Radiant ceilings (with 2, 3 and 4 pipes).

C. Heating Source: — Direct fired gas or oil fired boilers, Electric, District Steam (low and high pressure), District hot water (of low, medium and high temperature), and Solar energy.

D. Cooling Source: — District chilled water, Building central chilled water plant, Multiple individual cooling units, Heat pumps, and Solar energy.

E. Electric Energy Source: — Local utility, Total energy plant with heat recovery. In addition, the engineer must investigate the commercially available energy recovery schemes: Rotary regenerative heat exchangers (heat wheel), Heat pump, Heat pipe, Economizer cycles, Run-around systems, Three- and four-pipe heat recovery systems, 'Bootsrap' systems (heat from lights, people, etc.), Air-to-air plate exchangers, Off-season free cooling with centrifugal chillers, Energy reclamation from commercial refrigeration units, engines, turbines, boilers, heat producing equipment, hot water drainage, as well as High efficiency light sources and Solar energy utilization.

For clarification, following are brief descriptions of several of the above listed energy recovery equipment and systems:

The Rotary heat exchanger reclaims energy from exhaust air streams. It is installed between the exhaust and supply air ductwork and can recover about 70% of the thermal energy of the air flow, before it is spilled to the atmosphere. Heart of the system is a large, motor-driven wheel, filled with a very conductive metallic light-weight, non-clogging and bacteriostatic material. As the wheel rotates, it recovers heating or cooling energy (depending on the season) from the exhaust air and half a revolution later it transfers this energy to the incoming outside air. A built-in purge section reduces carry-over of exhaust air to incoming outside air to about 0.05% by volume.

Heat Pumps have been used extensively to reclaim energy. The air-to-air heat pumps are the most common type. It is a factory-built unitary package and is available in capacities up to about 5 tons. They are available in two thermal cycles: refrigerant changeover and air changeover. In the refrigerant changeover cycle, the condenser becomes the evaporator and the evaporator and condenser when the cycle is changed from the cooling to the heating mode.

The heat pump's air changeover cycle provides for the airstreams to be interchanged, and one heat exchanger coil is always the evaporator and the other is always the condenser. A set of dampers will direct the air flow such that the space is supplied either with hot or cold air, as required by the room thermostat.

A water-to-air heat pump uses water as a heat source and sink and uses air to transmit heat to and from the conditioned space. A typical design has the air blown across a finned coil during the cooling cycle, to cool and dehumidify it. A pipe within a pipe acts as a condenser. Heat absorbed in the finned coil is rejected at the heat exchanger; the heated water is sent to a cooling tower.

During the heating cycle, a

reversing valve changes the roles of the finned coil and heat exchanger. Now the refrigerant cools the water in the heat exchanger and this heat is rejected to the air at the coil.

Air-to-water heat pumps are often used in large buildings, where zone control is mandatory.

Water-to-water heat pumps use water as the heat source and sink for both heating and cooling operation. Heating-cooling changeover may be accomplished in either the refrigerant or the water circuit.

Earth to air and earth to water are two additional heat pump applications.

Heat pumps are well suited for use in buildings with high internal heat gains and with large interior spaces, such as office buildings, hospitals, schools, shopping centers, etc., collecting heat that otherwise would be thrown away and using it where needed.

The Heat Pipe is a relatively new development, one of the many spin-offs from the aerospace industry. A heat pipe acts like a superconductor of heat. It consists of a balanced arrangement of volatile liquid refrigerant and capillary wick permanently sealed inside a thin-walled metal pipe. A liquid-to-vapor-to-liquid circulation loop is then set up whenever heat is applied to or removed from any area of the pipe. If a warm stream of air is passed across one end, the refrigerant absorbs heat from the air and evaporates. Vapor flows down the pipe to the cold end, where a flow of cold air causes the vapor to condense and resaturate the porous wick. The liquefied refrigerant now flows along the wick to the warm end, where it is again evaporated. In winter, incoming cold outside air is warmed by the heat extracted from the exhaust. In summer, the reverse takes place.

Economizer cycle is the name commonly assigned to systems which use outside air for cooling, whenever the outdoor temperature and humidity conditions are suitable. There is no need to explain why the introduction of outside air without its prior heating or cooling will save energy. Controls must be such that motorized dampers will automatically modulate the amount of outside air supplied as a function of the indoor and outdoor conditions.

"*Bootstrap*" recovery systems will pick-up heat from the building interior areas via the chilled water circuit and transfer it to the perimeter areas and air preheat coils.

Water cooled luminaires, used in conjunction with vertical louvers, also accomplish this "heat transfer" from the interior to the perimeter of the building and, in addition, reduce the energy requirements for mechanical refrigeration.

Solar energy utilization for heating purposes has a good and successful track record in many parts of the world. Its potential is limitless and research for its commercial application is advanced. Flat plate collectors are available today for water heating and their application must be investigated on every project.

Off-season "free" cooling systems are generally incorporated into centrifugal chillers. Such systems can supply chilled water during periods when outdoor temperature is below that requiring refrigeration plant operation, without operating compressor. At a temperature of about 50F ambient, the refrigerant evaporates and cools the chilled water in the process. The refrigerant then migrates to the condenser, due to its lower pressure, created by the cooling tower water, condenses, and returns thereafter to the chiller to start a new cycle.

Light source selection is crucial to the overall building energy budget. The lighting system designer has a wide choice of light sources: incandescent, fluorescent, mercury vapor, metal-halide and tungsten-halogen for interior, and high-pressure sodium for outdoor use. Luminous efficiencies (lumens per watt) for these light sources are:

High pressure sodium	102-130
Metal-halide	80-100
Fluorescent	73-80
Mercury-vapor	45-55
Tungsten-halogen	19-22
Incandescent	11-22

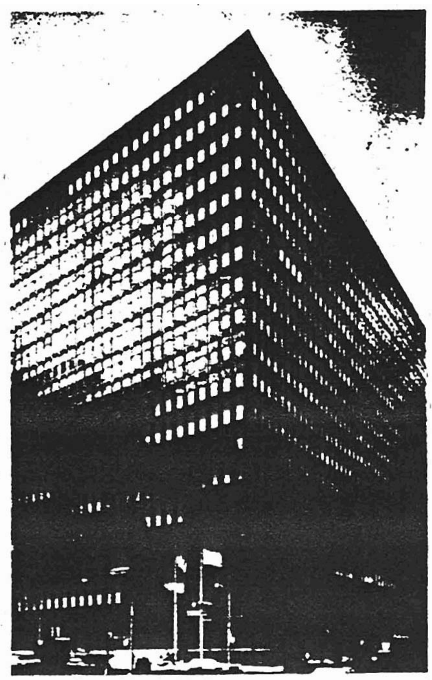
Thus, one must conclude that, to conserve energy, fluorescent or metal-halide lamps are best for interior applications and either high pressure sodium or metal-halide lamps for area flood lighting. Judicious lighting design could reduce its electric energy consumption by 50% and would lead to a 3% saving in nationwide energy use.

Conclusions

The purpose of this essay has been to highlight the essential role the consulting engineer must assume in our drive to conserve energy and to redefine his obligations on the building design team. We have attempted to explain why the consulting mechanical and electrical engineer must work with the architect from the project's inception and how his contribution will decisively affect the building's future energy use.

The time when governmental regulatory agencies will impose "energy use standards" upon buildings is not far away. "Energy impact statements" or "Building energy budgets" will perhaps soon be routine design requirements and life-cycle costing will be the basis for selecting mechanical and electrical systems, as well as the other building elements.

We cannot conclude without emphasizing the urgent need to have every existing building analyzed from an energy use viewpoint, in order to uncover waste and optimize the mechanical systems to reduce electric energy and fuel consumption. Existing structures designed on the basis of "first cost economics" present a wealth of possibilities for energy conservation measures. Consulting mechanical and electrical engineers possess the knowledge to advise owners of such buildings on how to best improve their mechanical systems operation, often at negligible cost when compared with the benefits they will return.



Gateway Center
Victor Gruen, Architect