The Space Congress® Proceedings

1978 (15th) Space - The Best Is Yet To Come

Apr 1st, 8:00 AM

# Identification of Cost Effective Energy Conservation Methods

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## IDENTIFICATION OF COST EFFECTIVE ENERGY CONSERVATION MEASURES

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### ABSTRACT

In addition to a successful program of readily implemented conservation actions for reducing building energy consumption at Kennedy Space Center, recent detailed analyses have identified further substantial savings for buildings representative of technical facilities designed when energy costs were low. The techniques employed for determination of these energy savings consisted of facility configuration analysis, power and lighting measurements, detailed computer simulations and simulation verifications. Use of these methods resulted in identification of projected energy savings as large as $330,000 a year (approximately two year break-even period) in a single building. Application of these techniques to other commercial buildings is discussed.

### INTRODUCTION

Figure 1 shows the familiar up, up, and away trend of energy costs over the last two decades. In discussing energy conservation in the late seventies, it is important to look at what energy costs were in the sixties and earlier, when a large majority of the current population of buildings was designed and constructed. When electricity cost between one and two cents per Kilowatt-hour and fuel oil was fifteen cents a gallon, it was only common sense for building designers to look elsewhere for cost reduction criteria. Those days, however, are long gone and we are now concerned with conserving energy in buildings which were over-designed for the actual loads and did not use least energy solutions for the design loads.

The energy conservation efforts of the National Aeronautics and Space Administration have been organized for more than four years, with the focal point being the Director, Office of Facilities at NASA Headquarters, and, supporting him, Energy Resource Managers from each field center. At Kennedy Space Center, both the Plant Engineering and Maintenance Divisions and elements of Design Engineering have been active in trying to reduce consumption of oil, electricity, and fuels for purposes other than transportation.

A goal of fifty percent reduction in energy consumption, including transportation, has been established for the entire agency, and the same for each field center. The time span for this reduction is from the end of fiscal year 1973 to the end of fiscal year 1985. At the end of fiscal year 1975, Kennedy Space Center had cut its energy use by 37 percent compared to base year 1973. Savings have resulted from a vigorous program of lighting reduction, heating, ventilation and air conditioning (HVAC) operating conditions and schedule adjustments, and eliminating careless or inattentive practices. However, further decreases will require more systematic study, and indeed this has already begun.

In 1977, two things occurred that increased the emphasis on analytical methods. First, the easy "quick-fix" solutions had already been implemented and the next few percent reduction was obviously going to require study of alternative modifications to building HVAC systems for both general office and more technically oriented structures. Second, the President's Executive Order 12003 was issued. This order established a 1975 base year, and implementation of audit and reporting schemes is yet to be resolved, especially as concerns NASA's already ongoing plan. The draft implementation plan called for all federal buildings above 30,000 square feet to be audited by the end of fiscal year 1978, and all federal buildings above 5,000 square feet by the end of fiscal year 1979. Although the Energy Act was not passed by the Congress in 1977, the guidelines for consumption indices set by General Services Administration and resulting from Standard 90-75 of the American Society of Heating, Refrigerating and Air Conditioning Engineers

(ASHRAE) point to needed improvements in HVAC systems.

Studies of energy conservation potential at technical facilities and more general buildings have been conducted by the Energy System Group of the Planning Research Corporation, Systems Services Company (PRC/SSc). This report discusses methodology and findings of the NASA - PRC/SSc studies. PRC/SSc is now deeply involved in this work and we expect to have completed audits on many of the major facilities at the Cape by the end of this year. We have selected the Central Instrumentation Facility (CIF) and the Orbiter Processing Facility (OPF) as being representative of the situations we have encountered.

To illustrate the difference between 1960 and 1980 design criteria, Figure 2 shows the capacities of the HVAC supply air handlers in the CIF building. We see that only about one quarter of the design supply air is really needed to satisfy energy conservation standards present ASHRAE standards - 126,000 CFM insteat of 530,000 CFM. The factor for return air handlers is even less.

We have found in our studies to date that heating, ventilating, and air conditioning systems are by far the largest energy consumers. Figure 3 shows the percentages for the CIF and OPF buildings. The difference in the proportions between the two buildings is that the chilled water supply for the OPF comes from a utility annex and is not included in the building energy budges. In both cases, high temperature hot water also comes from an external source.

## TECHNIQUES

The major steps in our energy conservation audits are shown in Figure 4.

Data collection is of course the first item on the agenda. Architectural or contractor drawings are usually available, though they may be deep in some dusty vault behind the furnace room. Floor plans, Air Handling Unit (AHU) zones, furnace and chiller performance, pump and fan sizes, and lighting data can be read from such drawings, as can building materials, glazing, and insulation information which is essential for external heat gain and loss computations. Internal head loads from people, electrical equipment, machinery, and so forth, must also be determined. This phase can be the most time-consuming (and expensive) in the entire audit, depending on the availability of the information. Many modern buildings also have quite sophisticated utility control systems which record actual performance and energy consumption data. These records can also be of great value to the audit team.

In theory, an energy conservation audit could be performed on the basis of paper information. (Figure 5) In practice, a walk through is absoutely essential to valid energy-saving recommendations. The audit team must "know the building", or at least develop a feeling for how the building systems actually operate and interrelate. A walk through will also disclose differences between the "as-built" condition shown on the drawings and the "as-is" condition which is the result of modifications and changes which have accumulated over the years. It will also reveal the results of maintenance practices or malpractices which strongly affect energy efficiency.

The PRC Energy Conservation Group uses the NECAP computer program for simulating building energy use. (Figure 6) This acronym stands for the NASA Energy Cost Analysis Program. It was developed at NASA's Langley Research Center and is one of only a few commercially available programs useful in energy audits. Because of the many and continuing improvements NASA has made to it, it is one of the most comprehensive programs in actual field use for handling building loads and transient responses for conservation analyses on existing buildings.

The first NECAP run gives us a common baseline simulating the building as it currently operates.

Having all this information in hand, we then retreat behind that facade common to all engineering organizations, known as "the analysis phase". Here we organize the data, compare system performance with current ASHRAE standards, and look for areas of inefficiency and waste. We also review the NECAP baseline and perform hand calculations to verify certain critical points in its output. We do this to satisfy ourselves that the NECAP program accurately represents this particular building and also to assure that we have correctly formulated our inputs to the computer. We then postulate changes that appear to be promising and perform hand calculations as a preliminary check on their effectiveness. These changes may encompass anything from cooling towers to light bulbs. As a minimum, we check all pumps and fans, window shading, electrical equipment loads, chillers, boilers, insulation losses, and conditioned air leakage. As noted above, our experience to date has indicated that we should concentrate most heavily on the various aspects of air circulation design and operation and we do spend more effort on that than on other areas.

Having devised several alternative modes of energy management and potential modifications for the building in question, we go back to the computer and run through various combinations of conservation alternatives. NECAP gives us total energy comsumption, in Kilowatt-hours and BTU's, for each run and we are thus able to select the most cost effective set of recommendations. These annual savings, combined with estimates of modification costs, then enable us to compute a payback time according to accepted criteria.

## DISCUSSION - CIF

Figure 7 is a picture of the Central Instrumentation Facility at KSC. It is a three-story building, with about 135,000 square feet of floor space, and has curtain walls of pre-cast concrete and insulation sandwich. It contains offices and laboratories but its primary purpose is to house telemetry terminals, data handling equipment, and computers. It is a self-contained unit except for electric power and high temperature hot water from the Central Power Plant. The CIF was designed in 1961.

An earlier chart (Figure 2) showed the large amount of air circulation that was designed into this building - a factor of four over what we eventually found to be needed in view of today's standards. Over the years, this excess of circulation had been reduced, both intentionally and unintentionally, but unfortunately without a commensurate reduction in power consumption. Several by - passes from supply directly to return had been installed, fresh air intakes had been blanked off, damper and louver controls had been disconnected or rusted beyond use, and vapor barriers on insulation had broken down. As a point of interest, we noticed early in our analysis of the CIF that not only was fan power very high but also that the consumption of high temperature hot water was very low. What was happening was that electrical energy from the fans was heating the air after dehumidification chilling, leaving very little for the terminal re-heat units to do. This kind of comparative analysis of all energy use patterns is a very worthwhile part of the conservation audit.

Figure 8 shows the recommendations we made for energy conservation in the CIF building. In addition to these, we investigated but did not recommend several other measures. These include:

- Turning off water coolers reducing the need for rest room exhaust fans by the use of chemical deodorants.
- Use of a more highly reflective paint to improve indoor lighting.
- External louvers and reflective film for windows.

The reasons for not recommending these changes, each of which would have saved energy, were varied but in most cases the payback period was longer than two years.

The CIF building is served by a centralized Utility Control System (UCS) which automatically turns HVAC equipment on and off, subject to override by operators who centrally monitor UCS data in real time. Much of this data - run times, amperages, temperatures - is also recorded for reference or analysis. Figure 9 is a good example of data recording, a case which enabled us to arrive at a definitive conclusion about cooling tower utilization practice. The data shown consists of minute-by-minute readings of amperage to a water chiller compressor, cooling tower fan on-off positions (fans number 2 and 3 were on continuously, fan number 1 cycled on and off, and fan number 4 was off). The data shows that the circuit was indeed very responsive to cooling demand. Amperage to the compressor rose in two steps as ambient temperature increased during the morning and cooling water temperature out of the condenser increased correspondingly. Cooling tower fan cycling, however, increased the delta T across the towers and held the cooling water into the condenser at a nearly constant temperature.

## DISCUSSION - OPF

The Orbiter Processing Facility is a very different building from the CIF. (Figure 10) It will house the Orbiter Space Craft while they are on the ground and contains all the access platforms, cranes, and auxiliary and emergency equipment necessary for refurbishing the orbiter and for removing, installing, and checking the payload modules. In addition, the building has offices, storage areas, and a computer room. The High Bay roofs are ninety-three feet above grade. The floor area totals 94,000 square feet and the enclosed volume is 6 million cubic feet. High Bay walls are constructed of steel sheet, insulation, and corrugated steel panels, while the Low Bay and Annex are of concrete block.

Another significant difference between the two buildings is that the OPF is not yet completed. The energy audit was accomplished in the absence of any operating data and, in some instances, without knowing the "as-built" condition.

A similarity between the two buildings is that both air handling systems were over-designed by about the same factor. In the case of the OPF, recently designed, the excess was caused by stringent air cleanliness requirements, calling for more air changes then would otherwise be required. The requirement for four air changes per hour was subsequently relaxed and comfort requirements prevailed for the energy audit.

The extensive use of electricity for orbiter servicing equipment constituted a major heat load on the building and we calculated the power consumption in quite some detail, based on equipment lists and use patterns supplied by NASA. Two shifts is expected to be the norm, with standby conditions for 88 hours per week. The air handling system is complicated by the inclusion of an emergency mode to handle accidental spillage of hypergolic propellant, a highly toxic material.

Figure 11 shows the air handling cases which we simulated with the NECAP program. This analysis led to our recommendation to operate only one of two 44,000 CFM fans in only one of the two AHU's in each High Bay. (All four fans were already in place, so we could not save the procurement expense).

Figure 12 shows the major energy conservation recommendations for the OPF. Again, less significant but valid recommendations were also made and several conservations options were investigated but failed to meet a two-year payback criteria.

## SUMMARY

We have been able to recommend to NASA cost saving modifications which average over $280,000 and 8.5 million Kilowatt-hours per year, for each building. Extrapolating this average over the audits we expect to have performed by the end of this year, we can predict cost savings of well over $3.0 million per year.

Our work convinces us that an energy conservation audit is an extremely valuable investment. The energy audit tools and skills described in this paper are highly cost effective and general enough to apply to buildings spanning the range of the construction cycle – from unfinished to refurbished several times. In addition highly cost effective conservation measures ranging from large and complex to simple and readily adopted are consistently identified by these techniques.


## ACKNOWLEDGEMENT

The authors would like to acknowledge the assistance of many members of NASA Design Engineering and Operations particularly F. Ruggieri, R. Sykes, R. Gramling for their many suggestions and frequent assistance.


FIGURE 2

Central Instrumentation Facility Supply Air Handlers

| Zone | Original Design | Energy Conservation Recommended Setting |
|---|---|---|
| 1A | 30,000 CFM | 11,600 CFM |
| 1B | 30,000 CFM | |
| 2A | 36,000 CFM | 4,475 CFM |
| 2B | 38,000 CFM | 6,500 CFM |
| 3A | 40,000 CFM | 41,241 CFM |
| 3B | 84,000 CFM | |
| 4A | 40,000 CFM | 18,950 CFM |
| 4B | 67,000 CFM | |
| 5A | 40,000 CFM | 32,500 CFM |
| 5B | 35,000 CFM | |
| 6A | 31,000 CFM | 11,000 CFM |
| 6B | 31,000 CFM | |
| 7A | 30,000 CFM | — |
| Total | 530,000 | 126,000 |

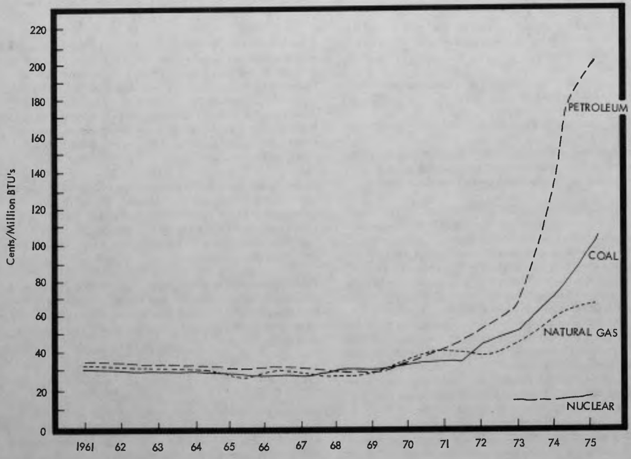


Figure 1. Energy Costs

FIGURE 3

ELECTRICAL ENERGY CONSUMPTION

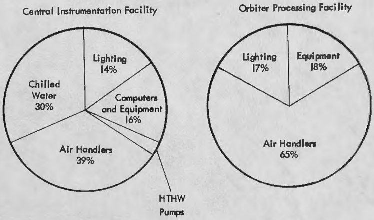


Figure 4. Energy Audit Procedures Employed

Data Collection

- Preliminary walk through of building to
  - Identify low cost, readily implemented energy conservation projects.
  - Plan detailed data collection procedures
- Determine energy consumption amounts by fuel type
- Establish building occupancy profile and activity level
- Delineate building configuration parameters
  - Envelope materials and dimensions
  - HVAC system types, sizes and status
  - Lighting levels (designed and actual)
  - Electrical/thermal distribution systems
  - Energy control systems
- Separate energy use due to process equipment

Data Analysis

- Comparison of data with standard checklists for identification of unusual situations.
- Creation of NECAP computer model baseline for both model and building energy use verifications.
  - Insertion of actual building operating conditions into model (e.g. air circulation rate)

Identification of Energy Conservation Alternatives

- Scrutiny of checklists of conservation opportunities for similar or analogous situations.
- Comparison of current procedures with good practice standards.
- Delineation of previous design requirements and their relation/applicability to present energy use.

Evaluation of Cost Savings

- Manual evaluation of simple conservation opportunities
- Simulation of complex alternatives with computer program
  - Hour-by-hour calculation of transient heat transfer in and out of building for a full year
  - Use of local weather conditions data
  - Use of actual building temperatures

Determination of Project Cost/Benefits

- Use current cost analysis techniques and data
- Project fuel cost escalations
- Application of project evaluation criteria
  - Time payback
  - Net present value

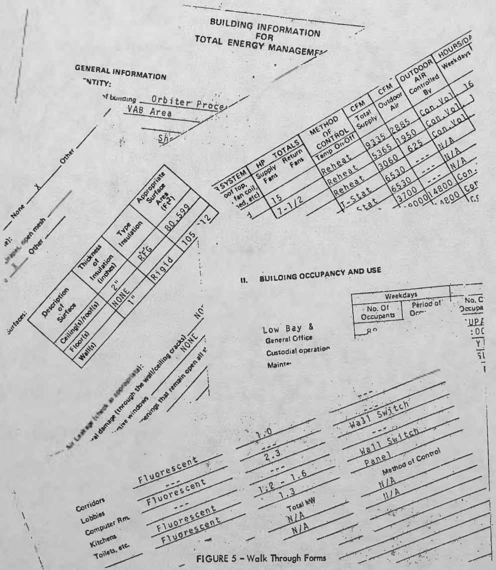


FIGURE 5 – Walk Through Forms

| EQUIPMENT AND ENERGY CONSUMPTION ANALYSIS | FACILITY/ADDRESS CIF KSC INDUSTRIAL AREA | | DATE/PROJECT 10_21_77 AIR AND LIGHTS | | USER AND SYSTEM IDENTIFICATION F A MARCH SYSTEM NO. 1 | | |
|---|---|---|---|---|---|---|---|
| | ENERGY CONSUMPTION | | | | | | |
| | JULY | AUG. | SEPT. | OCT. | NOV. | DEC. | TOTAL |
| MONTHLY BTU/1000 | | | | | | | |
| HEAT (MBH) | | | | | | | |
| MAX. DEMAND | -4.4 | -3.9 | -57.0 | -1427.8 | -2275.8 | -4564.9 | |
| CONSUMPTION | -17.2 | -25.2 | -352.7 | -73540.8 | -225106.5 | -481915.0 | -1053294.7 |
| COOL (MCB) | | | | | | | |
| MAX. DEMAND | 10635.9 | 10156.9 | 10395.6 | 9125.8 | 8483.5 | 8077.6 | |
| CONSUMPTION | 4149151.9 | 4152315.9 | 3808672.2 | 2835321.0 | 2303633.2 | 1808319.9 | 35980987.1 |
| ELECTRICITY | | | | | | | |
| LIGHTS AND BUILDING EQUIPMENT | | | | | | | |
| INTERNAL | | | | | | | |
| DEMAND(KW) | 914.1 | 914.1 | 914.1 | 914.1 | 914.1 | 914.1 | |
| CONS.(KWH) | 379758.4 | 390642.8 | 373943.6 | 379758.4 | 373943.6 | 301331.7 | 4471368.7 |
| EXTERNAL | | | | | | | |
| DEMAND(KW) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| CONS.(KWH) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| HEAT (INCL. BOILER AND AUXILIARIES, AND HOT WATER PUMPS | | | | | | | |
| DEMAND(KW) | 13.4 | 13.4 | 13.4 | 13.4 | 13.4 | 13.4 | |
| CONS.(KWH) | 9945.0 | 9945.0 | 9624.2 | 9945.0 | 9624.2 | 9624.2 | 116774.1 |
| COOL (INCL. CHILLERS, WATER PUMPS, AND COOLING TOWER FAN | | | | | | | |
| DEMAND(KW) | 927.1 | 880.6 | 903.6 | 787.1 | 615.7 | 600.3 | |
| CONS.(KWH) | 429321.3 | 443391.7 | 395088.4 | 278811.2 | 230968.2 | 204168.8 | 3656269.0 |
| FANS | | | | | | | |
| DEMAND(KW) | 45.4 | 45.4 | 45.4 | 45.4 | 45.4 | 45.4 | |
| CONS.(KWH) | 34394.8 | 34394.8 | 33285.3 | 34394.8 | 33285.3 | 33285.3 | 403661.2 |
| TOTAL | | | | | | | |
| DEMAND(KW) | 1900.6 | 1854.3 | 1877.3 | 1760.8 | 1589.4 | 1574.0 | |
| CONS.(KWH) | 853919.5 | 878374.4 | 811941.5 | 702909.4 | 647621.2 | 548410.0 | 8648273.0 |

FIGURE 6 - NECAP Output

Figure 8. Proposed Energy Conservation Projects for the CIF

| Projects | Savings,** S $/yr | Cost of Project Implementation | Simple Payback Time, Years |
|---|---|---|---|
| 1. Block off a/c louvers to lobby | 745 | - | 0 |
| 2. Seal cargo doors | 810 | 270 | 0.33 |
| 3. Install Economizer | 4,600 | 3,000 | 0.65 |
| 4. Reinsulate chilled water pipes | 2,870 | 2,380 | 0.83 |
| 5. Increase lighting efficiency | 22,200 | 30,920 | 1.39 |
| 6. Reduce internal air circulation and Reduce fresh air intake | 301,000 | 684,000 | 2.27 |
| 7. Shade windows | 1,790 | 4,400 | 2.45 |

* Negative sign indicates an increase. kWh/y represents electrical savings. Btu/yr represents fuel savings

**1980 dollars $0.04/kWh, $0.465/gallon of oil

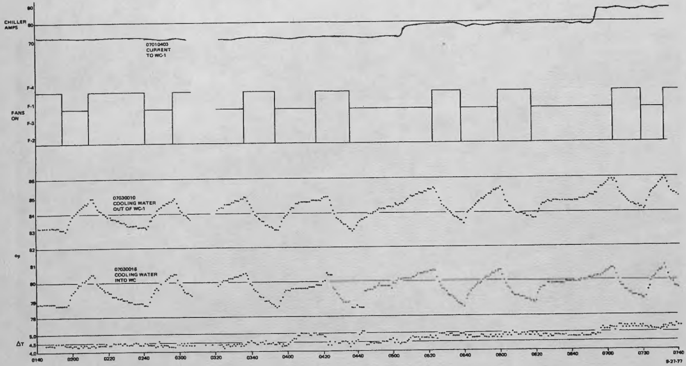


FIGURE 9 – Control System Data

**FIGURE 10 Orbiter Processing Facility**

FIGURE 11 - AHU Cases Simulated with NECAP

| No. | Case | Area | Airflow | Air Changes per hour | Damper Stop |
|---|---|---|---|---|---|
| 1 | Base Case, reheat | | Full | 4 | |
| 2 | VAV | High Bays | Full | 4 | 10% |
| 3 | Bypass | High Bays | Full | 4 | |
| 4 | Reheat | High Bays | 1/2 | 2 | |
| 5 | VAV | High Bays | 1/2 | 2 | 10% |
| 6 | Bypass | High Bays | 1/2 | 2 | |
| 7 | Reheat | High Bays | 1/4 | 1 | |
| 8 | VAV | High Bays | 1/4 | 1 | 10% |
| 9 | Bypass | High Bays | Approx. 1/4 | 1 | |
| 10 | VAV | Low Bay, Annex | FULL | | 10% |
| 11 | VAV | Low Bay, Annex | FULL | | 50% |
| 12 | Drop ceiling | High Bays, MSC existing HVAC | | | |

FIGURE 12 - OPF ENERGY CONSERVATION RECOMMENDATIONS

| Project | $/Yr Savings | Cost of Implementation | Simple Payback Time, Years |
|---|---|---|---|
| VAV Control High Bay | 190,000 | 12,000 | 0.06 |
| VAV, Low Bay Annex | 45,000 | 43,000 | 0.96 |
| Conversion of Incandescent Lights to Hg. Vapor on Platform | 1,741* | 1,152** | 0.66 |
| Total | 237,000 | 56,152 | |

* Energy Savings = $614/Yr, Manpower Savings due to Lamp Life $1127/Yr.

** Cost Involves Price of Lamps (Direct Replacement is possible using Self Ballasted Hg. Lamps)