

PROCEEDINGS



**U.S. POSTAL SERVICE
SYMPOSIUM
COMPUTER PROGRAM FOR
ANALYSIS OF ENERGY
UTILIZATION**

In affiliation with
**NATIONAL SECURITY
INDUSTRIAL ASSOCIATION**



**AUGUST 26, 1971
INTERNATIONAL BALLROOM
WASHINGTON HILTON HOTEL**

PROGRAM

Registration – International Ballroom

Opening Music – Military Band

Call to Order

J. Kenneth Fleetwood
Chief, Office of Technical Liaison
United States Postal Service

Presentation of Colors

National Anthem

Welcoming Remarks

Robert E. Isaacs
United States Postal Service

U.S. Postal Service Construction Program

Brigadier General George A. Rebh, USA
Assistant to Chief of Engineers for Postal
Construction Support,
U.S. Army Corps of Engineers

Introduction to the Program

Sam W. Milnark
Editor, Air Conditioning & Refrigeration
Business

**Position of the American Society of Heating,
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Inc.**

Robert H. Tull, Chairman
ASHRE Task Group

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**Description of the Program and Details of
the Load Program**

Metin Lokmanhekim
Manager, Computer Applications
General American Research Division

**Description of Systems Simulation and
Economic Sub-Programs**

Robert H. Henninger
Member, GARD Team

Cocktails and Lunch – International Ballroom

**Utilization of the Program for other than
Postal Facilities**

Dr. T. Kusuda
National Bureau of Standards

**Application of the Program in Specific
Projects – Use in a 250 Bed Hospital and 6
Smaller Buildings**

Z. Cumali, President
Consultants Computation Bureau

**Application of the Program in Specific
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Building in Chicago**

Dr. Richard Stillman
IBM

**Application of the Program in Specific
Projects – Use in Canadian Public Buildings**

Robert S. Bycraft, M.E.
Department of Public Works
Ottawa, Canada

Break

Question and Answer Session

Adjourn

COORDINATORS:

Gerard Beroset, U.S. Postal Service
John Hunter, U.S. Postal Service
Paul Newman, NSIA

UNITED STATES POSTAL SERVICE
SYMPOSIUM
COMPUTER PROGRAM FOR ANALYSIS OF ENERGY UTILIZATION

26 AUGUST 1971

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PROCEEDINGS

MR. FLEETWOOD: Please come to order, will everyone rise for the presentation of the Colors and the National Anthem.

MR. FLEETWOOD: Our thanks to the Joint Military Color Guard under the direction of Sergeant Phillips, and the Marine Band under the direction of Drum Major Jipperson.

Please rise for the playing of the Marine Hymn.

MR. FLEETWOOD: I would now, at this time, like to introduce Mr. Robert E. Isaacs, U.S. Postal Service, Office of the Senior Assistant Postmaster General for Mail Processing, coordinator for the major building program and facility modernization. He will give some welcoming remarks and introduce General Rebh. Mr. Isaacs.

MR. ISAACS: Gentlemen, it certainly is my honor to have the privilege to welcome all of you to Washington, and to this particular seminar, and especially to have the opportunity of standing here as an architect. In front of so many engineers, I'm not real sure how particularly safe that is. Perhaps there are some architects here that can give support.

Also, I would like to bring you greetings from the Postmaster General, Mr. Blount, who unfortunately, on the schedule that he is now keeping, found it impossible to be here this morning to bring you his personal greetings. But I was with him yesterday, and mentioned the fact again that this was happening. He is in total support of the program.

And as you probably know, the United States Postal Service has a new identity; it is a new identity as of July 1, 1971. We in the Postal Service find this extremely exciting, and certainly the tremendous challenge ahead as it relates to the reorganization and to the mail processing.

I think that the reorganization, as has been said many times, is certainly dedicated to provide the American people with a better, more efficient, faster and a more economical mail service. Last year the United States Postal Service handled some 86 billion pieces of mail. Now, no matter how you cut it, that's a lot of paper and a lot of mail.

We see an increase of about 3 percent per year in the volume of mail, so you start projecting that and see where we end up.

Now, to accomplish this type of monumental task that we have ahead of us, there certainly is a need of more facilities and better facilities. And this somewhat is the purpose of this seminar here today. First of all, you will be told how the building program relates to the Postal Service; and more important, how it relates to the environment and the computer program. We in the Postal Service are extremely proud to have this opportunity to bring this program to you. I think that you are going to find it a tremendous tool, and one that is extremely beneficial. It has been to us, and it will be to you.

As I read through the program, you will notice that I'm only allotted a period of five minutes, and I have gone through three of those already. I don't know, really, what that is telling me. Maybe they are telling me I am an architect, and architects only have to try to cover up engineers' mistakes.

As we move into this reorganization, I am reminded of the story where one of our postmasters had been attempting to get information. He called the regional office, and the operator said, "Hello", and he asked for a certain person to relay him some information, and that person was not there. He finally said, "Well, you know while I am talking to you maybe you can help me with my question. And she said, "Mr. Smith, when I said hello, I told you everything I know."

It gives me great pleasure at this point to introduce to you the next speaker, who will bring you some words of wisdom relating to the construction program. As you know, a few months ago the United States Postal Service entered into an agreement with the United States Army Corps of Engineers to become our real estate and construction arm. The sheer volume, as we look at our construction program, in the amount of some \$2 billion over the next five years, made this almost an impossibility for the Postal Service to do this internally. As a result, we had to look to and for an organization who had experience in this type of thing and who also had manpower and the know-how.

This criteria seemed to fit the Corps of Engineers, and this is what happened. It is my pleasure, now, to introduce to you, Brigadier General George Rebh, who is the Assistant to the Chief of Engineers in the Postal Construction Support Office, here at the Forrestal Building in Washington. General Rebh.

GENERAL REBH: Gentlemen, it is a real pleasure for me to be here with you this morning, for at least two reasons. First, this is really my first public appearance since becoming associated with the postal construction program. Secondly, it is good to be associated with engineers again, because, really, it is the AE firms and the construction industry that the Corps depends upon so heavily to accomplish its large construction programs. Additionally, it is the teamwork that is developed during peacetime between the AE firms, the contractors and the Corps, that has proved such a national valuable asset during periods of emergency. And the postal construction program affords the Corps another opportunity to broaden and strengthen these bonds -- and especially with the engineers.

We in the Corps feel very privileged to have been asked to participate in the Postal Service program, because it promises to be one of the most exciting, dynamic periods in the history of the Postal Service, especially when we consider the new, modern facilities that are involved.

I would like to mention the extent of the participation of the Corps and also how we intend to handle it internally within the Corps. On the 26th of September last year, Mr. Blount wrote Mr. Laird requesting use of the Corps because of this accelerated, expanded construction program which he had in mind. On the 8th of October, Mr. Laird replied that he was happy to make available the Corps to provide real estate design and construction services, and that he was authorizing the Secretary of the Army, Mr. Rezor, to enter into negotiations with the Post Office, to develop the terms and conditions by which we would work.

On the 11th of March, an agreement was signed between Mr. Blount, the Postmaster General, and Secretary of the Army Rezor, establishing these relationships and responsibilities. Now, this agreement pertained only to the major facilities program; this included those facilities that were greater in cost than \$2 million construction value, or were greater than 50,000 square feet in area.

To handle this program, the Corps is using its existing organization. There has just been one new element established, and that is my office, which is the Corps of Engineers Postal Construction Support Office, located in the Office of the Chief of Engineers, to accomplish the interface with the Postal Service, and also to manage the program internally within the Corps. This central interface marks one of the chief differences between this program and all other programs the Corps has been associated with.

In the case of the NASA program, the ICBM program, our Air Force work and Army work, the interface is at the local district level; but here, under the postal program, for this major facility portion, the interface is at the Washington level. The real estate acquisition services, the construction services, will be accomplished by our district organization. We have made one exception, with regard to design, and we have selected six districts to handle the design for this major program.

Along the East Coast, they are the New York District, the Norfolk District, and the Savannah District, in the central part of the country, Kansas City, Fort Worth, and on the West Coast, Sacramento. The reason we did this is because the new system involves sophisticated mechanization, and we wanted to establish an expertise within certain elements. The other course of action would be to have all construction districts handle the design. Well, in this case there would have been this repetitive learning, inventing the wheel all over again, so we felt they were more economical, and we achieved better design by handling it with these six districts.

I want to emphasize that we are not doing any in-house design. It will all be handled by AE firms. These six districts that I have mentioned will manage the AE effort.

In the middle of May, Mr. Blount announced his reorganization plan, and in doing so, for all practical purposes, eliminated the real estate, design and construction capability of the fifteen regions. Those fifteen regions have now been consolidated into five regions. And as I see, that capability has been eliminated, to all practical purposes. He approached the Corps and asked the Corps to take over the regional programs.

Now, what this involved was the leasing of facilities, the administering of these leasings, the repairs and improvements involved in these leased facilities, and the new construction of small post offices that the regions would have handled. Again, we are using our existing organization to accomplish this because they can be separated up into several programs. Each division has developed its own implementing plan, and it is going to vary between divisions, but you'll find the factor that determines why they have varied is the concentration of population.

For example, in the North Atlantic Division, we have four districts, New York, Philadelphia, Baltimore, and Norfolk. All of these will be handling real estate, design and construction. Whereas, in the more sparsely settled parts of the country, for example, down in the Southwest part of the United States, the Fort Worth District will be handling the real estate, design and construction. However, in terms of the supervision and inspection of construction, all districts will participate.

So if you have any areas that you are particularly interested in, either contact our office or the division offices and you will be able to find out which districts you should contact.

Again, in this program, all the design effort will be handled by AE's. There may be some exceptions on very small facilities, or in small repair and improvements projects as they will be done in-house by the Corps. But for all practical purposes it will be handled by AE firms.

To give you some order of the magnitude of the effort involved, taking the major facilities program, there are twenty for FY 72,

starting with the real estate design process and there are 23 preferential mail facilities and 14 bulk mail facilities. This program will measure out in about \$600 million in construction value. On the smaller facilities program, the 518 new small post offices, 60 percent of these, it is estimated, will be government-owned; 40 percent will be leased-built. These 518 projects have a construction value of \$125 million. The repair and improvements of existing facilities is estimated to be in the neighborhood of \$40 million.

So if you add those up, you get roughly \$750 million of construction effort for FY 72.

In conclusion, we are embarked upon a large, extensive program which reaches into all sections of the country. We feel highly privileged to be associated with the Postal Service in this great endeavor, and we look forward to working with you as individuals in your firms and bringing this new, modern system into reality. Thank you very much.

MR. FLEETWOOD: Thank you, General Rebb. I would like now to introduce Sam W. Milnark, Editor of Air Conditioning & Refrigeration Business. Mr. Milnark has been closely associated with the principal in the development of the program. He will make a few remarks and introduce those that are contributing here today and participating in the program. Mr. Milnark.

MR. MILNARK: Good morning, everyone. It is good to see so many of you out there.

I am sure all of you have heard how great this computer program is. Now you want to know how to use it. However, I am going to talk a bit more on its greatness.

In a few minutes, the cavalcade of experts on today's program will do their best to help you make the computer program work. Meanwhile, I will try to bring you up to date, the who, why, when and where of it.

The Postal Service selected me as your introductory speaker because I have probably talked about the computer program more than anyone else in the industry. Actually, I have talked to at least 40,000 people, four times each. A hundred and sixty thousand doesn't seem possible, but not so hard when you have written four articles published in four different issues of our magazine in the last four years.

It was just about this time of year four years ago, when I was in Washington interviewing people in the Department of Commerce, when I overheard a telephone conversation. I heard the words, "computer program," "system simulation," and a lot of other technical expressions I don't even remember anymore. I asked the man, after he hung up, who he had been talking to. He said, Jim Anders, of the Bureau of Research and Engineering in the Postal Service. He also said that Anders was working on a computer program for energy analysis and systems selection that was like putting the blueprint into the computer and then the computer spits out the best system, based on a lot of facts.

I got Anders' phone number, and a week later I was back in Washington interviewing him. He began to spin a yarn that took me to the top of the blue sky. I could hardly believe what the man was saying. Then, gradually, he started making sense, and put me down on the practical, good earth.

Why should the Postal Service, of all government branches, spend a million dollars on a computer program on energy analysis and system design? The answer came fast and sharp. At that time the Postal Service

was planning a \$5 billion Renaissance, a plan to build 5000 new postal buildings, upgrade existing mail handling equipment, and remodel many existing buildings. The Postal Service wasn't planning on owning all the 5000 new buildings, but it was planning on all the building and environmental control systems to be built on specs set by the Postal Service.

Anders said there just would not be enough manpower around to do that much engineering in the time allotted, that the computer program could slash the engineering time to the bone, that it could save millions in equipment and it could save even more in the long run on energy by eliminating all the fudge factors in the design and selection needed in the steady state method of load calculation. Anders said the computer program would save at least 35 percent in the cost of new equipment by eliminating the fudge factors, and 30 percent in operating and maintenance costs. And since the Postal Service has an annual utility bill of \$50 million, you can see the interest in saving on operating costs.

My next question was, "Can this computer program be used in any commercial building other than postal buildings?" Anders said, "A space is a space. Certainly, the program can be used in many buildings, with minor modifications." At that very moment, I learned that the entire program, roughly \$1 million worth of research, would be available to anyone in the industry when it was finished and tested.

Now, that was four years ago. I am not practically clairvoyant, but I can do a lot with the word "if." If the program got finished, if it proved workable, if the bugs could be taken out of it, and if the industry accepted it and used it, then, the Postal Service would be making a tremendous contribution to the industry.

I wrote the first article back in February of 1968, which explained all the great things that the computer program would do, and the fact that it might be available in one year. Did I ever get letters! Engineers from all over the country wanted to know more about when the program would be ready, but it did not turn out to be that fast. There were so many bugs in the program, you had to wear a mosquito net when you used it. Anders' bosses were on his neck to get the program finished, and there were a lot of skeptics, even many today, who said the program was too complicated to work, that it could never be used on buildings outside of the Postal Service; that equipment manufacturers could never supply the performance data that the program required.

Even the original name that Anders and I gave the program bombed out. We called it "TACS" for "Thermo-dynamic Analysis Computer System." The Postal Service now calls it, "Computer Program for Analysis of Energy Utilization."

The second article appeared a year later, in January, 1969. It was just as enthusiastic as the first, but the program still was not finished. However, it was being debugged and verified. The Postal Service had the National Bureau of Standards test and verify TACS in the field. Three large existing postal buildings were monitored by a computer for one year. The computer recorded data at 450 points on the operation of these three systems, some 15,750,000 observations. The idea was to actually record how these systems operated, and how much energy was consumed in a period of one year. Then the system designs of these three buildings were simulated on TACS, and the results were compared and verified.

However, bugs in the program turned into monsters. The system simulation and the transient heat-transfer portions of the program were much more difficult to write than expected. In this article we said the Postal Service would have TACS ready by the summer of that year.

However, it was two years later before we published the third article, January of this year. The program was finished, the if's were worked out, and the program was ready for industry to evaluate. More than 500 engineers responded to that article, requesting the program manuals offered by the Postal Service through our magazine.

I think, to sum it up, I would like to quote Paul Wyckoff, who is Chief Engineer at Chrysler-Air Temp. I interviewed Paul when I was field-researching one of the articles on TACS. His company does a lot of engineering on the computer, and they know a lot about writing programs. Here is what he had to say about TACS and Jim Anders:

"We know how difficult it is to develop computer programs that are relatively simple compared to TACS. It takes a man with a lot of guts, a man that must stick with it, even though he runs into failure time and time again. Believe me, we know what he is up against. It will be a tremendous contribution to the industry if he can produce a program like TACS that really works."

And that is why the experts are here today, to show you how TACS really works, and how you can use it.

Now because so many of you responded to our article on TACS in January in requesting the program manuals, and because so many of you have called the Postal Service for information on using TACS, the Postal Service decided to set up this symposium. Maybe the Industrial Liaison Department of the Postal Service cannot do much about faster

mail delivery, but I think they have done a great job in making TACS available to our industry and have used a lot of foresight in setting up this symposium. These people are extremely aware of the great energy shortage in our nation, and they know that by using a computer program like TACS for system design and energy analysis, it will do a lot to help us conserve the energy we have left.

I think that Jim Anders and all the postal officials and especially Gerry Berozet, for setting up this symposium deserve a big hand for the contribution they have made to our industry and nation.

Will you stand up, Jim Anders and Gerry Berozet.

Jim Anders is now with Hittman Associates, and he will deliver a few informal remarks.

MR. ANDERS: I want to thank Gerry Berozet for inviting me to be on this program today, and also thank Sam for making sure I got here.

I wish to recall a little bit of background on why the Postal Service decided that they needed the computer program. First of all, I think we recognized, both myself and my superiors, that we needed a method for selecting the most economical combination of systems and energy supplied to a building. And we needed that early, in other words, before we actually submitted our design requirements to an AE, to design the building.

I still feel that that is a valid reason for such a program as this. We have been trying to estimate energy consumptions for future buildings ever since I can remember, and I am a pretty good sized puppydog now, and it is a problem. We started out early on with the degreed-A method, and we found a lot of things wrong with that. And that applied only to heating energy. When we tried to use cooling degreed-A's. or when

cooling degree-A's tried to become a method of estimating the refrigeration requirements, or energy requirements for air conditioning systems or cooling systems -- all heating and cooling systems are air conditioning systems, so bear with me.

A cooling system, when we tried to use cooling degree-A's, we found that there were many, many bugs in that. And I don't think even till this day there is an official acceptance of a definition of a cooling degree-A. If I am wrong in that, Bob (Tull), let me know.

But we decided that we needed such a device, such a program, or such a tool. Further, we needed something whereby we could actually evaluate existing systems, because we had a tremendous modification program coming up. Not only that, but we also recognized the fact that we had some highly inefficient systems, and I think that is a use that this particular program can be put to that will be an excellent thing in the near future.

Actually, a byproduct of this program, not originally intended, became a design tool, per se. And yet when we got into the program and found out what power it had, what it could do, we knew it really could do a tremendous number of things for the man who understands the program and knows how to use it. It really can. It can become a specific design tool in actual selection of equipment, both from a standpoint of maximum performance requirements, maximum load, and at the same time minimum load, and I think this is still a place where a lot of us make mistakes. When we don't look at the minimum requirements that a machine has to do in order to stay on the line or go off the line, and things like this, we waste an awful lot of energy just doing that.

It can do that, but further, I think Mr. Isaacs has left, it might be well for us to indicate that we can actually demonstrate to an architect what his fenestration is going to look like with the sun shining on it before he sees the building, if he will tell us what that fenestration looks like by taking the shadow routine out of the program and running it separately. And I am sure that Mr. Lokmanhekim will be glad to discuss that with you.

But the program is so structured that when you come to understand the program and its interrelation, and the sub-routine interrelationships with each other, they can be broken out for little jobs like that if you want to use them that way. But I think there is a far more important reason today for this program.

I have read several reports of late, and I am sure you have too, concerning our energy resources. In the world today Fossil fuels are rapidly being depleted. And I do believe that it is not going to be very long and I would say within the next five years that where any commercial project is going to be required, government action or economic action will require such an analysis as this before the energy operating system is selected for the building.

There is a tremendous competition among the utilities today for total energy and I use that "energy" generically, not specifically -- for total energy systems. In order to use those systems, and use them effectively and economically, you have got to know what they are. But further than that, I think this conservation of our energy resources is going to become so important that we are going to be forced into evaluating every system prior to its design, as to whether or not it will economically and advantageously conserve energy.

Further, I believe that within ten years, just about every energy-using device, all the way from the home TV set, freezer, and what have you, will be required to go through an energy consumption evaluation before it is allowed to be marketed. I believe that our energy resources situation is that critical. And I think if you will just peruse the literature that is being written today concerning our energy resources, you will come to the same conclusion.

So I think this program, or a program like it is probably the first of a whole batch of programs that will be coming along, all based on the same basic algo-rhythms that this is written around, and most assuredly, I think, based on the same mathematics. We are not going to change any heat transfer functions or characteristics, or anything like that. The program's not going to do that. We all know that. But it is going to let us take advantage of the calculating procedures whereby we can identify the most economical system and the most economical energy supply to that system. And I think this is the most important thing.

MR. MILNARK: Thank you, Jim.

When a question comes to mind, write it on the card, and periodically, probably before the break and before lunch, pass them on to the center aisle. Someone will collect them. These cards will be passed on to the panel later, to be answered.

Now, in case there are more questions than we have time to answer here, don't feel you have been slighted, because all the questions will be answered. They will be answered by the panel, and they will be included in the complete transcript that each of you will receive. We are going to try to answer them all here, but in case we don't, we will handle it that way.

Our next speaker is Mr. Robert Tull, Chairman of the ASHRAE Task Group, and he will relate the position of the American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc., on the program. Bob?

MR. TULL: Thank you, Sam. Good morning, ladies and gentlemen.

I am glad to have this opportunity to talk to you this morning on the occasion of this symposium on the U.S. Postal Service's Computer Program for the Analysis of Energy Utilization. I am glad for two particular reasons. First, it gives me an opportunity to give a little sales pitch on ASHRAE, and second, it lets me talk about my favorite ASHRAE project, the Task Group on Energy Requirements for Heating and Cooling Buildings.

It would be interesting to know how many of you in this audience are members of ASHRAE. I will not ask for a show of hands, because I recognize a great many of you, but I feel sure that a goodly number of you are presently ASHRAE members. But for any of you who are not, I would like to suggest that if you are going to be involved in this subject of the problems of heating and cooling buildings, or the analysis of energy utilization in buildings, you should seriously consider applying for membership in ASHRAE.

Now, why do I say that? Well, as the ad writers would say, because this is where the action is. In this field of engineering activity, ASHRAE is a very unique engineering society, and you can benefit by being a part of it. It not only holds technical meetings, similar to the one recently completed here in Washington, and publishes a Journal and transactions, as many other engineering societies do, it is, I believe, the only professional engineering society that plans, sponsors, and supports a broad research and technical program using its own funds,

and is set up to operate in cooperation with other organizations which may benefit by its administrative and monitoring program.

This program, which is coordinated by almost a hundred technical committees and task groups under the Society's Research and Technical Committee, provides the basic engineering information and the technical authorship for the ASHRAE Guide and Data Book. The Guide, as it is known in the industry, is the authoritative Bible of engineering practice and technical data in this field of engineering.

You are probably all familiar with the Guide and Data Book, which is now published as a four-volume series. The three volumes of applications, systems, and equipment, are each brought up to date, revised, and republished, on a three-year cycle. The fourth volume, the Handbook of Fundamentals, is updated and republished about every five years. The present Fundamentals volume, which was first published in 1967, is scheduled for revision and republication in 1972.

If you are involved in this field of engineering, you owe it to yourself and to your profession to support this unique and exclusive research and technical program. Now, many of you, I am sure, are familiar with the Green Book, the 1967 Handbook of Fundamentals. In it are the basic tables of engineering data on thermal insulation, design, heat transmission co-efficients of building components, weather data, design conditions, and the approved ASHRAE procedures for calculating design heating and cooling loads.

The standardizing and publishing of this information helps the practicing engineers to establish a uniform basis for designing, sizing, applying heating and cooling systems. For these purposes, the ASHRAE

design load calculations are quite suitable, and are widely used by heating and airconditioning engineers.

It has been recognized for many years, however, that the design load calculation does not provide a suitable basis for the calculation of energy requirements and/or the operating cost of a heating and air conditioning system. There are several reasons for this. One, the design weather conditions used for the design load calculation, are selected to reflect the extreme weather conditions under which the system must perform satisfactorily. In actual operation, however, these extreme conditions may be encountered only for a few hours, or for a few days, or perhaps not at all in any one year of operation.

The heating and cooling load for energy calculations, on the other hand, must take into account the weather as it actually occurs throughout the heating and cooling system -- season. Second, the design load calculation determines the heating load under a steady-state heat flow at the heating design condition. It determines the design cooling load under an assumed periodic change in outdoor weather, based on the cooling design conditions. Neither of these calculations consider the weather as it actually occurs, as a non-periodic, continuously varying function of outdoor temperature, solar radiation, wind speed and direction, and humidity.

Third, the design load calculation provides a single heating load value, and a single cooling load value. For an energy calculation, however, these loads need to be represented as a time series of values which are related to the weather, the building occupancy, and the operating schedules throughout the complete heating and cooling season. Thus, even while the 1967 Handbook of Fundamentals was being written

and published, it was recognized that a basic new calculation procedure needed to be developed to provide the basis for calculating the energy requirements for heating and cooling buildings.

Responding to that need, the ASHRAE Board of Directors established the Task Group on Energy Requirements, which began work on this problem in 1967. The Task Group includes research scientists from both the National Bureau of Standards and the National Research Council of Canada. It includes college professors of mechanical engineering, practicing, consulting, and industry engineers, and the developers and operators of several computer programs for determining energy requirements.

Since 1967, this task group has been meeting on a schedule of about two days every two months, and we are beginning to make some significant progress on our assignment. Let me briefly describe our approach to this task, the progress we have made so far, and some of the problems we still face.

Obviously, the first step in such a program is the development of an accurate procedure for calculating the heating and cooling loads that are suitable for energy calculations. As described earlier, such a procedure must calculate the loads in the form of a time series, which presently is hour by hour, related to the weather, the building occupancy, the varying internal loads, and the operating systems schedules. Such a calculation procedure has been developed, and it was based on the work of Stevenson and Metallis at the National Research Council, and Doctor Tom Kusuda at the Bureau of Standards.

The Task Group Subcommittee on Heating and Cooling Loads, first released this procedure in June of 1968, for limited distribution to engineers working in this field. Comments, criticism and suggestions

were requested and received. Based on this review and some further work by the subcommittee, this procedure was improved, refined, and is now released for general distribution. A bulletin which is entitled, "The Procedure for Determining Heating and Cooling Loads for Computerized Energy Calculations" is now available on order from the ASHRAE Headquarters in New York City. The bulletin contains a description of the new calculation procedure, which is based on the use of thermal response factors for determining the heat flow through the building structure and the use of weighting factors to relate the heat flow and the internal loads to the actual system heating and cooling loads.

The bulletin lists, describes in details the sub-routine algorithms required for the calculations. We are all indebted to Dr. Tom Kusuda, who appears later on this program, and to his committee, for their excellent work in developing this new calculation procedure.

Since the Postal Service computer program was being developed at the same time as the ASHRAE load calculation procedure, and since Metin Lokmanhekim was on Dr. Kusuda's sub-committee of the Task Group, it could be expected that the Postal Service program would be based on the ASHRAE procedure, or vice versa. I am not sure which is based on which, but they are essentially the same.

This has been fortunate for the Task Group since it has given us an immediate operating check on the algorithms involved in the published procedure. So, essentially, the first step of our task is completed. We are continuing to study and refine the procedure with a view to reducing the calculation time involved in the hour-by-hour computation; but we have released a workable procedure, which we hope and believe will provide the basis for load calculations for energy requirement studies of the future.

The second step of our task is to develop calculation procedures which will determine the response of heating and air conditioning systems to the calculated heating and cooling loads, and from this response determine the hour-by-hour energy requirements of the systems.

At the time we began this development, we knew of no calculation procedure that attempted to accurately translate the loads through the component and system performance characteristics into the system energy requirements. At this stage, all energy calculations have resorted to some approximation procedure to relate the heating and cooling loads to the partial load performance characteristics of the system. Such an approximation has been essential in the past because of the tremendous complexity of more rigorous considerations and determinations.

But the availability of large, fast computers makes possible the development of a new methodology for this step, and rather than attempt to refine past approximation procedures, the task group decided to take a more fundamental approach. The Task Group Subcommittee on System and Equipment Energy, under the chairmanship of Professor Will Stecker at the University of Illinois, is developing a new systems simulation procedure, which will make it possible to calculate the response of the complete system to the hour-by-hour load changes, based on the performance characteristic of the system and its components.

This phase of our work is progressing more slowly. As a first, introductory step, the Subcommittee published a bulletin in 1969 entitled, "Proposed Procedures for Simulating the Performance of Components and Systems for Energy Calculations." Since that time, there has been a considerable amount of work done in this area -- both within and outside the Task Group. Based on this further work, and updated and expanded

second edition of this bulletin has just been released and is available from ASHRAE Headquarters.

Now, because of the great amount -- the great number of system components, and the variety of air conditioning systems in use today, it is probable that this phase of our task may result in the publication of a sort of guide to systems simulation techniques and procedures, rather than to a single, comprehensive calculation procedure. Such a guide would help the heating and air conditioning engineer to develop the proper calculation procedures for the specific system or systems in which he is interested.

The Postal Service program has been developed around certain specific systems and, I believe, makes use of many of the elements of the system simulation procedures proposed by the Task Group.

Now, as one might expect, the development of these simulation procedures leads to a few problems. For instance, in the hour-by-hour and day-to-day operation of heating and air conditioning equipment, the system and components operate over a wide range of their available capacity. Actual full-load operation probably occurs for only a few hours in a day, or a few days in a year. During most of the year, the components and the system operate at some partial load or off-design condition for which performance information is seldom available.

In order to properly simulate the performance of the system, it is essential that the partial load performance of all of the components, be known and be made available to the computer programmer. For instance, it is essential to know the energy input versus output, of such components as centrifugal compressors, reciprocating compressors, and condensing units, package chillers, and so forth, over a wide range of operating conditions.

Further, preferably, this information should be in -- available in equation form suitable for use by computers. For some manufacturers, this presents little or no problem. For others, it represents a considerable departure from their present policy and practice of presenting performance information, and it represents a considerable investment in time and effort to develop the information.

The Task Group has brought this problem to the attention of equipment manufacturers, and is making slow but steady progress in having such information made available. We expect this progress to accelerate as manufacturers recognize and accept the need for this information.

We look on this system simulation program not only as a development project for the Task Group, but also as an educational problem for practicing engineers and computer programmers. We anticipate that both the developmental and the educational phases of the program will require a period of years for completion and full acceptance.

Within the Task Group we have a subcommittee called the Computer Users Applications Subcommittee. This group includes the developers and operators of many of the widely used energy calculation programs in this country. It acts as a sort of overview committee to look at the overall problems of energy calculations and provide a practical, practitioner's criticism of the Task Group's approach to these problems. This subcommittee is presently tackling a problem of considerable interest and significance to all energy calculations. The problem concerns the weather data, or the external ambient input data to be used by the computer program.

If one wants to predict the energy requirements for a given building as an element of an estimated owning and operating cost, it is essential

that the predicted energy requirement be typical or average of the energy requirements over an extended period of years. For this reason, there is need to establish standard, external ambient input data for each local area, which can be used by all engineers working in this area to provide a common basis for their energy calculations. Standard external ambient input data must provide an hour-by-hour record of the external input parameters used and needed by the calculations.

When one considers that the 1967 Handbook of Fundamentals lists design weather data for approximately 1000 locations in the United States and around the world, the magnitude of the problem of establishing standard external ambient input data for energy calculations becomes evident. The subcommittee now has several suggestions under review and will, I hope, come up with a reasonable proposal within the next few months.

Now, no program of this magnitude and importance could be considered complete if it did not include some plans to check on the validity of its findings. The Task Group program includes such a check, in the form of a field-test study, to validate and refine the proposed calculation procedures in one or more well-instrumented field buildings.

Originally, several buildings were considered as potential test sites. Four were then selected for an initial study of the cost of instrumentation and the cost of data gathering. From these four, one was selected. It is the Law Office Building on the campus of the Ohio State University in Columbus, Ohio. Elaborate instrumentation has been installed in this building, and data gathering is now underway.

Basically, the objective of this field test is to calculate the energy requirements of the building and then check them against the

actual measured energy requirements. This will be done successively over short periods of time to get a repeated check on the accuracy of the calculations and to determine how this may vary throughout the year. The program is being conducted and continuously monitored by a very competent research team of the Mechanical Engineering Department of the University. And you can be sure it will be very closely followed by the Task Group.

To give you an idea of ASHRAE's commitment to this energy calculation program, the committed costs of the presently planned field test program is slightly over a quarter of a million dollars, and this is being paid for out of ASHRAE funds. We all realize that the test results of this study of one building is just that -- a study of the results of studying one building, the results of studying one building. The Task Group has recommended additional studies on other types of buildings, in other geographical locations, with other types of heating and air conditioning systems, and using different research teams to validate the calculation procedure.

At the present time, however, additional research funds of such amounts are not available within the Society. I mention this just in case any of you in the audience have extra, uncommitted funds of this magnitude and would like to invest in a worthy cause. If you do, you can please see me at the coffee break.

To sum up ASHRAE's position relative to the calculation on energy requirements for heating and cooling buildings, the ASHRAE activity is centered in the program of the Task Group on Energy Requirements. To date, this Task Group has, one, released for general distribution, a bulletin on "The Procedure for Heating and Cooling Loads for Computerized

Energy Calculations." This bulletin is now available on order from ASHRAE Headquarters in New York City.

Second, we have released for limited distribution, the bulletin on "Proposed Procedures for Simulating the Performance of Components and Systems for Energy Calculation," and a second, revised edition of this bulletin is now available from ASHRAE Headquarters.

Third, we have initiated and will continue to develop, a program with equipment manufacturers to make performance data available in equation form.

Fourth, we have undertaken a program to establish standard external ambient input data for computerized energy calculations.

Fifth, we have established a field test program to validate and refine our calculation procedure. The Task Group plans to sponsor a continuing series of forums, symposia, and technical papers at the ASHRAE Annual and Semi-annual Meetings, to broaden the understanding and the acceptance of the new load calculation and system simulation techniques and procedures.

If you are actively involved in such energy calculations or in the analysis of energy utilization, I urge you to attend and participate in these events, to keep abreast of the developments, and to assist the Task Group in its development program. Your comments, criticisms and suggestions are welcome.

We still have several years of hard work ahead of us before we can consider our task complete. Now, several people have raised questions about whether ASHRAE, when this program is done, will prepare and issue a computer program for the calculation of energy requirements. This subject has been considered at the highest levels of the Society, and

a policy decision has been made that ASHRAE will not enter into the issuing of computer programs. We feel this is a commercial project for people who are in business, and it is not the province of the Society to compete with those people. So it our function to make calculation procedures available, and it is the function of the practicing engineers to make use of these procedures as best suits their purposes.

There has been considerable thought by practicing engineers that these procedures are so comprehensive and so complex that they have practically little value to the practicing engineer. And we recognize the fact that these are complex procedures. But we took the position at the beginning that it was the function of our study to develop as complete and comprehensive a calculation procedure as present knowledge and present computer technology would let us. After we have done that, we can always step back and try to find ways of simplifying these procedures.

The Task Group has now reached this stage, and we are now focusing our attention on ways of simplifying, reducing computer times, and making these programs more practical for the use of practicing engineers. We have now under consideration ways in which we will evaluate the accuracy and the sensitivity of the different elements of the calculation to the accuracy of the program, so that we can provide some guidance to the practicing engineer on which elements of the program he can leave out and what each of these elements will contribute to, in relation to the accuracy of the end-result.

So you can see that we have years of work ahead of us. You have years of work ahead of you in getting acquainted with this sort of thing, and we hope that we can all work together in carrying this program forward. Thank you very much.

MR. MILNARK: I would like to make good use of this time to handle a few questions and answers before lunch. We are about twenty minutes ahead of schedule, and we should have some time available. I think that this next presentation by General American Research will stimulate some questions, so rather than holding them all until the end of the program, we may have time to do it just before lunch.

Again, write your questions down on the cards, and pass them to the center aisle, and we will handle what we can after General American's presentation.

Our next topic, "Description of the Program and Details of the Load Program," will be delivered by Metin Lokmanhekim, Manager, Computer Applications, General American Research Division.

A description of "Systems Simulation and Economic Sub-Programs" will be presented by Mr. Robert H. Henninger, Member, GARD Team.

ABSTRACT

The accurate calculation of the energy requirements and heating and cooling equipment sizes for buildings is one of the most important, as well as one of the most difficult, problems facing the air conditioning engineer. It is important because energy cost is an essential and significant element of the building's overall owning and operating cost and very likely could be the determining factor in selection of the air conditioning system for a new structure. The problem is difficult because of its complexity. It not only requires accurate determination of the heating and cooling loads, taking into account the varying influences of weather and operating schedules, but also determination of the performance of heating and cooling systems under varying conditions of partial load.

The Computer Program For Analysis of Energy Utilization does all of the above and more. Developed for the U.S. Postal Service for use in design of postal facilities, the computer program is capable of:

- 1) simulating the thermal response of a building to all sources of heat gains and losses,
- 2) accounting for all non-thermal energy requirements in the facility or on the sites,
- 3) translating the building operating schedule into total energy demand and consumption costs, and identify the peak capacity requirements of heating and cooling equipment, and
- 4) allowing for an economic analysis that would select the most economical total owning and operating cost equipment and energy source (gas, oil, coal, steam or electricity, or combinations).

1. INTRODUCTION

The Problem

The need for rational air conditioning decision has existed since men left the trees to seek refuge in the caves. And systems have been overdesigned since the first cavemen ran out of firewood in early March.

Correct sizing of equipment and the accurate determination of energy requirements has always been difficult, not because the physics or economics is conceptually elusive, but because the task requires a huge amount of computation. For example, the correct prediction of loads on the heating and cooling equipment is important because the maximum loads determine the size, and hence the initial cost, of the system components, while the summation over time of the energy required by the system to meet the load schedule represents a large fraction of system operating costs and may therefore determine the choice of system. If the maximum loads are under-estimated, the equipment may be undersized and fail to do its job, and if the maximum loads are overestimated, the equipment will be larger, and more expensive than necessary. The calculation of heating and cooling loads requires that many factors, including the following, be accounted for.

- 1) Astronomy of the sun
- 2) Cloud cover
- 3) Shadows cast by complex shapes
- 4) Transient heat transfer in structures
- 5) Heating and cooling system response
- 6) Schedules of occupancy, equipment, and lights.

Before the advent of the computer, only a crude heating and cooling energy calculation was practical and the engineer had to rely mainly on his

experience. Weather was approximated by degree days, transient heat conduction was approximated by equivalent temperature differentials, and combined radiative/convective boundary conditions were approximated using the sol-air temperature. Heating and cooling equipment was therefore oversized, as a hedge against a poor guess, and energy requirements could not be predicted with enough accuracy for the user to make a rational choice between different systems.

Such inexactness in determining energy requirements and heating and cooling equipment sizes for buildings is rapidly becoming a problem for a number of reasons. Rising construction costs and the increasing value of floor space are driving building owners to insist that equipment be no larger than absolutely necessary. Competition between energy suppliers is stiff and their claims are often conflicting, while energy utilization equipment and methods are more varied now than at any time in the past. Thus, accurate cost comparisons are necessary. Architects and building owners would like the flexibility of knowing quickly and accurately the effects of changes in such factors as design, materials, and building orientation on heating and cooling costs. Not having this information inhibits progress in building design. Last, and perhaps most important, many experts predict an energy shortage which will boost energy costs substantially. Energy requirements, which entail the greatest amount of guesswork in conventional calculations, probably will become the dominant factor in the selection of heating and cooling equipment. A better method is therefore required to accomplish purposes which, although multi-faceted, may be summarized into the following three tasks:

- (1) Determine energy requirements so as to: assess operating cost; compare building designs, types of system, and choice of energy source with respect to operating cost; and guarantee adequacy of the system in the face of energy shortages.

- (2) Size equipment so as to: insure adequate capacity; eliminate excessive overdesign; assess initial and upkeep cost; and compare building designs, types of system, and choice of energy source with respect to initial and upkeep cost.
- (3) Assess total cost so as to: compare building designs, types of system, and choice of energy source with respect to total owning and operating cost; and aid economic planning.

The Solution

Fortunately, modern high speed digital computers make possible the detailed calculations required for rational air conditioning decisions. It is only necessary to code into computer language the well known principles of physics and economics, the implementation of which was previously impractical. This is the philosophy of the present program.

That does not imply that the program includes nothing new. Many problems posed by the load calculation are unsolvable by hand. Mathematical techniques had not been developed for solving these problems because such developments could not be rewarded with a solution. The engineers who wrote the program had to find the appropriate mathematical algorithms and then code them into computer language. For example, no method was available for computing the shapes and areas of shadows cast by objects of arbitrary shape upon surfaces of arbitrary shape. Yet such a method of shadow analysis was required for calculation of heat gain due to solar radiation. The need for parsimony also requires a degree of originality. Load calculations are tedious even by computer standards, so where algorithms for solving a problem already existed, they often had to be streamlined to save computer time and to reduce computer memory requirements. For example, a series truncation technique cut the time required to compute transient heat transfer through a thick wall by more than 50 percent.

The program presented here uses the most advanced techniques known to the modern air conditioning engineer to accomplish the three tasks of air conditioning calculation. It provides the prospective user of air conditioning equipment with a practical tool for comparing the initial and operating costs of various heating and cooling systems so that he may choose the system which in the long run costs him the least.

2. BASIC STRUCTURE OF PROGRAM

The computer program consists of four main sub-programs executed in sequence, with the output of one becoming the input to the next. The function of each sub-program is summarized below.

- 1) Load Calculation Sub-program. Calculates sensible and latent components of hourly heating and cooling loads, for each space* in the building, for a selected period of time. This sub-program is supported by wall and roof selection sub-sub-programs.
- 2) Thermal Loads Plot Sub-program. Plots, with the support of the Punch Sub-sub-program, the load profile of any space for any period of time. Comparisons between plots permit the grouping of compatible spaces into fan system control zones**. This grouping is achieved with the help of the Editing Sub-sub-program.
- 3) Systems Simulation Sub-program. Computes hourly energy requirements from the heating and cooling loads computed by the load program.

The System Simulation Sub-program takes into account the ventilation

* Space is defined as a room or a group of rooms which would be treated as a single load.

** Zone is defined as group of spaces whose loads are closely correlated and which can therefore be lumped together as a single load on the equipment.

air requirements, fan system performance, and the partial load characteristics of the heating and cooling equipment.

- 4) Economic Analysis. Calculates the annual owning and operating costs of various combinations of heating and cooling plants.

3. LOAD CALCULATION SUB-PROGRAM

The Load Calculation Sub-program, a complex of heat transfer, environment, and geometry subroutines, computes the loads, both heating and cooling, imposed upon the building air conditioning system by each space at each hour. The input to the Load Calculation Sub-program reflects building architecture, building structure, the building surroundings, local weather, and the pertinent astronomy of the sun. The output from the Load Calculation Sub-program consists of hourly weather and psychrometric data and hourly sensible loads, latent loads, return air lighting loads and equipment and lighting power consumption for each space.

The Load Calculation Sub-program consists of a set of subroutines, small programs each of which performs an engineering calculation, and a main program which reads the required data, directs the flow of information from one subroutine to another, and writes the output on paper and magnetic tape. The logic flow chart (Figure 1) shows, schematically, the interrelationship of subroutines within the Load Calculation Sub-program. A brief description of each subroutine is given in Table 1.

Loads are computed on the basis of actual recorded weather data for a selected year, accurate evaluation of heat gain due to solar radiation, and coincident simulation of transient heat transfer in the building's structure. Weather data is taken from magnetic tape available from the U. S. Weather Bureau. Solar radiation is computed by combining hourly sun position and

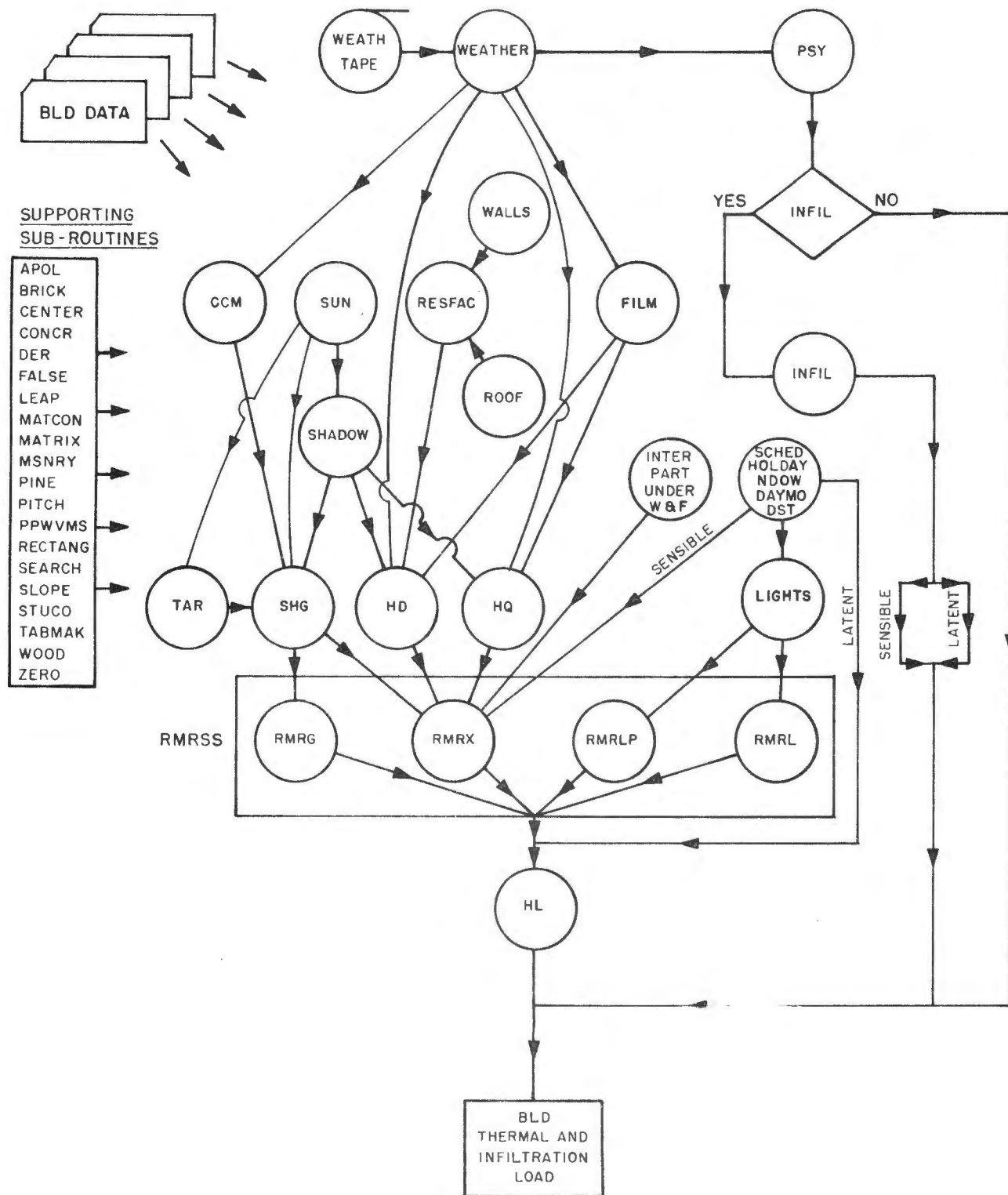


Figure 1 INTERRELATIONSHIP OF LOAD CALCULATION
SUB-PROGRAM SUBROUTINES

TABLE 1

LOAD CALCULATION SUB-PROGRAM SUBROUTINES

Name of the Subroutine	Function
APOL	Calculates area and orientation of an irregular surface
CCM	Calculates cloud cover modifier
CENTER	Centers the headings of output
DAYMO	Determines day of month
DST	Determines Daylight Saving Time
FILM	Calculates outside heat transfer film coefficient
HD	Calculates heat gain through slowly responding surfaces (Delayed surfaces)
HL	Calculates sensible and plenum return air heating and cooling load due to a space
HOLIDAY	Determines holiday
HQ	Calculates heat gain through quickly responding surfaces (Quick surfaces)
INF	Calculates infiltration air loads due to a space
LEEP	Determines whether the year is a leap-year
NDOW	Determines day of week
PSY and PPWVMS	Calculates psychrometric data
RECTANG	Calculates vertex coordinates of a rectangular surface
RESFAC and DER FALSE MATRIX SLOPE ZERO	Calculates response factors for walls and roofs

TABLE 1 (CONT'D)

Name of the Subroutine	Function
RMRSS and RMRG RMRL RMRLP RMRX	Calculates room hourly weighting factors
ROOFS and MSNRY PITCH WOOD	Determines thermal and physical properties of a selected roof construction
SEARCH	Limits shadow pictures to certain times and certain surfaces
SCHED	Determines lighting, people, and equipment schedules
SHADOW and MATCON	Calculates shadow shapes and areas
SHG	Calculates heat gain through windows
SUN1	Calculates daily data on solar radiation
SUN2	Calculates hourly data on solar radiation
SUN3	Calculates solar data which depends on orientation of a surface
TABMAK	Tabulates output
TAR	Calculates glass absorption and transmission factors
WALLS and BRICK CONCR PINE STUCO	Determines thermal and physical properties of a selected wall construction
WEATHER	Decodes weather tape

cloud cover with a new procedure for predicting shadows. Transient heat transfer is computed using the Convolution Principle.

Hourly Weather Data

The program uses hourly weather data, obtained on magnetic tape from the U. S. Weather Bureau, to calculate heating and cooling loads. Weather tapes of past years are available for enough weather stations throughout the United States so that a tape is most likely available for a station within 100 miles of the site of any building being considered. The load sub-program (see Section 7) reads the weather tape, as it runs, to realistically simulate the changing meteorological conditions to which the building is continuously exposed. The data read from the weather tape and a brief summary of the uses to which they are put are listed below.

- Dry-bulb temperature (used in computing heat transfer and sensible loads)
- Wet-bulb temperature (used in computing humidity ratio and latent loads)
- Wind velocity (used in computing outside surface heat transfer film coefficient)
- Barometric pressure (used in computing density of air)
- Cloud type and amount (used in computing heat gain and heat loss by radiation between the building and the sky)

Hourly Solar Radiation Data

The amount of heat gained by the building through an exterior surface (roof, exterior walls, or window) depends upon the radiant environment to which the surface is exposed. This radiant environment may be simulated more accurately by a computer than by hand calculations because the computer can evaluate the components of radiant environment on an hourly basis. The program makes hourly calculations of the following components of the radiant

environment for each exterior surface:

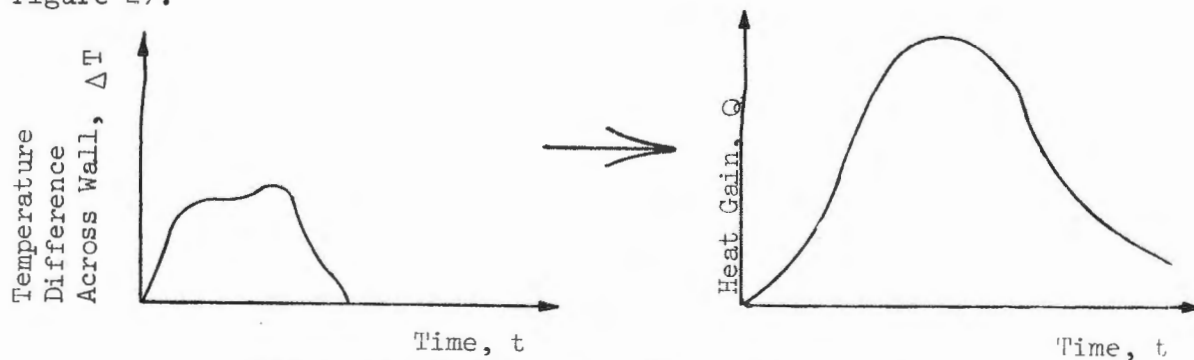
- angle of incidence of the sun's rays
- direct normal intensity
- brightness of sky and ground
- re-radiation to sky
- shadows cast upon the surface.

By combining these data with such constants of the surface as emissivity, shape factor between surface and sky, and shape factor between surface and ground, the program arrives at hourly radiation fluxes in Btu/hr.

The Convolution Principle

The program takes account of heat storage in the building's structure by a mathematical device called the convolution principle. The example of heat gain through a thick wall will illustrate how the convolution principle works.

The value of heat gain (Q) into the building through a thick wall, for a constant inside air temperature, depends on the present value, and the past history, of the temperature difference (ΔT) between the inside air and the outside surface of the wall. In other words, the graph of the schedule of Q versus time (t) depends on the graph of the schedule of ΔT versus t (see Figure 2).

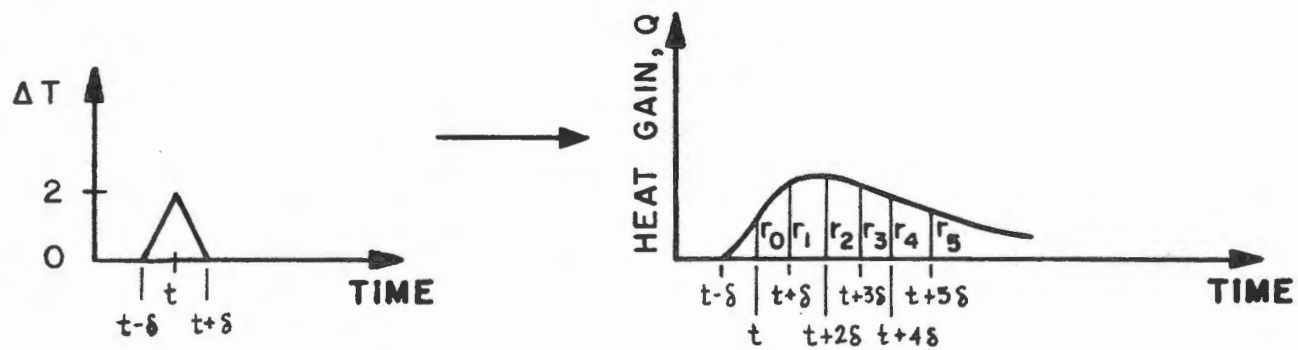


DEPENDENCE OF HEAT GAIN SCHEDULE
ON TEMPERATURE DIFFERENCE SCHEDULE

Were it necessary to compute Q for each hour, on the basis of the hourly history of ΔT , the differential equation of heat conduction would have to be repeatedly solved by numerical methods, and the computation time would be prohibitive even with a fast computer. Fortunately, the problem can be simplified so that Q need be determined as a function of t for only one temperature difference schedule. The one temperature difference schedule for which the program must compute a heat gain schedule is called the triangular pulse, and the values of Q which the triangular pulse elicits, at successive equal time intervals after the peak of the pulse, are called the response factors (r_0, r_1, r_2, \dots) of the wall (see Figure 3).

Any arbitrary schedule of ΔT (Figure 4a) may be squared off to give a schedule (Figure 4b) of approximate temperature differences, $\Delta T'$, whose values agree with those of ΔT at integral multiples of the time interval, δ . This schedule of approximate temperature differences, $\Delta T'$, may be resolved into a series of triangular pulses ($\Delta T_1, \Delta T_2, \Delta T_3, \Delta T_4$, and ΔT_5 of Figure 4c) which, when added together, give exactly $\Delta T'$. Each of these component pulses has a base width, or duration, of 2δ , a peak occurring at each integral multiple of δ , and a height equal to the value of $\Delta T'$ at the time of the pulse's peak. Each such pulse alone would elicit its own schedule of heat gains as shown in Figures 4d, 4e, 4f, 4g, and 4h. The pulse ΔT_1 , for example, would elicit the heat gain schedule Q_1 (see Figure 4d), the pulse ΔT_2 would elicit Q_2 (see Figure 4e) and so on. The heat gain schedules elicited by the individual pulses are all the same except for two differences. Their heights are proportional to the heights of the pulses which elicit them, and each is moved to the right, on the time axis, as far as the pulse which produced it.

The values of the individual responses, $Q_1 \dots Q_5$, may be added, at each value of time, to give the curve of sums (Figure 4i). A mathematical principle



T = OUTSIDE SURFACE TEMPERATURE

T_0 = INSIDE AIR TEMPERATURE

$$\Delta T = T - T_0$$

Figure 3 HEAT GAIN SCHEDULE FOR A TRIANGULAR TEMPERATURE PULSE SHOWING RESPONSE FACTORS

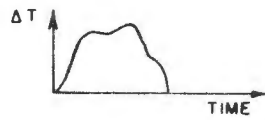


FIGURE 4a

ACTUAL ΔT SCHEDULE ACROSS WALL



FIGURE 4b

APPROXIMATE ΔT SCHEDULE



FIGURE 4c

THE COMPONENT PULSES



FIGURE 4d

FIRST COMPONENT PULSE AND HEAT GAIN IT ELICITS



FIGURE 4e

SECOND COMPONENT PULSE AND HEAT GAIN IT ELICITS

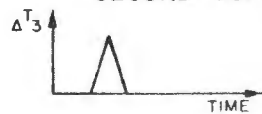
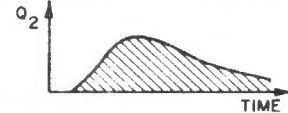


FIGURE 4f

THIRD COMPONENT PULSE AND HEAT GAIN IT ELICITS

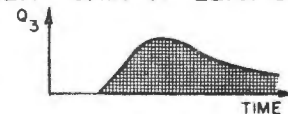


FIGURE 4g

FOURTH COMPONENT PULSE AND HEAT GAIN IT ELICITS

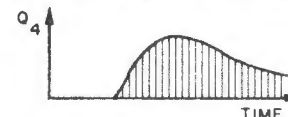


FIGURE 4h

FIFTH COMPONENT PULSE AND HEAT GAIN IT ELICITS



FIGURE 4i
CURVE OF SUMS

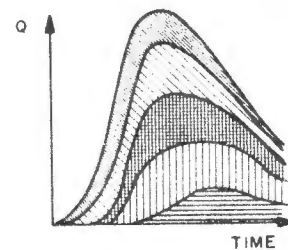


Figure 4 THE CONVOLUTION PRINCIPLE

known as the superposition theorem asserts that the curve of sums is exactly the heat gain schedule which would be elicited by the approximate temperature difference schedule, $\Delta T'$. Due to the smoothing effect of the heat transfer process, ΔT and $\Delta T'$ give nearly the same heat gain schedule. Therefore the curve of sums is very nearly the heat gain schedule elicited by the original temperature difference schedule, ΔT . This method of resolution and recombination is called the convolution principle.

To the air conditioning engineer, the convolution principle means that the difficult problems of transient heat transfer can be solved, for each simulated hour, by adding and multiplying very few numbers. The convolution principle, as applied to heat gain through a thick wall, is expressed mathematically by the equation

$$Q_j = \sum_{i=0}^n r_i \Delta T_{j-i} \quad (1)$$

where: Q_j equals the heat gain at the hour j ; ΔT_{j-i} equals the temperature difference i hours previous to hour j ; r_i equals the i^{th} response factor for the wall; and n equals the number of hours of the temperature difference history which significantly effect Q_j . Notice that the response factors are the only information about the wall which appears in equation 1. Thus, the response factors characterize completely the thermal properties of the structure of the wall and, alone describe how the structure absorbs and releases heat over a prolonged period of time.

The program allows the user to specify either actual thermal data - that is, layer by layer thicknesses, conductivities, and specific heats - which the program will convert to response factors, or the response factors themselves. Tables of response factors are now available for a variety of structures.

Where neither the layer by layer thermal data nor the response factors of a wall or roof are known, a feature is available to generate approximate response factors from these simplified data: U-factor; conditions (summer or winter) to which the U-factor applies; material of outside layer, and thickness of insulation, if present. The wall and roof construction subroutine works by selecting a wall or roof construction from a stored library of constructions standardized by ASHRAE, to fit the simplified data. The load program uses the response factors of the selected construction.

A cost saving feature of the load sub-program is the use of a subtle modification of equation 1 which allows n to equal infinity while saving a good deal of computer time. That is, all previous hours of the temperature difference schedule are taken into account - very inexpensively.

The load sub-program uses the convolution principle for the following three purposes.

- 1) To compute the exterior surface temperature of a thick wall at each simulated hour on the basis of past temperatures and present radiation and convection data.
- 2) To compute heat gain as already described.
- 3) To compute the time delay between heat gain to a space and the resulting loads on the air conditioning system. In this last case, the series of numbers which characterizes the structures (room furnishings, floors, partitions) are called room weighting factors, rather than response factors.

To summarize, the convolution principle is used by the load sub-program to simulate, with great accuracy, the transient heat conduction taking place within the structures of the building. Various experiments with the program indicate that the convolution principle, when used in heating and cooling

load calculations, gives more realistic values of the maximum loads and more accurate estimates of the times of their occurrence. For example, the program shows that maximum cooling loads occur several hours after the hottest time of the day, at which time some buildings are unoccupied. For practical purposes, this means that the equipment specified with the help of the program will be smaller than equipment specified as a result of hand computation, and that the elusive demand figures for utility services can be determined accurately, allowing a realistic estimation of energy costs.

4. THERMAL LOADS PLOT SUB-PROGRAM

One of the initial tasks performed by the engineer in preparing his input for the Load Calculation Sub-program is the breaking of the building into spaces*. One engineer might carry the task to extremes and call every room a space, while another engineer might combine several rooms into a space because he knows from past experience that these rooms will have similar load profiles.

Before running the Systems Simulation Sub-program (Section 7), again, the engineer must give consideration to the definition of areas within the building but this time in terms of fan zones rather than spaces. More often than not, especially in large buildings, several spaces will be grouped and controlled off of one thermostat. We speak of the area being controlled by a thermostat as a fan zone. Economic considerations tell us to use as few thermostats and fan systems as possible, but comfort considerations tell us otherwise. Through the use of the Thermal Loads Plot Sub-program, the engineer can call for load profile plots for any or all spaces and thereby graphically compare the profiles to determine compatible grouping of spaces into zones.

* See page 4 for definition.

If, initially, care was taken to break the building directly into fan zones, use of the Thermal Loads Plot Sub-program would probably not be required. If, however, it is decided to define fan zones differently from spaces, then use can be made of the Editing Sub-sub-program to combine and reorder the output tape from the Load Calculation Sub-program and create a new tape of format compatible for use by the Systems Simulation Sub-program.

In summary, use of the Thermal Loads Plot Sub-program gives the engineer a tool whereby he can more rationally set up fan zones within a building.

5. SYSTEMS SIMULATION SUB-PROGRAM

The Systems Simulation Sub-program performs three important tasks:

- (1) Sizes energy-consuming heating and cooling equipment (chillers, boilers, pumps, cooling towers, etc.) and fan systems using peak zone and peak building heating and cooling loads determined by the Load Calculation Sub-program.
- (2) For each hour of the analysis, sums together zone thermal loads and ventilation air loads through use of the characteristics of each fan system to obtain the hourly output requirements that must be provided by the heating and cooling plants.
- (3) Through the use of part load performance data from typical systems, converts the thermal requirements into energy requirements.

Since the types of buildings constructed by the Postal Service range in size from 10,000 square feet all the way up to several million square feet, the System Simulation Sub-program has been broken into two parts: the Central System Simulation Sub-program, for large buildings (usually with floor areas 35,000 square feet and larger), and the Packaged System Simulation Sub-program,

for small buildings (usually with floor areas less than 35,000 square feet) where the Postal Service generally uses packaged or unitary equipment. The Central System Simulation Sub-program is capable of simulating the following thermal distribution systems (earlier referred to as fan systems).

- Single Zone System
- Multi-Zone System
- Dual-Duct System
- Unit Ventilator
- Unit Heater
- Single Zone Reheat System
- Radiant Floor Panel Heating

To simulate these systems is meant to imitate the action of the control system in order to realistically determine the heating and/or cooling requirement that the distribution system is demanding from the heating and cooling plant for the hour under consideration. The distribution system control schedules used in the program are particularly suited to Postal Service specifications.

The heating and cooling plant combinations within the range of the Central System Simulation Sub-program include the following:

(1) Conventional Systems

- Hermetic Reciprocating Chiller with Gas, Oil, or Steam Heat
- Hermetic Centrifugal Chiller with Gas, Oil, or Steam Heat
- Open Centrifugal Chiller with Gas, Oil, or Steam Heat
- Steam Absorption Chiller with Electric or Steam Heat

(2) Total Electric System

- Hermetic Reciprocating Chillers with Electric Heat
- Hermetic Centrifugal Chiller with Electric Heat

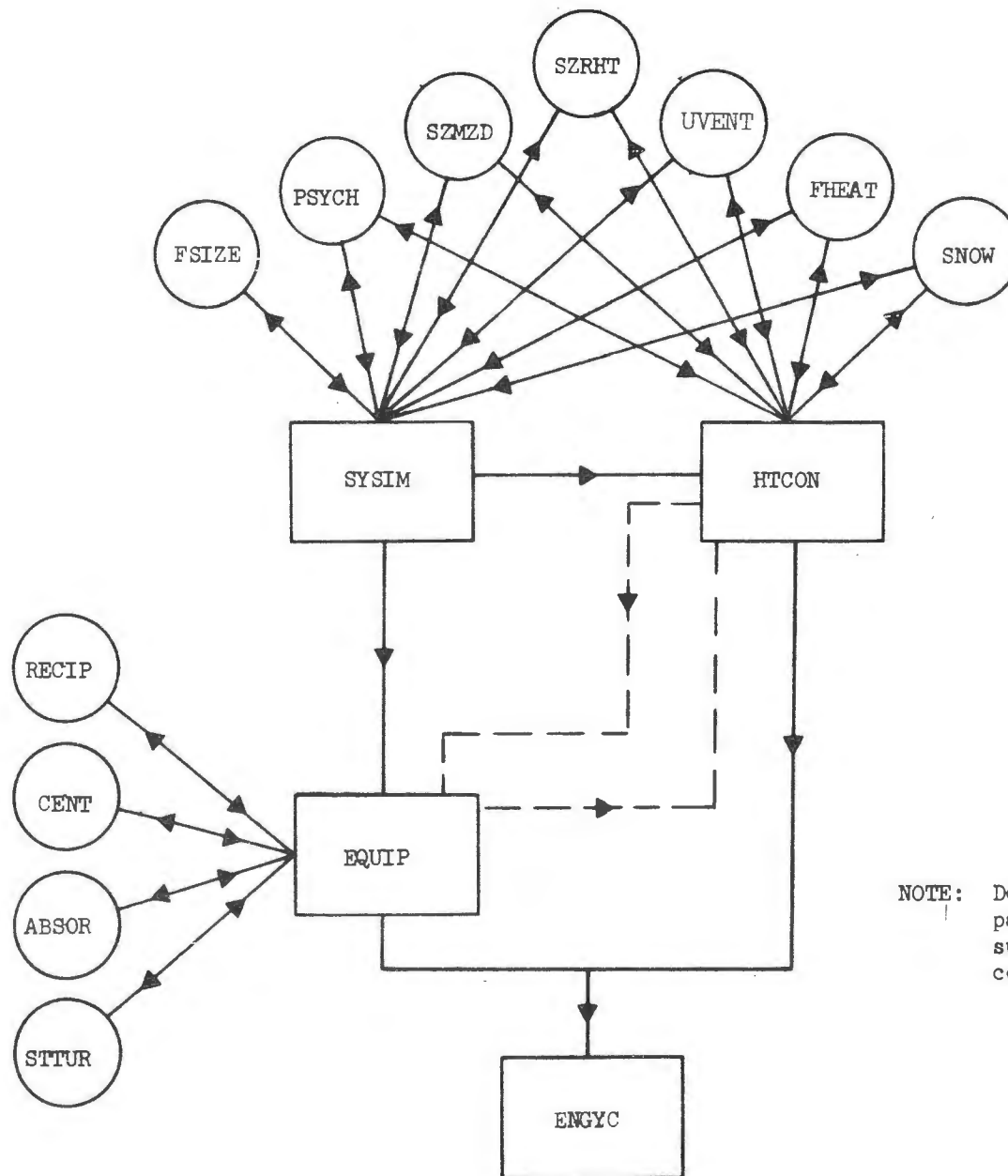
- Open Centrifugal Chiller with Electric Heat
- (3) Total Gas Systems
- Steam Absorption Chiller with Gas Heat
 - Steam Turbine-Driven Open Centrifugal Chiller with Gas Heat
- (4) Total Oil Systems
- Steam Absorption Chiller with Oil Heat
 - Steam Turbine-Driven Open Centrifugal Chiller with Oil Heat
- (5) On-Site Generation Systems
- Total Gas with Steam Absorption Chiller, Gas Heat and Gas Engine-Generation Sets
 - Total Oil with Steam Absorption Chiller, Gas Heat and Diesel Fuel Engine-Generation Sets

The Packaged Systems Simulation Sub-program is capable of analyzing the following systems:

- (1) Electric Air Conditioning (DX Coil) with Gas Heating
- (2) Electric Air Conditioning (DX Coil) with Oil Heating
- (3) Reversible Cycle Heat Pump with Electric Resistance Heating
- (4) Gas Air Conditioning with Gas Heating

For the above-mentioned heating and cooling systems, simulation here not only entails imitating the action of the overall control systems, but also the simulating of the part load performance characteristics so that an accurate estimate of the unit's energy consumption can be made.

Taking a closer look at the structure of the Systems Simulation Sub-program reveals that it is actually made up of 15 smaller programs or sub-routines. Table 2 gives a short description of each subroutine and Figure 5 illustrates their logical interrelationship. Subroutine SYSIM directs the flow of logic through the sub-program and controls the order in which calculations are to be performed. The sequence of calculations is generally as follows.



NOTE: Dotted line indicates path of logic taken for summer operation of heat conservation machines.

Figure 5 INTERRELATIONSHIP OF SYSTEM SIMULATION SUB-PROGRAM SUBROUTINES

TABLE 2

SYSTEM SIMULATION SUB-PROGRAM SUBROUTINES
AND THEIR FUNCTION

NAME OF THE SUBROUTINE	FUNCTION
SYSIM	Controls the operation of the entire Systems Simulation Sub-program by executing the subroutines in their proper order.
FSIZE	Sizes the air flow quantities for each fan zone.
HTCON	Simulates the operation of the heat conservation system.
SZRHT	Simulates the operation of single zone/reheat fan system.
SZMZD	Simulates the operation of single zone, multi-zone and dual-duct fan systems.
UVENT	Simulates the operation of unit ventilator and unit heater systems.
FHEAT	Simulates the operation of floor panel heating systems.
PSYCH	Calculates the psychrometric properties of moist air.
EQUIP	Simulates the operation of heating and cooling central systems and on-site generation systems.
RECIP	Simulates the operation of reciprocating water chillers.
CENT	Simulates the operation of hermetic centrifugal water chillers.
ABSOR	Simulates the operation of steam absorption water chillers.
STTUR	Simulates the operation of steam turbines.
SNOW	Simulates the operation of snow-melting systems.
ENGYC	Prints out annual energy consumption summary in a form similar to POD Form No. 2215.

- 1) The zone air flows are sized using the peak hourly heating and cooling zone loads.
- 2) The central heating and cooling plant components (chillers, boilers, pumps, etc.) are sized based upon the peak building heating and cooling loads.
- 3) An hour-by-hour analysis of the building's thermal distribution systems is performed. Each distribution system is examined individually and the hourly heating and/or cooling requirements calculated and summed to give the total demand that is being placed on the central plant.
- 4) At the end of an hour's calculation, after the last distribution system has been examined, the EQUIP subroutine is called upon to convert the total thermal requirements into hourly energy requirements based upon the type of equipment under investigation.
- 5) At the end of the analysis period, a monthly summary of the building's energy consumption is printed.

A more detailed explanation of this output, as well as others extracted from the Systems Simulation Sub-program, is given in Section 8.

6. ECONOMIC ANALYSIS SUB-PROGRAM

The Economic Analysis Sub-program determines the annual owning and operating cost by taking into account all life cycle costs for each heating/cooling combination analyzed by the Systems Simulation Sub-program. Life cycle costs are those expenditures which occur either singularly or periodically over the life of the building and include cost of energy, cost of equipment in terms of first costs and replacement costs which occur if the expected life of the equipment is less than that of the building, cost of maintenance (material and labor), cost of periodic overhaul (material and labor), salvage

value of equipment at the end of building life, and costs of floor space which might result due to the unavailability of space occupied by equipment for other purposes.

The only aid that the program gives the engineer in estimating these life cycle costs for input to the Economic Analysis Sub-program is in the area of energy cost and equipment cost. Energy costs can be determined using the monthly energy consumption summary from the Systems Simulation Sub-program and utility rate schedules for the locale in which the building is to be situated. Equipment costs can be obtained from equipment supplier based upon the equipment quantities and capacities supplied by the Systems Simulation Sub-program. All other life cycle costs must be estimated by the engineer based upon operating practices and procedures of the agency for which the building is being constructed. Once the life cycle costs have been accumulated and entered into the Economic Analysis Sub-program, the sub-program then proceeds to determine the present value of all life cycle costs over the expected life of the building and calculate the total owning and operating annuity which is construed to mean the uniform annual cost, considering all life cycle costs, to the owner during the life-time of the building.

7. SEQUENCE OF SUB-PROGRAM USE

The sequence of using sub-programs depends upon the information the engineer wishes to obtain and if he can initially break the buildings into fan system control zones rather than just spaces. Figure 6 illustrates the paths of sub-program sequencing that can be taken as a function of the engineer's decisions. As the engineer becomes more adept at breaking a building directly into control zones, the need for space load plots and/or re-grouping of spaces will diminish.

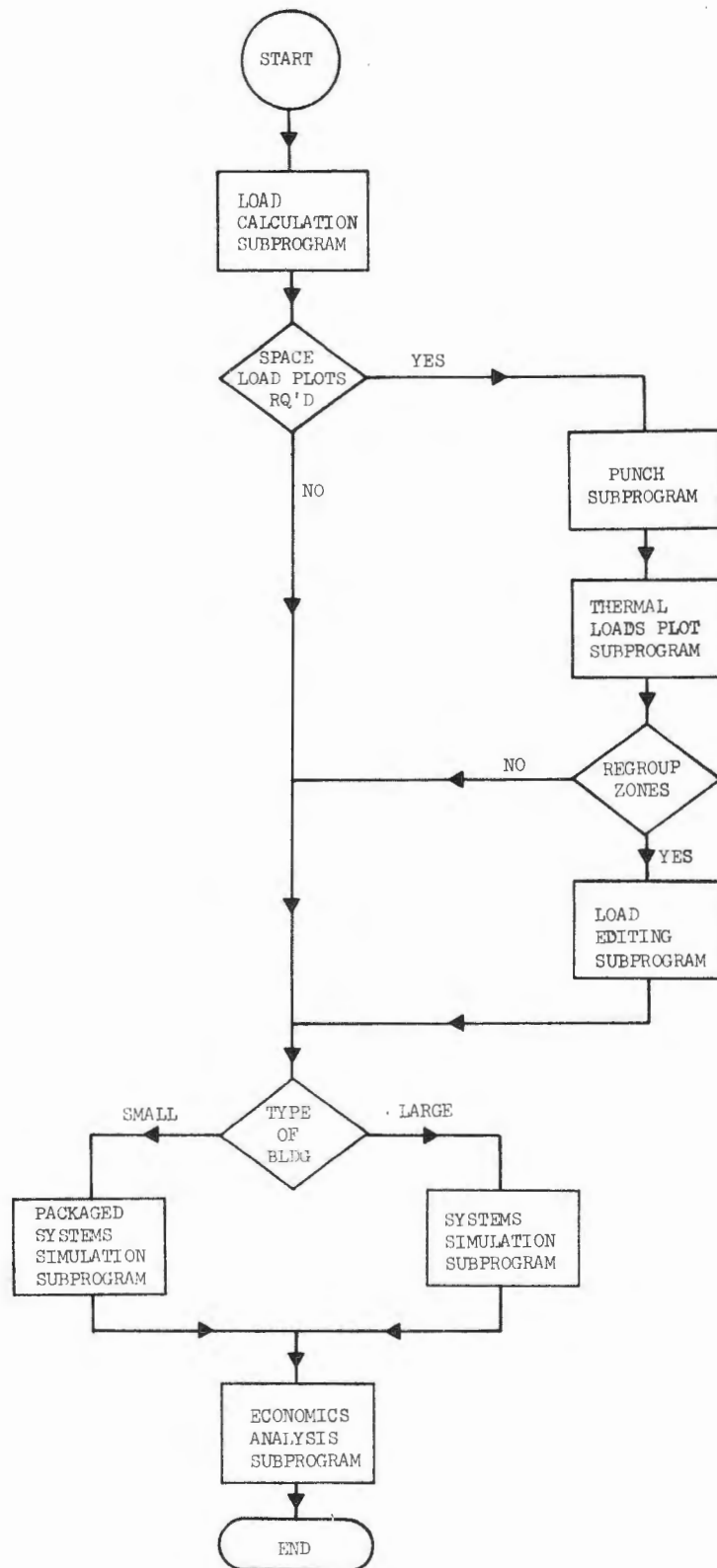


Figure 6 THE PATHS OF SUB-PROGRAM SEQUENCING

The card input data required by some of the sub-programs cannot be prepared until the output of another sub-program has been examined. For example, the proper grouping of spaces into control zones, and then control zones into fan systems required for the Systems Simulation Sub-program, probably cannot be done until the results of the Thermal Load Plot Sub-program are reviewed to establish which spaces have similar load profiles. Neither can monthly energy costs be calculated and inputted to the Economics Analysis Sub-program until the monthly energy consumption summary has been received from the Systems Simulation Sub-program. Nor can the engineer collect the necessary equipment cost data required by the Economics Analysis Sub-program until the Systems Simulation Sub-program tells him the quantity and capacity of the chillers, boilers, cooling towers, etc.. Figures 7 and 8 illustrate the dependence of input upon output for small and large buildings, respectively. For small buildings, where use of all sub-programs is probably not required, the engineer can elect to use only the Load Calculation Sub-program, the Packaged Systems Simulation Sub-program, and the Economics Analysis Sub-program. If experience indicates no need for economic evaluation of fuels, energy and equipment variations, then the engineer can elect to run only the Load Calculation Sub-program for the peak heating and cooling months. This would indicate maximum and minimum heating and cooling requirements for proper capacity equipment selection.

8. INPUT AND OUTPUTS OF EACH SUB-PROGRAM - EXAMPLE

Load Calculation Sub-program

The input to the Load Calculation Sub-program includes on tape, the weather data, and on cards, the geometry of the building and its surroundings; the thermal properties of wall and roof construction; the type and orientation of windows; and the operating schedules of occupancy, lighting, and equipment.

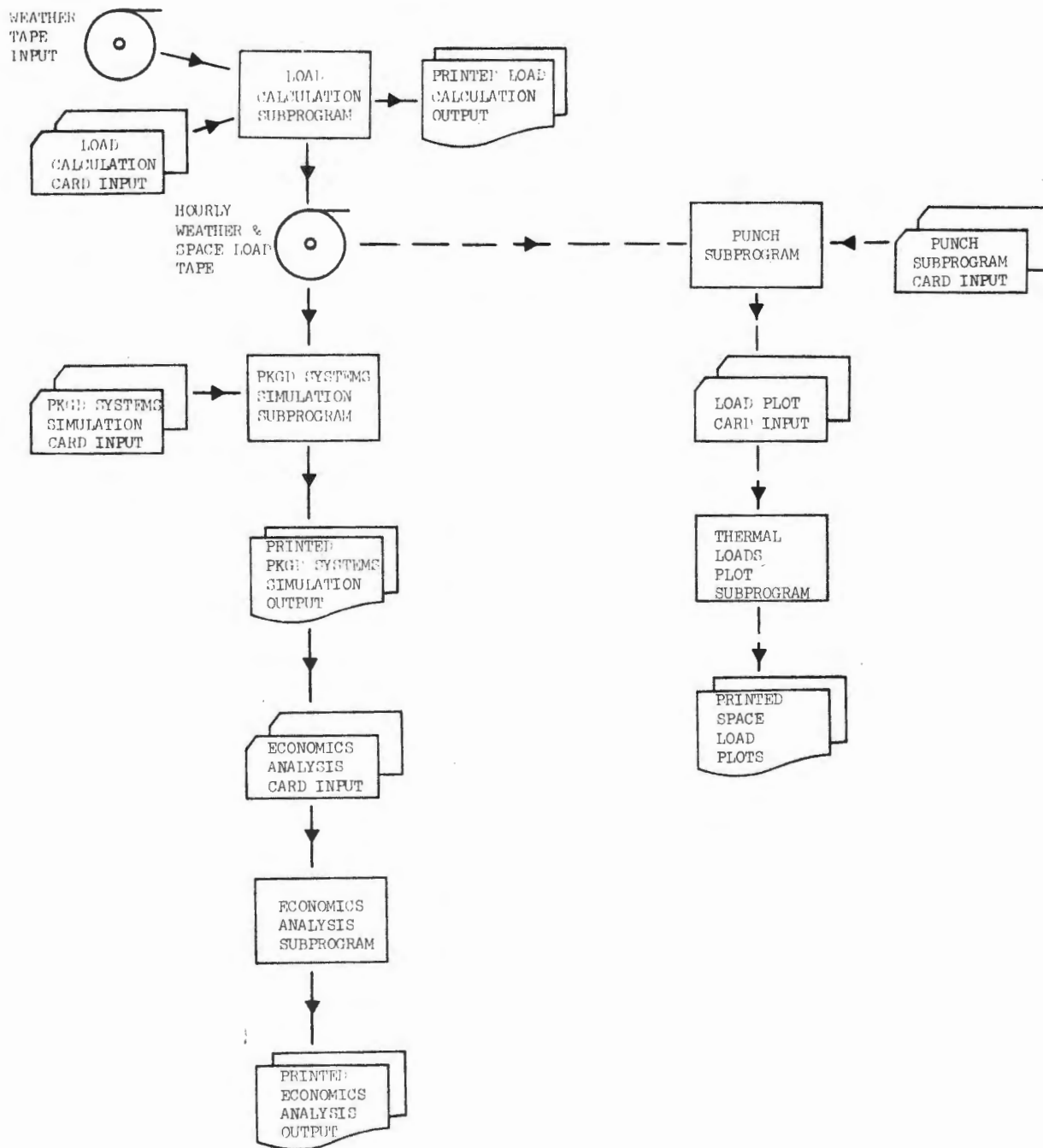


Figure 7 ANALYSIS OF SMALL BUILDINGS

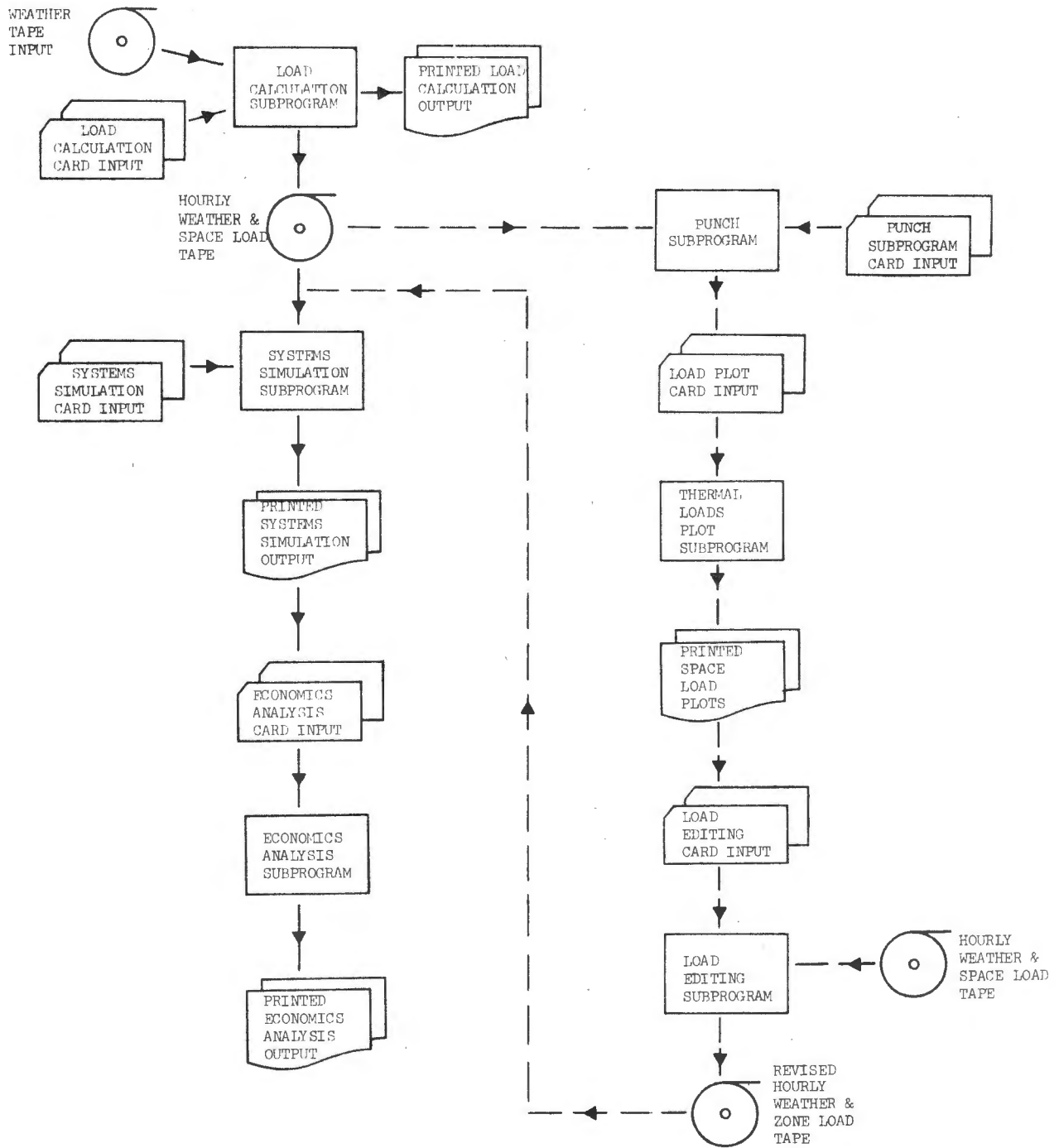


Figure 8 ANALYSIS OF LARGE BUILDINGS

The output from the Load Calculation Sub-program is well illustrated by the example: the GARD building located in Niles, Illinois was run through the program. Figures 9, 10 and 11 show the building's exterior; the configuration of the penthouse and cooling tower on the roof; and the floor plan, indicating overall dimensions and the eight spaces into which the building was broken for the analysis.

The mandatory output received from the Load Calculation Sub-program includes the building identification (Figure 12), weather year information and length of study (Figure 13), the building thermal and infiltration loads summary (Figure 14) indicating the peak heating and cooling loads that occurred for the weather year under investigation, and the space maximum and minimum heating and cooling loads summary (Figure 15). The Load Calculation Sub-program also creates an output tape on which is summarized for each hour of the year: the hour number; sun index; dry-and wet-bulb temperatures; wind velocity; humidity ratio; pressure; enthalpy and density of outside air; and for each space: the space number, space sensible load, space latent load, plenum return air lighting load, and the power consumption for lights and equipment.

Optional output from the Load Calculation Sub-program includes wall and roof specifications (Figures 16 and 17) for a given maximum U-factor, listing of data on load tape (Figures 18 and 19), and shadow pictures. Figures 20, 21, and 22 illustrate the shadow pictures for various building surfaces at the hour designated.

Thermal Loads Plot Sub-program

The inputs to the Thermal Loads Plot Sub-program are the space number, the number of days to be plotted, the starting date, and the tape output of the load program.

The output is a strip chart graph (Figure 23) detailing the heat gain or loss for each hour plus the maximum heat gain or loss for the period.

Systems Simulation Sub-program

The inputs to the Systems Simulation Sub-program are the output tapes of the Load Calculation (or Editing Support) Sub-program, the fan system characteristics, the chiller operating characteristics, and the types of heating/cooling combinations and energy sources to be analyzed. To illustrate the output of the Systems Simulation Sub-program, the air conditioning system contained within the GARD building was simulated. Figure 24 schematically shows the system which is a high pressure dual-duct air distribution system with a central gas boiler for heating and a centrifugal water chiller for cooling.

Figures 25 through 28 show the outputs of the System Simulation Sub-program for the GARD building analysis. Fan system characteristics and supply air requirements for each fan system and control zone within the building are summarized in Figures 25 and 26. The sources of the numbers appearing on these outputs are as follows:

- (1) type of fan system - input
- (2) fan brake horsepower - calculated, based upon fan total pressure
(input) and total air quantity circulated by fan
- (3) number of zones - input
- (4) set-point temperature - input, assumed to apply to all zones
of the fan system
- (5) total air flow - the sum of the zone supply air requirements
which are calculated based upon actual peak heating and
cooling loads determined by the Load Calculation Sub-program
and ventilation air requirements.

- (6) minimum outside air - calculated, based upon USPS standards of 10% of circulated air or one air change, whichever is greater, plus exhaust air requirements.
- (7) exhaust air quantities - input
- (8) percent ventilation air - calculated as the ratio of minimum outside air quantity to total air flow.

Figure 27 summarizes the heating, cooling and distribution equipment sized by the program for use in estimating hourly energy consumptions. The type of chiller and boiler is chosen by the engineer and inputted to the program, thus allowing the program to size this equipment as well as pumps, cooling towers and other energy consuming equipment. No fudge factors or safety factors are used in sizing equipment. The actual peak building heating and cooling requirements calculated by the Load Calculation Sub-program with ventilation air requirements added to them, are used to size all components.

Figure 28 illustrates the energy consumption summary that is received from the Systems Simulation Sub-program. Each month, for the duration of the analysis, the consumption and demand figures for each energy source used in the building is summarized. At the top of the table, energy consumption is summarized in terms of Btu's of heating and cooling that the boiler and chiller had to provide to the building during each month. By means of this energy consumption summary and local energy rate schedules, these data can be turned into estimates of dollars.

Economic Analysis Sub-program

The inputs to the Economic Analysis Sub-program are the monthly energy costs, the installed equipment costs, equipment life, maintenance and overhaul costs, and anticipated annual percentage increase of labor and material.



Figure 9 GARD BUILDING



Figure 10 PENTHOUSE AND COOLING TOWER

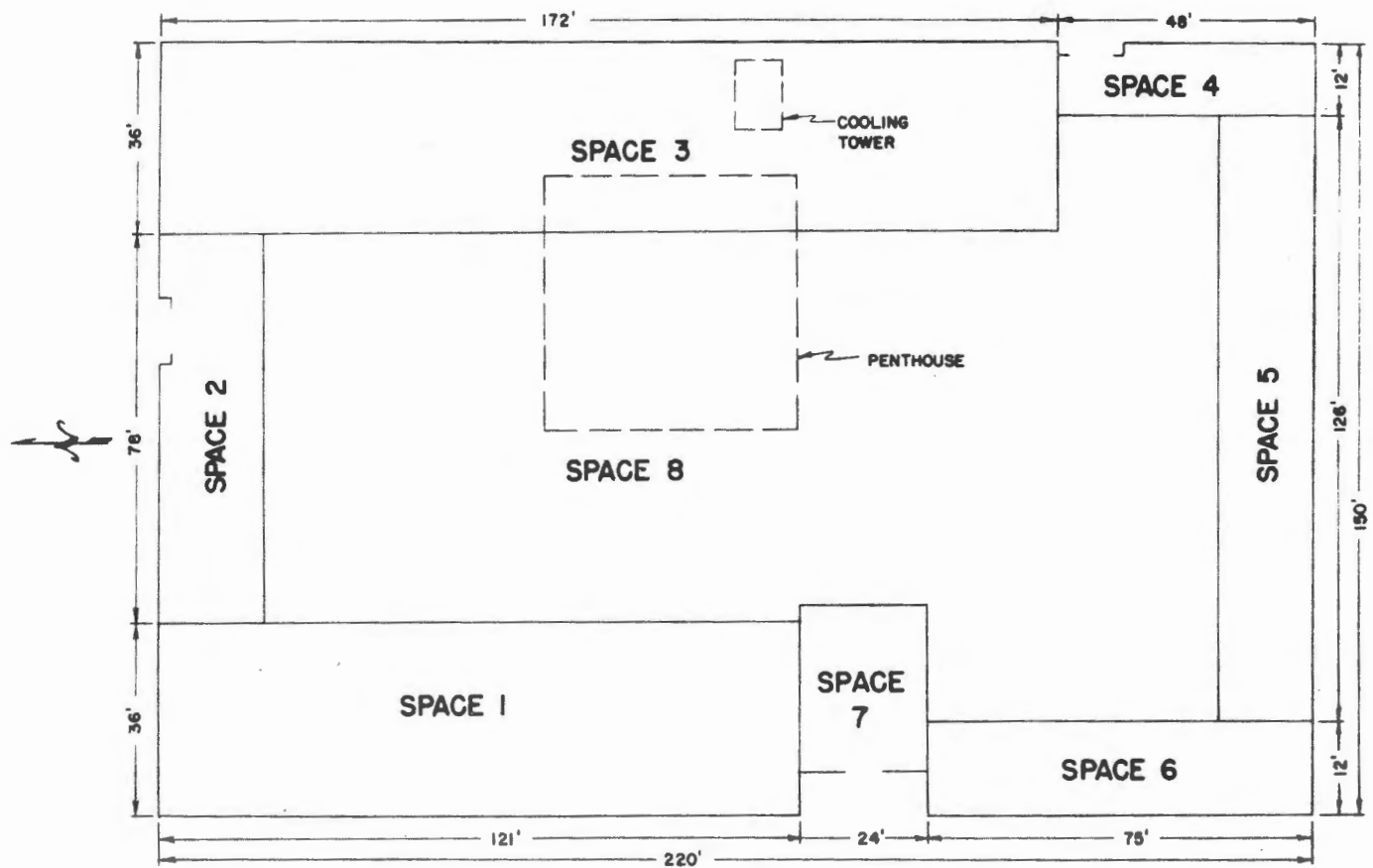


Figure 11 Floor Plan of GARD Building

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* ANALYSIS OF ENERGY UTILIZATION OF *  
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*  
* GARD OFFICE BUILDING *  
*  
*  
* FACILITY *  
*  
*  
* NILES, ILLINOIS *  
*  
*  
ENGINEER - M. LOKMANHEKIM AND R. HENNINGER *  
PROJECT NO - 91364 *  
DATE - 7 MAY 1971 *  
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[illegible]

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* ANALYSIS OF ENERGY UTILIZATION OF
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* GARD OFFICE BUILDING
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* NILES, ILLINOIS
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* ENGINEER - M. LOKMANHEKIM AND R. HENNINGER
* PROJECT NO - 91364
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*               FACILITY                                           *  
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*               NILES, ILLINOIS                                    *  
*                                     *  
*                                     *  
ENGINEER   - M. LOKMANHEKIM AND R. HENNINGER                     *  
PROJECT NO - 91364                                                *  
DATE       - 7 MAY 1971                                          *  
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ENGINEER - M. LOKMANHEKIM AND R. HENNINGER *  
PROJECT NO - 91364 *  
DATE - 7 MAY 1971 *  
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Figure 12 BUILDING IDENTIFICATION

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*****  
*  
*  
*          IN THIS RUN  
*  
* - U. S. WEATHER BUREAU 1440 WEATHER TAPE OF STATION 14819 IS USED.  
*  
* - THE FIRST DATA OBTAINED FROM WEATHER TAPE IS FOR 0TH HOUR OF 01/01/1957.  
*  
* - THE LENGTH OF THIS STUDY IS 365 DAYS.  
*  
* - THE INITIAL OUTSIDE SURFACE TEMPERATURE IS 17 DEGREES FAHRENHEIT.  
*  
*****
```

- ```

*
*
* IN THIS RUN
*
* - U. S. WEATHER BUREAU 1440 WEATHER TAPE OF STATION 14819 IS USED.
*
* - THE FIRST DATA OBTAINED FROM WEATHER TAPE IS FOR 0TH HOUR OF 01/01/1957.
*
* - THE LENGTH OF THIS STUDY IS 365 DAYS.
*
* - THE INITIAL OUTSIDE SURFACE TEMPERATURE IS 17 DEGREES FAHRENHEIT.
*

```

Figure 13 WEATHER YEAR AND LENGTH OF STUDY INFORMATION

|                                                                                                                       |            |     |            |         |       |                   |      |        |      |         |
|-----------------------------------------------------------------------------------------------------------------------|------------|-----|------------|---------|-------|-------------------|------|--------|------|---------|
| *****                                                                                                                 |            |     |            |         |       |                   |      |        |      |         |
| * BUILDING THERMAL AND INFILTRATION LOADS SUMMARY *                                                                   |            |     |            |         |       |                   |      |        |      |         |
| * COOLING DESIGN HOUR TEMPERATURE HUM. RAT. PRESSURE PLENUM LOAD BUILDING THERMAL AND INFILTRATION LOADS TOTAL LOAD * |            |     |            |         |       |                   |      |        |      |         |
|                                                                                                                       | DEGREES    |     | LBS WATER  | INCHES  | BTU   | BTU PER HOUR      |      |        |      | BTU     |
|                                                                                                                       | FAHRENHEIT |     | PER        | OF      | PER   | SENSIBLE          |      | LATENT |      | PER     |
|                                                                                                                       | DB         | WB  | LB DRY-AIR | MERCURY | HOURL | RAD.+TRAN.+INTER. | INF. | PEOPLE | INF. | HOURL   |
|                                                                                                                       |            |     |            |         |       | +PEOPLE           |      |        |      |         |
| 4024                                                                                                                  | 96.        | 77. | .016157    | 29.44   | 0.    | 600297.           | 0.   | 32735. | 0.   | 633032. |
| * 16.HOUR OF 17 JUNE *                                                                                                |            |     |            |         |       |                   |      |        |      |         |
| * HEATING DESIGN HOUR TEMPERATURE HUM. RAT. PRESSURE BUILDING THERMAL AND INFILTRATION SENSIBLE LOAD *                |            |     |            |         |       |                   |      |        |      |         |
|                                                                                                                       | DEGREES    |     | LBS WATER  | INCHES  |       | BTU               |      |        |      |         |
|                                                                                                                       | FAHRENHEIT |     | PER        | OF      |       | PER               |      |        |      |         |
|                                                                                                                       | DB         |     | LB DRY-AIR | MERCURY |       | HOURL             |      |        |      |         |
| 319                                                                                                                   | -7.        |     | .000357    | 29.61   |       | -549274.          |      |        |      |         |
| * 7. HOUR OF 14 JAN. *                                                                                                |            |     |            |         |       |                   |      |        |      |         |
| *****                                                                                                                 |            |     |            |         |       |                   |      |        |      |         |

Figure 14 BUILDING THERMAL AND INFILTRATION LOADS

## SPACE MAXIMUM AND MINIMUM HEATING AND COOLING LOADS SUMMARY

\* \* \*

| SP.NO | MAX. HEAT.<br>BTU/HOUR | HOUR              | MIN. HEAT.<br>BTU/HOUR | HOUR               | MAX. COOL.<br>BTU/HOUR | HOUR               | MIN. COOL.<br>BTU/HOUR |                    |
|-------|------------------------|-------------------|------------------------|--------------------|------------------------|--------------------|------------------------|--------------------|
| 1     | -102188.               | 7.HOUR OF 14 JAN. | -4.                    | 2.HOUR OF 30 APR.  | 141423.                | 16.HOUR OF 17 JUNE | 15.                    | 1.HOUR OF 18 MAY   |
| 2     | -42376.                | 7.HOUR OF 14 JAN. | -9.                    | 4.HOUR OF 1 JULY   | 34823.                 | 17.HOUR OF 17 JUNE | 0.                     | 7.HOUR OF 29 JUNE  |
| 3     | -141839.               | 7.HOUR OF 14 JAN. | -2.                    | 13.HOUR OF 3 JAN.  | 167166.                | 16.HOUR OF 17 JUNE | 4.                     | 4.HOUR OF 13 SEP.  |
| 4     | -27366.                | 7.HOUR OF 14 JAN. | -6.                    | 14.HOUR OF 13 NOV. | 22021.                 | 9.HOUR OF 17 JUNE  | 0.                     | 20.HOUR OF 13 MAR. |
| 5     | -70283.                | 7.HOUR OF 14 JAN. | -3.                    | 18.HOUR OF 13 OCT. | 73210.                 | 13.HOUR OF 18 SEP. | 0.                     | 22.HOUR OF 11 OCT. |
| 6     | -44066.                | 7.HOUR OF 14 JAN. | -5.                    | 21.HOUR OF 21 SEP. | 51700.                 | 16.HOUR OF 17 JUNE | 0.                     | 4.HOUR OF 7 JUNE   |
| 7     | -13655.                | 6.HOUR OF 14 JAN. | -1.                    | 22.HOUR OF 3 MAY   | 20187.                 | 16.HOUR OF 17 JUNE | 1.                     | 7.HOUR OF 11 SEP.  |
| 8     | -107503.               | 7.HOUR OF 14 JAN. | -12.                   | 4.HOUR OF 2 SEP.   | 147626.                | 16.HOUR OF 30 JULY | 88.                    | 5.HOUR OF 6 JULY   |

Figure 15 SPACE MAXIMUM AND MINIMUM HEATING AND COOLING LOADS SUMMARY

WALL SPECIFICATIONS- EXTERIOR- BRICK OR ROUGH PLASTER  
 MAX. OVERALL U= 0.152 BTU/HR-FT<sup>2</sup>-F  
 WINTER CONDITIONS OUTSIDE

STD. ASHRAE WALL SELECTION IS AS FOLLOWS

| LAYER                                      | DESCRIPTION                                                                    | THKNS<br>FT. | CONDTVTY<br>B/HR-FT-F | DNSTY<br>LB/FT <sup>3</sup> | SP HT<br>B/LB-F | RESISTANCE<br>HR-FT <sup>2</sup> -F/B |
|--------------------------------------------|--------------------------------------------------------------------------------|--------------|-----------------------|-----------------------------|-----------------|---------------------------------------|
| 1                                          | 4.000 IN. MASÓNRY, BRICK, COMMON                                               | 0.333        | 0.417                 | 120.00                      | 0.200           | 0.0                                   |
| 2                                          | 0.500 IN. CEMENT MORTAR                                                        | 0.0          | 0.0                   | 0.0                         | 0.0             | 0.0                                   |
| 3                                          | 4.000 IN. CONCRETE, SAND + GRAVEL AGGREGATE (NOT DRIED) 140 LB/FT <sup>3</sup> | 0.333        | 1.042                 | 140.00                      | 0.250           | 0.0                                   |
| 4                                          | AIR SPACE                                                                      | 0.0          | 0.0                   | 0.0                         | 0.0             | 0.97                                  |
| 5                                          | 1.000 IN. INSULATING MAT'L BLANKET, MINERAL WOOL, FIBROUS                      | 0.083        | 0.027                 | 0.50                        | 0.157           | 0.0                                   |
| 6                                          | 0.375 IN. BUILDING BOARD, GYPSUM OR PLASTER BOARD                              | 0.031        | 0.094                 | 50.00                       | 0.259           | 0.0                                   |
| 7                                          | 0.500 IN. GYPSUM PLASTER, SAND AGGREGATE                                       | 0.042        | 0.470                 | 105.00                      | 0.200           | 0.0                                   |
| 8                                          | INSIDE SURFACE STILL AIR                                                       | 0.0          | 0.0                   | 0.0                         | 0.0             | 0.68                                  |
| OVERALL U= 0.156 BTU/HR-FT <sup>2</sup> -F |                                                                                |              |                       |                             |                 |                                       |

Figure 16 WALL SPECIFICATION OUTPUT

ROOF SPECIFICATIONS-            PITCHED ROOF  
                                       MAX. OVERALL    U= 0.211 BTU/HR-FT<sup>2</sup>-F  
                                       SUMMER CONDITIONS OUTSIDE

STD. ASHRAE ROOF SELECTION IS AS FOLLOWS

| LAYER                                      | DESCRIPTION                                                           | THKNS<br>FT. | CONDTVTY<br>B/HR-FT-F | DNSTY<br>LB/FT <sup>3</sup> | SP HT<br>B/LB-F | RESISTANCE<br>HR-FT <sup>2</sup> -F/B |
|--------------------------------------------|-----------------------------------------------------------------------|--------------|-----------------------|-----------------------------|-----------------|---------------------------------------|
| 1                                          | 0.500 IN. ROOFING, ASBESTOS-CEMENT SLATE SHINGLES                     | 0.042        | 0.833                 | 120.00                      | 0.200           | 0.0                                   |
| 2                                          | 0.063 IN. BUILDING PAPER, VAPOR-PERMEABLE FELT                        | 0.005        | 0.087                 | 44.00                       | 0.324           | 0.0                                   |
| 3                                          | 0.781 IN. BUILDING BOARD, PLYWOOD                                     | 0.065        | 0.067                 | 34.00                       | 0.650           | 0.0                                   |
| 4                                          | AIR SPACE                                                             | 0.0          | 0.0                   | 0.0                         | 0.0             | 0.85                                  |
| 5                                          | 0.750 IN. INSULATING MAT'L, ACOUSTICAL TILE (WOOD OR CANE FIBERBOARD) | 0.063        | 0.035                 | 15.00                       | 0.200           | 0.0                                   |
| 6                                          | INSIDE SURFACE, STILL AIR                                             | 0.0          | 0.0                   | 0.0                         | 0.0             | 0.92                                  |
| OVERALL U= 0.215 BTU/HR-FT <sup>2</sup> -F |                                                                       |              |                       |                             |                 |                                       |

Figure 17 ROOF SPECIFICATION OUTPUT

```

*
*
* IN THE FOLLOWING PAGES
*
*
* THE FIRST LINE OF EACH PRINTED BLOCKS GIVES
*
* TIME - HOURS, STANDARD TIME FROM FIRST HOUR OF JANUARY
* SUN INDEX - IF EQUAL TO ONE SUN IS DOWN, IF EQUAL TO ZERO SUN IS UP
* DRY-BULB TEMP. - DEGREES FAHRENHEIT
* WET-BULB TEMP. - DEGREES FAHRENHEIT
* WIND VELOCITY - KNOTS
* HUMIDITY RATIO - LBS WATER PER LB DRY-AIR
* PRESSURE - INCHES OF MERCURY
* ENTHALPY - BTU PER LB DRY-AIR
* DENSITY - LBS DRY-AIR PER CUBIC FOOT
*
* THE FOLLOWING LINES OF EACH PRINTED BLOCKS GIVES
*
* SPACE NUMBER
* SPACE SENSIBLE LOAD - BTU PER HOUR
* SPACE LATENT LOAD - BTU PER HOUR
* PLENUM RETURN AIR LIGHTING LOAD - BTU PER HOUR
* SPACE LIGHTING AND EQUIPMENT POWER - KILOWATTS
*

* NOTE - THE LOADS EXCLUDES OUTSIDE VENTILATION AIR LOADS
*

```

Figure 18 FORMAT OF LOAD TAPE PRINTOUT

|    |            |    |    |     |         |       |      |         |
|----|------------|----|----|-----|---------|-------|------|---------|
| 24 | 1          | 9. | 8. | 9.  | .000760 | 29.76 | 2.97 | .084054 |
| 1  | -84085.15  |    |    | .00 |         | .00   | .00  |         |
| 2  | -34972.60  |    |    | .00 |         | .00   | .00  |         |
| 3  | -117508.69 |    |    | .00 |         | .00   | .00  |         |
| 4  | -22311.35  |    |    | .00 |         | .00   | .00  |         |
| 5  | -56935.47  |    |    | .00 |         | .00   | .00  |         |
| 6  | -35888.25  |    |    | .00 |         | .00   | .00  |         |
| 7  | -11224.05  |    |    | .00 |         | .00   | .00  |         |
| 8  | -91414-31  |    |    | .00 |         | .00   | .00  |         |

Figure 19 EXAMPLE OF LOAD TAPE PRINTOUT



AREA OF THE SURFACE = 5836.60 FT\*\*2  
SHADED AREA OF THE SURFACE = 728.68 FT\*\*2

Figure 20 SHADOW OF PENTHOUSE AND COOLING  
TOWER ON PART OF ROOF





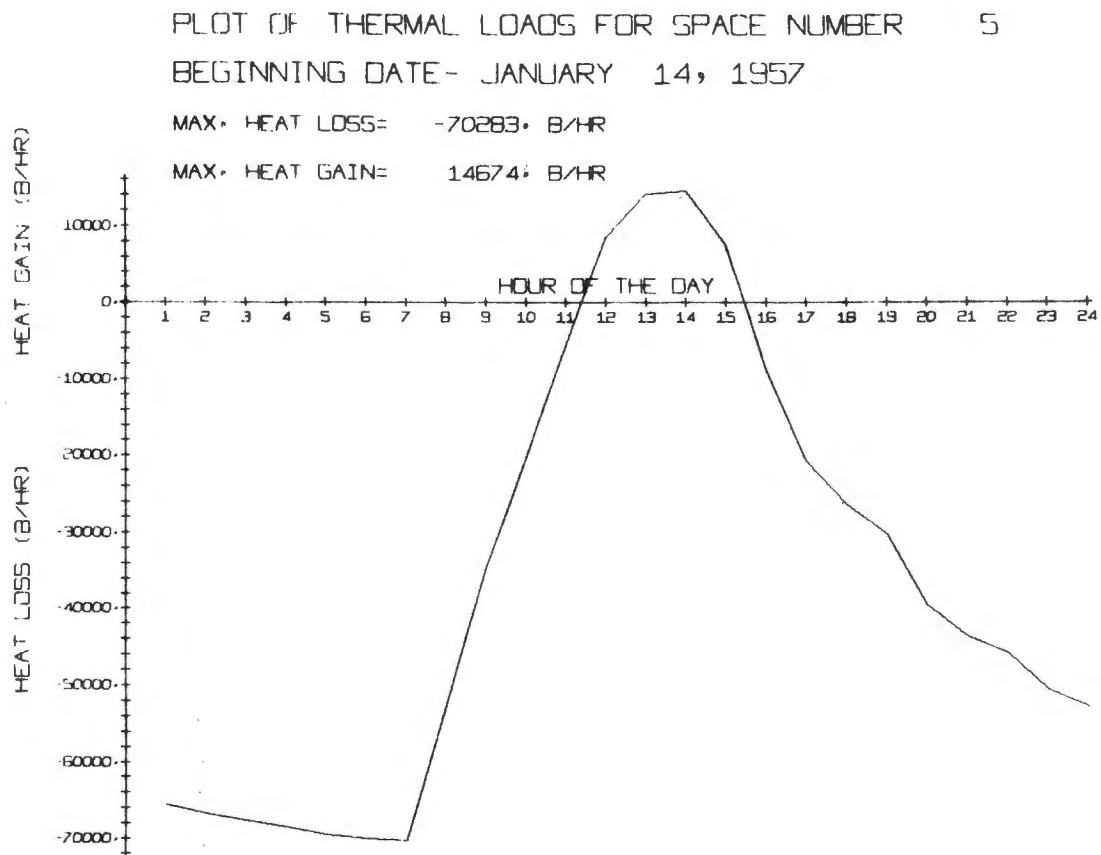


Figure 23 A ONE-DAY THERMAL LOAD PLOT OF A SPACE

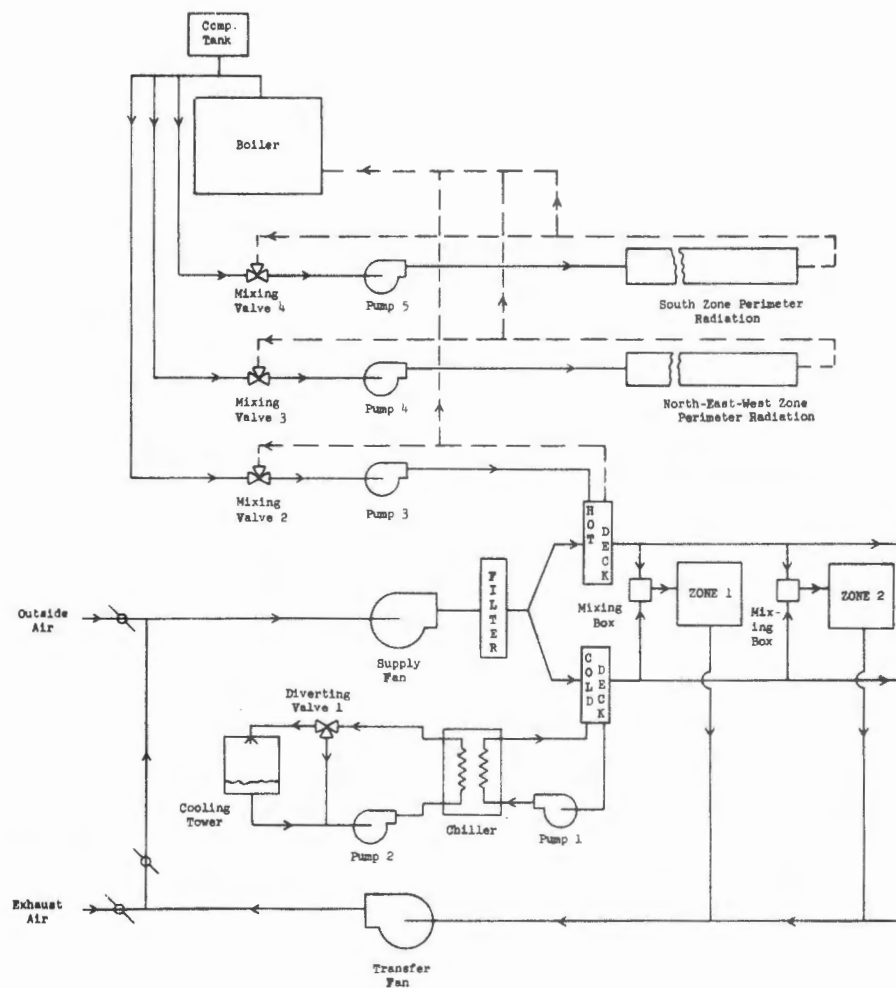


Figure 24 SCHEMATIC OF AIR CONDITIONING SYSTEM  
OF GARD BUILDING

GARD OFFICE BUILDING  
SYSTEM SIMULATION AND ENERGY ANALYSIS

NILES, ILLINOIS

7 MAY 1971

91364

SUMMARY OF FAN SYSTEM CHARACTERISTICS

| FAN SYSTEM | TYPE | FAN BHP | NO. OF ZONES | SET POINT | TOTAL CFM | MIN. O.A. CFM | EXH. CFM | PERCENT VENT. A1 |
|------------|------|---------|--------------|-----------|-----------|---------------|----------|------------------|
| 1          | DDS  | 31.7    | 8            | 72.0      | 26820.    | 10214.        | 5550.    | 38.1             |

Figure 25 SUMMARY OF FAN SYSTEM CHARACTERISTICS

GARD OFFICE BUILDING  
SYSTEM SIMULATION AND ENERGY ANALYSIS

NILES, ILLINOIS 7 MAY 1971

91364

SUMMARY OF ZONE AIR FLOWS

| FAN SYSTEM | ZONE | SUPPLY CFM | EXHAUST CFM |
|------------|------|------------|-------------|
| 1          | 1    | 5317.      | 0.          |
| 1          | 2    | 1355.      | 0.          |
| 1          | 3    | 6118.      | 0.          |
| 1          | 4    | 839.       | 0.          |
| 1          | 5    | 2834.      | 0.          |
| 1          | 6    | 2006.      | 0.          |
| 1          | 7    | 766.       | 0.          |
| 1          | 8    | 7585.      | 5550.       |

Figure 26 SUMMARY OF ZONE AIR FLOWS

GARD OFFICE BUILDING  
SYSTEM SIMULATION AND ENERGY ANALYSIS

NILES, ILLINOIS

7 MAY 1971

91364

SUMMARY OF EQUIPMENT SIZES

TYPE OF CHILLER = HERMETIC CENTRIFUGAL  
NO. OF CHILLERS = 1  
SIZE OF CHILLERS = 108.4 TONS

TYPE OF BOILER = GAS  
NO. OF BOILERS = 1  
SIZE OF BOILERS = 1595.0 MBTU

NO TERMINAL REHEAT USED

COOLING TOWER FAN REQUIREMENT 28805. CFM 1.0 IN. S.P. 5.7 BHP

BOILER AUXILIARY HORSEPOWER REQUIREMENT (FAN,BLOWER,PUMP) 2.4 BHP

TOTAL FAN PLANT HORSEPOWER FOR BUILDING 31.7 BHP

SUMMARY OF PUMP SIZES

| LOCATION        | TOTAL GPM | TOTAL HEAD (FT) | TOTAL BHP |
|-----------------|-----------|-----------------|-----------|
| CHILLED WATER   | 230.      | 55.0            | 6.7       |
| CONDENSER WATER | 288.      | 50.0            | 7.6       |
| HEATING WATER   | 159.      | 120.0           | 10.1      |

Figure 27 SUMMARY OF EQUIPMENT SIZES

|                                                                        |                                                             |           |                                     |           |                                                                                   |          |
|------------------------------------------------------------------------|-------------------------------------------------------------|-----------|-------------------------------------|-----------|-----------------------------------------------------------------------------------|----------|
| POST OFFICE DEPARTMENT<br>EQUIPMENT AND ENERGY<br>CONSUMPTION ANALYSIS | FACILITY/ADDRESS<br>GARD OFFICE BUILDING<br>NILES, ILLINOIS |           | DATE/PROJECT<br>7 MAY 1971<br>91364 |           | ENGINEER/SYSTEM IDENTIFICATION<br>M. LOKMANHEKIM AND R. HENNINGER<br>SYSTEM NO. 1 |          |
| -----                                                                  |                                                             |           |                                     |           |                                                                                   |          |
|                                                                        | ENERGY CONSUMPTION                                          |           |                                     |           |                                                                                   |          |
|                                                                        | JAN.                                                        | FEB.      | MARCH                               | APRIL     | MAY                                                                               | JUNE     |
| -----                                                                  |                                                             |           |                                     |           |                                                                                   |          |
| MONTHLY BTU/1000                                                       |                                                             |           |                                     |           |                                                                                   |          |
| HEAT (MHB)                                                             |                                                             |           |                                     |           |                                                                                   |          |
| MIN. DEMAND                                                            | -160.6                                                      | -138.9    | -111.3                              | -90.2     | -77.4                                                                             | -75.0    |
| MAX. DEMAND                                                            | -1495.6                                                     | -1078.1   | -1038.4                             | -837.0    | -515.3                                                                            | -368.3   |
| CONSUMPTION                                                            | -595788.9                                                   | -381713.8 | -362776.2                           | -207429.6 | -111286.9                                                                         | -15587.2 |
| COOL (MCB)                                                             |                                                             |           |                                     |           |                                                                                   |          |
| MIN. DEMAND                                                            | .0                                                          | 144.4     | 118.9                               | 120.8     | 117.6                                                                             | 116.3    |
| MAX. DEMAND                                                            | .0                                                          | 295.0     | 453.5                               | 886.3     | 894.5                                                                             | 1245.0   |
| CONSUMPTION                                                            | .0                                                          | 964.6     | 5745.8                              | 64022.8   | 97649.5                                                                           | 274993.6 |
| ELECTRICITY                                                            |                                                             |           |                                     |           |                                                                                   |          |
| LIGHTS AND MOTORS                                                      |                                                             |           |                                     |           |                                                                                   |          |
| INTERNAL                                                               |                                                             |           |                                     |           |                                                                                   |          |
| DEMAND (KW)                                                            | 111.2                                                       | 111.2     | 111.2                               | 111.2     | 111.2                                                                             | 111.2    |
| CONS. (KWH)                                                            | 38892.9                                                     | 34775.5   | 38465.9                             | 38892.9   | 39460.2                                                                           | 36904.3  |
| EXTERNAL                                                               |                                                             |           |                                     |           |                                                                                   |          |
| DEMAND (KW)                                                            | .0                                                          | .0        | .0                                  | .0        | .0                                                                                | .0       |
| CONS. (KWH)                                                            | .0                                                          | .0        | .0                                  | .0        | .0                                                                                | .0       |
| HEAT                                                                   |                                                             |           |                                     |           |                                                                                   |          |
| DEMAND (KW)                                                            | 9.3                                                         | 9.3       | 9.3                                 | 9.3       | 9.3                                                                               | 9.3      |
| CONS. (KWH)                                                            | 6682.7                                                      | 6162.9    | 6701.3                              | 5050.6    | 3935.4                                                                            | 788.9    |
| COOL                                                                   |                                                             |           |                                     |           |                                                                                   |          |
| DEMAND (KW)                                                            | .0                                                          | 24.2      | 31.1                                | 59.9      | 59.6                                                                              | 90.5     |
| CONS. (KWH)                                                            | .0                                                          | 133.8     | 485.2                               | 5201.3    | 8263.0                                                                            | 21600.6  |
| TOTAL                                                                  |                                                             |           |                                     |           |                                                                                   |          |
| DEMAND (KW)                                                            | 120.5                                                       | 135.5     | 142.4                               | 171.1     | 170.9                                                                             | 201.7    |
| CONS. (KWH)                                                            | 45575.6                                                     | 41072.2   | 45652.4                             | 49124.9   | 51658.6                                                                           | 59293.8  |
| GAS                                                                    |                                                             |           |                                     |           |                                                                                   |          |
| HEAT                                                                   |                                                             |           |                                     |           |                                                                                   |          |
| DEMAND (THERMS)                                                        | 18.7                                                        | 13.5      | 13.0                                | 10.5      | 6.4                                                                               | 4.6      |
| CONS. (THERMS)                                                         | 7447.4                                                      | 4771.4    | 4534.7                              | 2592.9    | 1391.1                                                                            | 194.8    |
| COOL                                                                   |                                                             |           |                                     |           |                                                                                   |          |
| DEMAND (THERMS)                                                        | .0                                                          | .0        | .0                                  | .0        | .0                                                                                | .0       |
| CONS. (THERMS)                                                         | .0                                                          | .0        | .0                                  | .0        | .0                                                                                | .0       |
| GENERATION                                                             |                                                             |           |                                     |           |                                                                                   |          |
| DEMAND (THERMS)                                                        | .0                                                          | .0        | .0                                  | .0        | .0                                                                                | .0       |
| CONS. (THERMS)                                                         | .0                                                          | .0        | .0                                  | .0        | .0                                                                                | .0       |
| TOTAL                                                                  |                                                             |           |                                     |           |                                                                                   |          |
| DEMAND (THERMS)                                                        | 18.7                                                        | 13.5      | 13.0                                | 10.5      | 6.4                                                                               | 4.6      |
| CONS. (THERMS)                                                         | 7447.4                                                      | 4771.4    | 4534.7                              | 2592.9    | 1391.1                                                                            | 194.8    |

Figure 28 SUMMARY OF VARIOUS ENERGY CONSUMPTIONS



|                                                                        |                                                             |          |                                     |           |                                                                                   |           |            |
|------------------------------------------------------------------------|-------------------------------------------------------------|----------|-------------------------------------|-----------|-----------------------------------------------------------------------------------|-----------|------------|
| POST OFFICE DEPARTMENT<br>EQUIPMENT AND ENERGY<br>CONSUMPTION ANALYSIS | FACILITY/ADDRESS<br>GARD OFFICE BUILDING<br>NILES, ILLINOIS |          | DATE/PROJECT<br>7 MAY 1971<br>21364 |           | ENGINEER/SYSTEM IDENTIFICATION<br>M. LOKMANHEKIM AND R. HEININGER<br>SYSTEM NO. 1 |           |            |
| ENERGY CONSUMPTION                                                     |                                                             |          |                                     |           |                                                                                   |           |            |
|                                                                        | JULY                                                        | AUG.     | SEPT.                               | OCT.      | NOV.                                                                              | DEC.      | TOTAL      |
| MONTHLY BTU/1000                                                       |                                                             |          |                                     |           |                                                                                   |           |            |
| HEAT (MHB)                                                             |                                                             |          |                                     |           |                                                                                   |           |            |
| MIN. DEMAND                                                            | .0                                                          | -97.9    | -93.2                               | -86.4     | -118.5                                                                            | -140.9    |            |
| MAX. DEMAND                                                            | .0                                                          | -196.3   | -434.4                              | -647.8    | -978.0                                                                            | -1260.9   |            |
| CONSUMPTION                                                            | .0                                                          | -1957.7  | -48891.6                            | -171922.7 | -325282.0                                                                         | -413638.9 | -2634275.3 |
| COOL (MCB)                                                             |                                                             |          |                                     |           |                                                                                   |           |            |
| MIN. DEMAND                                                            | 127.6                                                       | 131.2    | 131.5                               | 136.5     | 183.6                                                                             | .0        |            |
| MAX. DEMAND                                                            | 1198.5                                                      | 1301.0   | 1007.9                              | 574.2     | 260.6                                                                             | .0        |            |
| CONSUMPTION                                                            | 411340.0                                                    | 343962.7 | 150345.9                            | 30923.7   | 1515.6                                                                            | .0        | 1381464.2  |
| ELECTRICITY                                                            |                                                             |          |                                     |           |                                                                                   |           |            |
| LIGHTS AND MOTORS                                                      |                                                             |          |                                     |           |                                                                                   |           |            |
| INTERNAL                                                               |                                                             |          |                                     |           |                                                                                   |           |            |
| DEMAND (KW)                                                            | 111.2                                                       | 111.2    | 111.2                               | 111.2     | 111.2                                                                             | 111.2     |            |
| CONS. (KWH)                                                            | 39460.2                                                     | 39460.2  | 36904.3                             | 40454.5   | 36904.3                                                                           | 37471.6   | 458046.8   |
| EXTERNAL                                                               |                                                             |          |                                     |           |                                                                                   |           |            |
| DEMAND (KW)                                                            | .0                                                          | .0       | .0                                  | .0        | .0                                                                                | .0        |            |
| CONS. (KWH)                                                            | .0                                                          | .0       | .0                                  | .0        | .0                                                                                | .0        | .0         |
| HEAT                                                                   |                                                             |          |                                     |           |                                                                                   |           |            |
| DEMAND (KW)                                                            | .0                                                          | 9.3      | 9.3                                 | 9.3       | 9.3                                                                               | 9.3       |            |
| CONS. (KWH)                                                            | .0                                                          | 129.9    | 2014.1                              | 5439.0    | 6608.4                                                                            | 6905.4    | 50398.7    |
| COOL                                                                   |                                                             |          |                                     |           |                                                                                   |           |            |
| DEMAND (KW)                                                            | 86.5                                                        | 100.8    | 68.4                                | 38.0      | 23.7                                                                              | .0        |            |
| CONS. (KWH)                                                            | 30381.2                                                     | 26735.8  | 13332.4                             | 3208.0    | 161.3                                                                             | .0        | 109503.2   |
| TOTAL                                                                  |                                                             |          |                                     |           |                                                                                   |           |            |
| DEMAND (KW)                                                            | 197.7                                                       | 212.1    | 179.6                               | 149.3     | 134.9                                                                             | 120.5     |            |
| CONS. (KWH)                                                            | 69814.4                                                     | 66325.9  | 52250.8                             | 49102.1   | 43674.0                                                                           | 44377.0   | 617948.7   |
| GAS                                                                    |                                                             |          |                                     |           |                                                                                   |           |            |
| HEAT                                                                   |                                                             |          |                                     |           |                                                                                   |           |            |
| DEMAND (THERMS)                                                        | .0                                                          | 2.5      | 5.4                                 | 8.1       | 12.2                                                                              | 15.8      |            |
| CONS. (THERMS)                                                         | .0                                                          | 24.5     | 611.1                               | 2149.0    | 4041.0                                                                            | 5170.5    | 32928.4    |
| COOL                                                                   |                                                             |          |                                     |           |                                                                                   |           |            |
| DEMAND (THERMS)                                                        | .0                                                          | .0       | .0                                  | .0        | .0                                                                                | .0        |            |
| CONS. (THERMS)                                                         | .0                                                          | .0       | .0                                  | .0        | .0                                                                                | .0        | .0         |
| GENERATION                                                             |                                                             |          |                                     |           |                                                                                   |           |            |
| DEMAND (THERMS)                                                        | .0                                                          | .0       | .0                                  | .0        | .0                                                                                | .0        |            |
| CONS. (THERMS)                                                         | .0                                                          | .0       | .0                                  | .0        | .0                                                                                | .0        | .0         |
| TOTAL                                                                  |                                                             |          |                                     |           |                                                                                   |           |            |
| DEMAND (THERMS)                                                        | .0                                                          | 2.5      | 5.4                                 | 8.1       | 12.2                                                                              | 15.8      |            |
| CONS. (THERMS)                                                         | .0                                                          | 24.5     | 611.1                               | 2149.0    | 4041.0                                                                            | 5170.5    | 32928.4    |

Figure 28 CONTINUED

The output on paper gives the monthly and yearly energy, machine and equipment costs, and the interest-adjusted cost imposed by the total owning and operating annuity.

#### 9. CLOSING REMARKS

At the present time, different versions of the computer program are available to run on Control Data 3600, 6400, and 6600; Univac 1108; and IBM 360 computer systems. The program is written in Fortran IV, the most widely used scientific programming language, so that the program is easily adaptable to any computer system available to the user.

Where the size of the investment justifies the expense of repeated computations, the program may be used, as follows, in all stages of building decision-making.

1. Pre-design selection of the basic system and energy source.
2. Evaluation, during the design stage, of specific design concepts and modifications.
3. Evaluation, during construction, of contractor proposals for deviations from the construction plans and specifications.
4. Monitoring the operation and maintenance of the finished building so as to provide the greatest return on utility dollars.

Both the effort required for input data preparation and computer running times depend on the complexity of the building under consideration and the degree of analysis desired. Both input data preparation and computer running times decrease as the engineer gains experience with the program. Depending upon computer system used and the complexity of the building, the running time on the computer varies between 1/50 and 1/200 second per space per hour.

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18. S. W. Milnark, "Computer Program of the Future ... Now!", Air Conditioning & Refrigeration Business, January, 1971.
19. G. P. Mitalas, "An Experimental Check on the Weighting Factor Method of Calculating Room Cooling Load", ASHRAE Annual Meetings, Denver, Colorado, 30 June - 2 July, 1969.

Due to recording difficulties, Dr. Tom Kusuda's presentation cannot be included in the proceedings.

The next topic, "Application of the Program in Specific Projects -- Use in a 250 Bed Hospital and 6 Smaller Buildings," Mr. Z. Cumali, Director, Consultants Computation Bureau.

MR. CUMALI: Ladies and Gentlemen. We have been involved with the development of this program, probably, since its inception in 1967. And around that time I started attending the meetings of the Task Group on Energy Requirements, and as the program went on, we participated in one part of it, in that we did a feasibility study on the mathematical representation of weather data to basically simplify and reduce computation time in energy calculations. Through these sources we have had access to all the programs and have had an unusual opportunity to follow it through since that time.

You may ask what is our particular interest in this program. We are basically a consulting firm in mechanical engineering, and you might say computer sciences, in the San Francisco area; and we are also associated with a consulting engineering firm in that area, Case & Gutman and Associates. Our basic task is to advise consulting engineers on special problems, computer applications, software engineering, and things of this type. So our basic interest in this program was that, in case when our clients asked whether they should use a particular program or not, is to give them advice whether they should or they should not.

Therefore, we have tried to look at this as a product and follow its development and then when somebody asks us a question, we should be able to give them an honest and straightforward answer. So this basically is part of our involvement in this development.

Our first experiences with the program were when the first version came up in 1968, with the data provided by GARD people, to test the program on the computers that were available to us, and we have had a fairly good time looking at various parts of it. And then we really felt so confident that when a consulting engineering group in Australia asked us to give advice on how to use this program, we said we would be more than happy to do so.

But it turned out that the experience we had gained in using it on a small building was not enough and adequate to use on a very large one -- even though for parts of it. So we had three man-weeks of effort and which ended up in a no-go situation. So in the second one we decided perhaps we should really look into this more carefully, analyze the input, really go into the logic and look at the various kinds of details. And we had this opportunity when another client, in this case the Southern California Edison Company wanted us to put this program on a 32 K CDC 3400, which they had at their offices in Los Angeles. This turned out to be, again, a very big task, because what happened is that we ended up getting into the guts of the program. It is written in a very interesting fashion.

The first part, which essentially ties all the routines together in the load portion of the program, is a monolithic block of about 2000 statements, and the remaining 2000 statements are the various subroutines that do this. So the major difficulty was breaking such a big block, and when one made changes at any one portion of, it didn't effect the remaining parts of the program.

We finally managed to put this on a 32K machine. The only difficulty was that we really couldn't fit more than 20 zones to run on a machine

this size. The way we accomplished this is basically by overlaying it -- meaning that we took all the input portions of the program, made it one, and we originally called this in to do all the input, and then kicked it out and called in the portion which simply did the calculations. This was the only way we could fit it in.

So at this time it appeared that the smallest machine this program should be run on must have at least 64,000 words of memory, or if you use bits, four times as many bits. Then, during this process it became apparent to us that if we really had planned on doing any major changes to suit anybody's taste as the development went along, that we had to do something about the first part, and that resulted in a fairly major effort to split it into approximately 17 subroutines on the first part.

This in effect gave us a map to the whole program, and any time we make changes, now, we just look at this map and make whatever changes we like and put it in without worrying too much what would happen, because it is already taken care of.

So in the meanwhile, while this was going on, we started making changes in the input. Since we were on the same floor with our associated consulting engineer office, we essentially had a built-in laboratory, because the people do actual design. So we would just pick up somebody in the office and feed him the input forms and find out what his reaction is, how long it took him, whether he liked certain parts of it, or not. So we tried this on about half a dozen different people over this period of two and a half years. This really gave us a very good insight of what people wanted, what people liked, and what people did not like.

So I think in this talk that I am carrying on, what I am really trying to do is share our experiences with you and how we started with the use of this program and came up to this end.

The first large project that we applied this on was the hospital down in Southern California. It was the Salvac Hospital. It was about a 250,000 square feet hospital, 250 beds, and we managed to describe this building. It was sort of unusual, had very many facets to the building, and we had 622 zones. Since we were running on a 64K machine, it took us groups of 17 runs to do this. And the input, to describe this building, was approximately 10,500 cards, averaging about five entries per card.

Realizing that this was taking so much input, we decided that there were some parts of the building which were mirror images of the other parts. So to give you an idea of what kind of versatility the program has, and this I think, is a very commendable feature, we took two routines out of the program, one a rectangular routine, and another one, a polygon routine, which described coordinates of a surface. By using these two routines, and with a small front-end program, the input that we defined for one wing of the building, we just had it automatically flipped over. So approximately 30 percent of this 10,500 card input was generated by machine. However, this was still done with the facilities we got out of the program itself.

This gave us a whole series of ideas, again, as to how to go at it. We are very much concerned with costs we have to pay dearly for our computer time, and if we don't, there comes a knock on our door. We ran this, basically, for four typical days. By the way, we emphasize essentially using the program for design calculations, not energy calculations. This is the part we are emphasizing.



We just took four typical days, and in order to bring it into a cyclic equilibrium, we ran each typical day four days and recorded the maximum-minimum values for the last four -- fourth day. The running time was quite reasonable, actually. It was approximately \$200.00 for these 17 runs on a CDC-6600. But the point to be made here is that we have to run this approximately two and a half times through this process because of input errors, so more like \$500.00, really, was spent. And we spent perhaps that much more in keypunching and computer time for making the various changes. The total amount of time we spent was slightly over two man-months, to get this project going, including some of the changes.

One of the things we learned here was that if you read the manual you get the idea it is implied that the building shadows are all calculated. I am really talking about the self-shadowing. Once you describe one surface, and you describe another surface, I personally got the impression that the shading of this surface, the shading that this surface created on another surface will automatically be calculated. Well, it turns out that you have to describe shading surfaces and the other kind of surfaces separately. And this was a bit of a surprise, because the second time we ran this building, we included the window reveal effect, and our loads were much less.

In the meanwhile, after this experience, we started as we go along, running it on small buildings. We ran it on small post offices, the Pacific Telephone and Telegraph Office Building, some recruitment buildings, and on a hospital addition. These were from about 10,000 to 20,000 square feet area buildings, and by this time we had enough experience. The total amount of time it would take us to run a building

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like this was two man-days or less and the running cost was really negligible. It was anywhere from \$10.00 to \$30.00, even including the keypunching. So by this time we had a very good user response from the people who were in the office.

Now, one of the things that was interesting to see was that the amount of response you get pretty much depends on the kind of people you give this to fill the input forms. For example, some design draftsmen or designers would find this work kind of boring; but if you just gave it to a draftsman, he considered this as an upgrade on his position, and he just went to it with a vengeance and did a very good job, perhaps much better job than a good engineer would. So this was another kind of a consideration that we had.

But the other interesting one was the span of attention, in that if input did not take, say, for more than a day, you got a very good result, and there were not very many mistakes; but if you took something like a week, then the latter part of the week would have very many errors. People simply got bored doing it. So these are certain kinds of things to keep in mind.

By this time, while we are running these buildings, the Salvac Hospital had run into some problems, and they did not have enough money. Instead of being a 250-bed hospital, it came down and became 150-bed hospital with rather major changes, which required a different kind of input. By this time we really improved input facilities. We had pretty well taken out most of the repetitive items. And what happened then, in this case, all we had were 1900 cards of input, which is less than one box. By this time the repetitive parts, the ones, the 3000 cards,

that we generated with our mirror-image routines were taken out as a cost measure. So the net reduction was approximately by a factor of four in terms of input. So this was very interesting. And the running costs came down too. They were about \$170.00, multiplied by two or two and a half for the usual safety factor, because you always run it more than once.

So the takeoff on this was not bad. It was less than three man-weeks to do this hospital. Now, we have one little difficulty, and that difficulty was, we gave this to one design draftsman who just really fought filling those forms, tooth and nail. He just did not want to do it. And we did not know that he wasn't the right type of person, but he'd had it. And he just totally objected to this coordinate form of input. He had never seen it before, and he did not want to have anything to do with it.

That was perhaps why it took three man-weeks. I thought we probably could have done it with a good man in something like less than two weeks, two man-weeks. Since this announcement came up, we have had a chance to run another building. This was a civic center building in Hannafin County in Minnesota. It is at the present time two 25-story towers, with an atrium in between, and slightly somewhat over a million square feet.

Now, again, as we went along, we just kept charging approximately 30 to 50 percent off whatever time we put into development, and still charge it to the project. This is sort of how things happen. And we are continually making improvements. And for this particular building, we were really quite pleased because I think the maximum total number of zones on this building were 2038. Naturally, we did not want to

run all of it. We picked up 240 typical zones and we had added by then a cyclametrics routine because we did not want to use the energy proportions. We wrote our own cyclametric routines for coil selection to get the ton-air loads essentially.

So the total of 240 typical zones took only 700 cards. And it is very interesting, the person who did this was a young astronomy student, a second-year astronomy student that had just had a course in celestial mechanics. He just loved it. He just did this in absolutely no time at all, something like three or four days, and the running costs were down to about \$90.00 at this time.

So by this, we have pretty well mastered the program, and it is almost a very usable production tool. I have described the chronology of what has been done. The kind of a reaction we got from approximately a dozen people who were in the office doing this work was:

Some people really objected to the coordinate form of input. They were used to things being next to things, over, above, or around things; but they were never used to describing things in terms of coordinates. And possibly, this could very well be done with a simple interfacing routine on the input, and insulate the user from the vagaries -- or, rather, the adverse portions of the coordinate form of input.

The other part was, since the program has such generality and allows you to really describe any kind of a building, and which is one of its strong points, this generality comes with some kind of a price in that, if you have this kind of generality, and if you have not provided any means for cutting down the repetitive items, then you pay for it by appropriately increasing the input. So this was one of the parts that people objected to.

For example, you describe a delayed surface, a surface which delays the passage of heat like a wall for example, and it requires two input cards on the front end to describe the properties of this wall, plus the third card, which describes the geometry and its location and orientation. So the first two cards, essentially, could very easily be eliminated if you described it on the first entry of the wall, and you could repeat those only after they changed.

So this kind of thing was the other one.

Now, the other one is, there is no echo output from this program. You know, you put all this in, put 10,500 cards of input, and then the only way you can go back is what your card output is; and in terms of the person who is not really too familiar with the programs, if there is an error someplace, the only way he can find it is a very detective manner of going through the memory map, going through the innards of the program and finding out where the error actually occurred. So this echo output is a very essential idea.

Some difficulty was found with the rigid ordering of input.

Now, there were all kinds of good reactions, too. They liked the idea that they could describe anything. Some of the draftsmen that we put this program to work on, went to all great lengths to describe all the little details of the building and had great fun doing it. And the shadowing aspects of this, in terms of its generality, are very good, because you can cover all kinds of unusual situations, either whether they be overhangs, whether they be buildings adjacent to it, whether they be trees, mountains. You can have all kinds of transmission factors coming through these.

And the other portion was that usually it has been our experience that calculations done by the ASHRAE Guide have always been on the safe side. At least this is one of the impressions that we have gotten, rightly or wrongly. This program, we feel, gives you more of a realistic result. So they liked this, and especially the fact that you could carry the input that you had for load analysis and carry on through an energy analysis. And this comprehensiveness was very much liked by the people.

And the other one that I have mentioned before -- was the fact that, oh, there are something like 50 routines in this program, at least on the load part. You will find out that with a little ingenuity, you can make all kinds of things, just using these routines with very small front-end programs. It is all there and all we have to do is go in there, look for it, and take advantage of it. And don't ever underestimate the power that the people who designed the program put in there; and this is essentially where they spent the major part of their effort, and I think they should be commended for doing it.

Now, if somebody comes and asks me and says, "Well, what would your recommendation be? Would you recommend that I use this program, or would you recommend that I shouldn't use the program?" My answer could change from a yes down to a definite no, and the reason would depend on the person. It would depend on the organization. I certainly would not recommend the use of this program to an organization which had no computer experience. They are just looking for trouble. However, some organization that has computer experience and can make use of this program should use this program and as a matter of fact would learn a lot by using the program.

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So this, essentially, is the kind of advice I can give to people. Just to say that you take the tape and put it underneath your arm and go to your computer center and expect to get output the next day, can be classified as wishful thinking. This is a very serious program. It is a large program, and the amount of useful results you get out of it is pretty well dependent on your input.

Now, what is the kind of time it takes to get started on this program? Well, as I say, it would depend on one's experience, but I like to be as honest here as possible. We have approximately one man-year of effort put into this program to bring it into the shape that it is. But I would suspect that anywhere from about three, four, five, six months and on, would be the kind of time necessary to put it into use.

These are the kinds of things that we went through, and this was approximately three years' experience.

Now, leaving that aside, let us look at what has been done, and what really needs to be done. I think this program had contributions from all people. There were contributions from ASHRAE, contributions from all the members here, the major contribution from the Postal Service -- Jim Anders, who stuck his neck out to see it through, that it got through -- and people who put it together, which at best was a very difficult job. So this is the right step, in the right direction, as a matter of fact, a very major step in the right direction.

Now, how can we improve on this? I am just trying to look into the future, and what are the kinds of things that can be done, taking advantage of the start.

Now, the major area that improvements can be expected in is an area called the data structure. We are all endowed with a very efficient

biological computer, which has pattern recognition capabilities of a very large magnitude, whereas the computer is the exact opposite. So whatever you feed into the computer, in order for the machine to make some sense out of it, it has to be pre-patterned; it has to be very well patterned. So the description of the geometry of the building and all its properties is something that should be given very great attention, because this is where I can foresee the advantages of the coordinate form of input over the conventional kind of input, because internally we have to represent it this way, and if you look at this program as a data base for other programs which will follow it -- for example, once you have done your load calculations and you have the basic building input data, there is really no reason why you cannot directly use that input for your ducts and other remaining programs which require building geometry, without having to put that information in again.

And for the same token, with attention paid to this area, it is not much of a problem to generate pictures off the building that you have, whether they be plans, sections, and so forth. The basic geometric information is the same. It is not any different; and the idea is to make use of this.

One area of this program that gave us some problems and which I think, really, ought to be looked at is the allocation of memory. There are approximately 180 variables which describe various geometric and other aspects of the building parts. And there are also 41 indices which tell you how large a memory allocation should be given to each variable.



Now, what happens is, you go into a building and this program has tremendous generality. If you try to use all this generality, all of a sudden you have run out of space. You do not run out of space because there is no more space, but in the standard FORTRAN language, you have to pre-allocate the space that you give to each variable. This sort of can be likened to a sparse matrix. If you have a 10,000 by 10,000 matrix, and all you are using is 200 positions in this matrix, you have the remaining 9,800 positions aiding, which since you have to allocate it by 100 by 100, you are stuck. You only make two percent use of the space available.

A dynamic allocation of memory is extremely important to make full use of the generality of this program. And therefore, the person does not have to count. He just goes in, and the program takes as much space as it needs. And this, we have found out to be a problem because we are running on a 64K machine. We have a limited number of zones that we could put this into, and we have to recompile it to fit various vagaries of the different kinds of buildings that we put in. And this, I think, is certainly not a user's program, from this point of view.

The other thing that I could think of that ought to be done is, again, on the input end -- either by getting a series of front-end programs to insulate the user from the coordinate form and put it in more conventional form -- because the machine can do this rather well -- or to generate some form of an input language for building descriptions. And there's very interesting techniques for doing it.

One other thing. A lot of people say that, "My God, this program is so detailed. I can't use it for a building smaller than such-and-such size." Well, that really is not true. It has all this generality,

and if you have the usual engineering expertise, which means essentially being able to make the right kind of approximations, you could just eyeball the building and feed only that information that you think is important. Therefore, whether the building is large or small is pretty well dependent on how you see the building yourself. You could make it complicated if you wish, but you could make it very, very simple. You could make it just down to a block. So this program can run one zone as well as as many zones as you like. So this is really no limitation.

And cost-wise, it is quite economical, especially the smaller the building, the cheaper it is, and the more successfully you can use it. Perhaps that is the way you should start using it.

Now, Doctor Kusuda mentioned the other aspect on constant space temperatures, and this, I think, is something that also has to be improved because most buildings don't run 24 hours a day, for example, especially if you are doing energy calculations. Systems go on and off and really space temperatures do change. And this has to be taken care of if you want it to run for buildings which do not operate 24 hours a day. Although you can turn schedules on and off, there is no provision for varying this temperature.

Now, the other one is in the area of the weighting factors. There are pre-built weighting factors which essentially are dependent on the kind of mass you expect to have in a building. I think some provision ought to be made to find the weighting factors, meaning how much of the instantaneous loads will the building fly effect reduce? And perhaps a pre-run with a small routine to generate these weighting factors to

be put into the machine ought to be done.

This sort of compares to what kind of hourly averaging you have to do, rather than the ASHRAE Handbook, whether you take three hours, five hours, or ten hours. So this is basically the idea.

Now, I think self-shadowing ought to be included. And now, the other thing is, regarding the speed of the program. As I say, for design purposes, the speed and cost are quite reasonable, but when it comes to energy calculations, then you do have some problems. The running speed depends pretty well on the kind of spaces you have. We have gotten calculations on a per-hour, per-zone basis, anywhere from two microseconds up to a hundred microseconds. And this pretty well depended on how many walls, how many things we had to have in each space.

So when you do this over 8,760 hours, on an average basis, it does amount to a fair amount of time. And we found out that some area of that can be improved is in the shadow portion. For example, with the way the shadow is done, you take a particular area and divide this into a certain number of zones, and then look at each of them. Perhaps some binary search and then there is some other algorithms. This ought to be looked into.

Now, this is how we as an organization see what the future steps ought to be. I am just trying to share these experiences for you. And don't ever forget that when we started this, we started with a finished or almost finished product, which was done by very dedicated people. Then we put our man-year of effort over and above this, and we are just reaping the benefits of it, but I don't want you to forget that.

One other thing that I think I would like to say. The program at the present time does not appear to be ready for optical character reading type of input. Perhaps a digitizer is more of a practical input medium to use with this program. After some modification on input has been done, perhaps an optical character -- meaning that you write it on a piece of paper and read it into the machine ought to be done then.

Now, regarding the energy analysis program, I think Mr. Bycraft is really going to talk about this. Our experience with the energy portion is somewhat limited. We basically ran some tests on it, and it did not happen for the particular job that we looked at, suit the requirements we had; but this is about all I can say.

And one major consideration we have is the expense of running it. As I say, we are a very small firm, and compared to all the speakers over here and the resources they have available to them, this kind of money really hurts us. But the kind of things that I foresee in here are to reduce these calculations by making a detailed calculation for a few days, obtaining some kind of a transfer or a response factor for the whole building and the system associated with it. And therefore, run the simulation of this for the whole year, to reduce computation. This would be one way.

As a matter of fact, this would probably reduce computations very significantly.

The other one is to be ahead and do some simulation on the weather data itself, and try to get some form of semi-close solution. These are possibly some of the ways that this problem can be overcome.

I would like to say one thing which really does not have anything to do with the energy analysis portion of this program, but just as a personal philosophy is that I believe there are so many different kinds of systems that nobody can really sit down and write a sub-routine to simulate them. There are as many systems as probably there are consulting engineers of each type. They all change their controls headings; they all change their equipment, and things of this nature.

So I think that perhaps a very fruitful approach to this would be to simply take the component approach. You simulate each class of components separately, and have the engineer tell the program in what sequence he wants these on. And have the program simulate that system exactly for him. This would take a larger program, but it would be one program that would meet most everybody's needs.

So I would like to stop at this point. I did the best I could to share our experiences with you, and would be more than happy to share it with you in the future.

Thank you very much.

MR. MILNARK: Thank you, Mr. Cumali.

Doctor Richard Stillman, from IBM, will now talk on the use of the program in the new IBM 52-story building in Chicago.

DR. STILLMAN: My interest in using the program is somewhat different than the other speakers you heard so far, in the IBM is building a new building in Chicago in which they are going to have computer control of the H-VAC system. That is one of the functions of the computer. And so my job was to take the Postal Service model,

make the modifications for our particular building, so that we could use it. And our main concern was, one, how much energy could you save?

In other words, let us run the building a standard method. Let's run it as if a computer were running the building and see how much energy you could save. This would give you an idea of how much money you could save in operating the building; and also, a second point would be, it would help you -- tell you how to run the building better. In other words, you put the computer on, you do the optimization calculations. The results are then available to you, and you can then run the building in a better manner, and so my point of view, as I say, is quite different, because we are out to see how much money we can save using a computer.

We are going to have somebody show these slides. Since I prepared the slides myself, they are not too good. But you will get the idea.

This first slide is a schematic of the building. The dark patch at the top, and then in the interior of the building are where the mechanical rooms are. Down below, you have your plaza area, which is mostly glass, where they have some marble our tri-routine ends. The north-south is the narrow face, and the east-west is your large face.

This next slide gives you an overall idea of the building. This is a Mies Van der Aall-C. F. Murphy building. It is 665 feet high, and it is 275 feet east-west, 125 north-south, and so on. It is 52 stories. Most of these are office floors; there are some mechanical floors; there are some special purpose floors, such as computer floors and cafeteria floors. It is a 1.8 million square foot building. The panels

are urethane aluminum, which are very light. They are about an inch thick, and this, in calculating the response factors, is one of the most difficult problems that I ran into that was to get this to work on the response factor calculations. I recommend that anybody that runs a building should take the response factor calculations from the program and run them beforehand, before you run them in the program, because the program runs and assumes that the data you get is valid. And if you get out invalid data from this particular routine, you are in trouble.

The one thing I would suggest is, you take this program out and do the response calculations beforehand and see that they come out correctly. I had to up the density of urethane by a factor of 40 to get it to come out anything reasonable.

The glass is a heat-type glass, double glazed glass. It is a bronze-tinted glass. And they have venetian blinds inside the building.

Next slide, please. In applying this program to a building this size, you can't possibly run for each space, each floor of the building. It would just fill up the computer and take too much computer time. But fortunately, on a building -- an office building, floor after floor after floor, is the same. And there is no reason that you have to do the calculations over and over again for floor after floor. So one of the modifications that I made to the load program was to allow what is called the duplication factor.

For example, look up at program number two. There is a duplication factor of 13. This means that essentially, I was representing 13 floors of the building on a particular side of the building, by just one space in the program. So that in the program, I am actually calculating for

49 spaces. The program is calculating for 49 spaces, but I have represented 285 spaces within the building. This saves a lot of calculation time, and yet you still get out the proper loads, the proper results from your program, and you do an awful lot less calculation. In this case, it is about a factor of 6 in terms of time; and also, it saves a lot in your core.

I also included some of the mechanical floors, even though they are not included in the air conditioning load as such. They are included in -- there is heat transfer from the mechanical rooms through the ceiling and the floor of the adjacent office areas, and so that I've included some of the mechanical rooms; and this sort of gives you an idea of the machinery and the load that would be on the ceilings and roofs of the adjacent floors.

Next slide, please. Here is the designation for so-called "delayed surfaces." We have 31 delayed surfaces. These are walls, roofs, things that retain heat over several hours, so that you are using the response factor, and that your impulse to the building is not instantaneous. It is a release over several hours. There are 26 windows, 26 so-called quick surfaces, which are in this case thermolium, around the windows, that we assume are quick surfaces. Even though they really aren't, I assumed that they were.

The reason I had to divide the plaza up quite a bit is there is several windows and a lot of shading on the plaza area. So the more shading and the better you want to get the results, you have to divide it up into smaller and smaller pieces.

And the delayed surfaces, there are 31 of them. There are seven different types of delayed surfaces that I am using. This involves the spandrils, the mechanical walls, the travertine, the roof, and an



underground wall and an underground roof.

Next slide, please. Well, it all sounds very simple using this program. You just read in the data, and you get it -- get the data debugged, and it runs. Well, the real world does not work that way. There are an awful lot of parameters that you have to feed into this program. I am a chemical engineer, so I don't know what to feed in. It took me a lot of learning. I can look up in handbooks suggested numbers in terms of absorption, heat transfer coefficients, radiation, and so on. But in reality, you have to do an awful lot of tuning unless you really know what you are doing.

And since we were working with a building which was already designed, and was being built, I decided to tune to the designer's conditions. This seemed to be the easiest way for me, in which I would adjust my parameters that I am feeding into the program, to come out with numbers which were similar to what the designer had specified they were going to be.

Now, the design is done, in this particular case, in five by five modules, in which they specified the BTU's from people in this module; they specified the standard five watts lights and power per square foot to the module, and then they did the calculations. Well, unfortunately, the program asked for the number of people, the number of BTU's per hour that people are giving off; and they asked for watts per square foot. And they are not equivalent. You may think they are equivalent, but the number of modules, the way the designer in this particular case did, where there's a hallway or a room not being used, that's not included. Well, in the program, you are reading in square foot, and you have to read in all the square foot involved.

That required a lot of tuning in which I had to adjust the number of people per floor, the BTU's that they are giving off, and a particular lot of adjustment was required on the watts per square foot. So that I finally got my people and light load to come out as the program values on the left, and the design values on the right, are fairly close in terms of the over-all total. And this is very critical in your calculations.

May I have the next slide please?

Other parameters that are required were in the window convection coefficients, ground reflectivity, and in your so-called form factors, between the sky and the window and the ground and the window. It is not quite as easy as, you just say, well, for example, they say, if you don't know what to put in, put in five-tenths for a number. Well it is very critical what you can put in. I have found that the answers could change by as much as 50 to 100 percent, depending on what combination of parameters I put in that program.

Since this program -- the building is not up yet, you have no measured values. You can't go there and measure what is the building actually doing. So again, what I had to do was adjust the parameters to try to match the designer's results. And these are some of the coefficients -- no use going into them in detail. But anyway, these are some of the coefficients that I adjusted to try to get the tuning.

May I have the next slide, please?

This, then, shows the program calculation, the maximum values, the design maximum values, and the design peak values. What I did was, I tuned the program peak sensible values, as you can see on the lower line on the right-hand side, what I did was tune those to the design

peak values. In terms of the heating and cooling load, since your equipment's going to be designed based on the peak load, what I thought would be the best thing to do was try to adjust my parameters so that I would come out fairly close to what the designer said the peak loads were going to be.

As you can see, the gain and loss are fairly close. I could have tuned it a little better, but it costs a lot of money in computer time, and a lot of effort. And to me that is very close to the result in terms of the peak design load, which was an interesting result. The design maximum values did not come out to be the same. The loss values are very close to being the same for the maximum values, but the maximum gain, your cooling load during the peak in the summer, the program calculated about 13 percent higher maximum load than was estimated by the designer. Personally, I would take the designer's values rather than the program but this is how it came out.

It is not as easy, to just plug it in and just start running it. It requires a lot more tuning. And also, apparently, they have changed the way that they are handling the sunshine radiation, how, through the windows, so that there has been a change in the program which I do not happen to have in my version of the program. The version of the program that I am using is one of the very first ones.

Anyway, a lot of time was spent in getting the program to match the designer's conditions before you ran the simulation, because it is very critical that you get the load, get the proper load, before you start running your equipment simulation.

May I have the next slide, please?

This gives you an idea of the calculation time. This particular

run for the Chicago building required 859 data cards. I am running on a Model 9 or, I was running on a Model 91 at that time. It takes about 14 minutes for the hour-by-hour calculation for one year on the 91. This was for 49 spaces, 39 delayed walls, 26 windows and 26 mollien. There are a lot of shadows and so on. There are quite a large number of inputs. It takes about 14 minutes. I am now running on a 195, which runs twice as fast, so it is 7 minutes for a run.

This gives you a feel for it takes a lot of computer time. Someone asked, "Could you run it on 1130?" You could run it on 1130 if you had the time and patience to wait, but for programs of this type, I recommend you get a big machine and run it on a big machine, because running an overlay is just a pain. I can put this program in, the whole program goes in and runs. There is no problem whatsoever. Get a big machine, it takes a few minutes; and the cost is way down compared to the blood, sweat and tears that you go through on a small computer.

Could I have the next slide, please?

I want to show you some of the computer output. Unfortunately, I do not think this is going to come out. But we will go through and see what happens. This is your typical first page that you get out.

Next slide, please. It tells you the weather tape, length of the study, and so on. I suggest that the first thing you do when you get your weather tape is, dump your weather tape if it is not what they tell you what is on the tape, it is not what is on the tape, it is not the way they say it is on the tape.

And if you try to run the way they say it is on the tape, you can waste an awful lot of time. So take W, or whatever it is, dump the

tape and find out what is really on that tape. And even then, I will show you one year where it just bombs out completely. There is a lot of problems with the weather tape. Find a year that you can use, and use the year. That is what I did.

May I have the next slide, please?

Here, then, is your third page output, in which this gives you your peak design heating and cooling, your hours and your loads, your temperatures, and so on. This particular case, peak cooling was in July; peak heating was in January. This is for the year 1955, for Chicago Midway Airport; and I ended up choosing this year because it was closest to the design values, in terms of the temperatures, the humidities, and so on. This came out fairly close to what the designer had used, so I chose this weather year.

Next slide, please.

This, then, is the output for all 285 spaces, showing the maximum and minimum loads on a given zone. First thing I did was put them in floating point. The program as it is originally written is in fixed point, and what you do is, you get stars out all across, because it cannot handle it. The size of the outputs. So the first thing you do is go through and convert everything to floating points, and no matter what you do, you at least get some results.

And once you find out, then, what the size of the numbers are, you can go back to fixed point, because as you can see, reading this is a mess; but at least you get some output.

Next slide, please.

One interesting thing we did has been mentioned over and over again, the shadow program was a very good feature of the program. What we did

was make a run in which we took out the shadow part of the program. Adjacent to the IBM building is a large apartment complex called Marina City Towers, or something of that sort. It is about 500, 600 feet tall. It is almost as tall as the IBM building, and it sits on the southwest corner of the building. And we were interested to see how the shadows from that building would fall on the west face of our building.

One of the things that we were using in the building, of course, are solar sensors. So you want to know, where do you put the solar sensors? This gives you an idea of where the shadows fall so that you at least have some idea where to place the solar sensors.

This -- I will show you on four slides. This is the first one. This is on the west face of the building. You can see the shadow falling across the building.

Could I have the next slide, please?

And the shadows -- this is an hour later. The shadow has moved across. Next slide.

It is farther across now, and then the next slide. This is just before the sun went down. This was 5:00 o'clock in the afternoon.

So this gives you an idea, then. You can see how the shadows move across the building. As I say, it is a very powerful feature in the program.

This, then, is the load program. This is the first program which you do the calculations to find out what are the loads on each face within your building. The next problem, then, is to simulate the operation of the building so that you can find out how much energy is going to be required to really run this building; and as I say, to find out how much energy you can save by running this building better.

Next slide, please.

This is the system that we have in Chicago, It is an all-electric building. We have a BTU pump in the building, a 1500-ton BTU pump. We have two 2500-ton chillers, auxiliary chillers. We have seven steam boilers, electric boilers, and they have 23 fan systems. They have eleven terminal re-heat, 12 perimeter induction units, and the design CFM was about 1,300,000.

What I had to do was rewrite entirely the systems program. I could not use the Postal Service system simulation program. I used it as a guide. It turns out it is a very useful guide in writing the program, the way the program is structured. But you have to go through and replace most of the subroutines, for any given job, unless of course you are running the way the Postal Service is. But our building is entirely different, and I will go through and show you the things that we had to change. But the building is quite different from the way the postal buildings are run, so that, essentially, I had to rewrite the entire system simulation program.

Could I have the next slide.

I am a chemical engineer, how is that?

And I don't know what I am doing. That is obvious, right there. It is going to take me about a year to rewrite the system simulation program, but let's look at it this way. I am doing all the design. In other words, I figure out everything that has to be done from scratch, knowing nothing. In other words, given a perimeter induction unit, how do you simulate it? Derive all the equations from the manufacturer's catalogues; derive all the equations -- you sit down, systems design the program, write the program, debug the program and get it all running. So I am doing the whole bit, and it is going to take me about a year.

I have no help, so it is just a one man-year. Now, we did make a run on the postal simulation program initially. I made one run just to see what the program would do, what sort of problems I would run into, so that these results here that I am going to show you, this particular slide, are for running the postal model.

There were only 133 data cards for the Chicago building systems specification. Again, we are running on a Model 91, it took a little over 18 minutes. Now, one thing, I have an old version of the program. I don't know whether the program has been changed or not, but you notice, the so-called search, which requires nine minutes, which is about half your computer time -- what happens is, in the fan design in the way the Postal Service does it, they want to go through and they want to find the maximum load on each of your zones. Well, what they do is, they take the load tapes, search it for the maximum zone in each -- find the maximum load in each zone.

So essentially, they go through and search this whole tape, which takes about nine minutes, using the 91. Well, you already have this data on the load, in which you have printed out this data. It is already an output from the load program, and so therefore, what you should do and what I have done later is, you take the output data from the load program and read it directly into the systems simulation program, which knocks off nine minutes out of the calculation. And there is absolutely reason to go through and search that tape.

I am running now on a Model 195. It takes a little over four minutes for systems simulation for one year, hour-by-hour. So we have got it down to a much more reasonable time.

Next slide, please.



In addition to the systems that the postal model has, I have also added a perimeter induction unit. And Chicago has the perimeter induction units on the outside, has the terminal re-heat on the inside. So this, then, is a typical print-out, which is -- I have used the print-out format from the postal model. That part of the program I am using.

This, then, prints out the 23 fan systems, what kind they are, and gives you an idea of the CFM and so on.

Next slide, please.

This gives you the CFM for each one of the individual zones.

Next slide, please.

When you have perimeter induction units, as I say, I have added this to the program. It goes through and gives you the type of unit you specify, the number of units per zone, and the GPM per unit, CFM per unit, and so on. This is the design calculation, which is done beforehand, which it sets up your perimeter induction units. It sizes them to meet the maximum heating and cooling loads.

Next slide, please.

This, then, is your equipment design, which again is, as I say -- I have used the postal output form. I have added towards the bottom -- one thing that is very frustrating is the postal model requires you to run either a summer or a winter mode. Well, in a big building, you have got to run heating and cooling all year round. Your cooling tower has to run all year round. So you have got to change the program. So I changed the program so that my cooling tower can run in the winter, and also I had the option where you can have river water or some other similar type source, because in the Chicago building we are using water from the Chicago River.

Also, of course, we have a double bonal on the heat pump, so I had to add that part to the program. Outside of that, the rest of the print-out is quite similar to the postal model.

Next.

Now to begin with, we go through the calculation, hour after hour. This is the summary print-out that you get. It is by month, in terms of your heating and cooling loads, your demands, and since this is an all-electric building, this gives you the electrical demand and consumption, month by month. This is a very useful output, very critical, because in many cases you are charged on your peak demand for the next, let us say, eleven months or something -- whatever your peak demand is, this is what you pay through the nose, for the next several months. So that the idea is, to try to keep that peak demand down.

The maximum demand turns out to be in January, which is 24,000 KW is the maximum demand calculated by the program. The people in Chicago estimated that 22,000 was going to be the maximum demand, so it is fairly reasonable. I know that my loads, as I pointed out before, my maximum loads are about 13 percent higher on the building than I think is really going to be, so I think that is a very close check on what the designer estimated and what the program is calculating.

Next slide, please.

Then we have for the rest of the year, and then, on the right-hand slide over there you have the totals, coming out. Again, the cooling demand and consumption will be very close to what the designer estimated, and again the cooling is somewhat larger than was estimated by the designer.

Next slide, please.

One major modification to the program, which as I say, I will discuss in a minute, is that we had to add the humidification -- dehumidification.

Apparently in postal buildings you do not humidify-dehumidify. You just run whatever it is. And this is a major change in the program. When you add this to your program, it changes it quite a bit. And so that -- on the bottom here we are printing out the demand and consumption of the -- for the humidification. Once again, the designer estimated the maximum demand would be 11.5 K-pounds. We came out 11.9 as our maximum. So again, it is a very close check between the design and the calculation.

Next slide, please.

This, then is the continuation. Next slide. May I have the next slide?

One thing that you can do with the program, the load program, is you can run through for various weather years and find out the load, the variation in load that you can expect over several years. I started in 1949, and 1951 bombed out on me, calculated up to about the end of December, and then all of a sudden the program went wild. There was something wrong with the weather tape. I did not have the time to go back and figure out what was wrong, but that is why I recommend that you go through separately and run the weather tape before you put it on your program. Because here I had expended almost 13 minutes of computer time when it bombed out on me. And it went through year after year.

You can see, the loads are fairly consistent, and a variation in the cooling load -- what I did was, I took the average sensible load and compared the maximum-minimum variation. It was about a four and a half percent difference over this span of time, and on the heating design load, there was about a 14 percent difference in load.

So this is the sort of thing that you can do using the program. You can go through and find out what sort of variability you would expect.

As I say, 1955 turned out to be close to the design conditions for our Chicago building, so that is the year that I used in most of my calculations.

Next slide, please.

As I said, one thing we are interested in is how much money can you save by the way you run your building? Well, here is a typical calculation that I have done in which, (a), I run the chillers fixed 42 degrees coming out of the chillers; I run the cold deck 50 degrees; I run the hot deck 140 degrees. These are all fixed throughout the year. (b), you run the chillers and cold deck-hot deck, you vary the set point of these -- of the chillers and of your cold and hot deck, based on the load in your zone. In other words, you go through and you figure out, if you have maximum cooling on the zone, then you of course run your cold deck at 50 degrees. If you have maximum heating required at a particular zone, then you run your hot deck at 140. Anything less than the maximum, you run it proportionately in between.

I just specified the ranges. You could pick out any other range that you wanted. This happens to be the range that I chose.

Let us take a BTU pump building using the terminal re-heat and the perimeter induction fan system. This is the Chicago building. How much does B save over A? Well, in this particular case, we saved 7 percent by running -- in terms of the way we have it outlined in B, as compared to the fixed conditions under A. This is a 7 percent savings in KW consumption throughout the year.

Unfortunately, we are going to take some of these figures with a grain of salt, because I didn't have the program running where I had to specify that during the summer you have to run always at 50 degrees. You have to run your coils at saturation. I allowed the coil to float in these

calculations, and when you run the coil during the summer when you have to dehumidify, you have got to run the coils at saturation, so you have got to hold it to 50. So in actuality, there was only a 5 percent savings in that case. But still, there is a saving, and this can be translated into an awful lot of money.

When it costs you a million dollars a year to run a building, 5 percent is worthwhile.

The next one was a BTU pump building in which it was all terminal re-heat systems, saved 35 percent, by running in terms of B rather than A. And in the last one, it was a dual duct system in which, again, you saved a lot. You saved 39 percent using B over A.

Now in addition to running the building this way, you can also do what is called optimization. Now, this is a so-called load optimization, in which you vary the way you set your chillers and your hot and cold deck based on load. But you can also, in addition to this, do some optimization. I am in the process now of writing the optimization program. I have only had the optimization program running with the terminal re-heat fan system -- this is your third one down, and in addition to this saving you can save another 15 or 20 percent by going to an optimization calculation. So this gives you an idea of what you can save in building operation.

Could I have the next slide, please?

This is the last slide. These are the sort of things that I feel have to be done if you want to use it in a real -- real, live building. The load model is in fairly good shape. As has been mentioned before, you have to change if it runs it at constant temperature. You are going to have to add a temperature setback schedule, which nights and weekends

and so on you change how you run your building. You don't hold your building, at, say, 75 degrees or whatever your temperature is. You cut it back overnight or during the weekends, so that this has to be put in the program, the load calculation program.

Also, in the load program you need what I call the large shadow option. And the way they run the shadow program now is, each little space, each little wall, each little window, whatever you are working with, you have got to set that up, calculate the shadows on each one of these little individual pieces. This is tremendous, time-consuming calculation. What I think should be done is, you should specify the whole building side, calculate the shadow on the building, and then reallocate those portions of the shadows to the given spaces. There is just no reason to go through this tortuous calculation of each little space when you can do it for the whole building once and then reallocate. So this is something that should be done to the program.

Now, the main emphasis, I think, is if anybody wants to use the program, you really have to rewrite the systems simulation program, because each system is different. You have got to write it for your particular system, and the main effort has to be spent in rewriting the systems program. The first thing you have got to do is, you have got to make the program fail-safe.

The way the program is written, it stops. That is the kindest way I can say it. When something goes wrong, it stops and gives you a little love message like "positive heating load." Well, that is not too informative. The program should be redone, in which if something goes wrong, you print out a message and say, "Something has happened, and I have taken this step." Maybe just set the load to zero -- "and I am going on." For example, in

in Chicago building we have an overhang over the plaza; and it is attached to several zones on the floors above. Now, this overhang absorbs heat, and one hot summer night it absorbed all this heat, and towards morning it was still giving out heat to the room, whereas the floors above it demanded -- wanted to be cooled -- I mean, wanted to be heated, because it was starting to get cool. They wanted to be heated, whereas the heat was still coming from the overhang, so it wanted to be cooled.

So we have a zone which is inconsistent, in which one part wants heating and one part wants cooling. Well, the program could not handle this the way it was written, and so it would bomb out on you. I have changed the program so no matter what the program asks for, it gets. If something goes wrong, it writes out a message, but it goes. And this is something that should be done.

As I said, also, you have to read in the maximum zone loads. There is no point in searching the tape for nine minutes. Read in the maximum zone loads.

You have got to run all year round. The building demands heating-cooling all year round. You cannot run summer-winter changeover temperatures, in which in the summer you get cooling, in the winter to get heating. You just cannot run a building that way when you have a large building. So that this is a major change to the program. You have to add humidification-dehumidification. This again is a major -- major change in the program. You have to add the all-year-round cooling tower operation, and you have to have a river water option or some other -- well water, whatever it is you want to use. City water. You have to add another option, so that it will run without your cooling tower.

And of course you are going to have to change your equipment design, your equipment operating strategy, and your fan design and your fan operating strategy. The strategy they have is for the way they want to run the postal buildings; it is entirely different from the way that the Chicago building was designed and runs. In addition, you have to -- or what we had put in, what is called the minimum energy damper algorithm.

When you add the humidification-dehumidification to your program, it becomes a linear programming optimization problem on how you can allocate your dampers. It is not a simple problem now of opening, closing dampers. You have the problem -- you have your outside conditions, inside conditions. You are either humidifying or dehumidifying, depending on what is going on and what the conditions are at that instant. There is an optimum answer how those dampers should be set. And it turns out this is a linear programming problem. And I have derived the -- it is a very simple algorithm once you figure it out. It took me a couple of days to figure it out, but once you figure out the problem, it is very simple.

The dampers are either opened or closed or modulated, depending -- if it is too cold or something, you have to modulate. You cannot bring in a minus-9 degree error 100 percent, but essentially it is a very simple answer, but it requires a lot of pre-calculation to come up with -- with the solution.

And again, we have the chiller, hot and cold deck, based on the load. We are running the building this way. We have added the perimeter induction units. Right now I am in the process of adding the optimization strategy, even though you set your chillers and your hot-cold deck based

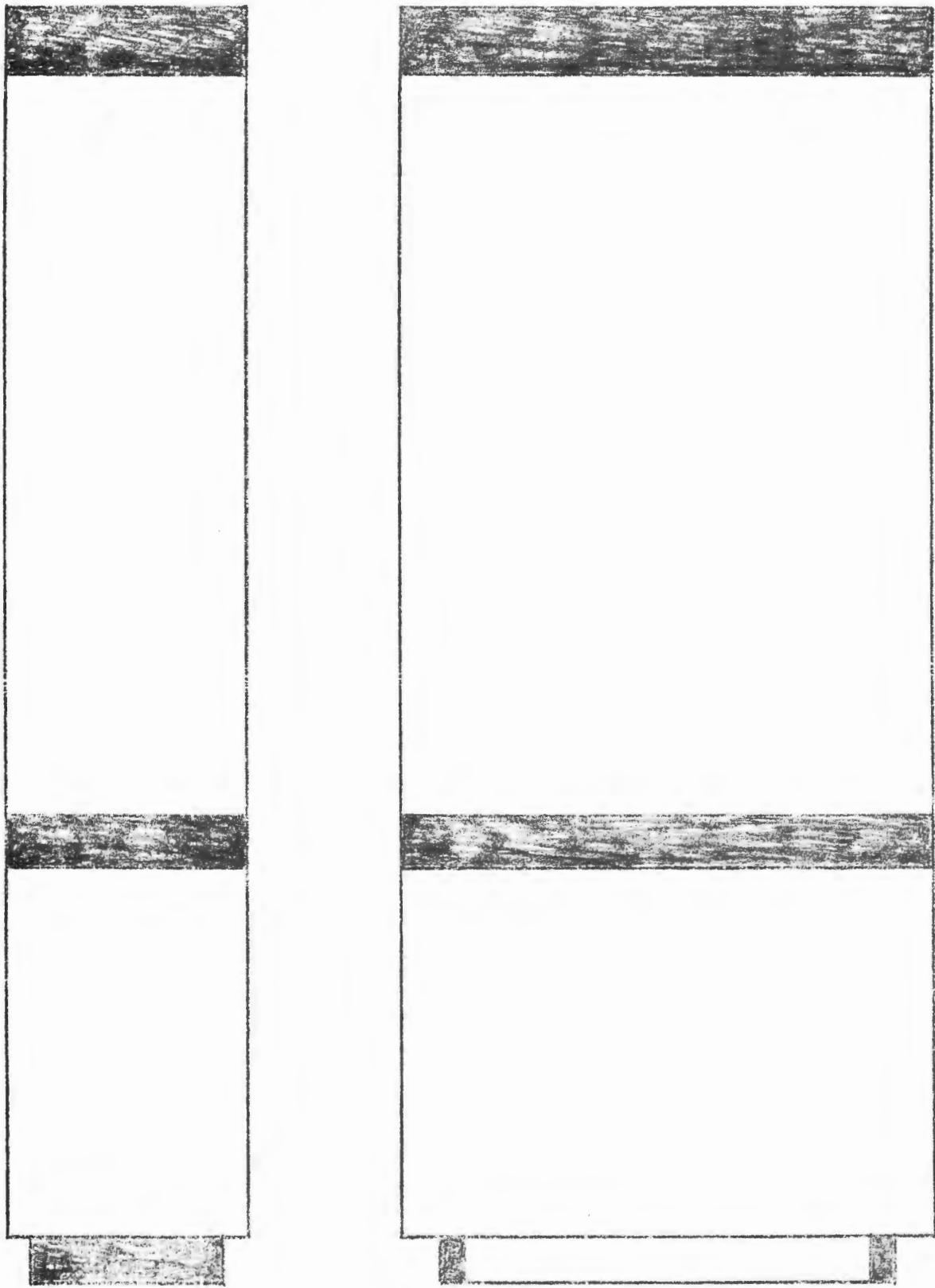


on loads, you can still get some more bucks out of the system by running it even better and putting in the optimization strategy.

And finally, something that should be put in there, when you put the temperature setback schedule in your load program, of course you are going to have to put your temperature setback schedule in your system simulation program, and in addition, you have to put a ventilation setback schedule in the systems simulation program. Because the load program gives you only the loads of the solar-weather loads and so on and internal loads. It does not give you the fan system loads, which is done in the systems simulation program.

So these are the sort of things that I feel have to be done to the program to make it usable. As I say, it is going to take me about a year, and the reason is because I do not know what I am doing. Certainly, anybody out there who is familiar with what is going on could probably do it in a month or two. Thank you.

MR. MILNARK: Well, I have got to say, that is not bad for a chemical engineer.



IBM CHICAGO BUILDING SCHEMATIC

IBM CHICAGO BUILDING 330 NORTH WABASH

MIES VAN DER ROHE - C. F. MURPHY ASSOCIATES

665 FEET HIGH

275 FEET EAST - WEST FACE

125 FEET NORTH - SOUTH FACE

|                    |                   |
|--------------------|-------------------|
| 52 STORY BUILDING: | 42 OFFICE         |
|                    | 5 MECHANICAL      |
|                    | 4 SPECIAL PURPOSE |
|                    | 3 LOWER LEVEL     |
|                    | 1 PLAZA           |

1.8 MILLION SQUARE FEET

BRONZE ALUMINUM - URETHANE SPANDRELS

BRONZE ALUMINUM MULLION

BRONZE - TINTED DOUBLE - GLAZED GLASS

BRONZE COLORED VENETIAN BLINDS

Table

## SPACE DESIGNATION FOR CHICAGO BUILDING

| <u>Prog.<br/>No.</u> | <u>Dup.<br/>Fac.</u> | <u>Space<br/>No.</u> | <u>Fan<br/>System</u> | <u>Description</u>     |
|----------------------|----------------------|----------------------|-----------------------|------------------------|
| 1                    | 1                    | 1                    | KM-S1                 | East plaza perimeter   |
| 2                    | 13                   | 2                    | 1M-S6                 | East 3-15 perimeter    |
| 3                    | 1                    | 15                   | 1M-S6                 | East 2 perimeter       |
| 4                    | 1                    | 16                   | 1M-S6                 | East 16 perimeter      |
| 5                    | 14                   | 17                   | 1M-S7                 | East 18-31 perimeter   |
| 6                    | 1                    | 31                   | 1M-S7                 | East 17 perimeter      |
| 7                    | 15                   | 32                   | 3M-S2                 | East 32-46 perimeter   |
| 8                    | 1                    | 47                   | 3M-S2                 | East 47 perimeter      |
| 9                    | 13                   | 48                   | 1M-S3                 | North 3-15 perimeter   |
| 10                   | 1                    | 61                   | 1M-S3                 | North 2 perimeter      |
| 11                   | 1                    | 62                   | 1M-S3                 | North 16 perimeter     |
| 12                   | 14                   | 63                   | 1M-S4                 | North 18-31 perimeter  |
| 13                   | 1                    | 77                   | 1M-S4                 | North 17 perimeter     |
| 14                   | 15                   | 78                   | 3M-S6                 | North 32-46 perimeter  |
| 15                   | 1                    | 93                   | 3M-S6                 | North 47 perimeter     |
| 16                   | 1                    | 94                   | KM-S2                 | West plaza perimeter   |
| 17                   | 13                   | 95                   | 1M-S13                | West 3-15 perimeter    |
| 18                   | 1                    | 108                  | 1M-S13                | West 2 perimeter       |
| 19                   | 1                    | 109                  | 1M-S13                | West 16 perimeter      |
| 20                   | 14                   | 110                  | 1M-S14                | West 18-31 perimeter   |
| 21                   | 1                    | 124                  | 1M-S14                | West 17 perimeter      |
| 22                   | 15                   | 125                  | 3M-S5                 | West 32-46 perimeter   |
| 23                   | 1                    | 140                  | 3M-S5                 | West 47 perimeter      |
| 24                   | 13                   | 141                  | 1M-S10                | South 3-15 perimeter   |
| 25                   | 1                    | 154                  | 1M-S10                | South 2 perimeter      |
| 26                   | 1                    | 155                  | 1M-S10                | South 16 perimeter     |
| 27                   | 14                   | 156                  | 1M-S11                | South 18-31 perimeter  |
| 28                   | 1                    | 170                  | 1M-S11                | South 17 perimeter     |
| 29                   | 15                   | 171                  | 3M-S3                 | South 32-46 perimeter  |
| 30                   | 1                    | 186                  | 3M-S3                 | South 47 perimeter     |
| 31                   | 13                   | 187                  | 1M-S1                 | North 3-15 interior    |
| 32                   | 1                    | 200                  | 1M-S1                 | North plaza interior   |
| 33                   | 1                    | 201                  | 1M-S1                 | North 2 interior       |
| 34                   | 2                    | 202                  | 1M-S2                 | North 16-17 interior   |
| 35                   | 1                    | 204                  | 1M-S2                 | North mechanical 1-2   |
| 36                   | 15                   | 205                  | 1M-S5                 | North 18-32 interior   |
| 37                   | 14                   | 220                  | 3M-S1                 | North 33-46 interior   |
| 38                   | 1                    | 234                  | 3M-S1                 | North 47 interior      |
| 39                   | 1                    | 235                  | 3M-S1                 | North mechanical 3-4-5 |
| 40                   | 13                   | 236                  | 1M-S12                | South 3-15 interior    |
| 41                   | 1                    | 249                  | 1M-S12                | South plaza interior   |
| 42                   | 1                    | 250                  | 1M-S12                | South 2 interior       |
| 43                   | 2                    | 251                  | 1M-S9                 | South 16-17 interior   |
| 44                   | 1                    | 253                  | 1M-S9                 | South mechanical 1-2   |
| 45                   | 15                   | 254                  | 1M-S8                 | South 18-32 interior   |
| 46                   | 14                   | 269                  | 3M-S4                 | South 33-46 interior   |
| 47                   | 1                    | 283                  | 3M-S4                 | South 47 interior      |
| 48                   | 1                    | 284                  | 3M-S4                 | South mechanical 3-4-5 |
| 49                   | 1                    | 285                  | KM-S3                 | Kinzie level           |

Table SURFACE AND WINDOW DESIGNATION

| <u>No.</u> | <u>Delayed Surfaces</u>   | <u>No.</u> | <u>Quick Surfaces<br/>and Windows</u> |
|------------|---------------------------|------------|---------------------------------------|
| 1          | East perimeter overhang   | 1          | East standard                         |
| 2          | North perimeter overhang  | 2          | North standard                        |
| 3          | West perimeter overhang   | 3          | West standard                         |
| 4          | South perimeter overhang  | 4          | South standard                        |
| 5          | South interior overhang   | 5          | East long                             |
| 6          | North interior overhang   | 6          | North long                            |
| 7          | East plaza spandrel       | 7          | West long                             |
| 8          | North plaza spandrel      | 8          | South long                            |
| 9          | West plaza spandrel       | 9          | East plaza                            |
| 10         | South plaza spandrel      | 10         | East plaza                            |
| 11         | East spandrel             | 11         | East plaza                            |
| 12         | North spandrel            | 12         | East plaza                            |
| 13         | West spandrel             | 13         | East plaza                            |
| 14         | South spandrel            | 14         | East plaza                            |
| 15         | East M 1-2 wall (1/12)    | 15         | East plaza                            |
| 16         | North M 1-2 wall (1/6)    | 16         | Northeast plaza                       |
| 17         | West M 1-2 wall (1/12)    | 17         | Northwest plaza                       |
| 18         | South M 1-2 wall (1/6)    | 18         | West plaza                            |
| 19         | East M 3-4-5 wall (1/34)  | 19         | West plaza                            |
| 20         | North M 3-4-5 wall (1/17) | 20         | West plaza                            |
| 21         | West M 3-4-5 wall (1/34)  | 21         | West plaza                            |
| 22         | South M 3-4-5 wall (1/17) | 22         | West plaza                            |
| 23         | Southeast travertine      | 23         | West plaza                            |
| 24         | South travertine          | 24         | West plaza                            |
| 25         | Southwest travertine      | 25         | Southwest plaza                       |
| 26         | Northwest travertine      | 26         | Southeast plaza                       |
| 27         | North travertine          |            |                                       |
| 28         | Northeast travertine      |            |                                       |
| 29         | Roof (1/34)               |            |                                       |
| 30         | Kinzie north wall         |            |                                       |
| 31         | Kinzie roof               |            |                                       |

Tabel

## PEOPLE, LIGHTS AND EQUIPMENT LOAD

| <u>Space</u> | <u>People</u> | <u>Btu/hr<br/>per<br/>Person</u> | <u>Watts<br/>per<br/>ft<sup>2</sup></u> | <u>Program</u>           |                          | <u>Design</u>            |                          |
|--------------|---------------|----------------------------------|-----------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
|              |               |                                  |                                         | <u>People<br/>Btu/hr</u> | <u>Lights<br/>Btu/hr</u> | <u>People<br/>Btu/hr</u> | <u>Lights<br/>Btu/hr</u> |
| Plaza        | 178           | 400                              | 3.5                                     | 71200                    | 266151                   | 48384                    | 294624                   |
| 2            | 40            | 550                              | 4.0                                     | 22000 (1)                | 468875                   | 82050                    | 470420                   |
| 3-15         | 2418          | 400                              | 3.75                                    | 967200                   | 5714414                  | 1000350                  | 5735340                  |
| 16-17        | 196           | 400                              | 4.68                                    | 78400 (2)                | 1096488                  | 156300                   | 1046168                  |
| 18-31        | 2828          | 400                              | 3.9                                     | 1131200                  | 6400144                  | 1123500                  | 6441400                  |
| 32-46        | 3150          | 400                              | 4.05                                    | 1260000                  | 7121039                  | 1258500                  | 7215400                  |
| 47           | 214           | 400                              | 4.15                                    | 85600                    | 486548                   | 85125                    | 488050                   |
| Kinzie       | 100           | 700                              | 4.5                                     | 70000                    | 401272                   | 34600                    | 148790                   |
| Total        | 9124          |                                  |                                         | 3685600                  | 21954841                 | 3788809                  | 21840192                 |
| Sum Total    |               |                                  |                                         | 25640441                 |                          | 25629001                 |                          |

(1) Lunch hour value 242000 Btu/hr.

(2) Daily maximum 97600 Btu/hr.

PARAMETER TUNING

|                            |      | <u>FIRST</u> | <u>FINAL</u> |      |
|----------------------------|------|--------------|--------------|------|
| WINDOW COEFFICIENTS:       | REI  | 0.69         | 0.568        |      |
|                            | REA  | 1.14         | 0.812        |      |
| GROUND REFLECTIVITY:       | ROG  | 0.3          | 0.1          | HIGH |
|                            |      | 0.3          | 0.3          | LOW  |
| WINDOW-SKY FORM FACTOR:    | FFWS | 0.5          | 0.4          |      |
| WINDOW-GROUND FORM FACTOR: | FFWG | 0.5          | 0.4          |      |

INTERNAL SHADING COEFFICIENTS

SURFACE ABSORPTIVITY

UNDERGROUND TEMPERATURES

Table      LOAD PROGRAM TUNING FOR CHICAGO BUILDING

|                                   | <u>Program Maximum Btu/hr.</u> |             | <u>Design Maximum Btu/hr.</u> |             | <u>Design Peak Btu/hr.</u> |             |
|-----------------------------------|--------------------------------|-------------|-------------------------------|-------------|----------------------------|-------------|
| <u>Space</u>                      | <u>Gain</u>                    | <u>Loss</u> | <u>Gain</u>                   | <u>Loss</u> | <u>Gain</u>                | <u>Loss</u> |
| Plaza                             | 1387409                        | 1544586     | 1427995                       | 1539000     | 1221120                    | 1539000     |
| 2                                 | 1263521                        | 555184      | 993805                        | 610340      | 857125                     | 610340      |
| 3-15                              | 13522886                       | 4978545     | 11892465                      | 5100420     | 10115625                   | 5100420     |
| 16-17                             | 2193554                        | 972237      | 1989610                       | 962000      | 1716250                    | 962000      |
| 18-31                             | 14874916                       | 5361426     | 13059270                      | 5492760     | 11145750                   | 5492760     |
| 32-46                             | 16224570                       | 5744325     | 14378575                      | 5885100     | 12328375                   | 5885100     |
| 47                                | 1270439                        | 500225      | 1027305                       | 453840      | 890625                     | 453840      |
| Kinzie                            | 334865                         | 426090      | 358620                        | 203820      | 252760                     | 203820      |
| Total                             | 51072160                       | 20082618    | 45127645                      | 20247280    | 38527630                   | 20247280    |
| Program Peak Sensible Load Values |                                |             |                               |             | 38875920                   | 19990624    |



LOAD MODEL

3817 FORTRAN CARDS

859 DATA CARDS FOR CHICAGO BUILDING SPECIFICATION

IBM 360/91 RUN TIME FOR HOUR BY HOUR CALCULATION FOR YEAR:

|         |    |         |       |         |
|---------|----|---------|-------|---------|
| COMPILE |    |         | 49.36 | SECONDS |
| LINK    |    |         | 1.44  | SECONDS |
| EXECUTE | 12 | MINUTES | 58.02 | SECONDS |
| TOTAL   | 13 | MINUTES | 48.82 | SECONDS |



## ANALYSIS OF ENERGY UTILIZATION OF

IBM 52 FLR(1.8MFT2) OFFICE BUILDING

LOCATED AT

330 N. WABASH IN CHICAGO, ILLINOIS

ENGINEER - DICK STILLMAN  
PROJECT NO - 902-6001  
DATE - 6 NOVEMBER 1970

## IN THIS RUN

- U. S. WEATHER BUREAU 1440 WEATHER TAPE OF STATION 14819 IS USED.
- THE FIRST DATA OBTAINED FROM WEATHER TAPE IS FOR 0TH HOUR OF 01/01/1955.
- THE LENGTH OF THIS STUDY IS 365 DAYS.
- THE INITIAL OUTSIDE SURFACE TEMPERATURE IS 35 DEGREES FAHRENHEIT.

## BUILDING THERMAL AND INFILTRATION LOADS SUMMARY

| COOLING DESIGN HOUR                                                                                                                                                                                                                                                                                                                                                                                                                              | TEMPERATURE DEGREES FAHRENHEIT DB WB | HUM. RAT. LBS WATER PER LB DRY AIR | PRESSURE INCHES OF MERCURY | PLENUM LD. BTU PER HOUR                                      | -----BUILDING THERMAL AND INFILTRATION LOADS----- |              |                  |              | TOTAL LOAD BTU PER HOUR |                     |                                   |                                    |                            |                                                              |  |                       |     |          |       |                 |  |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|------------------------------------|----------------------------|--------------------------------------------------------------|---------------------------------------------------|--------------|------------------|--------------|-------------------------|---------------------|-----------------------------------|------------------------------------|----------------------------|--------------------------------------------------------------|--|-----------------------|-----|----------|-------|-----------------|--|
|                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                      |                                    |                            |                                                              | -----SENSIBLE-----                                |              | -----LATENT----- |              |                         |                     |                                   |                                    |                            |                                                              |  |                       |     |          |       |                 |  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                      |                                    |                            |                                                              | RAD.+TRAN.                                        | INFILTRATION | PEOPLE           | INFILTRATION |                         |                     |                                   |                                    |                            |                                                              |  |                       |     |          |       |                 |  |
| 4983<br>15 HOUR 27 JULY                                                                                                                                                                                                                                                                                                                                                                                                                          | 100. 77.                             | 0.015303                           | 29.33                      | 0.206896E 07                                                 | 0.38875920E 08                                    | 0.0          | 0.127747E 07     | 0.0          | 0.40152848E 08          |                     |                                   |                                    |                            |                                                              |  |                       |     |          |       |                 |  |
| <table border="1"> <thead> <tr> <th>HEATING DESIGN HOUR</th> <th>TEMPERATURE DEGREES FAHRENHEIT DB</th> <th>HUM. RAT. LBS WATER PER LB DRY-AIR</th> <th>PRESSURE INCHES OF MERCURY</th> <th colspan="2">BUILDING THERMAL AND INFILTRATION SENSIBLE LOAD BTU PER HOUR</th> </tr> </thead> <tbody> <tr> <td>630<br/>6 HOUR 27 JAN.</td> <td>-9.</td> <td>0.000226</td> <td>29.72</td> <td colspan="2">-0.19990624E 08</td> </tr> </tbody> </table> |                                      |                                    |                            |                                                              |                                                   |              |                  |              |                         | HEATING DESIGN HOUR | TEMPERATURE DEGREES FAHRENHEIT DB | HUM. RAT. LBS WATER PER LB DRY-AIR | PRESSURE INCHES OF MERCURY | BUILDING THERMAL AND INFILTRATION SENSIBLE LOAD BTU PER HOUR |  | 630<br>6 HOUR 27 JAN. | -9. | 0.000226 | 29.72 | -0.19990624E 08 |  |
| HEATING DESIGN HOUR                                                                                                                                                                                                                                                                                                                                                                                                                              | TEMPERATURE DEGREES FAHRENHEIT DB    | HUM. RAT. LBS WATER PER LB DRY-AIR | PRESSURE INCHES OF MERCURY | BUILDING THERMAL AND INFILTRATION SENSIBLE LOAD BTU PER HOUR |                                                   |              |                  |              |                         |                     |                                   |                                    |                            |                                                              |  |                       |     |          |       |                 |  |
| 630<br>6 HOUR 27 JAN.                                                                                                                                                                                                                                                                                                                                                                                                                            | -9.                                  | 0.000226                           | 29.72                      | -0.19990624E 08                                              |                                                   |              |                  |              |                         |                     |                                   |                                    |                            |                                                              |  |                       |     |          |       |                 |  |

# SPACE MAXIMUM AND MINIMUM HEATING AND COOLING LOADS SUMMARY

| SP. NO | MAX. HEAT.<br>BTU/HOUR                                       | HOUR            | MIN. HEAT.<br>BTU/HOUR | HOUR            | MAX. COOL.<br>BTU/HOUR | HOUR            | MIN. COOL.<br>BTU/HOUR | HOUR            |
|--------|--------------------------------------------------------------|-----------------|------------------------|-----------------|------------------------|-----------------|------------------------|-----------------|
| 1      | -0.747322E 06                                                | 3 HOUR 27 JAN.  | -0.58316E 02           | 12 HOUR 11 APR. | 0.469362E 06           | 14 HOUR 27 JULY | 0.50340E 02            | 24 HOUR 14 JULY |
| 2      | -0.131490E 06                                                | 6 HOUR 27 JAN.  | -0.24305E 02           | 13 HOUR 3 JAN.  | 0.282871E 06           | 9 HOUR 27 JULY  | 0.76094E 02            | 22 HOUR 19 MAY  |
| 15     | -0.189186E 06                                                | 6 HOUR 27 JAN.  | -0.24273E 02           | 22 HOUR 31 MAY  | 0.321134E 06           | 9 HOUR 27 JULY  | 0.21497E 02            | 4 HOUR 19 JUNE  |
| 16     | -0.148762E 06                                                | 6 HOUR 27 JAN.  | -0.46602E 01           | 4 HOUR 12 AUG.  | 0.320331E 06           | 9 HOUR 27 JULY  | 0.30578E 02            | 4 HOUR 12 JULY  |
| 17     | -0.131483E 06                                                | 6 HOUR 27 JAN.  | -0.40898E 01           | 2 HOUR 23 SEP.  | 0.284130E 06           | 9 HOUR 27 JULY  | 0.17090E 02            | 20 HOUR 10 JUNE |
| 31     | -0.148762E 06                                                | 6 HOUR 27 JAN.  | -0.46602E 01           | 4 HOUR 12 AUG.  | 0.320331E 06           | 9 HOUR 27 JULY  | 0.30578E 02            | 4 HOUR 12 JULY  |
| 32     | -0.131486E 06                                                | 6 HOUR 27 JAN.  | -0.29063E 01           | 19 HOUR 15 NOV. | 0.285389E 06           | 9 HOUR 27 JULY  | 0.16961E 02            | 2 HOUR 23 SEP.  |
| 47     | -0.148760E 06                                                | 6 HOUR 27 JAN.  | -0.26461E 02           | 1 HOUR 24 AUG.  | 0.321590E 06           | 9 HOUR 27 JULY  | 0.35664E 01            | 4 HOUR 12 AUG.  |
| 48     | -0.600341E 05                                                | 6 HOUR 27 JAN.  | -0.96128E 01           | 5 HOUR 16 SEP.  | 0.520050E 05           | 15 HOUR 27 JULY | 0.46445E 01            | 13 HOUR 8 MAY   |
| 61     | -0.875485E 05                                                | 6 HOUR 27 JAN.  | -0.11258E 02           | 21 HOUR 21 APR. | 0.671201E 05           | 13 HOUR 27 JULY | 0.10437E 01            | 20 HOUR 28 MAY  |
| 62     | -0.678854E 05                                                | 6 HOUR 27 JAN.  | -0.13109E 02           | 21 HOUR 20 SEP. | 0.576388E 05           | 15 HOUR 27 JULY | 0.23851E 02            | 4 HOUR 5 JULY   |
| 63     | -0.600333E 05                                                | 6 HOUR 27 JAN.  | -0.74370E 01           | 5 HOUR 16 SEP.  | 0.527336E 05           | 15 HOUR 27 JULY | 0.46523E 01            | 13 HOUR 8 MAY   |
| 77     | -0.678854E 05                                                | 6 HOUR 27 JAN.  | -0.13109E 02           | 21 HOUR 20 SEP. | 0.576388E 05           | 15 HOUR 27 JULY | 0.23851E 02            | 4 HOUR 5 JULY   |
| 78     | -0.600325E 05                                                | 6 HOUR 27 JAN.  | -0.52612E 01           | 5 HOUR 16 SEP.  | 0.535622E 05           | 15 HOUR 27 JULY | 0.0                    | 2 HOUR 18 JUNE  |
| 93     | -0.678846E 05                                                | 6 HOUR 27 JAN.  | -0.14203E 02           | 1 HOUR 3 MAY    | 0.584174E 05           | 15 HOUR 27 JULY | 0.22684E 02            | 23 HOUR 8 SEP.  |
| 94     | -0.746833E 06                                                | 3 HOUR 27 JAN.  | -0.13473E 03           | 6 HOUR 10 AUG.  | 0.713899E 06           | 17 HOUR 27 JULY | 0.13340E 02            | 7 HOUR 5 JUNE   |
| 95     | -0.131450E 06                                                | 6 HOUR 27 JAN.  | -0.22156E 02           | 24 HOUR 3 SEP.  | 0.520039E 06           | 17 HOUR 27 JULY | 0.16715E 02            | 24 HOUR 18 APR. |
| 108    | -0.189145E 06                                                | 6 HOUR 27 JAN.  | -0.20308E 01           | 6 HOUR 17 JULY  | 0.346170E 06           | 17 HOUR 27 JULY | 0.0                    | 20 HOUR 24 SEP. |
| 109    | -0.148721E 06                                                | 6 HOUR 27 JAN.  | -0.38316E 02           | 9 HOUR 20 OCT.  | 0.338957E 06           | 17 HOUR 27 JULY | 0.27879E 02            | 18 HOUR 21 FEB. |
| 110    | -0.131448E 06                                                | 6 HOUR 27 JAN.  | -0.20184E 02           | 24 HOUR 3 SEP.  | 0.301974E 06           | 17 HOUR 27 JULY | 0.28941E 02            | 2 HOUR 22 MAY   |
| 124    | -0.148721E 06                                                | 6 HOUR 27 JAN.  | -0.38316E 02           | 9 HOUR 20 OCT.  | 0.338957E 06           | 17 HOUR 27 JULY | 0.27879E 02            | 18 HOUR 21 FEB. |
| 125    | -0.131446E 06                                                | 6 HOUR 27 JAN.  | -0.18211E 02           | 24 HOUR 3 SEP.  | 0.303910E 06           | 17 HOUR 27 JULY | 0.29711E 02            | 2 HOUR 22 MAY   |
| 140    | -0.148719E 06                                                | 6 HOUR 27 JAN.  | -0.18945E 01           | 23 HOUR 21 APR. | 0.340893E 06           | 17 HOUR 27 JULY | 0.34891E 02            | 5 HOUR 4 MAY    |
| 141    | -0.599912E 05                                                | 6 HOUR 27 JAN.  | -0.15606E 02           | 19 HOUR 11 JUNE | 0.137289E 06           | 13 HOUR 19 SEP. | 0.0                    | 3 HOUR 29 JUNE  |
| 154    | -0.874958E 05                                                | 6 HOUR 27 JAN.  | -0.13109E 02           | 24 HOUR 22 JUNE | 0.168307E 06           | 13 HOUR 19 SEP. | 0.19485E 01            | 5 HOUR 12 AUG.  |
| 155    | -0.678328E 05                                                | 6 HOUR 27 JAN.  | -0.31895E 01           | 7 HOUR 24 JUNE  | 0.155601E 06           | 13 HOUR 19 SEP. | 0.22814E 02            | 6 HOUR 11 AUG.  |
| 156    | -0.599904E 05                                                | 6 HOUR 27 JAN.  | -0.68596E 01           | 19 HOUR 11 JUNE | 0.137782E 06           | 13 HOUR 19 SEP. | 0.57656E 01            | 3 HOUR 29 JUNE  |
| 170    | -0.678328E 05                                                | 6 HOUR 27 JAN.  | -0.31895E 01           | 7 HOUR 24 JUNE  | 0.155601E 06           | 13 HOUR 19 SEP. | 0.22814E 02            | 6 HOUR 11 AUG.  |
| 171    | -0.599995E 05                                                | 6 HOUR 27 JAN.  | -0.87573E 01           | 2 HOUR 6 OCT.   | 0.138275E 06           | 13 HOUR 19 SEP. | 0.18904E 01            | 19 HOUR 11 JUNE |
| 186    | -0.678320E 05                                                | 6 HOUR 27 JAN.  | -0.23125E 01           | 24 HOUR 23 JUNE | 0.156094E 06           | 13 HOUR 19 SEP. | 0.24174E 02            | 6 HOUR 11 AUG.  |
| 187    | NO HEATING IS REQUIRED IN THIS SPACE FOR THE PERIOD OF STUDY |                 |                        |                 | 0.134009E 06           | 16 HOUR 7 JAN.  | 0.10128E 05            | 3 HOUR 1 JAN.   |
| 200    | -0.253925E 05                                                | 9 HOUR 13 FEB.  | -0.12734E 01           | 4 HOUR 24 MAR.  | 0.101893E 06           | 17 HOUR 27 JULY | 0.36602E 01            | 22 HOUR 15 OCT. |
| 201    | -0.904121E 03                                                | 11 HOUR 13 FEB. | -0.80781E 01           | 4 HOUR 13 FEB.  | 0.180395E 06           | 13 HOUR 27 JULY | 0.94375E 01            | 5 HOUR 19 DEC.  |
| 202    | NO HEATING IS REQUIRED IN THIS SPACE FOR THE PERIOD OF STUDY |                 |                        |                 | 0.190289E 06           | 17 HOUR 29 APR. | 0.10128E 05            | 3 HOUR 1 JAN.   |
| 204    | -0.529175E 05                                                | 6 HOUR 27 JAN.  | -0.33829E 01           | 15 HOUR 11 APR. | 0.328734E 05           | 16 HOUR 2 AUG.  | 0.22451E 01            | 22 HOUR 17 JUNE |
| 205    | NO HEATING IS REQUIRED IN THIS SPACE FOR THE PERIOD OF STUDY |                 |                        |                 | 0.142912E 06           | 16 HOUR 7 JAN.  | 0.10128E 05            | 3 HOUR 1 JAN.   |
| 220    | NO HEATING IS REQUIRED IN THIS SPACE FOR THE PERIOD OF STUDY |                 |                        |                 | 0.150251E 06           | 16 HOUR 7 JAN.  | 0.10128E 05            | 3 HOUR 1 JAN.   |
| 234    | NO HEATING IS REQUIRED IN THIS SPACE FOR THE PERIOD OF STUDY |                 |                        |                 | 0.154883E 06           | 16 HOUR 7 JAN.  | 0.10128E 05            | 3 HOUR 1 JAN.   |
| 235    | -0.335145E 05                                                | 6 HOUR 29 JAN.  | -0.67527E 01           | 22 HOUR 22 SEP. | 0.416946E 05           | 17 HOUR 27 JULY | 0.77483E 01            | 12 HOUR 25 FEB. |
| 236    | NO HEATING IS REQUIRED IN THIS SPACE FOR THE PERIOD OF STUDY |                 |                        |                 | 0.134009E 06           | 16 HOUR 7 JAN.  | 0.10128E 05            | 3 HOUR 1 JAN.   |
| 249    | -0.250383E 05                                                | 7 HOUR 13 FEB.  | -0.13750E 01           | 5 HOUR 30 MAR.  | 0.102255E 06           | 17 HOUR 27 JULY | 0.0                    | 21 HOUR 13 NOV. |
| 250    | -0.904121E 03                                                | 11 HOUR 13 FEB. | -0.80781E 01           | 4 HOUR 13 FEB.  | 0.180395E 06           | 13 HOUR 27 JULY | 0.94375E 01            | 5 HOUR 19 DEC.  |
| 251    | NO HEATING IS REQUIRED IN THIS SPACE FOR THE PERIOD OF STUDY |                 |                        |                 | 0.190289E 06           | 17 HOUR 29 APR. | 0.10128E 05            | 3 HOUR 1 JAN.   |
| 253    | -0.529167E 05                                                | 6 HOUR 27 JAN.  | -0.16261E 02           | 22 HOUR 17 JUNE | 0.350472E 05           | 14 HOUR 2 AUG.  | 0.11772E 01            | 9 HOUR 28 MAY   |
| 254    | NO HEATING IS REQUIRED IN THIS SPACE FOR THE PERIOD OF STUDY |                 |                        |                 | 0.142912E 06           | 16 HOUR 7 JAN.  | 0.10128E 05            | 3 HOUR 1 JAN.   |
| 269    | NO HEATING IS REQUIRED IN THIS SPACE FOR THE PERIOD OF STUDY |                 |                        |                 | 0.150251E 06           | 16 HOUR 7 JAN.  | 0.10128E 05            | 3 HOUR 1 JAN.   |
| 283    | NO HEATING IS REQUIRED IN THIS SPACE FOR THE PERIOD OF STUDY |                 |                        |                 | 0.154883E 06           | 16 HOUR 7 JAN.  | 0.10128E 05            | 3 HOUR 1 JAN.   |
| 284    | -0.235138E 05                                                | 6 HOUR 29 JAN.  | -0.46111E 01           | 8 HOUR 25 FEB.  | 0.419844E 05           | 16 HOUR 2 AUG.  | 0.63186E 01            | 21 HOUR 21 APR. |
| 285    | -0.426090E 06                                                | 13 HOUR 13 FEB. | -0.30449E 02           | 16 HOUR 30 JULY | 0.334865E 06           | 17 HOUR 27 JULY | 0.14044E 03            | 24 HOUR 17 JUNE |

[illegible]

14:00

|      |   |     |     |          |       |       |          |
|------|---|-----|-----|----------|-------|-------|----------|
| 6566 | 0 | 77. | 10. | 0.004912 | 29.62 | 23.86 | 0.072582 |
|------|---|-----|-----|----------|-------|-------|----------|

SHADE AREA = 41.19 PERCENT

[illegible]







CHICAGO SYSTEM DESCRIPTION

ALL ELECTRIC BUILDING

1 1500 TON HERMETIC CENTRIFUGAL BTU PUMP

2 2500 TON OPEN CENTRIFUGAL CHILLERS

7 STEAM GENERATORS 16000 KW TOTAL

23 FAN SYSTEMS: 11 TERMINAL REHEAT

12 PERIMETER INDUCTION

1,300,000 CFM DESIGN

SYSTEMS SIMULATION

2256 FORTRAN CARDS

133 DATA CARDS FOR CHICAGO BUILDING SPECIFICATION

IBM 360/91 RUN TIME FOR HOUR BY HOUR SIMULATION FOR YEAR:

|         |    |         |       |         |
|---------|----|---------|-------|---------|
| COMPILE |    |         | 23.14 | SECONDS |
| LINK    |    |         | 0.96  | SECONDS |
| SEARCH  | 9  | MINUTES | 0.00  | SECONDS |
| EXECUTE | 8  | MINUTES | 49.30 | SECONDS |
| TOTAL   | 18 | MINUTES | 13.40 | SECONDS |

SUMMARY OF FAN SYSTEM CHARACTERISTICS

| FAN SYSTEM | TYPE | FAN BHP | NO. OF ZONES | SET POINT | TOTAL CFM | MIN. O.A. CFM | EXH. CFM | PERCENT VENT. AIR |
|------------|------|---------|--------------|-----------|-----------|---------------|----------|-------------------|
| 1          | SZRH | 23.5    | 1            | 75.0      | 27679.    | 2768.         | 0.       | 10.0              |
| 2          | PIU  | 79.8    | 3            | 75.0      | 44550.    | 11700.        | 0.       | 26.3              |
| 3          | PIU  | 79.8    | 2            | 75.0      | 44550.    | 11700.        | 0.       | 26.3              |
| 4          | PIU  | 85.1    | 2            | 75.0      | 47520.    | 12480.        | 0.       | 26.3              |
| 5          | PIU  | 35.5    | 3            | 75.0      | 19800.    | 4950.         | 0.       | 25.0              |
| 6          | PIU  | 35.5    | 2            | 75.0      | 19800.    | 4950.         | 0.       | 25.0              |
| 7          | PIU  | 37.8    | 2            | 75.0      | 21120.    | 5280.         | 0.       | 25.0              |
| 8          | SZRH | 33.1    | 1            | 75.0      | 38883.    | 3888.         | 0.       | 10.0              |
| 9          | PIU  | 79.8    | 3            | 75.0      | 44550.    | 11700.        | 0.       | 26.3              |
| 10         | PIU  | 79.8    | 2            | 75.0      | 44550.    | 11700.        | 0.       | 26.3              |
| 11         | PIU  | 85.1    | 2            | 75.0      | 47520.    | 12480.        | 0.       | 26.3              |
| 12         | PIU  | 35.8    | 3            | 75.0      | 19968.    | 4950.         | 0.       | 24.8              |
| 13         | PIU  | 35.5    | 2            | 75.0      | 19800.    | 4950.         | 0.       | 25.0              |
| 14         | PIU  | 37.8    | 2            | 75.0      | 21120.    | 5280.         | 0.       | 25.0              |
| 15         | SZRH | 128.3   | 3            | 75.0      | 110262.   | 34125.        | 0.       | 30.9              |
| 16         | SZRH | 23.4    | 2            | 75.0      | 22689.    | 4851.         | 0.       | 21.4              |
| 17         | SZRH | 135.9   | 1            | 75.0      | 116758.   | 34913.        | 0.       | 29.9              |
| 18         | SZRH | 145.8   | 3            | 75.0      | 125277.   | 35140.        | 0.       | 28.0              |
| 19         | SZRH | 128.4   | 3            | 75.0      | 110282.   | 34125.        | 0.       | 30.9              |
| 20         | SZRH | 23.4    | 2            | 75.0      | 22689.    | 4851.         | 0.       | 21.4              |
| 21         | SZRH | 135.9   | 1            | 75.0      | 116758.   | 34913.        | 0.       | 29.9              |
| 22         | SZRH | 145.8   | 3            | 75.0      | 125293.   | 35141.        | 0.       | 28.0              |
| 23         | SZRH | 15.5    | 1            | 75.0      | 18239.    | 5230.         | 0.       | 28.7              |

## SUMMARY OF ZONE AIR FLOWS

| FAN SYSTEM | ZONE | SUPPLY CFM | EXHAUST CFM |
|------------|------|------------|-------------|
|------------|------|------------|-------------|

|    |   |         |    |
|----|---|---------|----|
| 1  | 1 | 27679.  | 0. |
| 2  | 1 | 38610.  | 0. |
| 2  | 2 | 2970.   | 0. |
| 2  | 3 | 2970.   | 0. |
| 3  | 1 | 41580.  | 0. |
| 3  | 2 | 2970.   | 0. |
| 4  | 1 | 44550.  | 0. |
| 4  | 2 | 2970.   | 0. |
| 5  | 1 | 17160.  | 0. |
| 5  | 2 | 1320.   | 0. |
| 5  | 3 | 1320.   | 0. |
| 6  | 1 | 18480.  | 0. |
| 6  | 2 | 1320.   | 0. |
| 7  | 1 | 19800.  | 0. |
| 7  | 2 | 1320.   | 0. |
| 8  | 1 | 38883.  | 0. |
| 9  | 1 | 38610.  | 0. |
| 9  | 2 | 2970.   | 0. |
| 9  | 3 | 2970.   | 0. |
| 10 | 1 | 41580.  | 0. |
| 10 | 2 | 2970.   | 0. |
| 11 | 1 | 44550.  | 0. |
| 11 | 2 | 2970.   | 0. |
| 12 | 1 | 17160.  | 0. |
| 12 | 2 | 1488.   | 0. |
| 12 | 3 | 1320.   | 0. |
| 13 | 1 | 18480.  | 0. |
| 13 | 2 | 1320.   | 0. |
| 14 | 1 | 19800.  | 0. |
| 14 | 2 | 1320.   | 0. |
| 15 | 1 | 94887.  | 0. |
| 15 | 2 | 5550.   | 0. |
| 15 | 3 | 9825.   | 0. |
| 16 | 1 | 20729.  | 0. |
| 16 | 2 | 1960.   | 0. |
| 17 | 1 | 116758. | 0. |
| 18 | 1 | 114571. | 0. |
| 18 | 2 | 8436.   | 0. |
| 18 | 3 | 2271.   | 0. |
| 19 | 1 | 94887.  | 0. |
| 19 | 2 | 5569.   | 0. |
| 19 | 3 | 9825.   | 0. |
| 20 | 1 | 20729.  | 0. |
| 20 | 2 | 1960.   | 0. |
| 21 | 1 | 116758. | 0. |
| 22 | 1 | 114571. | 0. |
| 22 | 2 | 8436.   | 0. |
| 22 | 3 | 2287.   | 0. |
| 23 | 1 | 18239.  | 0. |

SUMMARY OF PERIMETER INDUCTION UNITS

| SYSTEM | ZONE | TYPE | UNITS/ZONE | CFM/UNIT | GPM/UNIT | PRIMARY CFM | COIL HEAT BTU/HR | COIL COOL BTU/HR |
|--------|------|------|------------|----------|----------|-------------|------------------|------------------|
| 2      | 1    | 5.   | 702.       | 55.0     | 1.00     | 38610.      | -4093805.        | 2924146.         |
| 2      | 2    | 6.   | 54.        | 55.0     | 1.50     | 2970.       | -371196.         | 265140.          |
| 2      | 3    | 6.   | 54.        | 55.0     | 1.50     | 2970.       | -371196.         | 265140.          |
| 3      | 1    | 5.   | 756.       | 55.0     | 1.00     | 41580.      | -4408713.        | 3149081.         |
| 3      | 2    | 6.   | 54.        | 55.0     | 1.50     | 2970.       | -371196.         | 265140.          |
| 4      | 1    | 5.   | 810.       | 55.0     | 1.00     | 44550.      | -4723624.        | 3374017.         |
| 4      | 2    | 6.   | 54.        | 55.0     | 1.50     | 2970.       | -371196.         | 265140.          |
| 5      | 1    | 1.   | 312.       | 55.0     | 1.00     | 17160.      | -1280059.        | 914328.          |
| 5      | 2    | 3.   | 24.        | 55.0     | 1.00     | 1320.       | -118734.         | 84810.           |
| 5      | 3    | 1.   | 24.        | 55.0     | 1.00     | 1320.       | -98466.          | 70333.           |
| 6      | 1    | 1.   | 336.       | 55.0     | 1.00     | 18480.      | -1378525.        | 984661.          |
| 6      | 2    | 1.   | 24.        | 55.0     | 1.00     | 1320.       | -98466.          | 70333.           |
| 7      | 1    | 1.   | 360.       | 55.0     | 1.00     | 19800.      | -1476991.        | 1054994.         |
| 7      | 2    | 1.   | 24.        | 55.0     | 1.00     | 1320.       | -98466.          | 70333.           |
| 9      | 1    | 6.   | 702.       | 55.0     | 1.00     | 38610.      | -4331505.        | 3093932.         |
| 9      | 2    | 6.   | 54.        | 55.0     | 2.20     | 2970.       | -397178.         | 283699.          |
| 9      | 3    | 6.   | 54.        | 55.0     | 2.20     | 2970.       | -397178.         | 283699.          |
| 10     | 1    | 6.   | 756.       | 55.0     | 1.00     | 41580.      | -4664699.        | 3331928.         |
| 10     | 2    | 6.   | 54.        | 55.0     | 2.20     | 2970.       | -397178.         | 283699.          |
| 11     | 1    | 6.   | 810.       | 55.0     | 1.00     | 44550.      | -4997892.        | 3569923.         |
| 11     | 2    | 6.   | 54.        | 55.0     | 2.20     | 2970.       | -397178.         | 283699.          |
| 12     | 1    | 6.   | 312.       | 55.0     | 1.05     | 17160.      | -1956263.        | 1397331.         |
| 12     | 2    | 6.   | 24.        | 62.0     | 2.20     | 1488.       | -191552.         | 136823.          |
| 12     | 3    | 6.   | 24.        | 55.0     | 2.20     | 1320.       | -176524.         | 126088.          |
| 13     | 1    | 6.   | 336.       | 55.0     | 1.07     | 18480.      | -2119548.        | 1513963.         |
| 13     | 2    | 6.   | 24.        | 55.0     | 2.20     | 1320.       | -176514.         | 126088.          |
| 14     | 1    | 6.   | 360.       | 55.0     | 1.08     | 19800.      | -2277661.        | 1626901.         |
| 14     | 2    | 6.   | 24.        | 55.0     | 2.45     | 1320.       | -177383.         | 126702.          |

SUMMARY OF EQUIPMENT SIZES

TYPE OF HEAT CONSERVATION MACHINE = HERMETIC CENTRIFUGAL  
NO. OF HEAT CONSERVATION MACHINES = 1  
SIZE OF HEAT CONSERVATION MACHINES = 1500.0 TONS

TYPE OF AUXILIARY CHILLER = OPEN CENTRIFUGAL  
NO. OF AUXILIARY CHILLERS = 2  
SIZE OF AUXILIARY CHILLERS = 2763.6 TONS

TYPE OF BOILER = ELECTRIC  
NO. OF BOILERS = 7  
SIZE OF BOILERS = 9072.0 MBTU

TOTAL HEATING CAPACITY = 63504.2 MBTU  
TOTAL COOLING CAPACITY = 7027.3 TONS  
PEAK SENSIBLE COOLING = 66352.7 MBTU  
PEAK LATENT COOLING = 17974.7 MBTU

TYPE OF TERMINAL REHEAT = ELECTRIC

RIVER WATER OR SIMILAR TYPE SOURCE USED IN CONDENSER WATER COOLING CIRCUIT

BOILER AUXILIARY HORSEPOWER REQUIREMENT (FAN, BLOWER, PUMP) 94.9 BHP

TOTAL FAN PLANT HORSEPOWER FOR BUILDING 1646.0 BHP

SUMMARY OF PUMP SIZES

| LOCATION        | TOTAL GPM | TOTAL HEAD (FT) | TOTAL BHP |
|-----------------|-----------|-----------------|-----------|
| CHILLED WATER   | 11244.    | 160.0           | 860.0     |
| CONDENSER WATER | 21082.    | 75.0            | 755.8     |
| HEATING WATER   | 6350.     | 70.0            | 212.5     |
| DOUBLE BUNDLE   | 2250.     | 72.0            | 75.3      |



IBM CCS &amp; REC DIVISION I FACILITY/ADDRESS

I DATE/PROJECT

I ENGINEER/SYSTEM IDENTIFICATION

EQUIPMENT AND ENERGY I IBM 52 FLR(1,244T?) OFFICE BUILDING I 6 NOVEMBER 1970 I DICK STILLMAN

CONSUMPTION ANALYSIS I 330 N. WABASH IN CHICAGO, ILLINOIS I 902-6001

I SYSTEM NO. 1

## ENERGY CONSUMPTION

JAN.

FEB.

MARCH

APRIL

MAY

JUNE

## MONTHLY BTU/1000

## HEAT (MMB)

MIN. DEMAND

-3267.3

-2010.3

-940.7

-162.4

-45.2

-3.3

MAX. DEMAND

-55082.7

-54663.1

-48909.6

-23082.3

-20099.5

-7781.3

CONSUMPTION

-17884464.0

-13913202.0

-12053819.0

-4259731.0

-2918586.0

-608234.4

## COOL (MCB)

MIN. DEMAND

502.5

651.8

1932.4

9095.6

9550.5

12750.5

MAX. DEMAND

21486.8

28523.0

41370.0

53509.3

60567.0

66416.8

CONSUMPTION

6720213.0

6923240.0

10508084.0

16096644.0

19302432.0

21638336.0

## ELECTRICITY

## LIGHTS AND MOTORS

## INTERNAL

DEMAND(KW)

7686.1

7686.1

7686.1

7686.1

7686.1

7686.1

CONS.(KWH)

2788186.0

2525790.0

2927002.0

2760426.0

2788180.0

2816411.0

## EXTERNAL

DEMAND(KW)

200.0

200.0

200.0

200.0

200.0

200.0

CONS.(KWH)

87000.0

77600.0

74600.0

65200.0

61200.0

54000.0

## HEAT

DEMAND(KW)

16533.7

16410.7

14724.9

6992.2

6118.3

2509.1

CONS.(KWH)

5497599.0

4281076.0

3731694.0

1384739.0

988116.8

247882.0

## COOL

DEMAND(KW)

2449.3

2812.8

3576.8

4163.2

4595.6

4979.0

CONS.(KWH)

1328034.0

1265535.0

1561637.0

1848602.0

2055081.0

2146716.0

## TOTAL

DEMAND(KW)

24419.7

24296.8

22611.0

14878.3

14004.3

12865.0

CONS.(KWH)

9700819.0

8150001.0

8294933.0

6058967.0

5892577.0

5265009.0

## GAS

## HEAT

DEMAND(THERMS)

0.0

0.0

0.0

0.0

0.0

0.0

CONS.(THERMS)

0.0

0.0

0.0

0.0

0.0

0.0

## COOL

DEMAND(THERMS)

0.0

0.0

0.0

0.0

0.0

0.0

CONS.(THERMS)

0.0

0.0

0.0

0.0

0.0

0.0

## GENERATION

DEMAND(THERMS)

0.0

0.0

0.0

0.0

0.0

0.0

CONS.(THERMS)

0.0

0.0

0.0

0.0

0.0

0.0

## TOTAL

DEMAND(THERMS)

0.0

0.0

0.0

0.0

0.0

0.0

CONS.(THERMS)

0.0

0.0

0.0

0.0

0.0

0.0

|                        |                                     |                 |                                |
|------------------------|-------------------------------------|-----------------|--------------------------------|
| IBM CCS & REC DIVISION | FACILITY/ADDRESS                    | DATE/PROJECT    | ENGINEER/SYSTEM IDENTIFICATION |
| EQUIPMENT AND ENERGY   | IBM 52 FLR(1.3MFT?) OFFICE BUILDING | 6 NOVEMBER 1977 | DICK STILLMAN                  |
| CONSUMPTION ANALYSIS   | 330 N. WABASH IN CHICAGO, ILLINOIS  | 902-6001        | SYSTEM NO. 1                   |

ENERGY CONSUMPTION

| JULY | AUG. | SEPT. | OCT. | NOV. | DEC. | TOTAL |
|------|------|-------|------|------|------|-------|
|------|------|-------|------|------|------|-------|

MONTHLY BTU/1000

HEAT (MBH)

|             |         |          |            |            |             |             |             |
|-------------|---------|----------|------------|------------|-------------|-------------|-------------|
| MIN. DEMAND | -15.1   | -6.7     | -13.4      | -8.4       | -487.1      | -1506.1     |             |
| MAX. DEMAND | -1313.9 | -5535.3  | -13429.9   | -23042.0   | -50420.6    | -50701.1    |             |
| CONSUMPTION | -2346.0 | -94483.5 | -1269002.0 | -4212714.0 | -11837004.0 | -17685872.0 | -86742384.0 |

COOL (MCB)

|             |            |            |            |            |           |           |             |
|-------------|------------|------------|------------|------------|-----------|-----------|-------------|
| MIN. DEMAND | 18818.4    | 16448.4    | 10564.9    | 8381.0     | 1562.7    | 1434.9    |             |
| MAX. DEMAND | 74190.4    | 66875.6    | 60551.7    | 52174.8    | 44377.9   | 25380.9   |             |
| CONSUMPTION | 21997552.0 | 28757120.0 | 20507776.0 | 15793870.0 | 9087304.0 | 6593334.0 | 193925872.0 |

ELECTRICITY

LIGHTS AND MOTORS

INTERNAL

|            |           |           |           |           |           |           |            |
|------------|-----------|-----------|-----------|-----------|-----------|-----------|------------|
| DEMAND(KW) | 7686.1    | 7686.1    | 7686.1    | 7686.1    | 7686.1    | 7686.1    |            |
| CONS.(KWH) | 2732202.0 | 2927003.0 | 2747007.0 | 2801611.0 | 2746988.0 | 2718769.0 | 33279520.0 |

EXTERNAL

|            |         |         |         |         |         |         |          |
|------------|---------|---------|---------|---------|---------|---------|----------|
| DEMAND(KW) | 200.0   | 200.0   | 200.0   | 200.0   | 200.0   | 200.0   |          |
| CONS.(KWH) | 61200.0 | 63200.0 | 70400.0 | 80600.0 | 86600.0 | 93000.0 | 874600.0 |

HEAT

|            |        |         |          |           |           |           |            |
|------------|--------|---------|----------|-----------|-----------|-----------|------------|
| DEMAND(KW) | 614.2  | 1851.0  | 4164.1   | 6980.4    | 15167.7   | 15249.9   |            |
| CONS.(KWH) | 2126.3 | 41893.6 | 456163.4 | 1372976.0 | 3667118.0 | 5444733.0 | 27116080.0 |

COOL

|            |           |           |           |           |           |           |            |
|------------|-----------|-----------|-----------|-----------|-----------|-----------|------------|
| DEMAND(KW) | 5521.4    | 5010.0    | 4594.6    | 4192.0    | 3784.2    | 2599.3    |            |
| CONS.(KWH) | 2729655.0 | 2552279.0 | 2087499.0 | 1866323.0 | 1451088.0 | 1314068.0 | 22206496.0 |

TOTAL

|            |           |           |           |           |           |           |            |
|------------|-----------|-----------|-----------|-----------|-----------|-----------|------------|
| DEMAND(KW) | 13407.4   | 12896.0   | 12480.7   | 14866.5   | 23053.7   | 23135.9   |            |
| CONS.(KWH) | 5525183.0 | 5584375.0 | 5361069.0 | 6121510.0 | 7951794.0 | 9570570.0 | 83476736.0 |

GAS

HEAT

|                |     |     |     |     |     |     |     |
|----------------|-----|-----|-----|-----|-----|-----|-----|
| DEMAND(THERMS) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |     |
| CONS.(THERMS)  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

COOL

|                |     |     |     |     |     |     |     |
|----------------|-----|-----|-----|-----|-----|-----|-----|
| DEMAND(THERMS) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |     |
| CONS.(THERMS)  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

GENERATION

|                |     |     |     |     |     |     |     |
|----------------|-----|-----|-----|-----|-----|-----|-----|
| DEMAND(THERMS) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |     |
| CONS.(THERMS)  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

TOTAL

|                |     |     |     |     |     |     |     |
|----------------|-----|-----|-----|-----|-----|-----|-----|
| DEMAND(THERMS) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |     |
| CONS.(THERMS)  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

IBM CCS & REC DIVISION I FACILITY/ADDRESS I DATE/PROJECT I ENGINEER/SYSTEM IDENTIFICATION  
EQUIPMENT AND ENERGY I IBM 52 FLR(1.8MFT2) OFFICE BUILDING I 6 NOVEMBER 1970 I DICK STILLMAN  
CONSUMPTION ANALYSIS I 330 N. WABASH IN CHICAGO, ILLINOIS I 902-6001 I SYSTEM NO. 1

| ENERGY CONSUMPTION     |        |        |        |        |        |       |
|------------------------|--------|--------|--------|--------|--------|-------|
|                        | JAN.   | FEB.   | MARCH  | APRIL  | MAY    | JUNE  |
| STEAM                  |        |        |        |        |        |       |
| HEAT                   |        |        |        |        |        |       |
| DEMAND(K LBS)          | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0   |
| CONS.(K LBS)           | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0   |
| COOL                   |        |        |        |        |        |       |
| DEMAND(K LBS)          | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0   |
| CONS.(K LBS)           | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0   |
| TOTAL                  |        |        |        |        |        |       |
| DEMAND(K LBS)          | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0   |
| CONS.(K LBS)           | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0   |
| OIL                    |        |        |        |        |        |       |
| HEAT                   |        |        |        |        |        |       |
| CONS.(K GALS)          | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0   |
| COOL                   |        |        |        |        |        |       |
| CONS.(K GALS)          | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0   |
| TOTAL                  |        |        |        |        |        |       |
| CONS.(K GALS)          | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0   |
| DIESEL FUEL GENERATION |        |        |        |        |        |       |
| CONS.(K GALS)          | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0   |
| HUMIDIFICATION         |        |        |        |        |        |       |
| DEMAND (K LBS )        | 11.9   | 11.9   | 11.9   | 9.3    | 8.9    | 4.9   |
| CONS. (K LBS )         | 6761.3 | 5663.3 | 5795.3 | 3026.0 | 2263.5 | 485.6 |

IBM CCS & REC DIVISION I FACILITY/ADDRESS I DATE/PROJECT I ENGINEER/SYSTEM IDENTIFICATION  
EQUIPMENT AND ENERGY I IBM 52 FLR(1.8MFT2) OFFICE BUILDING I 6 NOVEMBER 1970 I DICK STILLMAN  
CONSUMPTION ANALYSIS I 330 N. WABASH IN CHICAGO, ILLINOIS I 902-6001 I SYSTEM NO. 1

ENERGY CONSUMPTION

JULY AUG. SEPT. OCT. NOV. DEC. TOTAL

STEAM

HEAT

DEMAND(K LBS) 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
CONS.(K LBS) 0.0 0.0 0.0 0.0 0.0 0.0 0.0

CCCL

DEMAND(K LBS) 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
CONS.(K LBS) 0.0 0.0 0.0 0.0 0.0 0.0 0.0

TOTAL

DEMAND(K LBS) 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
CONS.(K LBS) 0.0 0.0 0.0 0.0 0.0 0.0 0.0

OIL

HEAT

142 CONS.(K GALS) 0.0 0.0 0.0 0.0 0.0 0.0 0.0

CCCL

CONS.(K GALS) 0.0 0.0 0.0 0.0 0.0 0.0 0.0

TOTAL

CONS.(K GALS) 0.0 0.0 0.0 0.0 0.0 0.0 0.0

DIESEL FUEL

GENERATION

CONS.(K GALS) 0.0 0.0 0.0 0.0 0.0 0.0 0.0

HUMIDIFICATION

DEMAND (K LBS ) 1.2 4.9 7.8 9.1 11.6 11.6

CONS. (K LBS ) 3.0 84.4 1041.3 2479.4 5175.8 6817.7 39596.4

Table

## CALCULATED DESIGN DATA FOR CHICAGO BUILDING

Cooling Design Data

| <u>Year</u> | <u>Hour</u> | <u>Day</u> | <u>D.B.</u><br><u>°F</u> | <u>W.B.</u><br><u>°F</u> | <u>Plenum</u><br><u>Btu/hr.</u> | <u>Latent</u><br><u>Btu/hr.</u> | <u>Sensible</u><br><u>Btu/hr.</u> |
|-------------|-------------|------------|--------------------------|--------------------------|---------------------------------|---------------------------------|-----------------------------------|
| 1955        | 15          | 27 July    | 100                      | 77                       | 2068960                         | 1277470                         | 38875920                          |
| 1954        | 15          | 11 June    | 96                       | 75                       | 2070046                         | 1277470                         | 37662317                          |
| 1953        | 15          | 30 June    | 97                       | 78                       | 2057873                         | 1277470                         | 38061624                          |
| 1952        | 15          | 22 July    | 95                       | 77                       | 2057873                         | 1277470                         | 37392826                          |
| 1950        | 15          | 11 July    | 91                       | 68                       | 2057873                         | 1277470                         | 37171639                          |
| 1949        | 15          | 30 June    | 93                       | 75                       | 2069947                         | 1277470                         | 38193557                          |

Heating Design Data

| <u>Year</u> | <u>Hour</u> | <u>Day</u>  | <u>D.B.</u><br><u>°F</u> | <u>Sensible</u><br><u>Btu/hr.</u> |
|-------------|-------------|-------------|--------------------------|-----------------------------------|
| 1955        | 6           | 27 January  | -9                       | 19990624                          |
| 1954        | 7           | 17 January  | -7                       | 20277214                          |
| 1953        | 7           | 1 February  | 4                        | 17632337                          |
| 1952        | 6           | 29 January  | -2                       | 18062094                          |
| 1950        | 3           | 24 November | -1                       | 18776148                          |
| 1949        | 6           | 30 January  | -4                       | 19283263                          |

ALL ELECTRIC BUILDING ENERGY SAVINGS

A. CHILLERS FIXED 42<sup>0</sup> F

COLD DECK FIXED 50<sup>0</sup> F

HOT DECK FIXED 140<sup>0</sup> F

B. CHILLERS 40 - 50<sup>0</sup> F BASED ON BUILDING COOLING LOAD

COLD DECK 50 - 60<sup>0</sup> F BASED ON ZONE COOLING LOAD

HOT DECK 85 - 140<sup>0</sup> F BASED ON ZONE HEATING LOAD

BTU PUMP BUILDING WITH SZRHT AND PIU FAN SYSTEMS

B SAVES 7% OVER A IN KWH CONSUMPTION FOR YEAR

BTU PUMP BUILDING WITH SZRHT FAN SYSTEMS

B SAVES 35% OVER A IN KWH CONSUMPTION FOR YEAR

CONVENTIONAL BUILDING WITH DD FAN SYSTEMS

B SAVES 39% OVER A IN KWH CONSUMPTION FOR YEAR

## FUTURE PROGRAM CHANGES

LOAD MODEL: TEMPERATURE SET BACK SCHEDULE

LARGE SHADOW OPTION

SYSTEMS: FAIL SAFE OPERATION

READ IN MAXIMUM ZONE LOADS

ALL YEAR OPERATION REPLACE CHANGEOVER

ADD HUMIDIFICATION-DEHUMIDIFICATION

COOLING TOWER-RIVER WATER OPTION

CHANGE EQUIPMENT DESIGN STRATEGY

CHANGE EQUIPMENT OPERATING STRATEGY

MINIMUM ENERGY DAMPER ALGORITHM

CHILLER AND HOT-COLD DECK BASED ON LOAD

ADD PERIMETER INDUCTION UNITS

OPTIMUM OPERATING STRATEGY

TEMPERATURE-VENTILATION SET BACK

MR. MILNARK: All right, before our break, one more topic, "Application of the Program in Specific Projects -- Use in Canadian Public Buildings," Bob S. Bycraft, M.E., Department of Public Works, Ottawa, Canada.

MR. BYCRAFT: Good afternoon.

We have been using the postal program for about six months now, and in fact that represents about my entire experience in the energy analysis business. I guess I am what you would call an instant expert, or maybe I am an expert because I am from a foreign country -- that is if you consider Canada a foreign country. And Mr. Nixon does.

I think he is going to make us pay for the program after all.

Actually, the Postal Service has been very generous to us, and perhaps America as a whole is suffering a bit from over generosity.

Well, the purpose of our first study was to develop a total systems analysis around the postal program. At the same time, we were attempting to get some relative and relevant cost-comparison information on a typical office building in the environment of the Canadian capital.

The numbers you get out of the computer are printed to the last dollar. Don't take that as a measure of their accuracy.

Could I have the first slide, please?

This slide will show how we set up our system for the study when we get it here.

First we define the building model, and input it to the postal load program. We evaluate the validity of the load output, and then run the postal systems simulation program. This gives the loads and load factors we need to calculate energy costs, as well as equipment sizes to cost the mechanical and electrical systems. We developed programs on a Wang-700 desk-top computer to calculate energy costs based on the utilities' actual



rate schedules. We also developed programs on the Wang to do our present value and annual cost calculations. We haven't used the postal economic analysis program, since we were interested in evaluating more system components than their program would allow.

We did use the same formulas, however, as they did, and concur with their technique. After we get our total cost on one building option, we just change the building parameter and run the whole system again.

May I have the next slide, please?

This was our building model, and you can more or less imagine what it is. The azimuth orientation of the building located in the city of Hull is shown at the top -- and incidentally, Ottawa and Hull are twin cities on either side of the Ottawa River. While Ottawa is the official capital, there is an increasing tendency toward a capital region, which will probably encompass both cities. The Ottawa building azimuth is shown at the bottom, and we will get that slide back again and you can take a look at it.

When we input this building to the computer, it was just one big thermal block. Each exposure had a huge window at the top and the wall at the bottom, and we did this to make it simple. In some additional studies we are doing now, we are defining similar thermal blocks, only the walls and the roofs and the windows do not fit together. The computer does not know that, and as long as you accommodate the shadow calculation properly, you do not have any problem.

What we were interested in -- why we defined the building so simple, was it cuts down input time and reduces errors and reruns, and it generally saves you money in computer time, while you evaluate what this program is doing. I think it is important that you start out on this basis.

The simpler your building is to begin with, the less problems you will have just from input errors alone.

You can see the azimuth at the top of Hull, and these are on-the-street directions of the city.

May I have the next slide, please.

This is some of the most important data on the building from a thermal point of view. There is about 400,000 gross square feet of floor area; 320,000 square feet of net usable space, or 80 percent; 40 percent of the exterior wall was glass, double-glazed with venetian blinds.

About 20 percent of the total air quantity was outside air. The lights and internal electrical load are four and a half watts per net square foot, and they were on from 8:30 to 8:30 five days a week. There is about one person every hundred square feet, and they are in the building from 8:30 to 5:00.

Go to the next slide, please.

These are the building peak loads. The length of each colored line is proportional to the individual load portion as we calculated it. The cooling loads are additive from the lights down here in the middle, and as you go up, they add together so that when we get to the second top line, we have the sum of the individual loads. The top line shows the program output and the total effect of the weighting calculation, and there is more than the weighting calculation. The system is simulated there, and there is some effect of outside air cooling. We are not quite sure what happens, because when the peak skin load occurs it may not necessarily be the same hour that the peak load occurs in the building. In fact, we are reasonably sure it is not.

The heating loads are shown at the bottom. It is obvious here the relative importance of the ventilation load. It is also obvious that the lights, people, transmission and solar and fan heat gains, heat the building even on a design day of minus-17 degrees.

Could I have the next slide, please?

We had to look for the elusive typical weather year. And that is my blood up there.

We ran the model through the ten years from 1957 to 1966, and these are the peak heating loads for the years 1962 to 1966, by month. Months are at the top, and the first five columns on the left show the variation in January 1966, three, four, five and six. We get a demand variation in January all the way from 9,150 in 1965 to 7,750 in 1963. The February variation is even worse.

In this study, we used 1963 as a typical year. What we have generally found out from these model studies on weather is that several years are fairly close to the average, and these five-year investigations just tell us what years are extremes and should be avoided.

We found, for example, that in 1957, at 35 percent more cooling load than the average on our model. In any case, I am convinced that when you are doing cost-comparison, which is what we have been doing, any weather year will give us fairly good relative costs. These summer demand loads look high, and we made a couple of changes to the system simulation program.

May I have the next slide.

This is the heart of our problem. This is the fan system used in the program. For most of our investigations, we treated the whole building as a single zone. By doing this, we effectively converted this system

into a variable volume system, thermodynamically, anyway. And that is because of the way the simulation is done.

The system only provides the energy required to off-set the load. We were not simulating the power reduction or the fan power, however in this system, the cold deck demand temperature, which is really the space cooling demand temperature as it is simulated, establishes the mixed air temperature if outside air is available for cooling. The program assumed that this was a heating load, when in fact the heating load is actually the outside air load, less the internal gain that caused the outside air to be brought in. We simply changed the equation in the program to do that.

Could I have the next slide, please?

This shows the effect that this change made. The red line shows the new values we got at the bottom when we changed this heating consumption. Now, this is actually a demand. The heating consumption figures were reduced similarly to this. In the process of this investigation, we became aware that the program calculations for the air system were based on CFM rather than pounds of air.

Please back up a slide.

The fan in this system, as in most systems, handles the air at or near 55 degrees. The percentage of outside air required to maintain 55 degrees is calculated on a volume basis. If we use this volume and the actual outside air density, at say, minus-20 degrees, we calculate 17 percent more pounds of air than are really required.

Next slide, please. One more.

We changed the cyclametric routines so the air density was fixed at .075 pounds, and that was a simple change. This shows the effect on the

peak heating load on our model. The peak was reduced 12 percent. The cooling peak also increased by about 3 percent. This fix-up has improved the accuracy, but we would be better off if we were working in pounds of air.

Next slide, please.

We also fixed the electrical demand calculation. For our purposes, we wanted a single electrical meter peak on the entire building. We found that the program assumed that the individual internal electrical peak, the external electrical peak, the heating peak and the cooling peak for any month occurred simultaneously. We changed the program and calculated the sum of the individual peaks every hour. The bottom curves show that even in the summer all the individual peaks were not simultaneous.

Incidentally, this was an all-electric building, which shows the greatest discrepancy in the electrical demand peak. The bottom line shows the new values.

Next slide, please.

These are the building options we considered. The first one was the base model located in the city of Hull environment. The second was an investigation on the same building, but with only half the lighting level of the first option. More like ten years ago, or perhaps an improved lighting efficiency. The third was a simulation of shutting off the ventilation air in the winter if the building was not occupied. The fourth was a comparison of a building defined as five zones instead of one, as an option one. Here we approached the simulation of the dual-duct system and the re-heat involved.

In comparison with the simulation of the variable volume system in option one. The fifth was the same building, but in the Ottawa environment.

The seventh was the Ottawa building, but with solar reflecting glass instead of venetian blinds. And the sixth was started out to use heat absorbing glass, but dropped it. But once you start numbering these systems, you get lost if you change any numbers.

Could we have the next slide, please?

For each option, we considered these energy system combinations. We assumed that the energy costs of the last two are the same, only their capital costs and maintenance costs changed. We used the actual utility rate schedules and calculated monthly energy bills. There were a total of 42 separate combined energy cost calculations done on a monthly basis. From this great bundle of data, I have tried to extract a few things which I think are significant.

Next slide, please.

This shows the cost comparison on the gas heating electric cooling energy system, and the all-electric energy system when we reduced the lighting level 50 percent. The gas heating cost went up 33 percent. The associated electric cost went down 37 percent, and since the electric cost was ten times the gas cost, there was a total energy cost reduction of 32 percent. By comparison, the all-electric system energy cost only reduced 13 percent; and it has probably been obvious to many of you for a long time that as lighting levels go up, electric heating becomes more competitive.

Next slide, please.

When we shut off the ventilation air in winter, when the building was unoccupied, the gas cost was reduced 95 percent. The total gas-electric energy cost was reduced 8 percent. The all-electric system cost was reduced 24 percent. In fact, the all-electric cost is \$6,000.00 less

than the associated electric costs with a gas-heated system.

There are two reasons for this. First, Quebec Hydro will give us a special rate for heating, and we are effectively buying the lighting at heating rates. Don't tell them.

Secondly, the heating occurs at off-peak power, and we are buying it at half a cent a Kilowatt, instead of the average, at around one cent.

Next slide, please.

This shows the effect of re-heat in the dual-duct system. The gas cost and effectively the heating load increased at almost 14 percent. In addition, the peak air volume was higher because the dual-duct system, increasing the fanning horsepower. This increased the electrical cost by two and a half percent, or a total increase of 3.4 percent. By comparison, the all-electric system increased only 1.6 percent. Apparently, the re-heat occurs at off-peak power rate, which is competitive with gas.

Next slide, please.

Because of the higher electric rate in Ottawa, the total gas-electric energy cost in Ottawa is 13 percent higher than in Hull. The all-electric system is even higher, with a cost difference of 26 percent more in Ottawa.

Next slide, please.

The solar reflecting glass increased the gas cost 10 percent. The solar glass cuts out sun that would have provided \$900.00 worth of useful heating. The associated electric cost, however, was reduced 5 percent, primarily because of refrigeration and fanning horsepower savings. This gives us a net saving of 4 percent. By comparison, however, the all-electric system cost increased .6 percent. Apparently the demand charges on electric heating are more severe than the savings on cooling.

Next slide, please.

This is a typical output from our total economic analysis. We did some 25 calculations like this on all the building and system options. Once we had the cost data established, it took us about a day on the Wang computer to produce all our final results.

I could go for a considerable time on the importance of capital and maintenance costs in a study of this type. I would like to isolate one case to make a point.

When we looked at the cost comparison of cutting the lighting power in half, we showed an energy saving of about \$32,500.00 per year. If we escalate that energy at 5 percent, with interest at seven and a half percent, the average saving over the 30-year life of the building is increased to \$45,500.00. Further, when we consider the smaller chillers, the reduced fan system, and so on, we came up with a total annual saving of \$107,500.00, more than twice the energy saving alone. This would justify considerable more capital if we could improve the lighting efficiency.

Could I have the lights on, please?

Officially, I cannot speak on behalf of the Canadian government, or even the Department of Public Works, but I am sure they share my expression of appreciation to the U.S. Postal Service for developing this program and making it available to us. It has put us years ahead in our energy studies. I consider it a noble and worthwhile first step towards solution of the whole energy and system analysis problem.

We need more people to get involved, more exchange of ideas. I encourage any of you to take up this challenge. Ultimately, the kind of cost implications I have shown today will force you to do it.

MR. MILNARK: Thanks much, Bob.



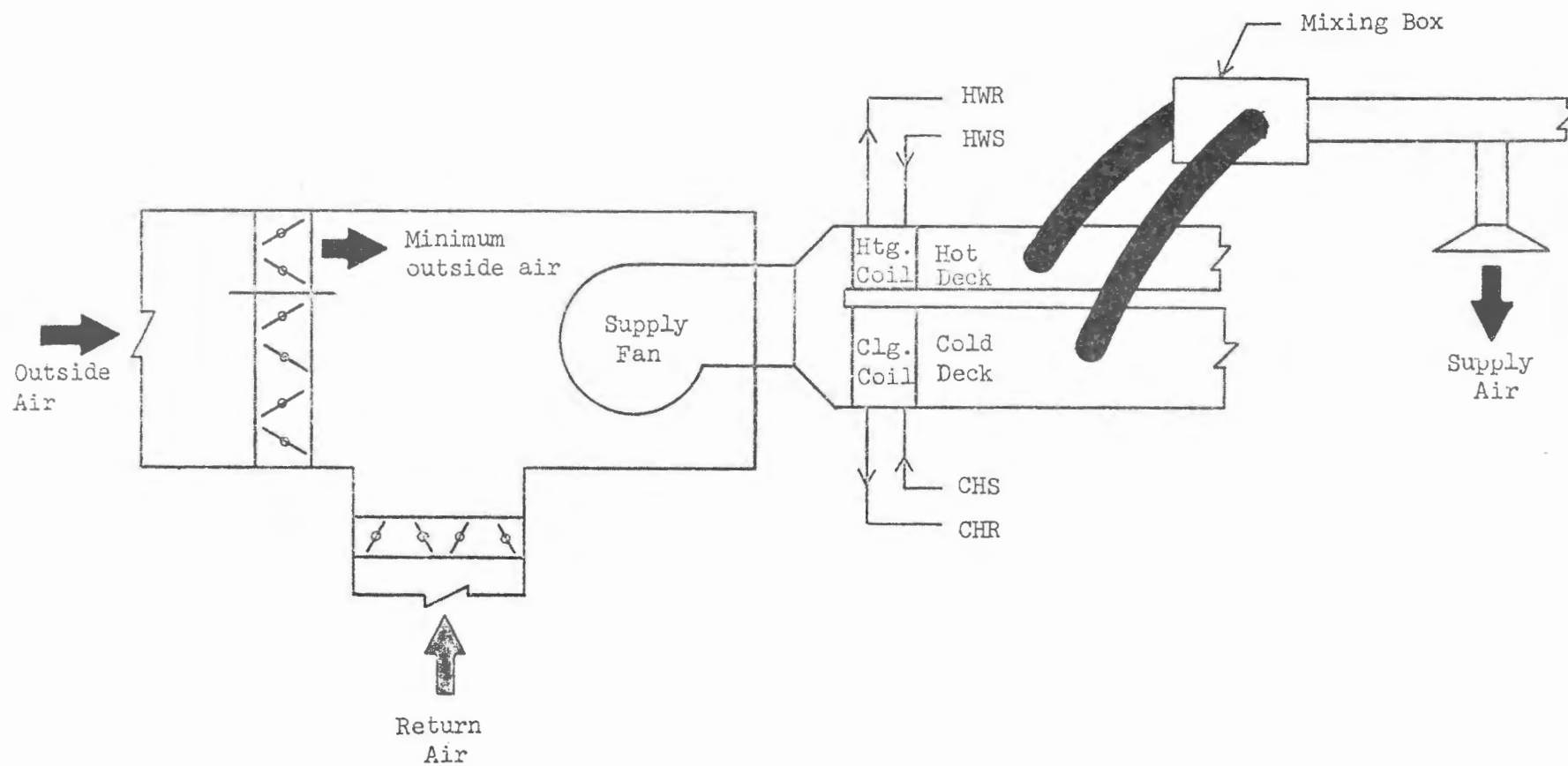


Figure 20 DUAL-DUCT FAN SYSTEM

## CAPITAL COSTS

\*\*\*\*\*

PROJECT MODEL CLASS 1 OPTION 7.2 GAS HOT WATER HEATING GAS ABSORPTION COOLING  
 BUILDING LIFE 30 YRS

| ITEM           | COST \$ | LIFE YRS | ESCALATION RATE % | INTEREST RATE % | PRESENT VALUE COST \$ | ANNUITY \$ |        |
|----------------|---------|----------|-------------------|-----------------|-----------------------|------------|--------|
| **             | *****   | ***      | ****              | ****            | *****                 | *****      |        |
| AIR SYSTEM     | 1       | 842000   | 30                | 3.0             | 7.5                   | 842000     | 71293  |
| HEATING SYSTEM | 2       | 263000   | 30                | 3.0             | 7.5                   | 263000     | 22268  |
| CONTROL SYSTEM | 3       | 202500   | 30                | 3.0             | 7.5                   | 202500     | 17145  |
| CENTRAL PANEL  | 4       | 61000    | 30                | 3.0             | 7.5                   | 61000      | 5164   |
| HEATING PLANT  | 5       | 76000    | 20                | 3.0             | 7.5                   | 108313     | 9171   |
| FLOOR SPACE    | 6       | 24000    | 30                | 6.0             | 7.5                   | 24000      | 2032   |
| COOLING PLANT  | 7       | 314000   | 17                | 3.0             | 7.5                   | 465781     | 39438  |
| FLOOR SPACE    | 8       | 20500    | 30                | 6.0             | 7.5                   | 20500      | 1735   |
| PLBG. & FIRE   | 9       | 405000   | 30                | 3.0             | 7.5                   | 405000     | 34291  |
| LIGHTING       | 10      | 650000   | 30                | 3.0             | 7.5                   | 650000     | 55036  |
| ELEC. POWER    | 11      | 650000   | 30                | 3.0             | 7.5                   | 650000     | 55036  |
| BUILDING       | 12      | 7427000  | 30                | 6.0             | 7.5                   | 7427000    | 628853 |
| TOTALS         |         |          |                   |                 |                       |            |        |
|                |         | *****    |                   |                 |                       | *****      | *****  |
|                |         | 10935000 |                   |                 |                       | 11119095   | 941467 |

## ANNUAL COSTS

\*\*\*\*\*

|                |    |        |    |     |     |          |         |
|----------------|----|--------|----|-----|-----|----------|---------|
| AIR SYSTEM     | 1  | 42100  | 30 | 6.0 | 7.5 | 1023341  | 86647   |
| HEATING SYSTEM | 2  | 13200  | 30 | 6.0 | 7.5 | 320857   | 27167   |
| CONTROL SYSTEM | 3  | 14175  | 30 | 6.0 | 7.5 | 344557   | 29174   |
| CENTRAL PANEL  | 4  | 1200   | 30 | 6.0 | 7.5 | 29168    | 2469    |
| HEATING PLANT  | 5  | 345    | 30 | 6.0 | 7.5 | 8386     | 710     |
| OP. MANPOWER   | 6  | 104472 | 30 | 8.0 | 7.5 | 3370609  | 285393  |
| COOLING PLANT  | 7  | 2700   | 30 | 6.0 | 7.5 | 65629    | 5556    |
| PLBG. & FIRE   | 9  | 20250  | 30 | 6.0 | 7.5 | 492224   | 41677   |
| LIGHTING       | 10 | 18250  | 30 | 6.0 | 7.5 | 443609   | 37560   |
| ELEC. POWER    | 11 | 18250  | 30 | 6.0 | 7.5 | 443609   | 37560   |
| BUILDING       | 12 | 405000 | 30 | 6.0 | 7.5 | 9844493  | 833545  |
| ELEC. ENERGY   | 13 | 95465  | 30 | 3.0 | 7.5 | 1579284  | 133719  |
| FOSSIL ENERGY  | 14 | 17233  | 30 | 3.0 | 7.5 | 285086   | 24138   |
| TOTALS         |    |        |    |     |     |          |         |
|                |    | *****  |    |     |     | *****    | *****   |
|                |    | 752640 |    |     |     | 18250859 | 1545322 |

## GRAND TOTAL

11687640

29369954

2486790

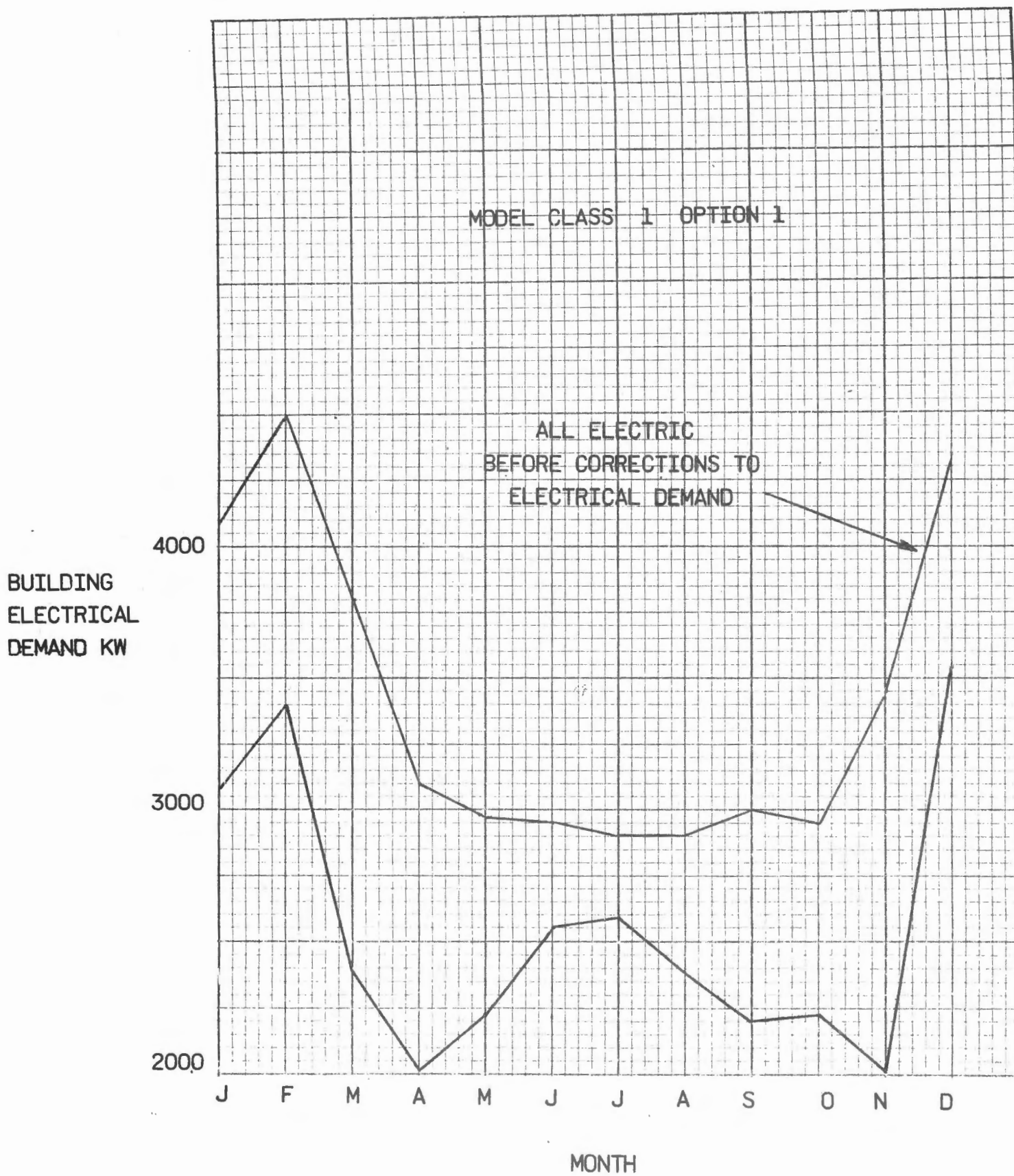
| GLASS<br>TYPE              |   | GAS<br>COST       | ELECTRIC<br>COST  | TOTAL<br>GAS-ELECTRIC<br>COST |   | ALL<br>ELECTRIC<br>COST |
|----------------------------|---|-------------------|-------------------|-------------------------------|---|-------------------------|
| <u>          </u>          |   | <u>          </u> | <u>          </u> | <u>          </u>             |   | <u>          </u>       |
| DOUBLE<br>GLAZED<br>BLINDS |   | \$8,495           | \$109,042         | \$117,537                     |   | \$146,958               |
| SOLAR<br>REFLECTING        |   | <u>\$9,404</u>    | <u>\$104,111</u>  | <u>\$113,315</u>              |   | <u>\$147,889</u>        |
|                            | + | \$909             | \$4,931           | \$4,222                       | + | \$931                   |
| % CHANGE                   | + | 10%               | 5%                | 4%                            | + | 0.6%                    |

| LOCATION          | GAS<br>COST       | ELECTRIC<br>COST  | TOTAL<br>GAS-ELECTRIC<br>COST | ALL<br>ELECTRIC<br>COST |
|-------------------|-------------------|-------------------|-------------------------------|-------------------------|
| <u>          </u> | <u>          </u> | <u>          </u> | <u>          </u>             | <u>          </u>       |
| HULL              | \$8,543           | \$95,303          | \$103,846                     | \$116,469               |
| OTTAWA            | \$8,495           | \$109,042         | \$117,537                     | \$146,958               |
|                   | <u>          </u> | <u>          </u> | <u>          </u>             | <u>          </u>       |
|                   | 48                | + 13,739          | + 13,691                      | + 30,489                |
| % CHANGE          |                   | + 14.4%           | + 13.2%                       | + 26%                   |

| AIR<br>SYSTEM       | GAS<br>COST       | ELECTRICAL<br>COST | TOTAL<br>GAS-ELECTRIC<br>COST | ALL<br>ELECTRIC<br>COST |
|---------------------|-------------------|--------------------|-------------------------------|-------------------------|
| <u>          </u>   | <u>          </u> | <u>          </u>  | <u>          </u>             | <u>          </u>       |
| VARIABLE<br>VOLUME  | \$8,543           | \$95,303           | \$103,846                     | \$116,469               |
| DUAL DUCT<br>REHEAT | \$9,718           | \$97,701           | \$107,419                     | \$118,347               |
|                     | <u>          </u> | <u>          </u>  | <u>          </u>             | <u>          </u>       |
|                     | \$1,175           | \$2,498            | \$3,573                       | \$1,878                 |
| % CHANGE            | 13.7%             | 2.5%               | 3.4%                          | 1.6%                    |

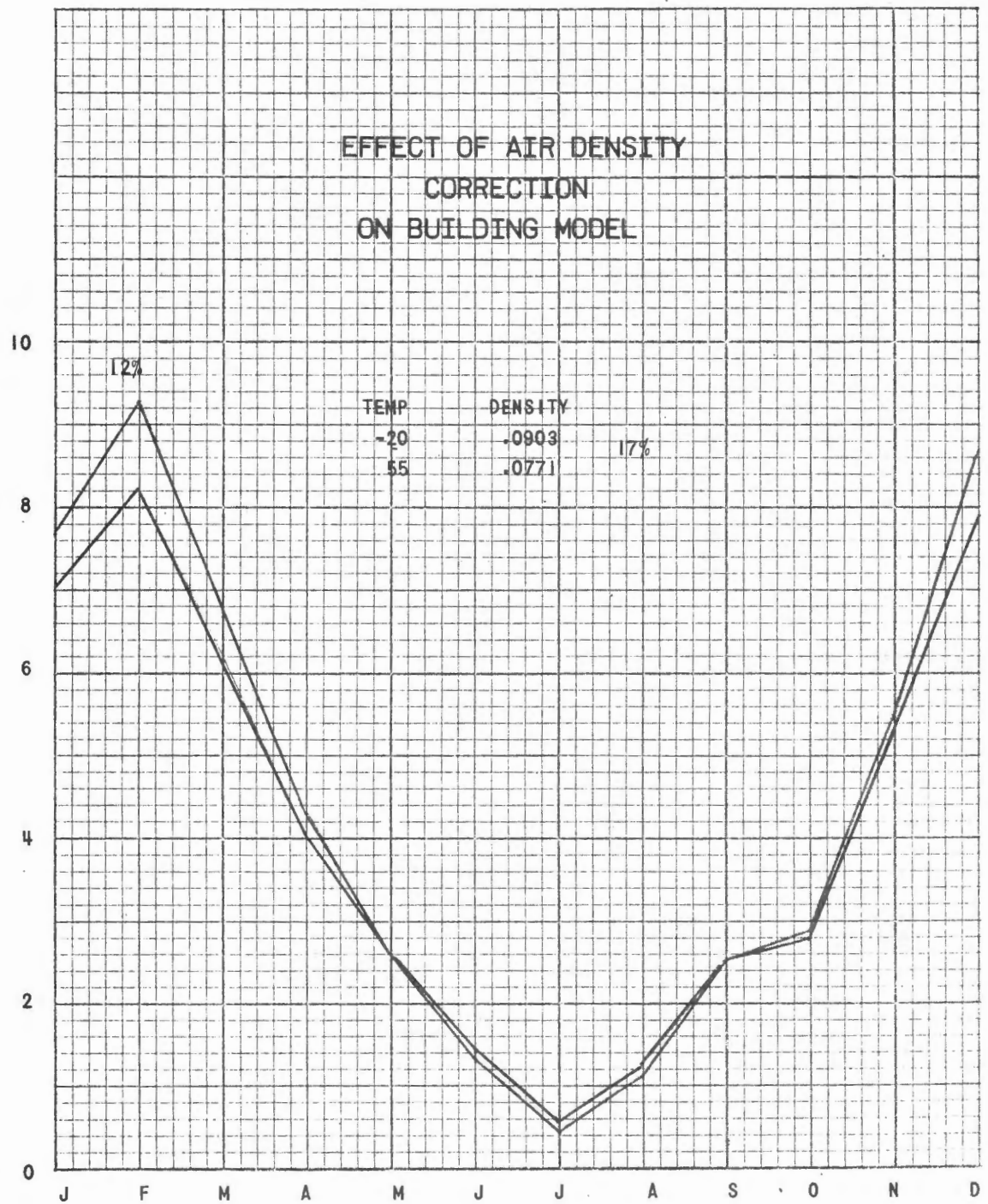
| VENTILATION       | GAS<br>COST       | ELECTRIC<br>COST  | TOTAL<br>GAS-ELECTRIC<br>COST | ALL<br>ELECTRIC<br>COST |
|-------------------|-------------------|-------------------|-------------------------------|-------------------------|
| <u>          </u> | <u>          </u> | <u>          </u> | <u>          </u>             | <u>          </u>       |
| 24 HOUR           | \$8,543           | \$95,303          | \$103,846                     | \$116,469               |
| 12 HOUR           | \$547             | \$95,034          | \$95,581                      | \$88,804                |
|                   | <u>          </u> | <u>          </u> | <u>          </u>             | <u>          </u>       |
|                   | \$7,996           | \$269             | \$8,265                       | \$27,665                |
| % CHANGE          | 95%               | 1%                | 8%                            | 24%                     |

| LIGHTING<br>LEVEL | GAS<br>COST       | ELECTRIC<br>COST  | TOTAL<br>GAS-ELECTRIC<br>COST | ALL<br>ELECTRIC<br>COST |
|-------------------|-------------------|-------------------|-------------------------------|-------------------------|
| <u>          </u> | <u>          </u> | <u>          </u> | <u>          </u>             | <u>          </u>       |
| 4.5W/SQ. FT.      | \$8,543           | \$95,303          | \$103,846                     | \$116,469               |
| 2.25W/SQ. FT.     | \$11,359          | \$59,937          | \$71,296                      | \$101,502               |
|                   | <u>          </u> | <u>          </u> | <u>          </u>             | <u>          </u>       |
|                   | + \$2,816         | \$35,366          | \$32,550                      | \$14,967                |
| % CHANGE          | + 33%             | 37%               | 32%                           | 13%                     |

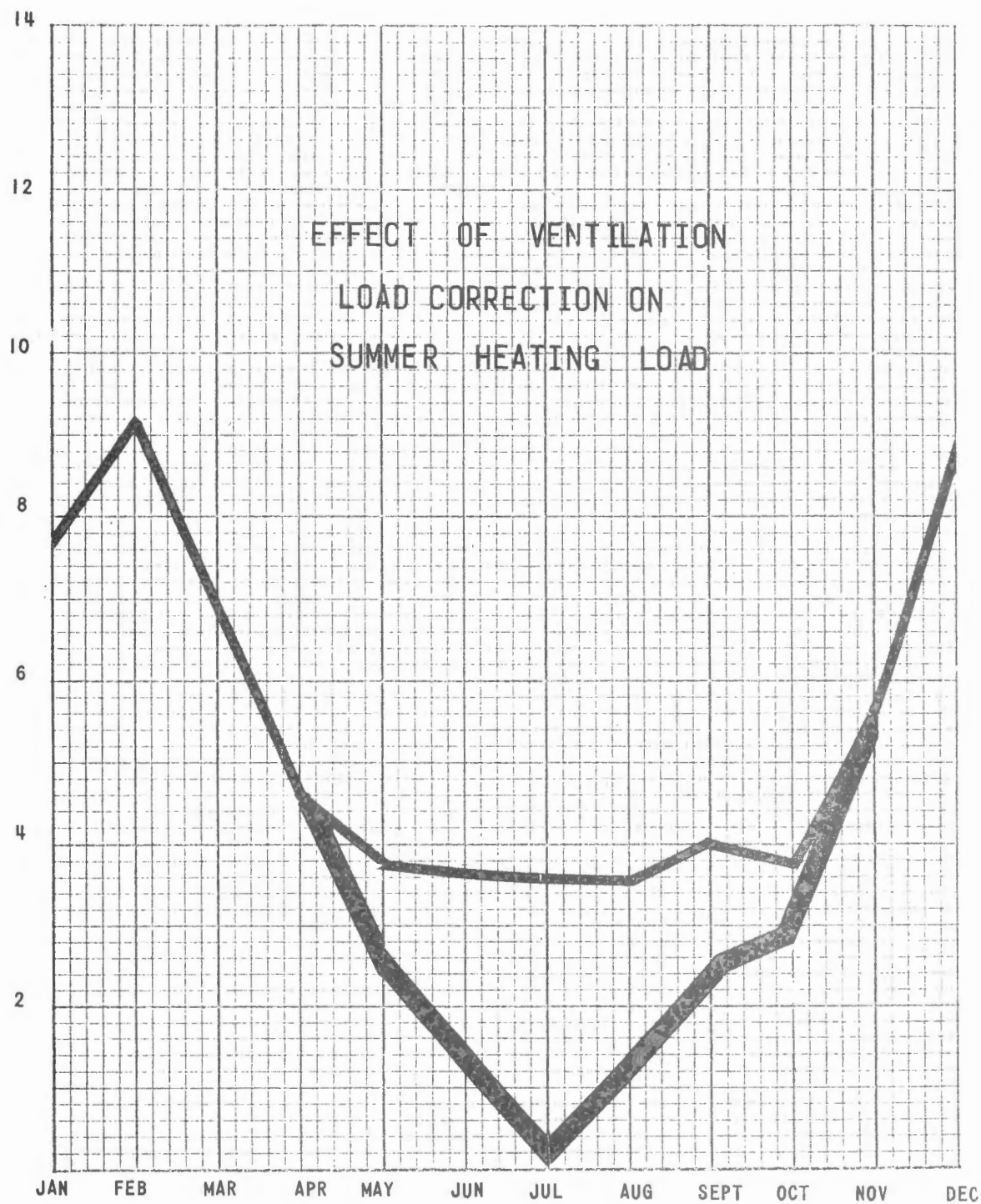




PEAK  
HEATING  
LOAD  
MBH



HEATING  
DEMAND  
 $10^6$  BTU



## BUILDING MODEL

FLOOR AREA    – GROSS 405,000 SQ. FT  
                      – NET    320,000 SQ. FT

WALLS & ROOF –  $U = 0.12 \text{ BTU/SQ. FT./}^{\circ}\text{F}$

WINDOWS        – 40% of EXTERIOR WALL  
                      – DOUBLE GLAZED  
                      – VENETIAN BLINDS    $SC=0.51$

VENTILATION    – 0.2 C.F.M. OUTSIDE AIR/NET SQ. FT.

ELECTRICAL  
  – INTERNAL        4.5 W/NET SQ. FT.  
                             SCHEDULE 8:30 – 8:30 MON. THRU. FRI.

  – EXTERNAL        20 KW (AFTER DARK)

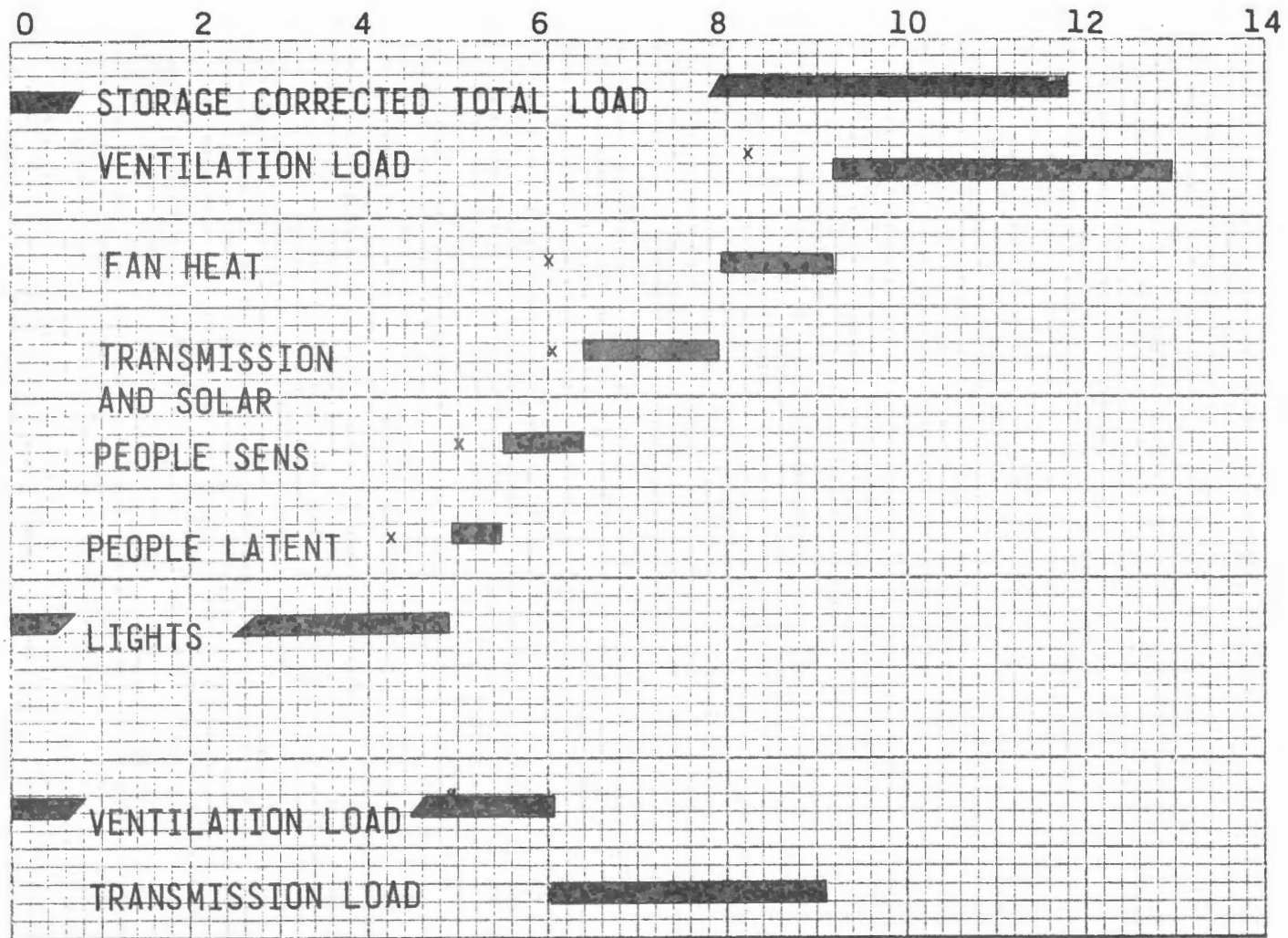
  – FAN STATIC PRESSURE 9"

  – PUMP HEADS 60 FT

OCCUPANCY      – OFFICE  
                      – 3200 PEOPLE  
                             SCHEDULE 8:30 – 5:00  
                             MON. THRU. FRI.

MECHANICAL    – AIR COOLING  
                      – HOT WATER PERIPHERAL HEATING

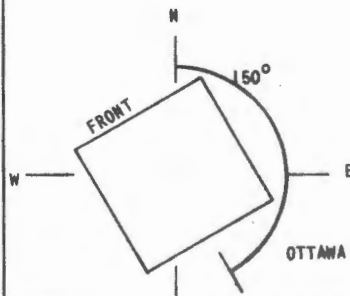
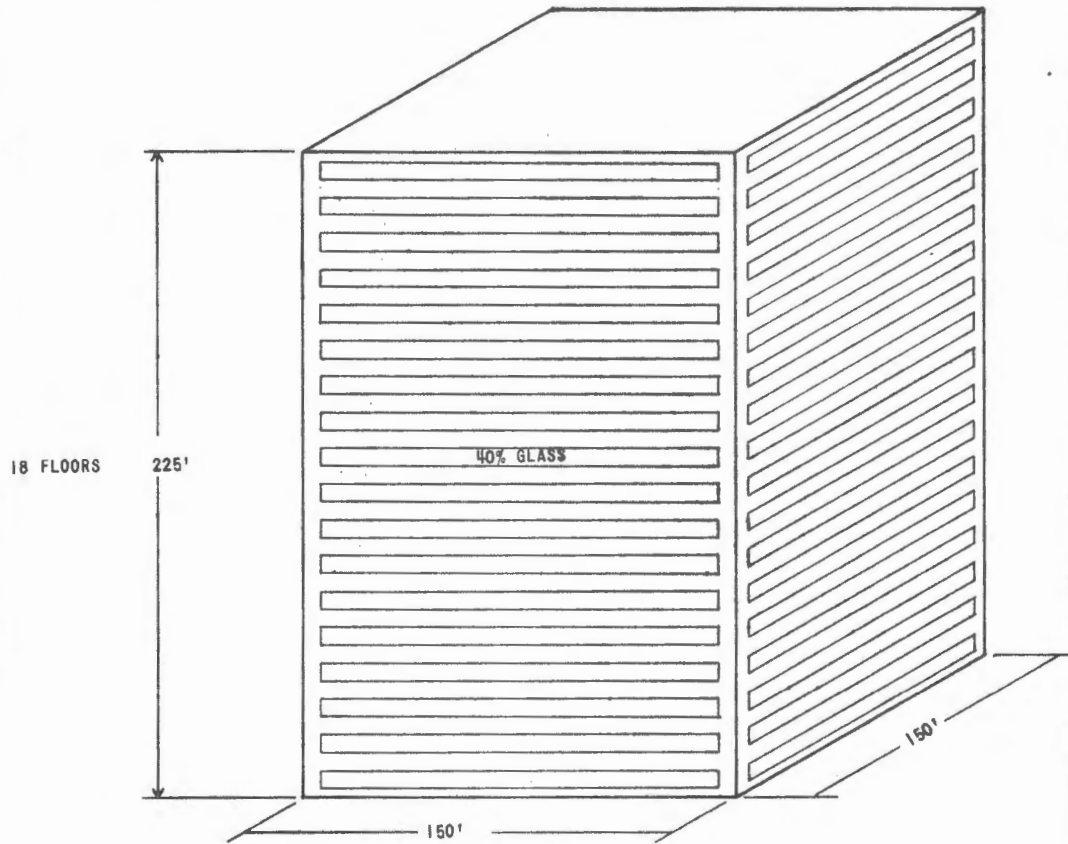
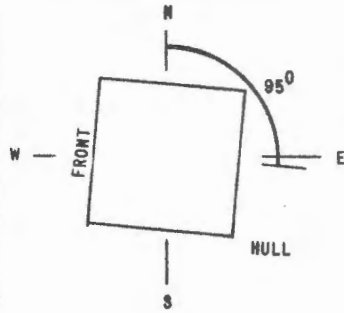
# THERMAL DEMAND LOAD $10^6$ BTU



COOLING  
LOADS

HEATING  
LOADS

# MODEL CLASS 1



DEPARTMENT OF PUBLIC WORKS

BUILDING CONSTRUCTION BRANCH

CANADA

J.A. Langford

DISTRICT ARCHITECT

DISTRICT ARCHITECT

Drawing title:

scale:

date

revisions

designed by:

date

drawn by:

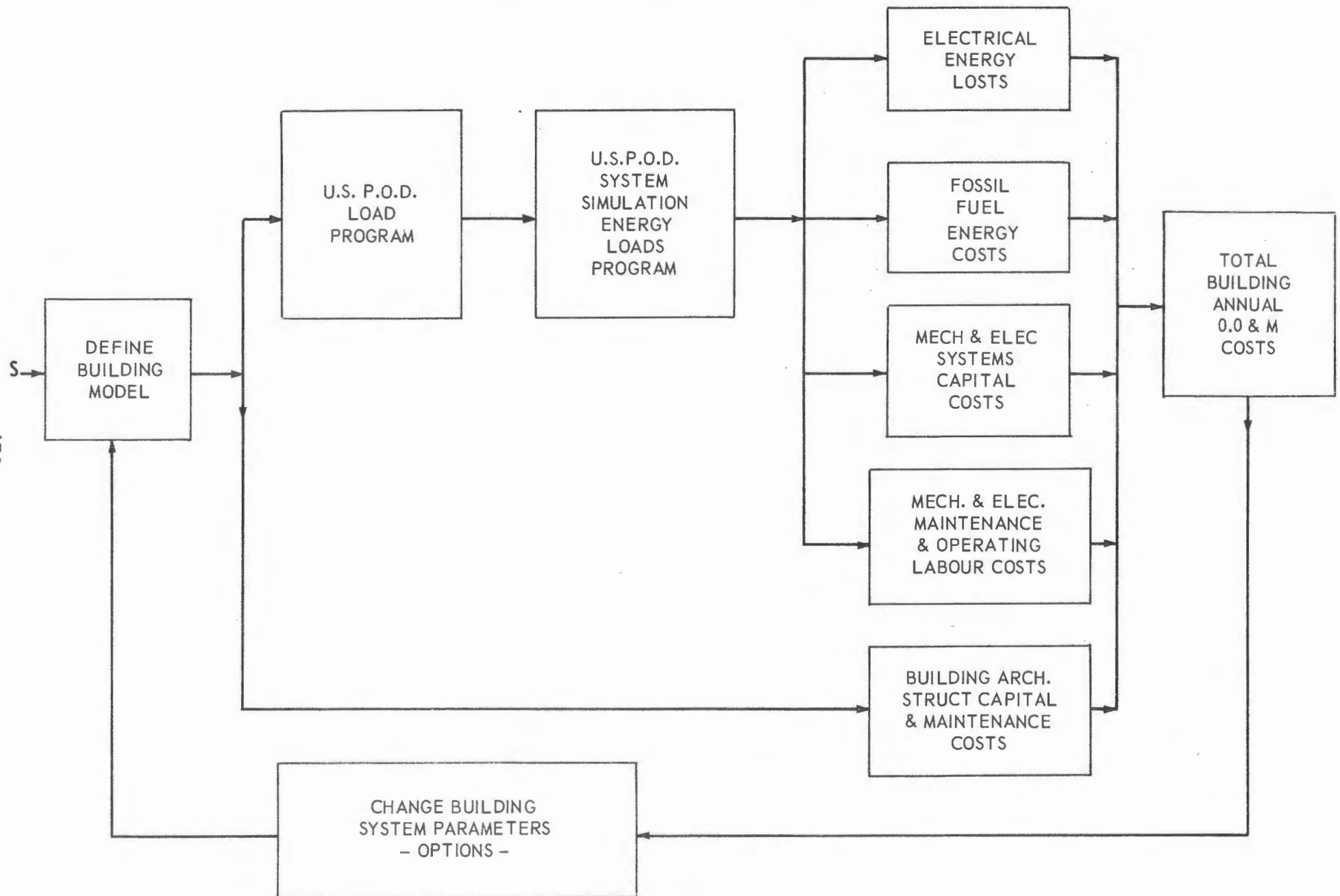
reviewed by:

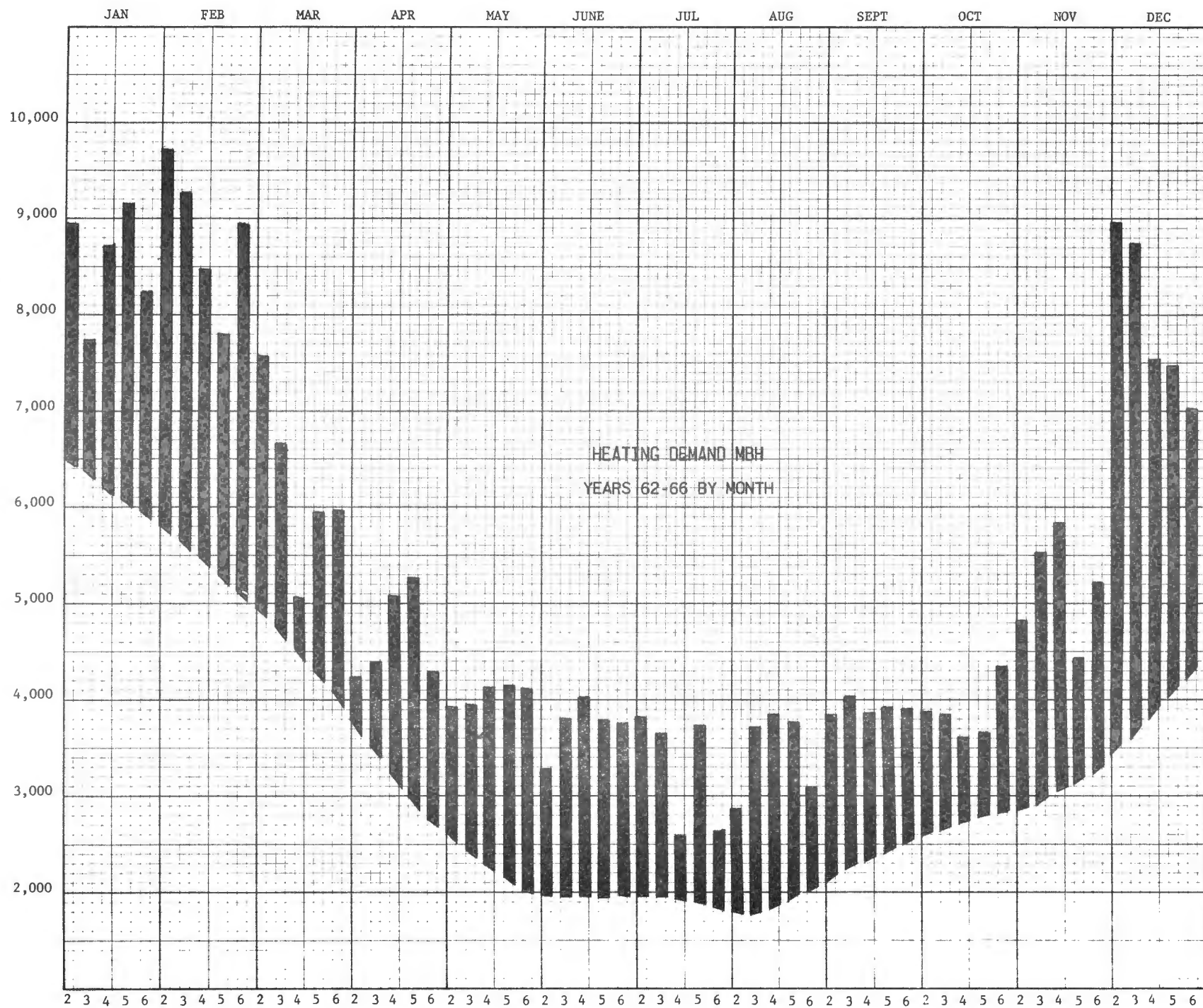
approved by:

job number:

Draw  
no.

# PRELIMINARY BUILDING ANALYSIS SYSTEM





One quickie announcement from Mr. Allen, Second Vice-President of APEC. Automated Procedures for Engineering Consultants, APEC, will hold an energy symposium at their annual meeting in Miami, this October 27 and 29. At this symposium, the energy requirements for a hypothetical building will be compared as calculated by nearly a score of programs.

Mr. Ken Fleetwood, from the Postal Service, now will make a few remarks and answer one question that was directed specifically to the Postal Service about the use of the program.

MR. FLEETWOOD: On behalf of the Postal Service, I would like to say that I think -- with tongue in cheek -- that we have accomplished a good bit of our objectives here today.

Up until today, the program had been reviewed by you people in print. Many questions, many inquiries, have been directed to us, and we felt that some type of informal meeting like this, where some of our users could cite their experiences and have a genuine critique of the program, would lay a basis for future refinements, and as one of the speakers had said today, there is any number of systems, any number of programs, possibly some consolidations. So that in the future we will all accomplish the mission that we have all set out to do.

Now, in this behalf I would like to especially thank the individuals who have contributed to this program in their presentations. I would like to thank the National Security Industrial Association for the role that they played in helping us put this program on. And more importantly, on behalf of the Postal Service, I would like to thank you, the principal representatives of the industry, for your enthusiasm in attending here today.

Thank you very much.



Now, I have one question here that has been directed to the U.S. Postal Service, which I will answer at this time, and then we will have a stretch break. Then we will return for a final question and answer session.

The question is, "Will the use of this program be required on Postal Service buildings? And if so, how will the AE be paid for it? Has this been done yet? What was the extra cost for a given building?"

Well, as you all know from Mr. Isaacs' and General Rebh's presentations here this morning, that we have been going through a lot of changes in the Postal Service. Our major building and modernization program is one of the primary changes. Now, when this program was initiated, we were doing our building and modernization program in-house. It was inaugurated to give us a basis for a more scientific and exacting approach to accomplishing this mission. Now, even then, at that time, we hired AE's at the outset to prepare the specifications and drawings, but we went through the artists' approach of examining those, determining whether the requirements were complete, and if the equipment and what not was tailored to do the job.

It is anticipated that the Corps in their assignment, in taking over our modernization and major building program, will continue to do this.

Now we will have a stretch break and return for final questions and answers. Thank you.

## QUESTIONS AND ANSWERS

Q: When and where can the program be obtained?

A: (Dr. Stillman) I am working on an internal project for the Real Estate and Construction Division of IBM. The program will belong to that division. They have not as yet decided whether the program will be released, how it will be released, or what is going to happen.

They also feel that some of my remarks are critical of the program. I do not want to leave that impression. As far as I am concerned, the load program is a very good program. The systems simulation program is just not useful for the type of buildings that we are interested in, it is as simple as that. It had to be rewritten. It is not critical, it is just that they do not have the things in the program that we need. For the post offices, they do. I feel that, realistically, any engineer who wants to use the program is going to have to make some changes.

Q: What did the designer use?

A: (Dr. Stillman) I tuned my model to the design calculations, and as far as I know, he used the ASHRAE procedures in the handbook. But you know, I am not that familiar with it.

Q: What will be the smallest IBM system the system will run on? What computation devices, CPU requirement, average run time, total programs?

A: (Mr. Lokmanhekim) The program can be run in any IBM 360 system, but our suggestion is, minimum configuration to use IBM 360-65 to obtain the cheapest, at least cheaper run. CPU minimum requirement depends upon the size of the building. The average running time changed from one over 50 seconds to one over 100 seconds per space per hour.

Q: How many man-hours did it take to prepare the computer inputs to make the complete run?

A: (Mr. Lokmanhekim) What we did in our GARD building was

to see how the engineers tried to understand the manuals and how they prepared the data. For this reason, we gave the assignment to an engineer who was not exposed to this program before. For him, the data take off took approximately three days, three man-days. And according to this gentlemen, he mentioned to me several times that if he does the same job again, it will take only one day. This tells me one thing; the first job is difficult, the second job becomes very simple.

The running time for the GARD building on computer took 15 minutes on a Univac 1108. For a full-year run on the load calculation, systems simulation takes only 2 minutes.

Q: Do you verify weather tapes prior to use in energy programs?

A: (Mr. Lokmanhekim) We at General American Research were involved with the U. S. Weather Bureau tape, for a Civil Defense program, several years before this program. We were very familiar with the tape and what the difficulties were in handling tape. We do not verify, but we have routines and check the possible troubles on the tape.

Q: Can you use this program on a GE time-sharing system?

A: (Mr. Lokmanhekim) Yes, you can use this program on a GE time-sharing system, except one routine -- weather decoding routine. This routine should be adjusted for GE time-sharing system. Right now, the U. S. Air Force is using this program on a GE time-sharing system.

Q: The 1967 methodology uses the time-averaging method for converting the heat-gain to cooling load. And in this particular portion, we are using the radiant portion, the long-wave radiation or short-wave radiation portion. But we are treating the convection portion instantaneous. The question is, Is this method still valid for the new methodology -- "new" means that new book we released.

A: (Dr. Kusuda) Yes, we only treat the radiation portion, the heat gets into the wall directly by the weighting factors portion; but the convection portion is always instantaneous. This is the way we assume it. Assumption may not be valid, but at least theoretically, the convection portion is more instantaneous than the radiation portion.

Q: Why is there a large difference in temperature profile when the insulation is inside or when insulation is outside?

A: (Dr. Kusuda) When insulation is outside, the large temperature fluctuation would be decreased considerably by the concrete. For that reason, the concrete structure does not store the heat and that is the reason that the temperature will be very stable inside when insulation is outside. If concrete is outside and insulation is inside, you can see outside heat will be stored in the concrete block, and that gets into the building. That is why we have a large temperature swing within the building when insulation is outside.

The idea is to minimize the energy requirements particularly, and also keep a very stable temperature and maintain the structural stability. Having insulation outside is the better choice than having insulation inside. This is against the conventional construction methods sometimes, so there might be difficulty there. By this particular example, we are simply showing the location of the insulation is effective for minimizing temperature fluctuation and also effective for reducing the energy requirements.

Q: How does the NBS data check routine, in conjunction with the graphic display system, work?

A: (Dr. Holmes) While we were checking the Postal Service program for the three postal buildings, we developed the graphic display routine so all we do is have a separate routine. After all the data cards are prepared, we run this coordinate system into the data check routine. This will then produce the isometric drawing of the building you put it in.

For instance, if you made a mistake, you could see window around here and wall around here and you could see that you did make a mistake, and sometimes you have some of the extortion misplaced or completely omitted. So this is an extremely powerful tool for checking the data. But unfortunately, this kind of graphic routine depends on having access to the large computer. It is not immediately usable. If anyone wants to play around with it, I will be glad to send some of the documents we have.

Q: What system simulation routines were verified by field test?

A: (Dr. Holmes) As far as I know, no system simulation has been verified by field test, but I may be wrong.

Q: Are these the correct numbers for the 250-bed hospital? 1000 keypunch and special processor charges, two man-months engineering for four design days. Can you estimate costs for 365-day energy analysis?

A: (Mr. Cumali) The costs given here for a one-time run are about \$200.00, and a good portion of this is spent initially to analyze the input data, compute the response factors, and then run for 16 days. On this basis, if we were to run the 620 zones for this hospital for three days, it would take approximately three hours of machine time, and it would depend on what time of the night you ran, but you would probably have a cost of around \$3,000.00 to \$4,000.00.

This would be the cost for running. Normally, when you are doing energy analysis, you do not run it for 620 zones. You just put it together in fan zones and run smaller portions of it.

Q: Are the changes and modifications your company has made to the program available to the public, or have they been incorporated in the present, official version?

A: (Mr. Cumali) To my knowledge, these changes have not been incorporated into the present official version. Some of them may have been, but one manual effort that we have put into this program for making changes is not available to the public in the Postal Service fashion.

Q: Why does a company need computer experiences?

A: (Mr. Cumali) I assume you mean systems and programming to use the program over. The basic reason was really this, first of all as Dr. Stillman said, when you get into a point in the program which it cannot handle, it simply stops.

So it does require computer experience. This is part of it. And the other part is, if you have not had computer experience, you probably would not have the patience to run the program.

Q: How would you suggest implementing the dynamic data allocation?

- A: (Mr. Cumali) We basically have made these changes. We have two versions of the program. One major change on the postal version is we have essentially completely rewritten a section which we will be making available publically sometime over the next year.
- Q: Is statistical data on maintenance and replacement costs for various types of systems available?
- A: (Mr. Henninger) I do not know of any. I know the group that is in the Postal Service that the program was turned over to, tried to develop some maintenance and replacement cost data. I do not know if it is available or not.
- Q: Does the program take into account the interest cost of money.
- A: (Mr. Henninger) Yes, when we first started considering as to how we were going to handle the economic analysis, we talked to the Bureau of Finance in the Postal Service and asked whether we would write the economic analysis of the program on the basis that the buildings are going to be federally owned or privately owned? The answer then was, and please remember this was back four or five years ago, that the economic analysis of programs should be written for a government-owned building. Therefore, we do not take into account any depreciation as such in our life-cycle cost analysis.
- However, we do account for salvage value of the equipment at the end of the building life. So in a sense, we do account for some depreciation.
- Q: Does the economic analysis take into account depreciation, maintenance and labor, in the annual owning and operating costs?
- A: (Mr. Henninger) Depreciation, no, only in the sense of salvage value; the annual cost of labor and maintenance, yes, there is that capability.
- Q: In the economic analysis, it would be helpful if the cost of money was included. Can this be added to the program?
- A: (Mr. Henninger) The answer is that it is already in the program. We do calculate cost based upon the present value technique.

- Q: Can this program provide an economic analysis of a centralized versus decentralized system?
- A: (Mr. Henninger) We do have the capability of analyzing some package systems, and this feature of the program could be used to evaluate centralized versus decentralized systems.
- Q: Can the program optimize building orientation?
- A: (Mr. Henninger) The answer is yes. By just, I believe, changing one input card in the load calculations of the program and running the program again, you can evaluate what effect the orientation has on the building.
- Q: Can the program optimize number of boilers, chillers, etc., based on the total-load and part-load characteristics?
- A: (Mr. Henninger) No, there is no optimization of how many boilers and so forth under the program. We size boilers and chillers based upon the assumption that the chillers are all equal size, for one thing. We then implement up from there, based upon the size of the equipment that the program is giving. In terms of boilers, the number of boilers is an input.
- Q: How are installation costs handled in the financial analysis input?
- A: (Mr. Henninger) The only help that the program gives you in determining installation costs is only in terms of how many of each type of equipment and the size and so forth that the program is calling out, and from there it would be up to the engineer to go out and get his first cost estimates.
- Q: Do you have an edit routine to verify all "Weather Bureau", and if so, what are the options? We have had trouble with obtaining weather data information with missing cards.
- A: (Mr. Bycraft) I understand that is a bigger problem in the States. Our weather records in Canada have been extremely good, but we do have an editing routine. We edit everything. We have to rewrite the format of the Canadian weather data in the format of the program, but I do not work alone. I have a lot of experts and they do this very easily, and weather data has not been a problem for us.

Q: When using the program for non-postal buildings, why would a consulting engineer want to increase his liability, increase his "trouble calls" and cut his fee by sizing equipment so marginal? Equipment is seldom operated optimally, due to incompetent operators, fouling of tubes, plugging of strainers, filters, etc.?

A: (Mr. Anders) The program does not necessarily design and select the equipment oversized or anything like that. In fact, my personal experience is this. I have far more trouble with oversized equipment than I do with undersized equipment. I have more trouble calls, more problems, more service, more maintenance, more everything.

You may say, "well I do not understand that kind of stuff?" Well, I have been in the service building a long time, and at the same time I have been fixing systems now for a great many years, and we have far more trouble with oversized systems. The principal reason for this is because it is fundamental. By definition, no system ever operates at full capacity, even if it is designed at optimum capacity requirements, it does not operate at full capacity under the ASHRAE calculating procedures, except for about two and a half percent of the time.

The rest of the time, the system is operating below minimum capacity on part-load conditions. We are not talking about designing in what I call ignorance factors. And that is what the program eliminates, really. In answer to this, I believe that through the use of a program of this nature, the consulting engineer is reducing his liability, his trouble calls, and I believe that when he becomes successful in applying it, he can increase his fee, because he can then give the client a much higher degree of reliability in the perfection of his system design than he could prior to this time.

And we say we are sizing the equipment marginal. This is not sizing the equipment marginal; it is sizing the equipment in such a way that it will respond to those thermal loads that are placed on it. Many of our systems today will not do that, especially at part-load.

Q: Can you estimate running time, input time, cost for about 200 zones, for a different system?

A: (Mr. Lokmanhekim) I cannot estimate the data preparation time. This depends on who you are using. I can



estimate the running time. Running time will be 1000 to 2000 hours. Actually, after you produce your load tape, the system simulation goes very easy.

Q: What is the cost of funding a complete program for a 100 space multi-story building?

A: (Mr. Lokmanhekim) We have done this thing exactly. We ran the Minneapolis Post Office building. It is a 109 space multi-story building and it took three hours and fifteen minutes on an IBM 360-65. In dollars, that means \$1000.00.

If you go to a bigger computer system, it will be cheaper.

Q: In calculating wall factor, does the computer consider wind direction and velocity effect on surface film coefficient?

A: (Mr. Lokmanhekim) The outside film coefficient is changed every hour according to wind velocity, not wind direction.

Q: Can the X, Y, Z coordinates to describe building geometry be used to describe circular buildings?

A: (Mr. Lokmanhekim) The answer to this question is, yes. You can even represent spherical buildings if you have it. We have done that.

Q: What established shape of terminal response curve for each increment of Delta-T? Is its shape similar for all materials?

A: (Mr. Lokmanhekim) The general shape is similar, but the coordinate, which is the response factor, changes according to thermal capacity of the material.

Q: What is the advantage of X, Y, Z coordinate system over conventional orientation areas, etc.? It appears to me that it takes more time and effort to prepare input.

A: (Mr. Lokmanhekim) It takes more time and effort to prepare input, but it gives you a more accurate result.

As Dr. Stillman mentioned in his example, shadow becomes very important sometimes. If you are going into a shadow routine, you need X, Y, Z coordinate system. Furthermore, X, Y, Z coordinate system not only helps in this kind of program, but I am sure some of you are familiar with the APEC concept of the overall building industry. If you go to some other field of engineering, like piping, electric distribution, etc., this X, Y, Z base data coordinate system helps you very much and that is the one you really have to work.

Q: In practical sense, is the program useful for analysis of existing heating, ventilation, air conditioning, insulation, to identify more economical and efficient operation for future?

A: (Mr. Lokmanhekim) Yes.

Q: Have you considered operational-type buildings with areas during which the interior temperature may cause periods of no interior cooling or heating?

A: (Mr. Lokmanhekim) Yes.

Q: There are indoor design conditions entered in the program. In the load calculation program, can both minimum outdoor air cycle and variable outdoor air cycle be simulated?

A: (Mr. Bycraft) The indoor temperature is fixed at 75 degrees F and the simulation in every outdoor cycle is in the simulation sub-programs except for on-sight generation systems.

Q: Does the program take into account the mass of interior items, file, cabinets, masonry, etc.?

A: (Mr. Lokmanhekim) At the present time, the postal version does not take that into account, only the floor. But in the program right now, we have the Z-component of the response factor already calculated. That means with some more calculation, you are able to include these things in the program. That means also, as Dr. Kusuda mentioned, varying inside temperatures. That can be easily done.

Q: Will the Postal Service maintain an official version of the program and provide periodic updates to users?

- A: (Mr. Lokmanhekim) To the best of my knowledge, the Postal Service does not provide any periodic updates and future plans are not known. Actually, the Postal Service has the first version of the program, and since then, I have maybe 100 versions. I change every day. We have our own flow charts to work on and since we do not use any files, there is no file laid out.
- Q: Is it possible to reduce the complexity and time required to input the building geometry and wall areas? What will be the advantaged time spent in inputting this data?
- A: (Mr. Lokmanhekim) As I mentioned, yes, it is possible. The advantage of putting this data in detail is doing more detailed calculations. Conservative estimates indicate 35 percent first costs and 30 percent operating and maintenance costs. This is what we were obtaining. Approximately, we are getting 30 percent lower size in the equipment selection.
- Q: Can a complex of buildings be studied with a center representation plan?
- A: (Mr. Lokmanhekim) Yes.
- Q: What is being done to simplify input data?
- A: (Mr. Lokmanhekim) As you see, in the presentation this afternoon, Mr. Cumali has done something, Dr. Kusuda has done something, Dr. Stillman has done something, and we have done something. But unfortunately, there are things that everybody did according to their own needs. The official postal version, as I mentioned, is the first version of the program.
- Q: Have alternate presentations to X, Y plotter output been developed?
- A: (Mr. Henninger) The plotting program that we provided to the Postal Service was for use on an IBM 1130 computer they had at the time. This was the only plotting capability that they had, and therefore, we wrote what we called a punch sub-program to read through the load tape which was prepared by the load calculations sub-program, punch out the data on cards so that this card input could then be inputted to the IBM 1130, which does not have a tape input capability, and make plots.

Q: There are several questions on the use of the economizer cycle and the way we use outside air cooling in the program.

A: (Mr. Anders) I think it was Dr. Stillman who said that we had no infiltration cycle or infiltration routine on this and it was needed. This is so. There is no infiltration sub-routine for this program. We eliminated this because of the philosophy of design that had been in existence by the Postal Service which is this; we would operate on a pressurized building basis. We set that at all-exhaust air, plus one air change, or ten percent of the circulated air, whichever is greater.

It was a pressurized building. There is another thing that we had very firmly fixed in our minds at that time from a design philosophy standpoint, and that was that we would use the outside air cycle to reduce the cooling load requirement. All of our control systems were designed on this basis, everything except that portion of the program that simulates on-site generation systems. That portion of the program uses only minimum outside air. It uses that on the basis of whatever the requirement might be, because we found that when we used on-site generation with heat recovery off the engines or turbines, that really and truly, most of the time our loads, our maximum loads, occurred in the summertime and we got no real benefit. In fact, we penalized the system and we either rejected that heat to the atmosphere to start with, and we especially did it, then, if we used outside air to reduce the cooling load.

There is no advantage to use the outside air cycle in an on-site generation system, using absorption refrigeration machines for heat recovery and cooling effect.

With the outside air cycle accomplished, I think Dr. Stillman may have misinterpreted when he said we did not run the refrigeration system in the wintertime and did not run the heating system in the summertime. We do turn the refrigeration machines off in a conventional system because we bring in outside air at the temperatures that it requires to cool the space. In other words, we let the space thermostat actually operate the outside and return-air dampers in order to bring in the exact temperature. If we need 60-degree air to cool the space, there is no sense in bringing out a mixed air -- bringing in a mixed air condition of 50 degrees and then having to heat that up to 60 degrees to cool the space. This was our philosophy there.

We designed our control systems that way. You can argue

with it. That is the way the program is written. If you do not like it, change it.

Q: Will the program indicate whether total boiler and/or chiller capacity should be in multiple units to facilitate economical operating costs, by only running part of the total equipment during periods of medium heating or cooling demands?

A: (Mr. Henninger) I might say that if you do not like the way the program has gone ahead and sized the equipment, certainly the total capacity of heating and cooling will stay the same, and for the purpose of inputting data to the economic analysis sub-program, you could just go ahead and size that equipment any way, well, no, you can't either. I take that back because certainly the way you would size it very much affects the part-load energy consumption that the system simulation sub-program takes.

It is important, I think, to realize that the program was set up to use chillers all the same size. That was the philosophy that we built into the program. And there is the capability of inputting to the systems simulation program, a minimum cut-off point. So there is that capability.

Q: Can the system simulation sub-program accommodate a refrigeration system which would be part electric refrigeration and part steam-absorption, such as might be required in the use of some electric refrigeration for a computer area?

A: (Mr. Henninger) No, I don't believe that the program has the capability. The engineer would choose a certain type of chiller for a certain run through the program, and the program assumes that all of the chillers are all that type. However, I do not see why it would not be very easy to modify the program, such that you could treat a problem like this.

Q: Are electric maximum demands for each type of load added to give total maximum demand, or is the total integrated to take into account diversity? Now, as input to the load calculation program, you input an hourly schedule of occupancy, lighting, and people for each space. I believe you are able to handle many different types of schedules for each space? Seven types?

A: (Mr. Henninger) Nine. What are they? One for each day of the week, plus Christmas and holiday time. Twenty-seven different types of schedules. So diversity is taken into account this way. Now, Mr. Bycraft was indicating that there was something wrong the way the program was summing together the electric demands together with the demand load, and I checked this out once before when Mr. Bycraft brought it to my attention, but I believe that when looking at the hourly electric loads, heating or cooling, it takes the maximum of the two, and adds in any other electrical consumption. I will have to go back and check it again, but I believe that is the way it was set up.

Q: Are there provisions in the sub-program, gas or oil fuels for heat recovery from prime movers?

A: (Mr. Henninger) In the on-site generation section of the systems simulation we do take into account heat recovery.

Q: Will any official effort be made to rectify the shortcomings brought out in today's talks?

A: There is no Postal decision at this time.

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