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CANADIAN PROGRAM FOR R and D ON ENERGY CONSERVATION IN BUILDINGS

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2.5 CANADIAN PROGRAM FOR R & D ENERGY CONSERVATION IN BUILDINGS

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ABSTRACT.- The program consists of two main parts:

1) Development of energy standards for buildings;

2) Development of alternatives to burning oil and natural gas for heating buildings.

The first part includes the development of improved methods and data for predicting the energy consumption of buildings, the training of designers in the use of the new methods, and the development of energy budgets for various kinds of occupancies, which can be used to judge the effectiveness of a building design from the energy point of view.

The second part deals with ways of utilizing uranium, coal, garbage and by-product heat from industrial processes for heating buildings and sanitary water. (There is a separate program for the utilization of solar energy for these purposes.) The approach that appears to be most promising involves a combination of district heating and the use of electricity.

SOMMAIRE.- Le programme consiste en deux parties principales:

1. L'élaboration de normes d'énergie pour les bâtiments;

2. La mise au point d'alternatives au chauffage au mazout et au gaz naturel des bâtiments.

La première partie comprend l'élaboration de méthodes améliorées et de données pour prédire la consommation d'énergie dans les bâtiments, la formation de concepteurs qui utiliseraient de nouvelles méthodes, et la planification de budgets en énergie pour divers genres d'usages, qui peuvent être utilisés pour juger de l'efficacité d'une conception de bâtiment au point de vue de l'énergie.

La deuxième partie trait des moyens d'utilisation de l'uranium du charbon, des ordures et de chaleur en sous-produit depuis certains précédés industriels pour le chauffage des bâtiments et de l'eau. (Il existe un programme indépendant pour l'utilisation de l'énergie solaire à ces fins.) L'approche qui semble la plus prometteuse implique la combinaison du chauffage urbain et l'utilisation de l'électricité.

The program for R & D energy conservation in buildings is a vital part of the Federal Government's plan to ensure that Canadians will continue to have enough energy to meet their essential requirements.(1) The plan also includes programs for conservation in the other sectors of energy use along with efforts aimed at increasing the rate of supply of energy from domestic sources. It should be noted, however, that, in the program, work on energy conservation in buildings has been accorded top priority.

Work on energy conservation in buildings has been singled out for special emphasis because almost 40 per cent of all the primary energy used in Canada is for heating buildings and producing electricity to power the lights, water heaters and other appliances that are used in buildings. There is fairly general agreement that the amount of energy needed to operate buildings can be reduced without requiring any substantial changes in the way we live. But it will require many changes in the way buildings are constructed and operated. Effecting these changes is the prime objective of the program for energy conservation in buildings and of the associated programs for research and development.

THE DEVELOPMENT OF AN ENERGY CONSERVATION STANDARD FOR BUILDINGS

The development of appropriate standards for energy use in space heating and cooling, heating service water, and lighting is an integral part of the energy strategy. The National Research Council has been assigned the task of coordinating the preparation of a standard that will be used for all new buildings constructed for Federal departments and agencies. It is expected that it will eventually be used by others beside Federal departments and agencies who are directly involved with buildings. With this possibility in mind, the standard is being prepared in a form that will allow it to be used for all new buildings in Canada if the authorities having jurisdiction choose to adopt it.

The standard will simply set out the maximum acceptable energy budgets for different types of occupancy and leave the designer free to decide how to meet the budget. This type of standard allows the designer the maximum possible scope for innovative design, but it carries with it a responsibility to make an accurate estimate of annual energy consumption. This approach is practical in Canada because the Department of Public Works has a series of computer programs that it is using to analyze the energy consumption of buildings at the preconstruction stage. The Department is making these programs available to designers all across the country on a royalty-free basis and is presenting training sessions to familiarize designers with the use of these programs.

It is obvious, however, that it will take several years to develop energy budgets for all types of buildings and to train an adequate number of designers to use the energy systems analysis techniques. Thus it is necessary to have a conventional type of standard that can be used on an interim basis. The American Society of Heating Refrigerating and Air-Conditioning Engineers has recently issued a semi-prescriptive type of standard for energy conservation in new buildings. A modified version of this standard will be used as a basis for developing energy budgets for buildings, and it will be proposed as the interim standard for Federal buildings in Canada.

The standard will be reviewed by a recently appointed Standing Committee of the NRC Associate Committee on the National Building Code. This committee may decide to endorse the standard, or a modified version of it, for inclusion in the National Building Code or as a supplement to the main code. This thorough review by knowlegeable persons from various parts of the building industry will enhance the standard's credibility and eventual acceptance by other jurisdictions.

The R & D activities related to this Energy Standard for Buildings fall into four main categories:

1) The further development of methods for analyzing designs at the preconstruction stage to predict the amount of energy that will be needed to operate the building. This includes carrying out tests on existing buildings to determine their airtightness, and then developing calculation procedures for predicting infiltration rates for new buildings. Recent papers by Tamura and Shaw(2,3,4) give the results of some of their studies on high-rise commercial buildings. Similar work is being done for school buildings and this will be extended to other types of buildings in the near future. Other current research studies relate to heating, ventilating and air conditioning equipment in buildings. Two recent papers by Elmahdy and Mitalas(5,6) present the results of their work on simulating the performance of air cooling and dehumidifying coils over the full range of operating conditions that obtain in Canadian buildings. This is a good example of the type of research that must be done before a building performance standard can be put into general use. Similar work is required for the other major components of HVAC systems.

It is usually not practical for designers and building inspectors to make elaborate computer calculations of energy consumption for all buildings, especially houses. The paper by Mitalas (7) outlining the net annual heat loss factor method for estimating heat requirements of buildings presents the results of an extensive set of computer calculations, but in a form that can be used in a very simple hand calculation procedure A companion study on predicting heat losses from basements is also nearing completion. The results of these and other similar studies will make it possible to have an energy budget type of standard even for very simple buildings. Associated with the development of methods of analysis is the task of making the techniques available to building designers and regulatory officials. The Department of Public Works is carrying the responsibility for the part of this activity related to Federal buildings (this is described in another paper at this Congress) and NRC will endeavour to enlist the Universities and Institutes of Technology in this part of the program also.

2) Another aspect of the research being done to assist in the development of rational energy standards for buildings is the development of minimum thermal resistance values for walls and roofs of residential-type buildings. The procedure outlined in Ref. (8) was developed for this purpose, and has been used to arrive at the minimum R-values called for in the modified version of the ASHRAE standard for energy conservation in new buildings.

Associated with this is the development of procedures and facilities for testing the performance of building enclosure elements under conditions that simulate those that obtain in Canadian buildings. The NRC has facilities for testing full size wall panels (3 m × 3 m) over a range of outside temperature from -50°C to +50°C while the inside temperature is kept constant at around +20°C. These facilities are also used to assist materials manufacturers with the development of new products and systems.

3) The third part of this work in support of the Energy Standard is concerned with determining the environmental conditions that are required for

various kinds of activities. This includes air conditions, e.g., temperature, humidity, quality, i.e., lack of contaminants, as well as lighting levels and space requirements. These factors determine the performance that the various service systems in the building must meet. There is, of course, a very strong coupling between these performance requirements and the energy used to operate the service systems.

The National Research Council and the Department of Public Works are both carrying out work in this field and plans have been developed to expand this activity as soon as new facilities are completed for work on lighting and air quality.

4) The fourth phase of the work on energy standards for buildings involves establishing annual energy budgets for various kinds of occupancies in different regions of the country. The approach that is being used is to analyze the energy consumption of various types of buildings that have been designed with the specific objective of achieving low life-cycle costs. A second, and complementary, activity is to monitor the energy used by "good" contemporary buildings in different parts of the country.

The Department of Public Works is taking the prime responsibility for both of these aspects of energy budget determination for large general office type buildings. The National Research Council is doing the analytical work on energy consumption in schools, while the monitoring of actual energy consumption is being done by those responsible for physical plant operation in several school boards. The energy budgets stipulated in the energy conservation standard will be based on data from both of these activities plus the judgement of those with experience in building design and operation.

There is one more technical activity related to the energy budgets: monitoring the operation of buildings to see if they are achieving the low energy consumption that is inherent in their design. Research is required to develop instrumentation packages that will make this monitoring of performance practical. Monitoring after construction is finished is viewed as a necessary step in the enforcement of the energy conservation standard for some types of buildings.

DEMONSTRATION PROJECTS

The second major component of the program for energy conservation in buildings is very closely tied in with the first; it involves building and monitoring demonstration buildings. The four objectives of this subprogram are to:

1) confirm the economic feasibility of building in conformance with the requirements of the energy standards,

2) check the validity of the analytical procedures and data that have been developed,

3) familiarize designers, contractors and operators with the energy conservation standards,

4) bring to light any problems with interpretation, implementation, or enforcement that may have been overlooked in the preparation of the standards.

These demonstration projects are really the "pilot-plant" phase of the development of the energy conservation standards. They will be carried out by the departments and agencies that have a prime responsibility for the construction and operation of federal buildings or buildings that are built as part of a federally funded program.

DEVELOPING ALTERNATIVES TO BURNING OIL AND NATURAL GAS FOR HEATING BUILDINGS

The R & D program goes beyond just reducing total per capita consumption of energy in buildings. Most of this energy is now obtained by burning oil or natural gas - both of which are in short supply and will probably become even more critical in the future. The program is also directed, therefore, toward developing practical ways of substituting energy derived from coal and uranium for the energy currently obtained from oil and gas. The building sector is of particular importance in this respect because other sources can be substituted for oil and gas much more easily and at lower cost than in any other sector.

The question of how to use these other primary fuels for heating buildings and sanitary water is tied in with the related problem of maximizing the beneficial use that is made of the total energy content of these fuels. In that sense it is a matter of energy conservation and, therefore, it falls into the conservation section of the energy R & D program.

It is taken for granted that uranium has to be converted into a secondary form at a special conversion plant, and the same probably holds for coal as well. The question that needs answering is "How should the energy be delivered to the buildings where it is needed?" There are three possibilities that are being considered:

1) In the form of electricity,

2) As hot water or steam,

3) As a synthetic fuel.

The criteria that are being used to judge which approach is best for different situations are: the cost of the heat delivered to the building and the amount of capital investment that would be required, the efficiency of utilization of the energy in the primary fuel; the effect on the environment; and the flexibility or ease of changing from one primary fuel to another at some time in the future.

The solutions that appear to be most promising involve a combination of electricity and hot water as the secondary forms of the energy. The central conversion facility would be a dual-purpose plant that produces both electricity and hot water. Fortunately a great deal of development work has been done on combined heat-power plants(9,10) in other countries and the results are available to us. There is thus no need for extensive experimental studies in Canada before these techniques can be applied. All that is needed is some feasibility studies for specific projects to see which of several possible approaches would be best for each specific situation. The expectation is that after completion of studies for several specific sites it should be possible to reach some general conclusions.

The Department of Energy Mines and Resources and the National Research Council are supporting engineering feasibility studies in cooperation with provincial agencies. These studies are expected to lead to some demonstration projects. The primary objective of EM & R in this is to develop a basis for government policies with regard to providing assistance for the construction of facilities for energy conversion and distribution that would reduce the country's dependence on oil and natural gas. The National Research Council's objectives are to identify the gaps in existing technical information that require further study, and to carry out these studies in conjunction with the demonstration projects.

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DISCUSSION

W.W. Stanzak (Canadian Institute of Steel Construction: My experience in prediction of fire resistance of building structures has indicated many pitfalls in making calculations of thermal behaviour of building elements. How far away are we from having a good base of field performance data to validate the computer programs?

D.G. Stephenson: I think it will be several years before there is a good base of field performance data to validate energy systems analysis programs. Some field results have been obtained already but they fall far short of being an adequate validation of the computation procedures for all types of buildings. For example, ASHRAE sponsored a project at Ohio State University to compare computed and metered heating and cooling loads and energy consumption for a building on the University campus. The results were not conclusive: there were significant differences between the computed and measured loads but it is not possible to say with certainty whether these differences were due to errors in the measurements or in the data used for the calculations. More studies on different types of buildings and with different types of mechanical systems are needed to fully validate the procedures. These projects are expensive and time consuming hence I think it will be a long time before there is an unimpeachable basis for the new analytical procedures.

R.W. Racine (B.C. Hydro and Power Authority): Refitting of existing buildings offers a relatively large potential for energy conservation, often with near term results. Unfortunately most refitting is limited to equipment and systems designed primarily for new construction and it seems most R & D is primarily directed at new construction. Would it not be advisable to now direct R & D to some of the specific problems faced in refitting energy wasteful areas such as low thermal resistance window, door, masonry, metal and wood construction and inefficient equipment and controls?

D.G. Stephenson: Yes, it would be a good idea to direct some R & D effort toward the special problems that occur in refitting existing buildings. I didn't intend to leave the impression that nothing is being done about refitting. The study on heat loss from basements, for example, is relevant to existing basements as well as to new construction. The special problem about refitting is cost: it costs far more to add insulation to an existing wall than it would have cost to put in more in the first place. Consequently it is a first priority to get new construction built with appropriate levels of insulation, and then to find economical ways of improving existing buildings.