Computer Program for Heating and Cooling Loads in Buildings

In the late 1960s, under the sponsorship of the Department of Housing and Urban Development, Tamami Kusuda began to develop a computer program to help architects and engineers predict the thermal performance of a building. Important enough at the time, this work was to balloon in significance in the context of the energy shortages and rapidly escalating energy prices of the 1970s. The computer program was named the National Bureau of Standards Load Determination (NBSLD) program [1,2]. It combined algorithms for transient conduction in the building structure, solar heat gains and radiant transfer, and convection between building surfaces and the room air to allow the prediction of temperatures and heating and cooling loads under dynamic conditions. Moreover, the algorithms employed in NBSLD were adopted by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) as a recommended procedure for computerized energy calculations. They were presented to the Society in a special publication [3] which was sold for many years.

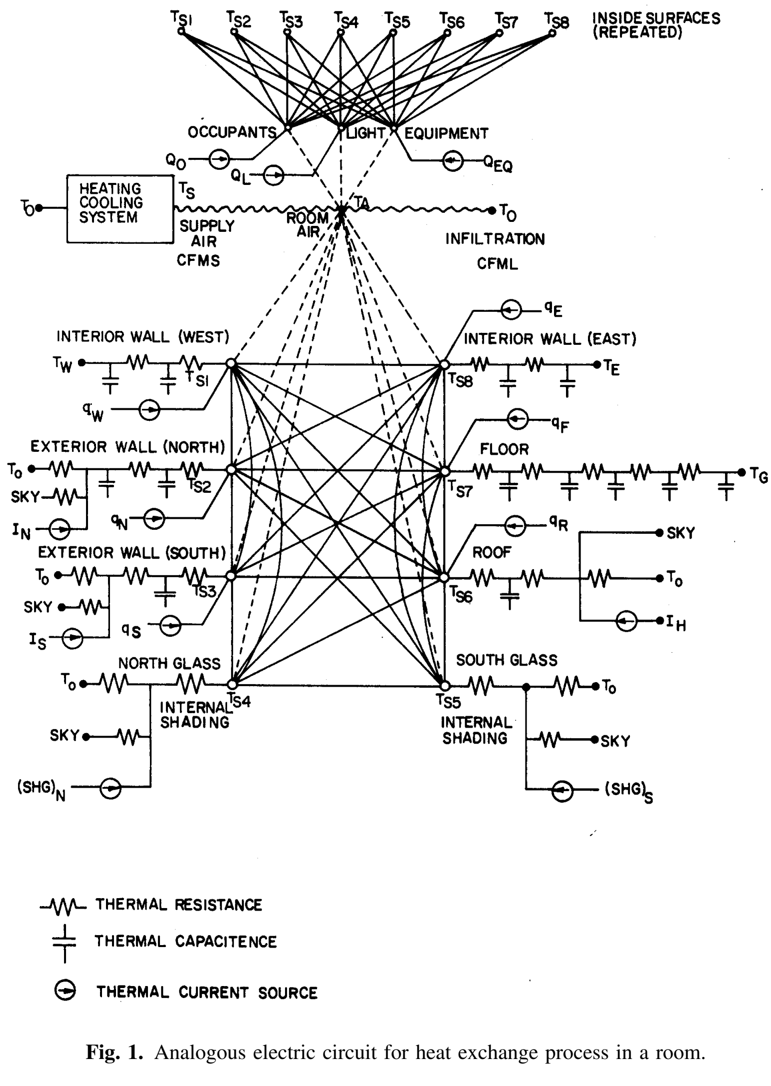

Fig. 1. Analogous electric circuit for heat exchange process in a room.

NBSLD simulated a very simple building model because of the computer limitations of its time. The model included the walls, windows, ceiling, and floor of a single space which might represent a room or an entire building. The user described the geometry of this space, the thermal properties of the building surfaces, optical properties of windows, air infiltration, heat sources such as equipment and occupants, and weather data, including temperature, humidity, and solar radiation values for periods from one day to an entire year. The program converted the building data into the coefficients of a set of simultaneous equations which were solved for temperatures of all the building components as they responded to the internal and external heat sources over time. By fixing the space air temperature to a desired value, the solution of the simultaneous equations gave the amount of energy that had to be added or removed, i.e., heating or cooling loads, necessary to maintain that temperature.

NBSLD was the result of many years of leadership in this field by Kusuda. His earlier work included development of numerical methods to quickly compute transient conduction through building walls [4] and to determine the thermal properties of moist air [5]. He organized the first three symposia on the Use of Computers for Environmental Engineering Related to Buildings. The first was held at NBS in 1970 [6], the second in Paris in 1974, and the third in Banff, Canada, in 1978. NBSLD was developed with the cooperation of ASHRAE's Task Group on Energy Requirements, in particular the Subcommittee on Heating and Cooling Load Calculations which Kusuda chaired. The members

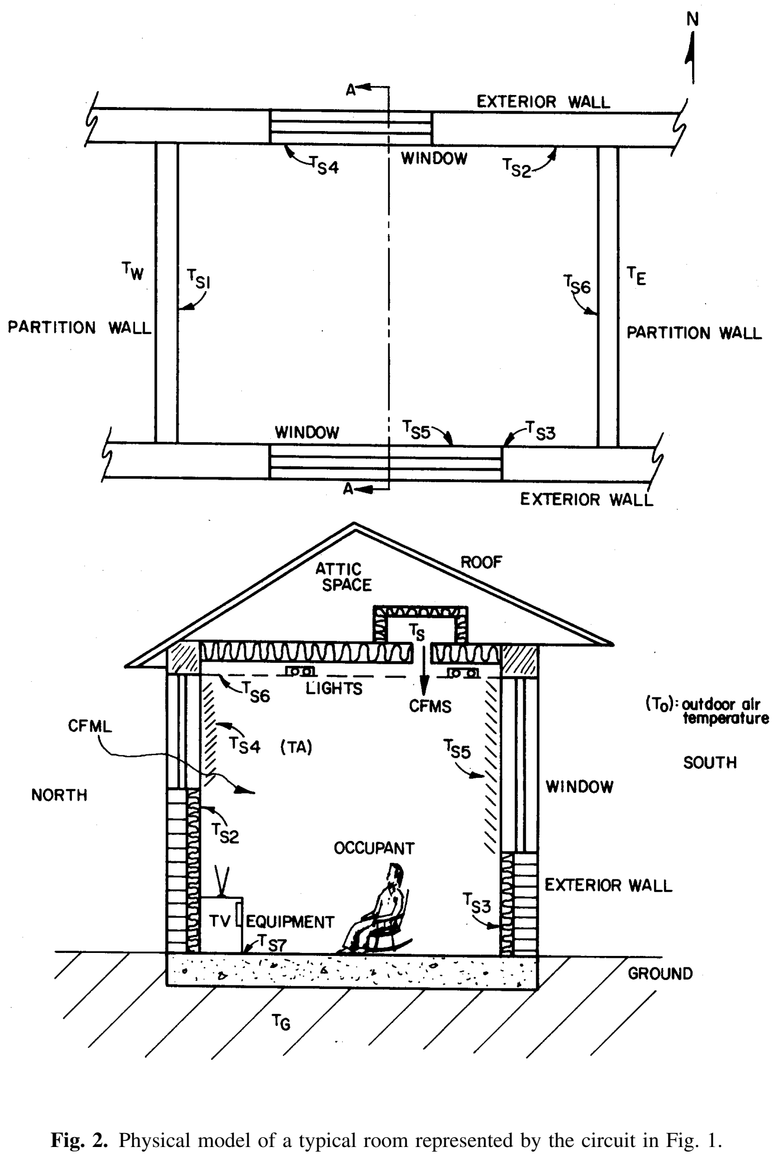

Fig. 2. Physical model of a typical room represented by the circuit in Fig. 1.

of the subcommittee shared their specialized work and computer algorithms. Kusuda developed and implemented the NBSLD framework for putting the algorithms together, and, together with NBS staff, filled in the missing components of the complete model. The Bureau's experimental facilities were used for validation of the program [7,8].

Kusuda's work with the Task Group on Energy Requirements and subsequent technical committees led to his recognition as a fellow of ASHRAE, the society's highest honor. In 1969 the Automated Procedures Engineering Consultants (APEC) awarded Kusuda its first Honorary Membership to recognize his pioneering work on the use of computers for heating, cooling and ventilating engineers.

NBSLD and related research were applied to the energy crisis of the 1970s in the analysis of energy conservation options for specific buildings [9] and in the development of general guidelines [10,11]. Kusuda's work continued in related areas, such as using sunlight in place of electric lighting [12] and studying heat exchange to the ground from buildings and pipes [13]. Recognition for this work includes a Lifetime Achievement Award from the International Building Performance Simulation Association and Silver and Gold Medals from the Department of Commerce.

In addition to the research and energy conservation design done with the NBSLD program, the documentation of its algorithms provided the basis for the development of other building energy simulation programs, both public and private. The algorithms were used almost immediately in the U.S. Army Construction Engineering Research Laboratory's (CERL) first building energy analysis program [14]. In the following years CERL developed new program code to simulate multiple rooms and allow a greater degree of integration of the building loads with the air handling system and plant equipment such as boilers and air conditioners. CERL's BLAST program [15] was released in 1977. The gradual development of multizone airflow calculations has led to a tool [16] for studying indoor air quality and even designing smoke control systems.

At present, the Department of Energy is developing the EnergyPlus program [17], which merges the best features of BLAST and the DOE-2 program. In particular, it is using the heat balance [18] concepts from BLAST which were derived from NBSLD. Because of the need to gather the latest such procedures in a single document, as was originally done by Kusuda, ASHRAE is currently working to provide improved algorithms based on a quarter century of research since the publication of the NBSLD algorithms.

Tamami Kusuda was born in Seattle, Washington. His family returned to Japan before World War II and lived there during the war (and the bombing). He received his B.S. degree from Tokyo University in 1947 and his M.S. and Ph.D. degrees from the University of Minnesota in 1952 and 1955.

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