

# **THERMAL MASS MODELING HOW WE GOT TO WHERE WE ARE TODAY**

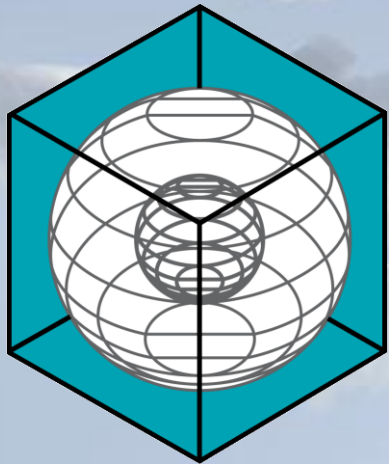
**Jeff S. Haberl, Ph.D., P.E., FASHRAE**

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**Chunliu Mao**

**March 2012**

**Dallas**



**Energy Systems Laboratory**

**Texas Engineering Experiment Station**

**Texas A&M University System**

# Distribution/Age of U.S. Commercial Buildings

New York City has thousands of new / old buildings



# Distribution/Age of U.S. Commercial Buildings

New York City has thousands of new / old buildings  
Same pattern for other U.S. cities, such as Chicago



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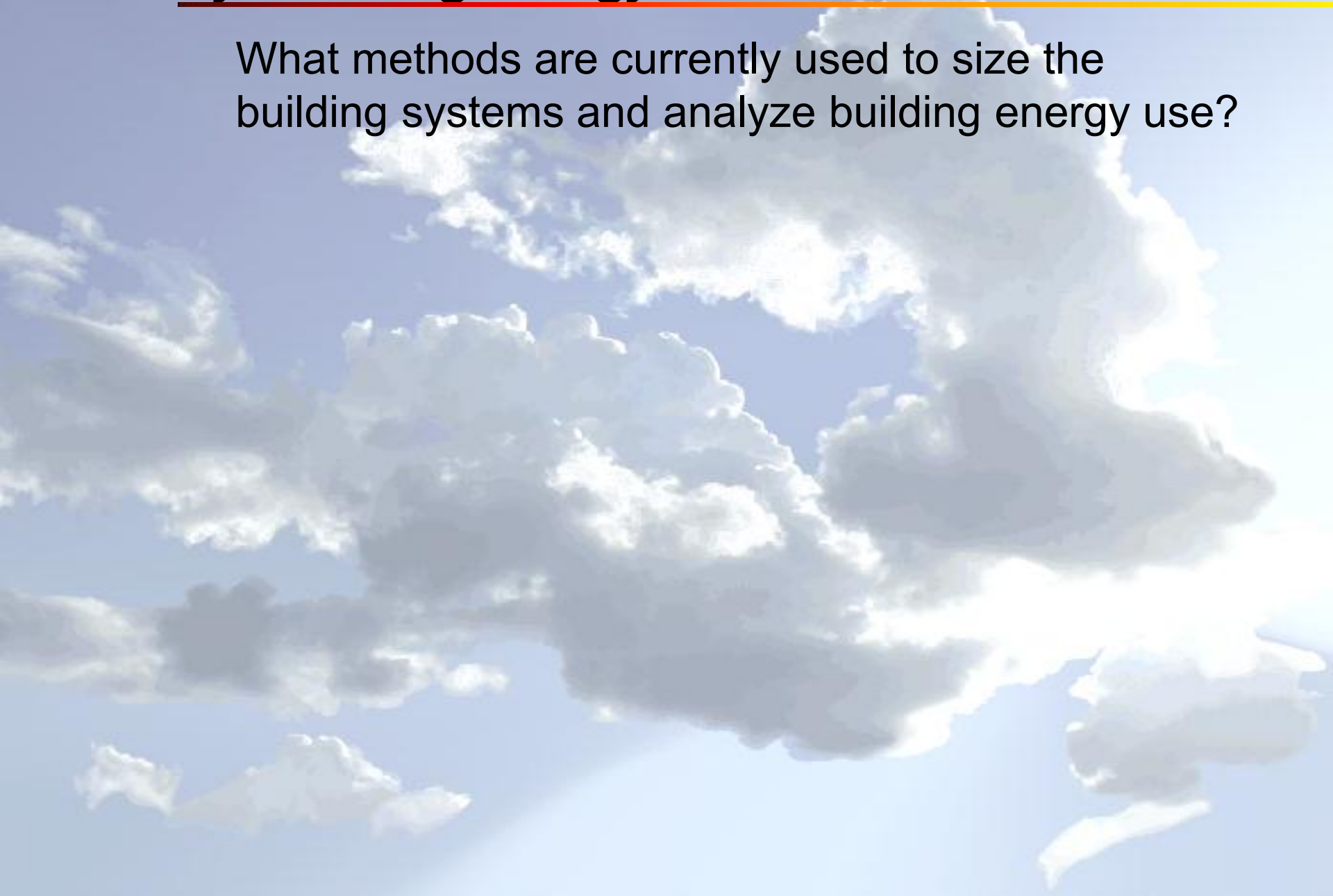


- *How are we going to create new high - performance buildings?*
- *Can we create high - performance buildings from existing buildings?*
- *What design methods were used to design existing buildings?*
- *How did the methods treat thermal mass?*



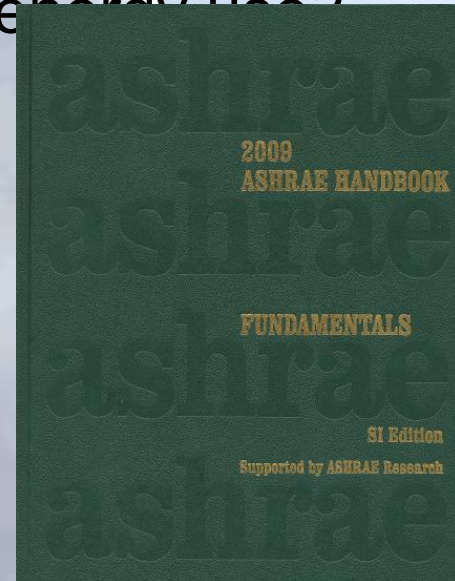
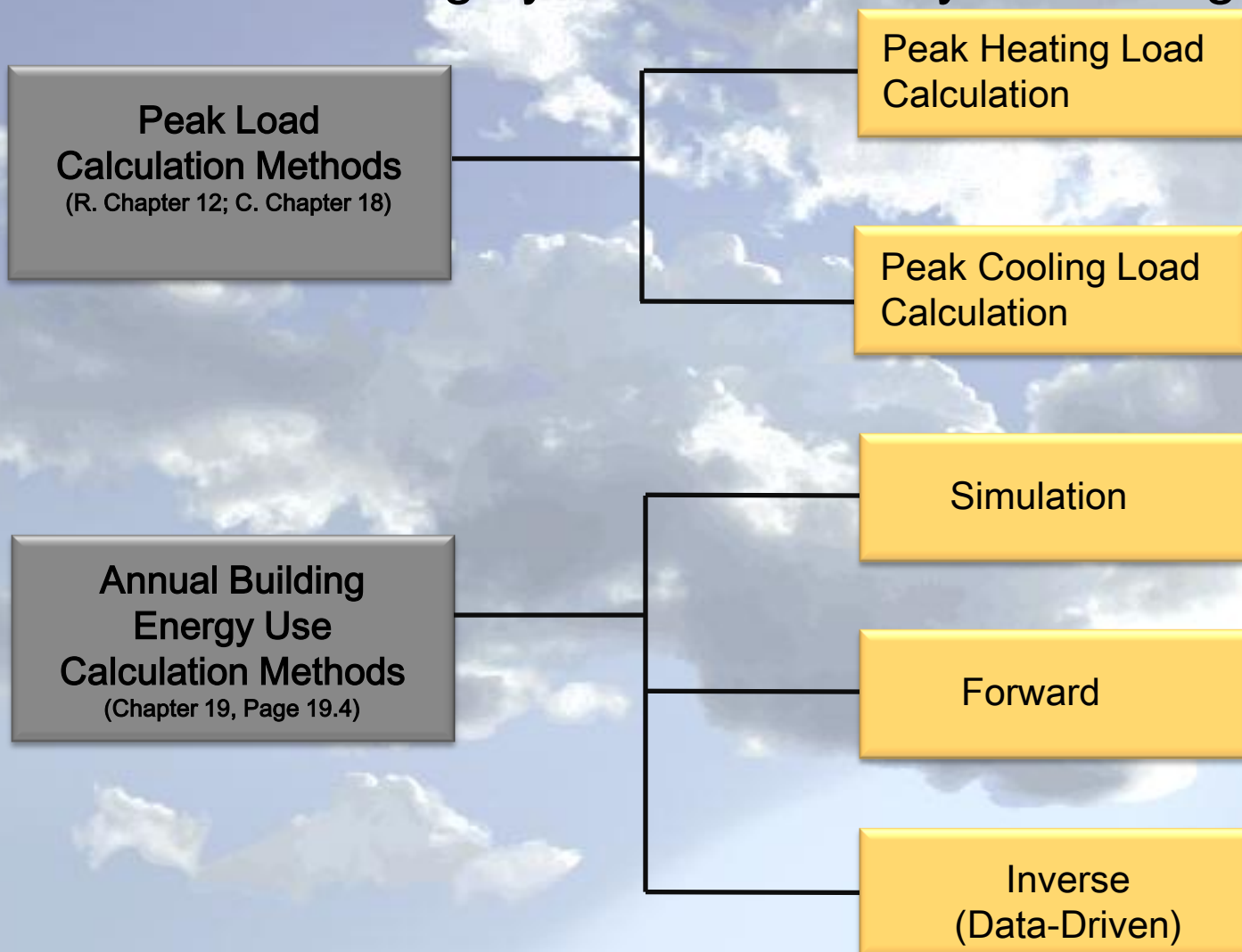
# History: Building Energy Load Calculation Methods

What methods are currently used to size the building systems and analyze building energy use?



# History: Building Energy Load Calculation Methods

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# History: Building Energy Load Calculation Methods

What methods are currently used to size the building systems and analyze building energy use?

Peak Load

Peak Heating Load  
Calculation

2009  
ASHRAE HANDBOOK

*How did the methods evolve  
from 1900 to Present?*

*How did these methods treat the use  
of thermal mass?*

Energy Use  
Calculation Methods  
(Chapter 19, Page 19.4)

Forward

Inverse  
(Data-Driven)

# History of ASHVE, ASRE, ASHAE, ASHRAE

## American Society of Heating, Refrigerating and Air-Conditioning Engineers

### The ASHRAE Centennial: 100 YEARS OF PROGRESS



A detailed timeline of ASHRAE's history from 1894 to 1994, featuring logos, portraits, and historical photographs. The timeline is organized into two rows of years, with a central blue ribbon graphic connecting the events.

**1894** Hugh Ferrel, elected to the National Association of Master Plumbers and Hot Water Plumbers, issues to appreciate an engineer's being a sign to technical culture, made as effort to establish a new engineering society.

**1895** On December 13th, in New York City, The American Society of Heating and Ventilating Engineers is established with 75 charter members.

**1899** ASHVE meets its first general annual or "summer" meeting in Saratoga Springs, NY.

**1901** Alfred Wolf designs a 300-ton compression HVAC system for comfort cooling and humidity control of the New York Stock Exchange.

**1902** Willis Carrier, working for The Buffalo Forge Company, designs a separate temperature and humidity control system for a bank and a film processing plant.

**1904** The American Society of Refrigerating Engineers is founded in Rochester, NY.

**1905** ASHVE elects John Starr as its first president at the first meeting in December.

**1906** Stuart Carrier, a North Carolina State engineer, coins the term "air conditioning".

**1908** The first international Congress of Refrigeration is held in Paris, France.

**1911** Willis Carrier presents his paper, "Rational Psychrometric Formulae," and publishes his psychrometric chart.

**1912** ASHVE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.

**1913** The first international association devoted exclusively to refrigeration.

**1915** ASHVE publishes its first engineering data book.

**1916** Margaret Knight becomes the first woman in the world to earn a degree in mechanical engineering.

**1917** Hahn-Brink invents the first increase in productivity after Margaret Knight.

**1918** ASHRAE introduces an automatic electric air system for household use.

**1919** ASHVE opens a research laboratory in the facilities of the U.S. Bureau of Mines in Pittsburgh.

**1921** John Allen is named Director of the ASHRAE Research Service.

**1922** Knowledge of air conditioning is disseminated throughout the world by Willis Carrier.

**1923** Dr. Mary F. Pennington, Assistant of the American Society of Refrigerating Engineers, is named Chairman of the ASHRAE Research Laboratory.

**1925** The first ASHRAE journal is established by ASHRAE in cooperation with the U.S. Patent Office, Johnson and the Bureau of Mines after receiving technological support from ASHRAE, humidity and air treatment.

**1928** ASHRAE Journal is published for the first time by ASHRAE and ASHRAE code is published in the book "Heating of Buildings".

**1929** Thomas Magley and others are named ASHRAE's first ASHRAE Research Lab.

**1930** First International Heating and Ventilating Exposition opens in the Commodore Hotel, Philadelphia, on January 27th.

**1932** ASHRAE publishes its first engineering data book.

**1938** Standard 55-1938, Safety Code for Mechanical Refrigeration is published by ASHRAE.

**1942** A study of Detroit Edison air-handling system is initiated.

**1944** ASHRAE Research Laboratory moves to Research Facility in Cleveland, Ohio.

**1946** ASHRAE buys a permanent facility at 1775 Central Avenue in Cleveland to house the Research Laboratory.

**1948** Twelve workers strike in New York City, causing new standards for temperature and humidity control in air conditioning.

**1950** ASHRAE publishes its first engineering data book.

**1951** The International Association of Refrigerating Engineers is founded in the ASHRAE Research Lab.

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**1961** ASHRAE publishes its first engineering data book.

**1967** The ASHRAE Handbook of Fundamentals begins publication.

**1969** ASHRAE celebrates 75th Anniversary, celebrating 75 years.

**1972** The first international ASHRAE meeting is held in New Orleans, the first to be sponsored by ASHRAE and ASHRAE.

**1973** ASHRAE publishes its first engineering data book.

**1975** ASHRAE Standard 55-75, "Standard for Thermal and Mechanical Environmental Conditions," is published.

**1976** ASHRAE Standard 62-75, "Standard for Ventilation of Buildings," is published.

**1979** ASHRAE publishes its first engineering data book.

**1981** ASHRAE publishes its first engineering data book.

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## AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS

Presented by the ASHRAE Historical Committee to commemorate the ASHRAE Centennial



# History of ASHVE, ASRE, ASHAE, ASHRAE



Barron

et In 1894:  
 • Hugh Barron, led an effort to establish a new engineering society

ng and Air-Conditioning Engineers



Centennial:  
 100 YEARS OF PROGRESS




<p><b>1915</b></p> <p>Journal of ASHRE begins publication.</p>	<p><b>1916</b></p> <p>Margaret Knight becomes the first woman in the world to earn a degree in mechanical engineering.</p>	<p><b>1917</b></p> <p>Helen Irwin becomes the first female scientist to receive a Ph.D. in mechanical engineering.</p>	<p><b>1918</b></p> <p>Automotive radiator with automatic electric fan gears for household use.</p>	<p><b>1919</b></p> <p>ASHRAE opens a research laboratory in the facilities of the U.S. Bureau of Mines in Pittsburgh.</p>	<p><b>1921</b></p> <p>John Allen is named Director of the ASHRAE Research Bureau.</p>	<p><b>1922</b></p> <p>Walter G. Brantley, chief of the ASHRAE Research Bureau, develops the first automatic compressor with distributional refrigerant.</p>	<p><b>1922</b></p> <p>Dr. E. P. Thompson, Professor of Mechanical Engineering at MIT, is named Chairman of the ASHRAE Research Laboratory.</p>	<p><b>1923</b></p> <p>Dr. E. P. Thompson, Professor of Mechanical Engineering at MIT, is named Chairman of the ASHRAE Research Laboratory.</p>	<p><b>1925</b></p> <p>The ASHRAE Journal is established by the ASHRAE members in New York City.</p>	<p><b>1928</b></p> <p>Arthur Lee is named President of ASHRAE.</p>	<p><b>1929</b></p> <p>U.S. House of Representatives approves the first federal building to be air conditioned.</p>	<p><b>1930</b></p> <p>First International Heating and Ventilating Exposition opens in the Corcoran Museum, Philadelphia, on January 27th.</p>	
<p><b>1932</b></p> <p>ASHRAE publishes the first Handbook of Mechanical Refrigeration.</p>	<p><b>1938</b></p> <p>Standard 55-1938, Safety Code for Mechanical Refrigeration, is published by ASHRAE.</p>	<p><b>1942</b></p> <p>A study of Detroit Edison reveals that a 10% increase in productivity after carbon cooling is installed.</p>	<p><b>1944</b></p> <p>Wind tunnel built for National Aeronautics Administration. Commission featuring a 20,000 sq. ft. cooling system.</p>	<p><b>1946</b></p> <p>ASHRAE Research Laboratory moves to Research Building in Cleveland, Ohio.</p>	<p><b>1948</b></p> <p>ASHRAE opens a permanent facility at 1775 Central Avenue in Cleveland to house the Research Laboratory.</p>	<p><b>1950</b></p> <p>Trade workers strike in New York City causes new automatic compressor with distributional refrigerant to be developed by Walter G. Brantley.</p>	<p><b>1951</b></p> <p>The Environmental Engineering Laboratory is established at the ASHRAE Research Lab.</p>	<p><b>1953</b></p> <p>Research on condenser tubes reveals that a 10% increase in efficiency can be achieved by using a new design.</p>	<p><b>1954</b></p> <p>ASHRAE Standard 55-1954, "Design Conditions for Heating and Cooling of Buildings," is published.</p>	<p><b>1955</b></p> <p>ASHRAE Standard 55-1955, "Design Conditions for Heating and Cooling of Buildings," is published.</p>	<p><b>1958</b></p> <p>ASHRAE Standard 55-1958, "Design Conditions for Heating and Cooling of Buildings," is published.</p>	<p><b>1959</b></p> <p>ASHRAE Standard 55-1959, "Design Conditions for Heating and Cooling of Buildings," is published.</p>	<p><b>1961</b></p> <p>ASHRAE Standard 55-1961, "Design Conditions for Heating and Cooling of Buildings," is published.</p>
<p><b>1967</b></p> <p>The ASHRAE Handbook of Fundamentals begins publication.</p>	<p><b>1969</b></p> <p>ASHRAE celebrates 75th Anniversary, membership approaching 25,000.</p>	<p><b>1972</b></p> <p>The International Conference on Building Energy Conservation is held in New Orleans, the first conference to be sponsored by ASHRAE and AIA.</p>	<p><b>1973</b></p> <p>ASHRAE Standard 55-1973, "Design Conditions for Heating and Cooling of Buildings," is published.</p>	<p><b>1975</b></p> <p>ASHRAE Standard 55-1975, "Design Conditions for Heating and Cooling of Buildings," is published.</p>	<p><b>1976</b></p> <p>ASHRAE Standard 55-1976, "Design Conditions for Heating and Cooling of Buildings," is published.</p>	<p><b>1979</b></p> <p>ASHRAE Standard 55-1979, "Design Conditions for Heating and Cooling of Buildings," is published.</p>	<p><b>1981</b></p> <p>ASHRAE Standard 55-1981, "Design Conditions for Heating and Cooling of Buildings," is published.</p>	<p><b>1982</b></p> <p>ASHRAE Standard 55-1982, "Design Conditions for Heating and Cooling of Buildings," is published.</p>	<p><b>1986</b></p> <p>ASHRAE Standard 55-1986, "Design Conditions for Heating and Cooling of Buildings," is published.</p>	<p><b>1989</b></p> <p>ASHRAE Standard 55-1989, "Design Conditions for Heating and Cooling of Buildings," is published.</p>	<p><b>1992</b></p> <p>ASHRAE Standard 55-1992, "Design Conditions for Heating and Cooling of Buildings," is published.</p>	<p><b>1994</b></p> <p>ASHRAE Standard 55-1994, "Design Conditions for Heating and Cooling of Buildings," is published.</p>	

## AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS

# History of ASHVE, ASRE, ASHAE, ASHRAE


## American Society of Heating, Refrigerating and Air-Conditioning Engineers

**The ASHRAE Centennial: PROGRESS**



**In 1894:**

- **ASHVE was established**



<b>18</b>														
	<b>1899</b>	<b>1901</b>	<b>1902</b>	<b>1904</b>	<b>1905</b>	<b>1906</b>	<b>1908</b>	<b>1911</b>	<b>1912</b>	<b>1913</b>				
	ASHVE meets to live permanent in "Summer" meeting in Saratoga Springs, NY.	Albert Weill designs a 300-ton compression HVAC system for comfort cooling and humidity control of the New York Stock Exchange.	Wiley Carter, working for the Buffalo Trust Company, designs a large-scale temperature and humidity control system for a bank and a military printing plant.	Refrigeration systems across America are expected to have a new impetus to meet the needs of air conditioning.	The American Society of Heating and Refrigerating Engineers is founded on December 19, 1905.	ASHVE elects John Starr as its first president at the inaugural meeting on December 19, 1905.	Walter Van Dyke Beckett, ASHVE member, is elected.	Start Carter, a North Carolina State engineer, coins the term "air conditioning".	The first International Congress of Refrigeration is held in Paris, France.	Wiley Carter presents historic paper, "Thermal Psychrometric Formulae," and publishes the psychrometric chart.	ASHVE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.	The first international association devoted exclusively to refrigeration.		
<b>1915</b>	<b>1916</b>	<b>1917</b>	<b>1918</b>	<b>1919</b>	<b>1921</b>	<b>1922</b>	<b>1923</b>	<b>1925</b>	<b>1928</b>	<b>1929</b>	<b>1930</b>			
Journal of ASHVE begins publication.	Margaret Knight becomes the first woman in the world to earn a degree in mechanical engineering.	Walter Peltz invents the first turbine compressor for ASHVE; patent ability transferred by Margaret Knight.	Suburban introduces air conditioning to suburban electric utility systems for household use.	ASHVE opens a research laboratory in the building of the U.S. Bureau of Mines in Pittsburgh.	John Allen is named Director of the ASHRAE Research Bureau.	Knowledge about using air conditioning is spread through a pamphlet, "Disinfectant and Sterilization," developed by Wiley Carter.	David F. Peabody is named ASHVE's first president.	Dr. Mary F. Peabody, ASHVE's first female member, is elected ASHVE's first female member and the first female ASHVE member.	The first ASHVE is established by ASHVE in cooperation with the U.S. Patent Office and the Bureau of Mines after receiving technological support in mechanical, electrical and air treatment.	Dr. Carl Boring is elected ASHVE's first president.	Thomas Magley and others are named ASHVE's first vice-presidents at the ASHVE General Meeting in the General Motors Research Lab.	U.S. House of Representatives introduces the first U.S. government building to be air conditioned.	First International Heating and Ventilating Exposition opens in the Corcoran Museum, Philadelphia, on January 27th.	
<b>1932</b>	<b>1938</b>	<b>1942</b>	<b>1944</b>	<b>1946</b>	<b>1948</b>	<b>1950</b>	<b>1951</b>	<b>1953</b>	<b>1954</b>	<b>1955</b>	<b>1958</b>	<b>1959</b>	<b>1961</b>	
ASHVE publishes the first ASHRAE Handbook.	Standard 55-1938, Safety Code for Mechanical Refrigeration is published by ASHVE.	A study of Detroit Edison work shows a 30% increase in productivity after comfort cooling is installed.	Walter Peltz built for National Aeronautics Administration a 20,000-ton cooling system.	ASHRAE Research Laboratory moves to Research Building in Cleveland, Ohio.	ASHRAE buys a permanent facility at 1775 East Avenue in Cleveland to house the Research Laboratory.	Trade workers strike in New York City results in a 10% increase in temperature and humidity control, making air conditioning a bargaining issue.	ASHVE publishes the first ASHRAE Handbook.	ASHVE publishes the first ASHRAE Handbook.	ASHVE publishes the first ASHRAE Handbook.	ASHVE publishes the first ASHRAE Handbook.	ASHVE publishes the first ASHRAE Handbook.	ASHVE publishes the first ASHRAE Handbook.	ASHVE publishes the first ASHRAE Handbook.	ASHVE publishes the first ASHRAE Handbook.
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The ASHRAE Handbook of Fundamentals begins publication.	ASHRAE celebrates 75th Anniversary, membership approaching 25,000.	New Armstrong and East Airpak units on the moon in space suits with the support and cooling systems.	The International Conference on Heating, Refrigerating and Air-Conditioning is held in New Orleans, the first conference to be sponsored by ASHRAE and IIR.	ASHRAE Standard 62-75, "Ventilation for Thermal and Mechanical Environmental," is approved.	ASHRAE Standard 90-76, "Energy Conservation in New Buildings," has a major impact on U.S. building codes.	ASHRAE Standard 90-76, "Energy Conservation in New Buildings," has a major impact on U.S. building codes.	ASHRAE Standard 90-76, "Energy Conservation in New Buildings," has a major impact on U.S. building codes.	ASHRAE Standard 90-76, "Energy Conservation in New Buildings," has a major impact on U.S. building codes.	ASHRAE Standard 90-76, "Energy Conservation in New Buildings," has a major impact on U.S. building codes.	ASHRAE Standard 90-76, "Energy Conservation in New Buildings," has a major impact on U.S. building codes.	ASHRAE Standard 90-76, "Energy Conservation in New Buildings," has a major impact on U.S. building codes.	ASHRAE Standard 90-76, "Energy Conservation in New Buildings," has a major impact on U.S. building codes.	ASHRAE Standard 90-76, "Energy Conservation in New Buildings," has a major impact on U.S. building codes.	

**AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS**

Presented by the ASHRAE Historical Committee to commemorate the ASHRAE Centennial

# History of ASHVE, ASRE, ASHAE, ASHRAE

## American Society of Heating, Refrigerating and Air-Conditioning Engineers

In 1895:

- ASHVE Transactions was first published

**1894**  
Hugh Ferriss, elected to the National Association of Master Plumbers and Hot Water Plumbers, agrees to technical matters, made an effort to establish a new engineering society.  
On December 13th, in New York City, the American Society of Heating and Ventilating Engineers is established with 75 charter members.  
1st Annual Meeting in January is held in Springfield, NY.

**1895**  
The first ASHVE Transactions is published.

**1901**  
Albert Wolf designs a 300-ton compression HVAC system for comfort cooling and humidity control of the New York Stock Exchange.

**1902**  
Willis Carrier, working for The Buffalo Forge Company, designs a large-scale temperature and humidity control system for people & William's printing plant.

**1904**  
The American Society of Refrigerating Engineers is founded in Philadelphia, PA.

**1905**  
ASHVE elects John Starr as its first president at the inaugural meeting in December.

**1906**  
Willis Carrier, a North Carolina State engineer, coins the term "air conditioning".

**1908**  
The first International Congress of Refrigeration is held in Paris, France.

**1911**  
Willis Carrier presents his paper, "Thermodynamic Formulae," and publishes his psychrometric chart.

**1912**  
ASHVE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.

**1913**  
The first international association dedicated to refrigeration.

**1915**  
Journal of ASHVE begins publication.

**1916**  
Margaret Knight becomes the first woman in the world to earn a degree in mechanical engineering.

**1917**  
Helen Irwin becomes the first female engineer in ASHVE, joined shortly thereafter by Margaret Knight.

**1918**  
ASHRAE introduces an automatic electric air system for household use.

**1919**  
ASHRAE opens a research laboratory in the facilities of the U.S. Bureau of Mines in Pittsburgh.

**1921**  
John Allen is named Director of the ASHRAE Research Service.

**1922**  
Knowledge of air conditioning is disseminated throughout the world by Willis Carrier.

**1923**  
Dr. Mary E. Pennington, Assistant of the American Society of Refrigerating Engineers, is named Chairman of the ASHRAE Research Laboratory.

**1925**  
The first ASHRAE journal is established by ASHRAE in cooperation with the U.S. Patent Office, the Bureau of Standards and the Bureau of Mines after receiving technological support from the government, municipalities and air treatment.

**1928**  
Carleton Beals travels the first of many U.S. patents pertaining to the book "Heating of Foods".

**1929**  
Thomas Mergler and others are named ASHRAE's first Engineers at the General Motors Research Lab.

**1930**  
First International Heating and Ventilating Exposition opens in the Corcoran Museum, Philadelphia, on January 27th.

**1932**  
ASHRAE publishes the first ASHRAE Handbook.

**1938**  
Standard 55-1938, Safety Code for Mechanical Refrigeration is published by ASHRAE.

**1942**  
A study of Detroit Edison indicates that increase in productivity after comfort cooling is installed.

**1944**  
Willis Carrier built for National Aeronautics Administration. Convective heating a 20,000 ton cooling system.

**1946**  
ASHRAE Research Laboratory moves to Research Facility in Cleveland, Ohio.

**1948**  
ASHRAE buys a permanent facility at 1775 Central Avenue in Cleveland to house the Research Laboratory.

**1950**  
Trade workers strike in New York City causes new standards for temperature and humidity control, making air conditioning a bargaining issue.

**1951**  
The Environmental Engineering Laboratory is established at the ASHRAE Research Lab.

**1953**  
Work on condenser coils continues - condenser coils proved to be essential.

**1954**  
ASHRAE changes its name to American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).

**1955**  
The ASHRAE Engineering Council is established by ASHRAE in cooperation with the U.S. Patent Office and placed at the President Institute of Philadelphia.

**1958**  
In December, members of both ASHRAE and ASHRAE vote in favor of a merger.

**1959**  
On January 28, ASHRAE officially begins operations.

**1961**  
The ASHRAE Journal is made available to all members.

**1961**  
ASHRAE Headquarters is established in the United Engineering Center in New York.

**1967**  
The ASHRAE Handbook of Fundamentals begins publication.

**1969**  
ASHRAE celebrates 75th Anniversary - membership approaching 25,000.

**1972**  
The International Conference on Heating, Refrigerating and Air-Conditioning is held in New Orleans, the first conference to be sponsored by ASHRAE and ARI.

**1973**  
Rising fuel prices lead ASHRAE to take major role in energy management.

**1975**  
ASHRAE Standard 55-75, "Standard for Thermal and Mechanical Environment," is approved.

**1976**  
ASHRAE Standard 62-75, "Standard for Indoor Air Quality," is approved.

**1979**  
The Environmental Engineering Laboratory is established in Atlanta, Georgia.

**1981**  
ASHRAE Standard 90-81, "Energy Efficient Building Design," is approved.

**1982**  
ASHRAE Standard 62-82, "Standard for Indoor Air Quality," is approved.

**1986**  
ASHRAE Standard 90-86, "Energy Efficient Building Design," is approved.

**1989**  
Under National Mutual Program for the construction of the world's tallest skyscraper, ASHRAE's energy code is adopted, new air-sealant technology becomes a major safety issue.

**1992**  
The Energy Policy Act of 1992, Public Law 102-486, was signed by President Bush.


**1994**  
ASHRAE celebrates its Centennial year with 80,000 members in 125 nations and 154 local chapters. ASHRAE's 75th Centennial year with 80,000 members in 125 nations and 154 local chapters.

## AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS

Source: <http://www.ashrae.org/about-ashrae/ashrae-and-industry-history>

# History of ASHVE, ASRE, ASHAE, ASHRAE

## American Society of Heating, Refrigerating and Air-Conditioning Engineers



### The ASHRAE 100 YEAR HISTORY

In 1904:

- ASRE was established


<p><b>1894</b></p> <p>Hugh Ferriss, elected to the National Association of Master Plumbers and Hot Water Fitters; issues to appreciate an engineer's training in regard to technical matters, made an effort to establish a new engineering society.</p>	<p><b>1895</b></p> <p>On September 13th, in New York City, The American Society of Heating and Ventilating Engineers is established with 75 charter members.</p>	<p><b>1899</b></p> <p>ASHRAE meets its first general annual or "Summer" meeting in Saratoga Springs, NY.</p>	<p><b>1901</b></p> <p>Albert Well designs a 300-ton compression HVAC system for comfort cooling and humidity control of the New York Stock Exchange.</p>	<p><b>1902</b></p> <p>Willis Carrier, working for The Buffalo Forge Company, designs a separate temperature and humidity control system for buildings and introduces a humidity ratio chart.</p>	<p><b>1906</b></p> <p>Clifford Carrier, a North Carolina State engineer, coins the term "air conditioning".</p>	<p><b>1908</b></p> <p>The first international Congress of Refrigeration is held in Paris, France.</p>	<p><b>1911</b></p> <p>Willis Carrier presents his historic paper, "Reasons for Mechanical Refrigeration," and publishes his psychrometric chart.</p>	<p><b>1912</b></p> <p>ASHRAE sponsors research at the U.S. Bureau of Standards to determine the latent heat of vapor of ice.</p>	<p><b>1913</b></p> <p>The first international association devoted exclusively to refrigeration.</p>					
<p><b>1915</b></p> <p>Journal of ASHRAE begins publication.</p>	<p><b>1916</b></p> <p>Margaret Knight becomes the first woman in the world to earn a degree in mechanical engineering.</p>	<p><b>1917</b></p> <p>Helen Frost becomes the first female engineer in ASHRAE; joined shortly thereafter by Margaret Knight.</p>	<p><b>1918</b></p> <p>ASHRAE introduces an automatic electric air system for household use.</p>	<p><b>1919</b></p> <p>ASHRAE opens a research laboratory in the facilities of the U.S. Bureau of Mines in Pittsburgh.</p>	<p><b>1921</b></p> <p>John Allen is named Director of the ASHRAE Research Bureau.</p>	<p><b>1922</b></p> <p>Knowledge of air conditioning is spread throughout the world by the publication of the Research Bulletin.</p>	<p><b>1923</b></p> <p>Dr. Mary F. Pennington, Assistant of the American Society of Refrigerating Engineers, is named Chairman of the ASHRAE Research Laboratory.</p>	<p><b>1925</b></p> <p>The first ASHRAE journal is published in cooperation with the U.S. Patent Office, Bureau and the Bureau of Mines after receiving technological support from the government, fundations and air treatment.</p>	<p><b>1925</b></p> <p>The first ASHRAE meeting is held in New York City, sponsored by the U.S. Patent Office, Bureau and the Bureau of Mines after receiving technological support from the government, fundations and air treatment.</p>	<p><b>1928</b></p> <p>Carroll Chaffee leads the first of many U.S. patents pertaining to the built-in heating of foods.</p>	<p><b>1929</b></p> <p>Thomas Mergler and others announce the first ASHRAE and ASRE code for Engineers in the General Motors Research Lab.</p>	<p><b>1930</b></p> <p>U.S. House of Representatives approves the first major U.S. government building to be air conditioned.</p>	<p><b>1930</b></p> <p>First International Heating and Ventilating Exposition opens in the Commodore Hotel, Philadelphia, on January 27th.</p>	
<p><b>1932</b></p> <p>ASHRAE publishes its first operating Data Book.</p>	<p><b>1938</b></p> <p>Standard 90A-1938, Safety Code for Electrical Refrigeration is published by ASHRAE.</p>	<p><b>1942</b></p> <p>A study of Detroit Edison indicates that heat loss through a furnace is reduced by 20% when combustion is retained.</p>	<p><b>1944</b></p> <p>Wind tunnel built for National Aeronautics Administration; Commission featuring a 20,000-ten cooling system.</p>	<p><b>1944</b></p> <p>ASHRAE Research Laboratory moves to Research Facility in Cleveland, Ohio.</p>	<p><b>1946</b></p> <p>ASHRAE buys a permanent facility at 1775 Central Avenue in Pittsburgh to house the Research Laboratory.</p>	<p><b>1948</b></p> <p>Trade workers strike in New York City causes new standards for temperature and humidity control; many air conditioning systems are damaged.</p>	<p><b>1950</b></p> <p>ASHRAE publishes its first operating Data Book.</p>	<p><b>1951</b></p> <p>The International Refrigeration Association is formed at the ASHRAE Research Lab.</p>	<p><b>1953</b></p> <p>Work on condenser safety systems - various safety systems are developed.</p>	<p><b>1954</b></p> <p>ASHRAE publishes its first operating Data Book.</p>	<p><b>1955</b></p> <p>ASHRAE publishes its first operating Data Book.</p>	<p><b>1958</b></p> <p>ASHRAE publishes its first operating Data Book.</p>	<p><b>1959</b></p> <p>ASHRAE publishes its first operating Data Book.</p>	<p><b>1961</b></p> <p>ASHRAE publishes its first operating Data Book.</p>
<p><b>1967</b></p> <p>The ASHRAE Handbook of Fundamentals begins publication.</p>	<p><b>1969</b></p> <p>ASHRAE celebrates 75th Anniversary - membership approaching 25,000.</p>	<p><b>1972</b></p> <p>New Air Conditioning and Heating, Refrigerating Exposition is held in New Orleans; the first exposition to be sponsored by ASHRAE and ASRE.</p>	<p><b>1973</b></p> <p>ASHRAE publishes its first operating Data Book.</p>	<p><b>1975</b></p> <p>ASHRAE Standard 62-75, "Standard for Minimum Air Quality in Buildings," is published.</p>	<p><b>1976</b></p> <p>ASHRAE publishes its first operating Data Book.</p>	<p><b>1979</b></p> <p>ASHRAE publishes its first operating Data Book.</p>	<p><b>1981</b></p> <p>ASHRAE publishes its first operating Data Book.</p>	<p><b>1982</b></p> <p>ASHRAE publishes its first operating Data Book.</p>	<p><b>1986</b></p> <p>ASHRAE publishes its first operating Data Book.</p>	<p><b>1989</b></p> <p>ASHRAE publishes its first operating Data Book.</p>	<p><b>1992</b></p> <p>ASHRAE publishes its first operating Data Book.</p>	<p><b>1994</b></p> <p>ASHRAE publishes its first operating Data Book.</p>		

### AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS



Source: <http://www.ashrae.org/about-ashrae/ashrae-and-industry-history>


# History of ASHVE, ASRE, ASHAE, ASHRAE

## American Society of Heating, Refrigerating and Air-Conditioning Engineers



*The ASHRAE Centennial*  
**100 YEARS OF PROGRESS**







**In 1905:**

- ASRE Transactions was first published

<b>1894</b>	Hugh Ferriss, elected to the National Association of Master Drafts and Map Makers. Ferriss to appreciate an engineer's training in regard to technical matters, made an effort to establish a new engineering society.	<b>1895</b>	On September 13th, in New York City, The American Society of Heating and Ventilating Engineers is established with 75 charter members.	<b>1899</b>	ASHVE meets its first general annual or "Summer" meeting in Saratoga Springs, NY.	<b>1901</b>	Albert Wolf designs a 300-ton compression HVAC system for comfort cooling and humidity control of the New York Stock Exchange.	<b>1902</b>	Walter Carter, working for The Buffalo Trust Company, designs a large-scale temperature and humidity control system for the bank and a related printing plant.	<b>1904</b>	The American Society of Refrigerating Engineers is founded on September 20th in New York City.	<b>1905</b>	ASHVE elects its first president, a non-engineer, in New York City.	<b>1908</b>	The first international Congress of Refrigeration is held in Paris, France.	<b>1911</b>	Wiley Center presents his book, "Thermal Psychrometric Formulae," and publishes the psychrometric chart.	<b>1912</b>	ASHVE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.	<b>1913</b>	The first international association devoted exclusively to refrigeration.						
<b>1915</b>	Journal of ASHRAE begins publication.	<b>1916</b>	Margaret Knight becomes the first woman in the world to earn a degree in mechanical engineering.	<b>1917</b>	Walter Frost invents the first "water" electric air conditioning system for household use.	<b>1918</b>	ASHVE opens a research laboratory in the facilities of the U.S. Bureau of Mines in Pittsburgh.	<b>1921</b>	John Allen is named Director of the ASHRAE Research Service.	<b>1922</b>	David T. Phelan designs the first "water" electric air conditioning system for household use.	<b>1923</b>	Dr. Mary E. Phelan, Professor at the University of Pennsylvania, becomes the first woman to become Chairman of the ASHRAE Research Laboratory.	<b>1925</b>	The first ASRE journal was established by ASHRAE in cooperation with the U.S. Patent Office, the Bureau of Standards and the Bureau of Mines after receiving technological reviews by the engineers, humidity and air treatment.	<b>1928</b>	Thomas Magley and others announce the first U.S. government building to be air conditioned.	<b>1929</b>	U.S. House of Representatives approves the first major U.S. government building to be air conditioned.	<b>1930</b>	First International Heating and Ventilating Exposition opens in the Commodore Hotel, Philadelphia, on January 27th.						
<b>1932</b>	ASHRAE publishes its first operating data book.	<b>1938</b>	Standard 55-1938, Safety Code for Mechanical Refrigeration is published by ASHRAE.	<b>1942</b>	A study of Detroit Edison reveals that the increase in productivity after comfort cooling is realized.	<b>1944</b>	ASHRAE Research Laboratory moves to Research Facility in Cleveland, Ohio.	<b>1946</b>	ASHRAE buys a permanent facility at 1775 Central Avenue in Pittsburgh to house the Research Laboratory.	<b>1948</b>	Trade workers strike in New York City ends new electrical construction and the building construction industry that had more and more new skyscrapers.	<b>1950</b>	ASHRAE publishes its first operating data book.	<b>1951</b>	The International Association of Refrigerating Engineers is formed at the ASHRAE Research Lab.	<b>1953</b>	ASHRAE publishes its first operating data book.	<b>1954</b>	ASHRAE publishes its first operating data book.	<b>1955</b>	ASHRAE publishes its first operating data book.	<b>1958</b>	ASHRAE publishes its first operating data book.	<b>1959</b>	ASHRAE publishes its first operating data book.	<b>1961</b>	ASHRAE publishes its first operating data book.
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*The ASHRAE Centennial*  
**100 YEARS OF PROGRESS**

**AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS**














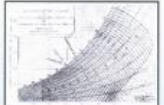

Presented by the ASHRAE Historical Committee to commemorate the ASHRAE Centennial

# History of ASHVE, ASRE, ASHAE, ASHRAE

## American Society of Heating, Refrigerating and Air-Conditioning Engineers




### The ASHRAE Centennial: 100 YEARS OF PROGRESS

     	     	  
<p><b>1895</b></p> <p>John P. Riddle is the President of ASHVE's first Annual Meeting.</p>	<p><b>1899</b></p> <p>First Annual Meeting, 1899</p>	<p><b>1901</b></p> <p>Second Annual Meeting, 1901</p>
<p><b>1902</b></p> <p>Dr. W. H. Williams presents his paper on "The South's First Air Conditioner"</p>	<p><b>1904</b></p> <p>ASHVE elects John Starr as its first president at the 10th Annual Meeting in December</p>	<p><b>1905</b></p> <p>ASHVE elects John Starr as its first president at the 10th Annual Meeting in December</p>
<p><b>1906</b></p> <p>Starts Central Air Conditioning in North Carolina</p>	<p><b>1908</b></p> <p>The first international Congress of Refrigeration is held in Paris, France</p>	<p><b>1911</b></p> <p>ASHVE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice</p>
<p><b>1912</b></p> <p>ASHVE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice</p>	<p><b>1913</b></p> <p>The first international exposition devoted exclusively to refrigeration</p>	<p><b>1915</b></p> <p>ASHVE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice</p>
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**In 1915:**

- Journal of ASHVE was first published



# History of ASHVE, ASRE, ASHAE, ASHRAE

## American Society of Heating, Refrigerating and Air-Conditioning Engineers

*The ASHRAE Centennial:*  
**100 YEARS OF PROGRESS**

1894-1915

1915-1922

1922-1954

1954-1994

**1894** Hugh Ferrel, elected to the National Association of Master Plumbers and Hot Water Fitters. Issues to appreciate an engineer's being in regard to technical matters, made an effort to establish a new engineering society.

**1895** On December 13th, in New York City, the American Society of Heating and Ventilating Engineers is established with 75 charter members.

**1899** Edward P. Feltus is elected as the first President of ASHVE at the first Annual Meeting in January.

**1901** The first edition of the ASHVE Transactions is published.

**1901** ASHVE reacts to live performance in "Summer" meeting in Saratoga Springs, NY.

**1902** Alfred Well designs a 300-ton compression HVAC system for comfort cooling and humidity control of the New York Stock Exchange.

**1915** ASHVE elects John De Haven as its first president of the American Society of Heating and Ventilating Engineers.

**In 1922:**

- **ASHVE Guide was first published**

**1915** Journal of ASHVE begins publication.

**1916** Margaret Knight becomes the first woman in the world to earn a degree in mechanical engineering.

**1917** Hahn trials becomes the first female inventor of the parcel delivery transmitter by Margaret Knight.

**1918** Suburban installations are available electric air systems for household use.

**1919** ASHVE opens a research laboratory in the facilities of the U.S. Bureau of Mines in Pittsburgh.

**1921** John Allen is named Director of the ASHVE Research Service.

**1921** Knowledge of air conditioning is developed by Willis Carrier.

**1925** The first test bank was established by ASHVE in cooperation with the U.S. Public Health Service and the Bureau of Mines after studying technological reactions to air conditioning, humidity and air treatment.

**1925** The first ASHVE exhibit is held at the First Theater in New York City, which provides the cost of most professional exhibitions.

**1928** Caroline Dreyfus flees for the first of many U.S. patents pertaining to the bulk-heating of foods.

**1928** Thomas Maggry and others are named ASHVE refrigerators at the General Motors Research Lab.

**1929** U.S. House of Representatives is established in the United States building to be air-conditioned.

**1930** First International Heating and Ventilating Exposition opens in the Commodore Hotel, Philadelphia, on January 27th.

**1932** ASHVE publishes the first ASHVE Safety Book.

**1938** Standard BR-1616, Safety Code for Electrical Refrigeration is published by ASHVE.

**1942** A study of Detroit Edison work shows a 10% increase in productivity after carbon cooling is installed.

**1944** Wind tunnel built for National Aeronautics Administration.

**1944** ASHVE Research Laboratory moves to research facility in Cleveland, Ohio.

**1946** ASHVE buys a permanent facility at 1775 East Avenue in Cleveland to house the Research Laboratory.

**1948** Twelve workers strike in New York City, causing new electrical temperature and humidity control in summer air conditioning to be developed by Willis Carrier.

**1950** ASHVE publishes the first ASHVE Transactions.

**1951** The Environmental Engineering Laboratory is established at the ASHVE Research Lab.

**1953** ASHVE publishes the first ASHVE Transactions.

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**1958** ASHVE publishes the first ASHVE Transactions.

**1959** ASHVE publishes the first ASHVE Transactions.

**1961** ASHVE publishes the first ASHVE Transactions.

**1967** The ASHRAE Handbook of Fundamentals begins publication.

**1969** ASHRAE celebrates 75th Anniversary, celebrating 25,000 members.

**1972** The first International Air-Conditioning, Heating, and Refrigerating Exposition is held in New Orleans, the first exposition to be sponsored by ASHRAE and ARI.

**1973** ASHRAE publishes the first ASHRAE Transactions.

**1975** ASHRAE Standard 62-75, "Ventilation for Thermal and Mechanical Environmental Control," is published.

**1976** ASHRAE Standard 90.1, "Energy Conservation in Buildings," is published.

**1979** ASHRAE publishes the first ASHRAE Transactions.

**1981** ASHRAE publishes the first ASHRAE Transactions.

**1982** ASHRAE publishes the first ASHRAE Transactions.

**1986** ASHRAE publishes the first ASHRAE Transactions.

**1989** ASHRAE publishes the first ASHRAE Transactions.

**1992** ASHRAE publishes the first ASHRAE Transactions.

**1994** ASHRAE publishes the first ASHRAE Transactions.

**AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS**

Presented by the ASHRAE Historical Committee to commemorate the ASHRAE Centennial

# History of ASHVE, ASRE, ASHAE, ASHRAE

## American Society of Heating, Refrigerating and Air-Conditioning Engineers

*The ASHRAE Centennial:*  
**100 YEARS OF PROGRESS**

Technology for a Better Environment  
**Centennial**  
1894-95 ~ 1994-95

**1894** Hugh Ferriss, elected to the National Association of Master Plumbers and Hot Water Plumbers, forms to appreciate an engineer's living in regard to his home values, leads an effort to establish a...

**1895** On December 13th, in New York City, The American Society of Heating and Ventilating Engineers is established with 25...

**1899** Edward P. Riddle is elected as the President of ASHVE at the first Annual Meeting in January...

**1901** The first edition of the ASHVE Transactions is published...

**1902** Albert Well designs a 300-ton compression HVC system for comfort cooling and humidity control system for the building & business printing plant...

**1904** Willis Carrier, working for the Buffalo Forge Company, designs a space heating, temperature and humidity control system for a building & business printing plant...

**1905** The American Society of Refrigerating Engineers is founded on September 20th...

**1906** ASRE elects John Starr as its first president at the inaugural meeting in December...

**1908** ASRE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice...

**1911** Willis Carrier presents his paper, "Thermal Psychrometric Formulae," and publishes the psychrometric chart...

**1912** The first international exhibition devoted exclusively to refrigeration...

**1913** The first international exhibition devoted exclusively to refrigeration...

**1918** The Refrigerating and Data Book for ASRE is first published...

**1923** Dr. Mary E. Pennington, Assistant to the American Society of Refrigerating Engineers, is named Chairman of the ASHRAE Committee on Research, Standards and Air Treatment...

**1925** The first ASRE journal is established by ASRE in cooperation with the U.S. Patent Office, Andrew and the Bureau of Mines after receiving technological assistance from the National Bureau of Standards...

**1928** The ASHRAE Journal is established by ASRE in cooperation with the U.S. Patent Office, Andrew and the Bureau of Mines after receiving technological assistance from the National Bureau of Standards...

**1929** Thomas Magley and others are named ASRE's first President at the General Meeting in the Grand Masonic Research Building in New York City...

**1930** The first international Heating and Ventilating Exposition opens in the Commodore Hotel, Philadelphia, on January 27th...

**1942** The ASHRAE Research Laboratory is established in Cleveland, Ohio...

**1944** ASHRAE Research Laboratory moves to Research Facility in Cleveland, Ohio...

**1946** ASHRAE buys a permanent facility at 1775 East Avenue in Cleveland, Ohio...

**1948** Trade workers at work in New York City are struck by a wave of labor unrest, making air conditioning and heating conditions in many buildings unbearable...

**1950** The ASHRAE Research Laboratory is established in Cleveland, Ohio...

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**1967** The ASHRAE Handbook of Fundamentals begins publication...

**1969** ASHRAE celebrates 75th Anniversary, commemorating its founding in 1894...

**1972** The International Air-Conditioning and Heating Refrigerating Exposition is held in New Orleans, the first exposition to be sponsored by ASHRAE and ARI...

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**AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS**

Presented by the ASHRAE Historical Committee to commemorate the ASHRAE Centennial



# History of ASHVE, ASRE, ASHAE, ASHRAE

## American Society of Heating, Refrigerating and Air-Conditioning Engineers

*The ASHRAE Centennial:*  
**100 YEARS OF PROGRESS**

<p><b>1894</b></p> <p>Hugh Ferriss, elected by the National Association of Master Plumbers and Hot Water Plumbers, issues to appreciate an engineer's service in regard to technical matters, made an effort to establish a new engineering society.</p>	<p><b>1895</b></p> <p>On December 13th, in New York City, the American Society of Heating and Ventilating Engineers is established with 75 charter members.</p>	<p><b>1899</b></p> <p>ASHRAE holds its first semi-annual or "summer" meeting in Saratoga Springs, NY.</p>	<p><b>1901</b></p> <p>Albert Wolf designs a 300-ton compression HVAC system for comfort cooling and humidity control in the New York Stock Exchange.</p>	<p><b>1902</b></p> <p>Willis Carrier, working for The Buffalo Forge Company, designs a separate temperature and humidity control system for buildings and influences a pending draft code.</p>	<p><b>1904</b></p> <p>ASHRAE sponsors the first Winter-ASHRAE symposium before the American Society of Heating and Ventilating Engineers to meet the needs of an "winter" climate.</p>	<p><b>1905</b></p> <p>The American Society of Heating and Ventilating Engineers is founded as the American Society of Heating and Ventilating Engineers.</p>	<p><b>1906</b></p> <p>ASHVE elects John Starr as its first president at the first meeting in December.</p>	<p><b>1908</b></p> <p>Stuart Carrier, a North Carolina State engineer, coins the term "air conditioning".</p>	<p><b>1911</b></p> <p>The first International Congress of Refrigeration is held in Paris, France.</p>	<p><b>1912</b></p> <p>Willis Carrier presents his historic paper, "Refrigeration for Air Conditioning and Humidity Control," published in the ASHRAE Transactions.</p>	<p><b>1913</b></p> <p>ASHRAE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.</p>	<p><b>1915</b></p> <p>ASHRAE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.</p>	<p><b>1916</b></p> <p>Journal of ASHRAE begins publication.</p>	<p><b>1917</b></p> <p>Margaret Knight becomes the first woman in the world to earn a degree in mechanical engineering.</p>	<p><b>1918</b></p> <p>Plans for the first ASHRAE Research Laboratory are initiated by Margaret Knight.</p>	<p><b>1919</b></p> <p>ASHRAE opens a research laboratory in the facilities of the U.S. Bureau of Mines in Pittsburgh.</p>	<p><b>1921</b></p> <p>John Allen is named Director of the ASHRAE Research Service.</p>	<p><b>1922</b></p> <p>Knowledge of air conditioning is disseminated throughout the world by Willis Carrier.</p>	<p><b>1928</b></p> <p>Margaret Knight becomes the first woman in the world to earn a degree in mechanical engineering.</p>	<p><b>1929</b></p> <p>ASHRAE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.</p>	<p><b>1930</b></p> <p>ASHRAE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.</p>
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<p><b>1932</b></p> <p>ASHRAE publishes the first ASHRAE Handbook.</p>	<p><b>1938</b></p> <p>Standard 55-1938, Safety Code for Mechanical Refrigeration is published by ASHRAE.</p>	<p><b>1942</b></p> <p>A study of Detroit Edison reveals that a 10% increase in productivity after carbon cooling is installed.</p>	<p><b>1944</b></p> <p>Willis Carrier built for National Aeronautics Administration, Cleveland, Ohio, a Government building with a 20,000-ton cooling system.</p>	<p><b>1946</b></p> <p>ASHRAE Research Laboratory moves to Research Facility in Cleveland, Ohio.</p>	<p><b>1948</b></p> <p>ASHRAE buys a permanent facility at 1775 Central Avenue in Cleveland to house the Research Laboratory.</p>	<p><b>1950</b></p> <p>Trade workers strike in New York City causes new standards for temperature and humidity control in commercial buildings.</p>	<p><b>1951</b></p> <p>ASHRAE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.</p>	<p><b>1953</b></p> <p>ASHRAE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.</p>	<p><b>1954</b></p> <p>ASHRAE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.</p>	<p><b>1955</b></p> <p>ASHRAE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.</p>	<p><b>1958</b></p> <p>ASHRAE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.</p>	<p><b>1959</b></p> <p>ASHRAE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.</p>	<p><b>1961</b></p> <p>ASHRAE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.</p>								
<p><b>1967</b></p> <p>The ASHRAE Handbook of Fundamentals begins publication.</p>	<p><b>1969</b></p> <p>ASHRAE celebrates 75th Anniversary, commemorating its 75th anniversary.</p>	<p><b>1972</b></p> <p>The International Conference on Heating, Refrigerating and Air-Conditioning is held in New Orleans, the first to be held in a city sponsored by ASHRAE and ARI.</p>	<p><b>1973</b></p> <p>ASHRAE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.</p>	<p><b>1975</b></p> <p>ASHRAE Standard 55-75, "Standard for Thermal and Mechanical Environmental Conditions," is published.</p>	<p><b>1976</b></p> <p>ASHRAE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.</p>	<p><b>1979</b></p> <p>ASHRAE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.</p>	<p><b>1981</b></p> <p>ASHRAE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.</p>	<p><b>1982</b></p> <p>ASHRAE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.</p>	<p><b>1986</b></p> <p>ASHRAE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.</p>	<p><b>1989</b></p> <p>ASHRAE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.</p>	<p><b>1992</b></p> <p>ASHRAE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.</p>	<p><b>1994</b></p> <p>ASHRAE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.</p>									


**In 1954:**









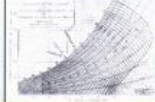
































- ASHVE changed its name to ASHAE

# History of ASHVE, ASRE, ASHAE, ASHRAE



## American Society of Heating, Refrigerating and Air-Conditioning Engineers

*The ASHRAE Centennial:*  
**100 YEARS OF PROGRESS**



<p><b>1894</b></p> <p>Hugh Ferriss, elected to the National Association of Master Plumbers and Hot Water Fitters. Issues to appreciate an engineer's training in regard to technical matters, made an effort to establish a new engineering society.</p> 	<p><b>1895</b></p> <p>On December 13th, in New York City, The American Society of Heating and Ventilating Engineers is established with 75 charter members.</p> 	<p><b>1899</b></p> <p>ASHVE holds its first general annual or "Summer" meeting in Saratoga Springs, NY.</p> 	<p><b>1901</b></p> <p>Albert Well designs a 300-ton compression HVAC system for the building and laundry system for the Hotel &amp; Millinery Building, New York.</p> 	<p><b>1902</b></p> <p>Willis Carrier, working for the Buffalo Forge Company, designs a separate temperature and humidity control system for the Hotel &amp; Millinery Building, New York.</p> 	<p><b>1904</b></p> <p>The American Society of Refrigerating Engineers is founded in Rochester, NY.</p> 	<p><b>1905</b></p> <p>ASHVE elects John Starr as its first president at the 1905 meeting in December.</p> 	<p><b>1906</b></p> <p>Stuart Carrier, a North Carolina basic engineer, coins the term "air conditioning".</p> 	<p><b>1908</b></p> <p>The first international Congress of Refrigeration is held in Paris, France.</p> 	<p><b>1911</b></p> <p>Willis Carrier presents his paper, "Rational Psychrometric Formulae," and publishes the psychrometric chart.</p> 	<p><b>1912</b></p> <p>ASHVE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.</p> 	<p><b>1913</b></p> <p>The first international opportunity is recognized in refrigeration.</p> 
<p><b>1915</b></p> <p>Journal of ASHRAE begins publication.</p> 	<p><b>1916</b></p> <p>Margaret Knight becomes the first woman in the world to earn a degree in mechanical engineering.</p> 	<p><b>1917</b></p> <p>John F. McGraw secures the first patent for the first increase in productivity after Margaret Knight.</p> 	<p><b>1918</b></p> <p>Substantive innovations in electrical electric air systems for household use.</p> 	<p><b>1919</b></p> <p>ASHRAE opens a research laboratory in the facilities of the U.S. Bureau of Mines in Pittsburgh.</p> 	<p><b>1921</b></p> <p>John Allen is named Director of the ASHRAE Research Service.</p> 	<p><b>1922</b></p> <p>Walter G. Pennington is named the first ASHRAE Research Laboratory.</p> 	<p><b>1923</b></p> <p>Dr. Mary E. Pennington, ASHRAE's first female member, becomes the first female member of the ASHRAE Research Laboratory.</p> 	<p><b>1930</b></p> <p>First International Heating and Ventilating Exposition opens in the Cornacoff Museum, Philadelphia, on January 27th.</p> 			
<p><b>1932</b></p> <p>ASHRAE publishes the first ASHRAE Handbook.</p> 	<p><b>1936</b></p> <p>Standard 55-1936, Safety Code for Electrical Refrigeration is published by ASHRAE.</p> 	<p><b>1938</b></p> <p>A study of Detroit Edison indicates that a 20% increase in productivity after certain cooling is realized.</p> 	<p><b>1942</b></p> <p>Willis Carrier built for National Aeronautics Administration.</p> 	<p><b>1944</b></p> <p>ASHRAE Research Laboratory moves to Research Facility in Cleveland, Ohio.</p> 	<p><b>1946</b></p> <p>ASHRAE buys a permanent facility at 1775 Central Avenue in Cleveland to house the Research Laboratory.</p> 	<p><b>1948</b></p> <p>Trade workers strike in New York City causes new standards for temperature and humidity control, making air conditioning a burgeoning new business.</p> 	<p><b>1950</b></p> <p>ASHRAE begins publication of the ASHRAE Transactions.</p> 	<p><b>1951</b></p> <p>The International Association of Refrigerating Engineers is formed.</p> 	<p><b>1953</b></p> <p>ASHRAE publishes the first ASHRAE Handbook.</p> 	<p><b>1954</b></p> <p>ASHRAE publishes the first ASHRAE Handbook.</p> 	
<p><b>1967</b></p> <p>The ASHRAE Handbook of Fundamentals begins publication.</p> 	<p><b>1969</b></p> <p>ASHRAE celebrates 75th Anniversary, commemorating its founding in 1894.</p> 	<p><b>1972</b></p> <p>The first international Air-Conditioning, Heating, and Refrigerating Exposition is held in New Orleans, the first exposition to be sponsored by ASHRAE and ARI.</p> 	<p><b>1973</b></p> <p>ASHRAE publishes the first ASHRAE Handbook of Energy Conservation.</p> 	<p><b>1975</b></p> <p>ASHRAE Standard 62-75, "Standard for Minimum Indoor Air Quality," is published.</p> 	<p><b>1976</b></p> <p>ASHRAE Standard 90-75, "Energy Conservation in New Buildings," is published.</p> 	<p><b>1979</b></p> <p>ASHRAE publishes the first ASHRAE Handbook of Energy Conservation.</p> 	<p><b>1981</b></p> <p>ASHRAE publishes the first ASHRAE Handbook of Energy Conservation.</p> 	<p><b>1982</b></p> <p>ASHRAE publishes the first ASHRAE Handbook of Energy Conservation.</p> 			


Jan.-Jun., 1959 President Jun. 1959-Feb. 1960

**In 1959: ASHAE and ASRE merged and became ASHRAE**

**1994**

ASHRAE enters its Centennial year with 80,000 members in 125 nations and 154 local chapters.



# History of ASHVE, ASRE, ASHAE, ASHRAE

## American Society of Heating, Refrigerating and Air-Conditioning Engineers

*The ASHRAE Centennial:*  
**100 YEARS OF PROGRESS**

Year	Event / Milestone
1894	Hugh Ferriss, elected to the National Association of Master Plumbers and Hot Water Fitters. Issues to appreciate an engineer's training in regard to technical matters, made an effort to establish a new engineering society.
1895	On December 13th, in New York City, The American Society of Heating and Ventilating Engineers is established with 75 charter members.
1899	ASHRAE meets its first general annual or "summer" meeting in Saratoga Springs, NY.
1901	Albert P. Willis designs a 300-ton compression HVAC system for comfort cooling and humidity control of the New York Stock Exchange.
1902	Willis Carrier, working for The Buffalo Forge Company, designs a separate temperature and humidity control system for buildings and influences printing work.
1904	Engineering education reformer Herbert Hoover supports a new engineering school in the name of an "engineer."
1905	The American Society of Refrigerating Engineers is founded on September 20th.
1906	ASHRAE elects John Starr as its first president at the inaugural meeting in December.
1908	Stuart Carrier, a North Carolina State engineer, coins the term "air conditioning."
1912	The first international Congress of Refrigeration is held in Paris, France.
1913	Willis Carrier presents his paper, "Thermal Psychrometric Formulae," and publishes the psychrometric chart.
1915	ASHRAE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.
1915	The first international association devoted exclusively to refrigeration.
1915	Journal of ASHRAE begins publication.
1916	Margaret Knight becomes the first woman in the world to earn a degree in mechanical engineering.
1917	John F. Kennedy becomes the first female inventor of ASHRAE, patent ability transformer by Margaret Knight.
1918	ASHRAE opens a research laboratory in the facilities of the U.S. Bureau of Mines in Pittsburgh.
1921	John Allen is named Director of the ASHRAE Research Service.
1922	Willis Carrier's office in Buffalo, New York, is the first to use a separate refrigeration system with dehumidification.
1922	David F. Peabody is named the first ASHRAE Research Laboratory.
1923	Dr. Mary E. Peabody, Assistant of Peabody Research Laboratory, is named Chairman of the ASHRAE Research Laboratory.
1925	The first ASHRAE Joint Meeting is established by ASHRAE in cooperation with the U.S. Patent Office, Bureau of Standards and the Bureau of Mines after receiving technological support in equipment, facilities and air treatment.
1928	Thomas Megaw and other ASHRAE and ASHRAE Joint Meeting members participate in the book "Heating of Buildings."
1932	ASHRAE publishes its first operating Data Book.
1938	Standard 55-1938, Safety Code for Electrical Refrigeration is published by ASHRAE.
1942	A study of Detroit Edison indicates that a 10% increase in productivity after comfort cooling is installed.
1944	Willis Carrier built for National Aeronautics Administration, Convair plant featuring a 20,000-ton cooling system.
1946	ASHRAE Research Laboratory moves to Research Facility in Cleveland, Ohio.
1946	ASHRAE buys a permanent facility at 1775 Central Avenue in Pittsburgh to house the Research Laboratory.
1948	Trade workers strike in New York City causes new electrical contractors to develop conditions for bargaining teams.
1950	ASHRAE publishes ASHRAE 55-1950, "Design Conditions for New Buildings," which is a major impact on U.S. building codes.
1951	The International Association of Refrigerating Engineers is formed at the ASHRAE Research Lab.
1953	Work on condenser safety systems - various safety systems to enhance safety.
1954	ASHRAE publishes ASHRAE 55-1954, "Design Conditions for New Buildings," which is a major impact on U.S. building codes.
1955	ASHRAE publishes ASHRAE 55-1955, "Design Conditions for New Buildings," which is a major impact on U.S. building codes.
1958	Dr. Robert M. Smith is elected ASHRAE President.
1959	On January 28, ASHRAE officially begins operations. The ASHRAE Journal makes its debut.
1961	<b>ASHRAE Guide and Data Book 1961: Fundamentals and Equipment</b> is published.
1967	The ASHRAE Handbook of Fundamentals begins publication.
1969	ASHRAE celebrates 75th Anniversary, celebrating 75 years.
1972	The International Air-Conditioning, Heating, and Refrigerating Exposition is held in New Orleans, the first exposition to be sponsored by ASHRAE and IIR.
1973	ASHRAE publishes ASHRAE 55-1973, "Design Conditions for New Buildings," which is a major impact on U.S. building codes.
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1981	ASHRAE publishes ASHRAE 55-1981, "Design Conditions for New Buildings," which is a major impact on U.S. building codes.
1982	ASHRAE publishes ASHRAE 55-1982, "Design Conditions for New Buildings," which is a major impact on U.S. building codes.
1986	ASHRAE publishes ASHRAE 55-1986, "Design Conditions for New Buildings," which is a major impact on U.S. building codes.
1989	ASHRAE publishes ASHRAE 55-1989, "Design Conditions for New Buildings," which is a major impact on U.S. building codes.

**In 1961: ASHRAE Guide and Data book was published**

# History of ASHVE, ASRE, ASHAE, ASHRAE

## American Society of Heating, Refrigerating and Air-Conditioning Engineers

### The ASHRAE Centennial: 100 YEARS OF PROGRESS



**1894** Hugh Ferriss, elected to the National Association of Master Plumbers and Hot Water Plumbers, issues to appreciate an engineer's service, a letter to technical editors, made an effort to establish a new engineering society.

**1895** On December 13th, in New York City, The American Society of Heating and Ventilating Engineers is established with 75 charter members.

**1899** Edward P. Feltus is installed as the first President of ASHVE at the first Annual Meeting in January.

**1901** The first edition of the ASHVE Transactions is published.

**1902** ASHVE holds its first semi-annual or "Summer" meeting in Saratoga Springs, NY.

**1904** ASHVE holds its first general annual or "Winter" meeting in Saratoga Springs, NY.

**1905** ASHVE holds its first general annual or "Winter" meeting in Saratoga Springs, NY.

**1906** Willis Carrier, a North Carolina State engineer, coins the term "air conditioning".

**1908** The first International Congress of Refrigeration is held in Paris, France.

**1911** Willis Carrier presents his paper, "Thermodynamic Formulae," and publishes his psychrometric chart.

**1912** ASHVE sponsors research at the U.S. Bureau of Standards to determine the heat of fusion of ice.

**1913** The first international association devoted exclusively to refrigeration.

**1915** Journal of ASHVE begins publication.

**1916** Margaret Knight becomes the first woman in the world to earn a degree in mechanical engineering.

**1917** Helen Irwin becomes the first female member of ASHVE.

**1918** ASHVE introduces its automatic electric air purifier for household use.

**1919** ASHVE opens a research laboratory in the facilities of the U.S. Bureau of Mines in Pittsburgh.

**1921** John Allen is named Director of the ASHVE Research Service.

**1922** Knowledge of air conditioning is codified in the ASHVE Handbook of Fundamentals.

**1923** Dr. Mary P. Pennington, Assistant of the ASHVE Research Laboratory, is named Chairman of the ASHVE Research Service.

**1925** The first ASHVE exhibit is held at the World's Fair in New York City.

**1928** Dr. Mary P. Pennington is elected ASHVE President.

**1929** U.S. House of Representatives approves the first major U.S. government building to be air conditioned.

**1930** First International Heating and Ventilating Exposition opens in the Commodore Hotel, Philadelphia, on January 27th.

**1931** ASHVE holds its first general annual or "Winter" meeting in Saratoga Springs, NY.

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**1961** ASHVE holds its first general annual or "Winter" meeting in Saratoga Springs, NY.

**1967** The ASHRAE Handbook of Fundamentals is first published.

**1972** The ASHRAE Handbook of Fundamentals is published.

**1973** ASHRAE celebrates its 75th Anniversary, commemorating its founding in 1898.

**1975** The International Air-Conditioning, Heating, and Refrigerating Exposition is held in New Orleans, the first exposition to be sponsored by ASHRAE and ARI.

**1976** ASHRAE Standard 55-75, "Environmental Acceptable Conditions in Workplaces," is published.

**1977** ASHRAE Standard 62-75, "Ventilation for Acceptable Indoor Air Quality," is published.

**1979** ASHRAE Standard 90-79, "Energy Conservation in New Buildings," is published.

**1981** ASHRAE Standard 90-81, "Energy Conservation in Existing Buildings," is published.

**1982** ASHRAE Standard 90-82, "Energy Conservation in Existing Buildings," is published.

**1986** ASHRAE Standard 90-86, "Energy Conservation in Existing Buildings," is published.

**1989** ASHRAE Standard 90-89, "Energy Conservation in Existing Buildings," is published.

**1992** The Energy Policy Act of 1992, Public Law 102-486, was signed by President Bush.

**1994** ASHRAE enters its Centennial year with 80,000 members in 125 nations and 104 local chapters.

**In 1967: ASHRAE Handbook of Fundamentals was first published**

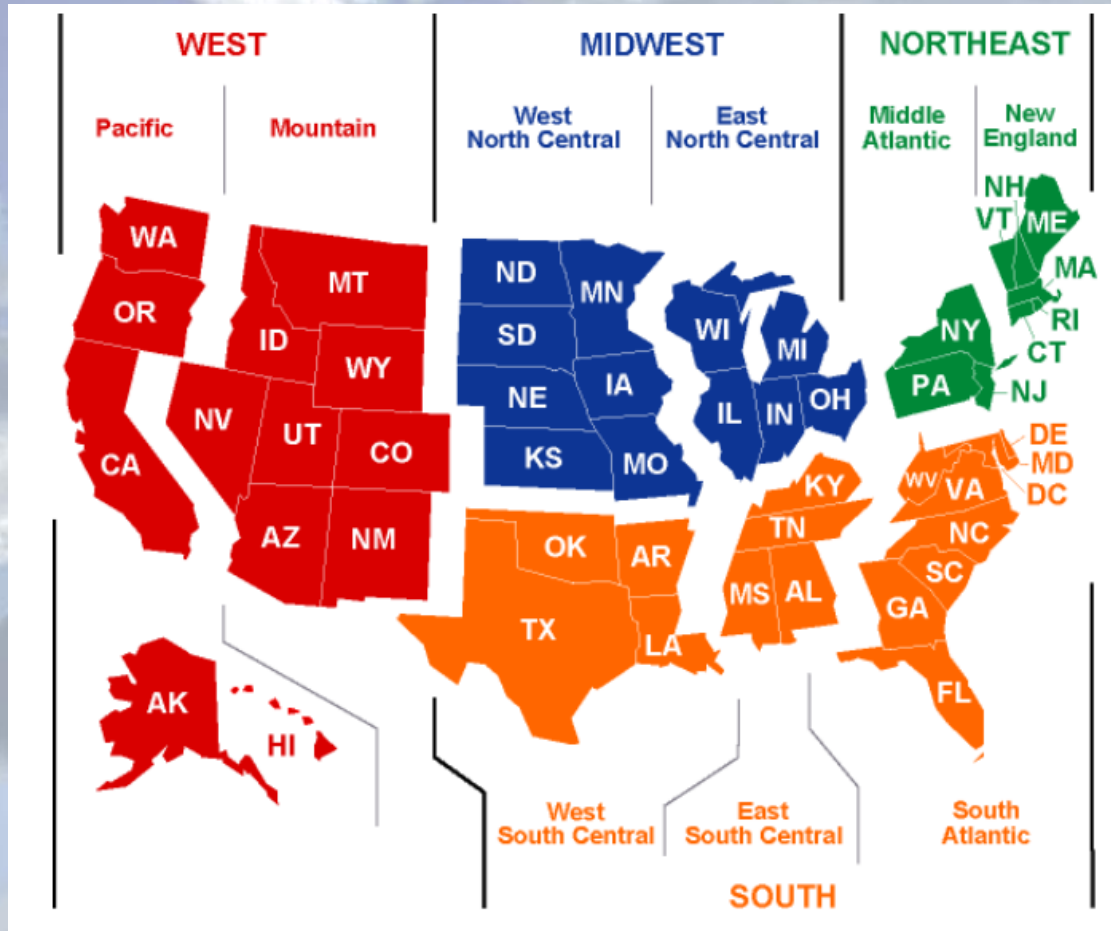
## AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS

Source: <http://www.ashrae.org/about-ashrae/ashrae-and-industry-history>



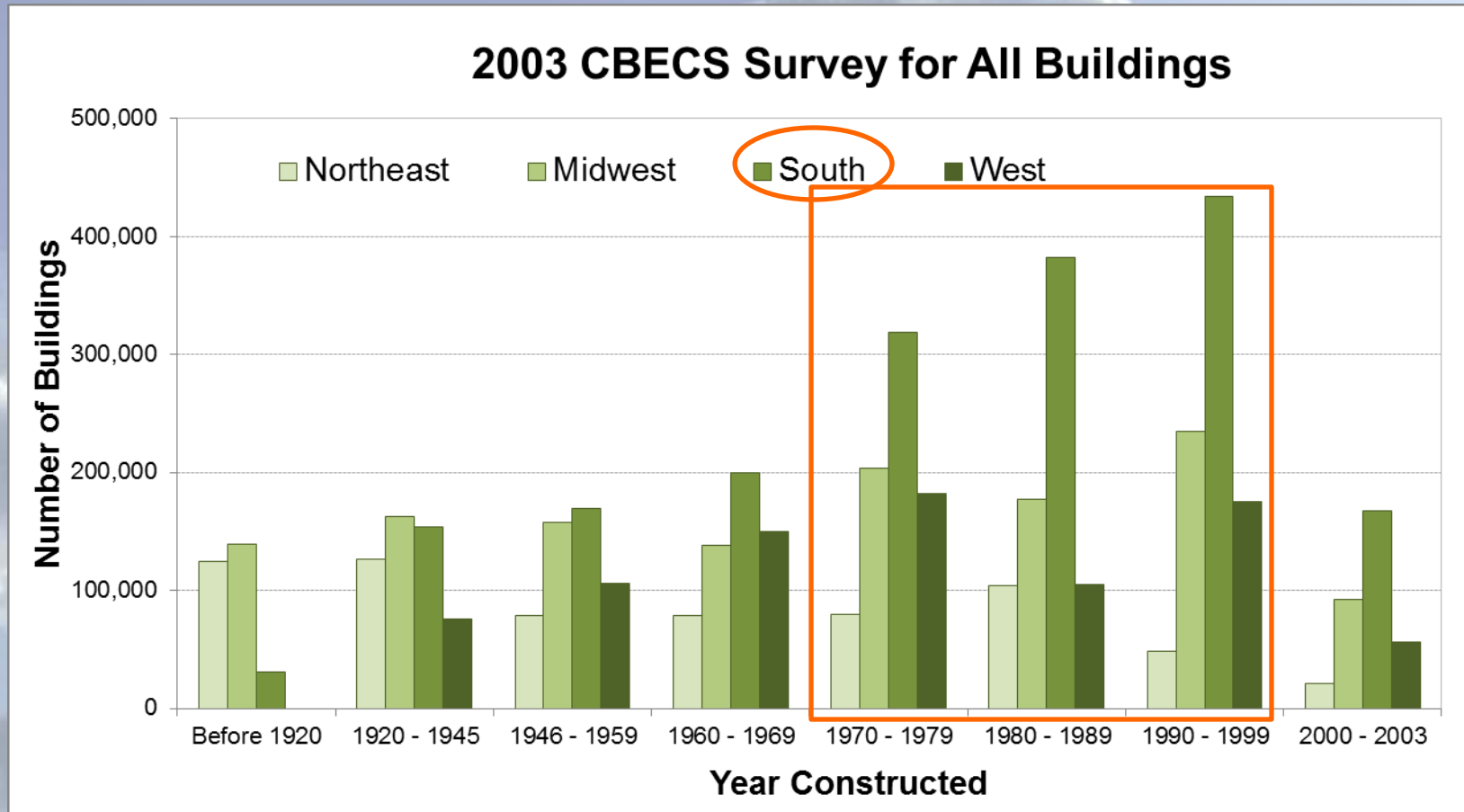
# Distribution/Age of U.S. Commercial Buildings

CBECS Survey: U.S. Census Regions and Divisions



Source: [http://www.eia.gov/emeu/cbecs/census\\_maps.html](http://www.eia.gov/emeu/cbecs/census_maps.html)

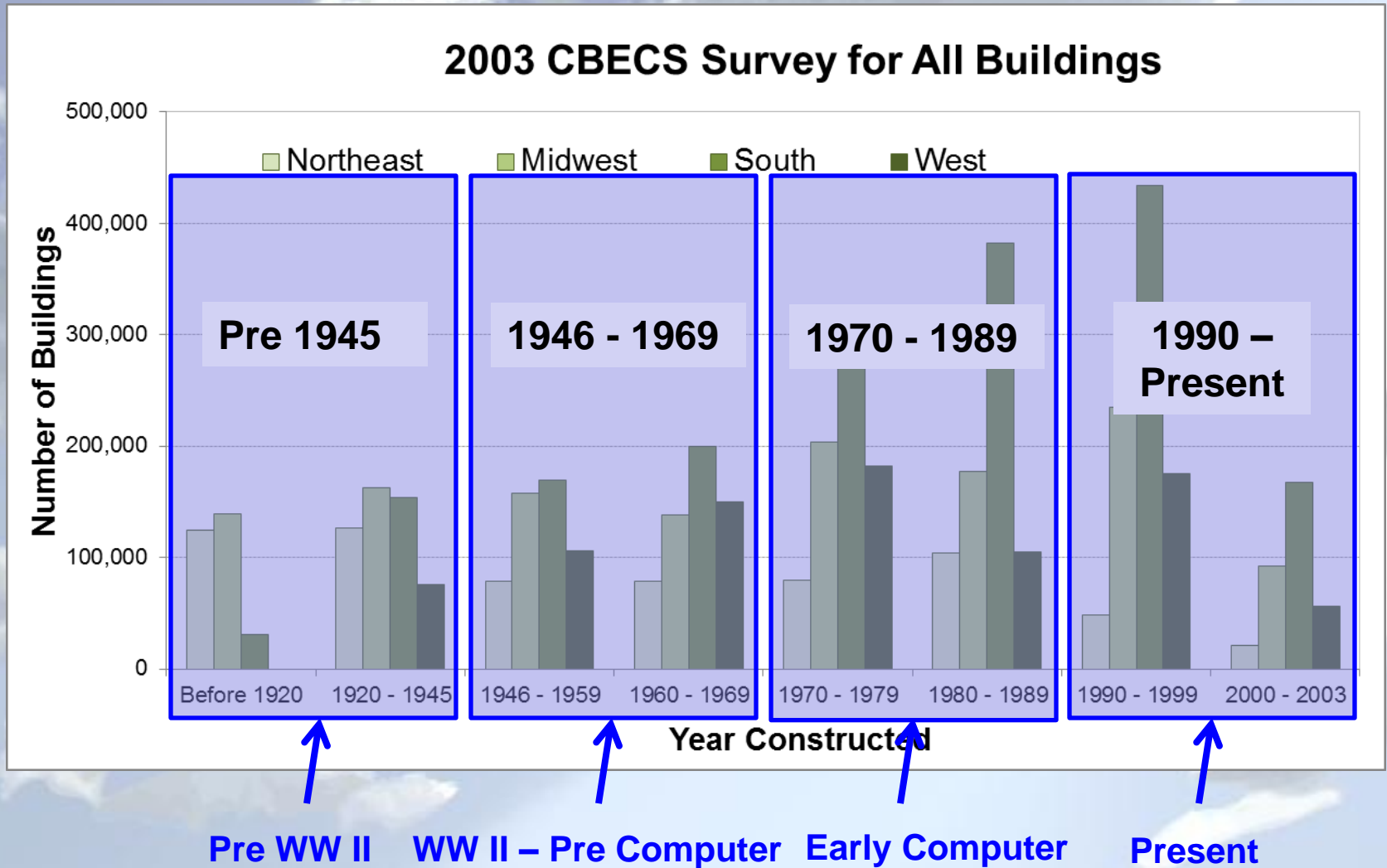
# Distribution/Age of U.S. Commercial Buildings



## Observations:

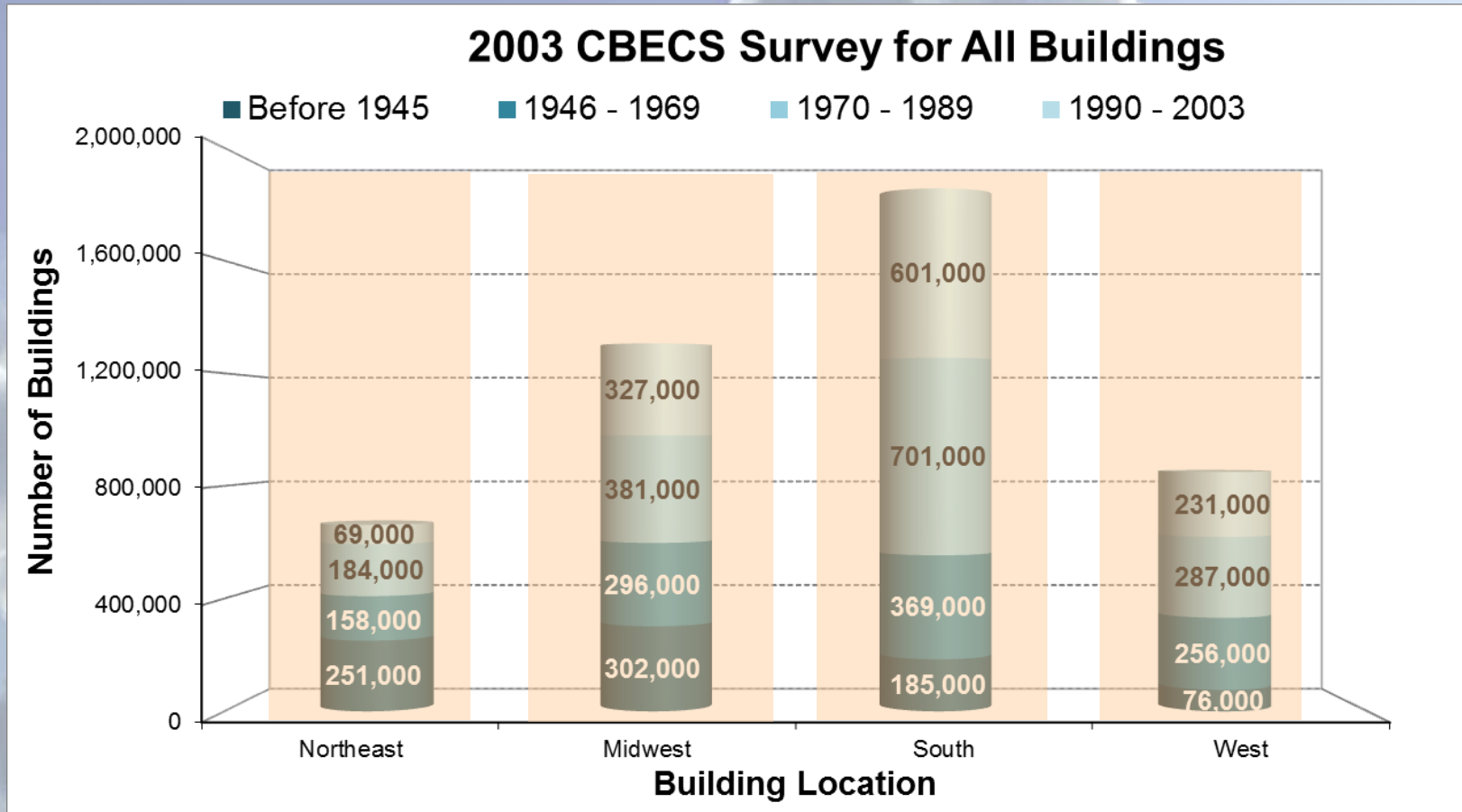
- 52.3% of the buildings were built from 1970 to 1999
- 39.7% of the buildings were built in South

# Distribution/Age of U.S. Commercial Buildings





# Distribution/Age of U.S. Commercial Buildings



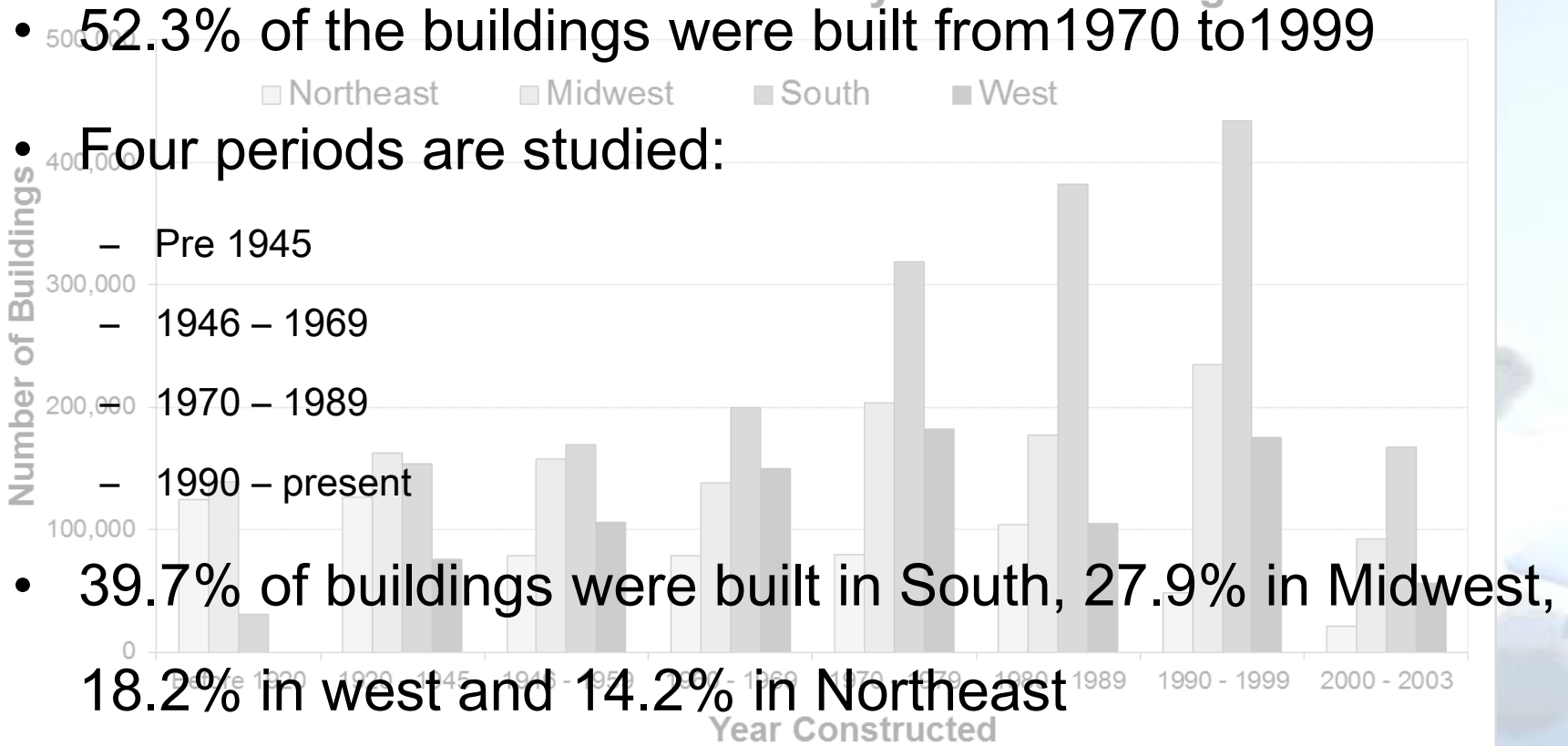
## Observations:

- 39.7% of buildings were built in South
- 27.9% in Midwest, 18.2% in West and 14.2% in Northeast

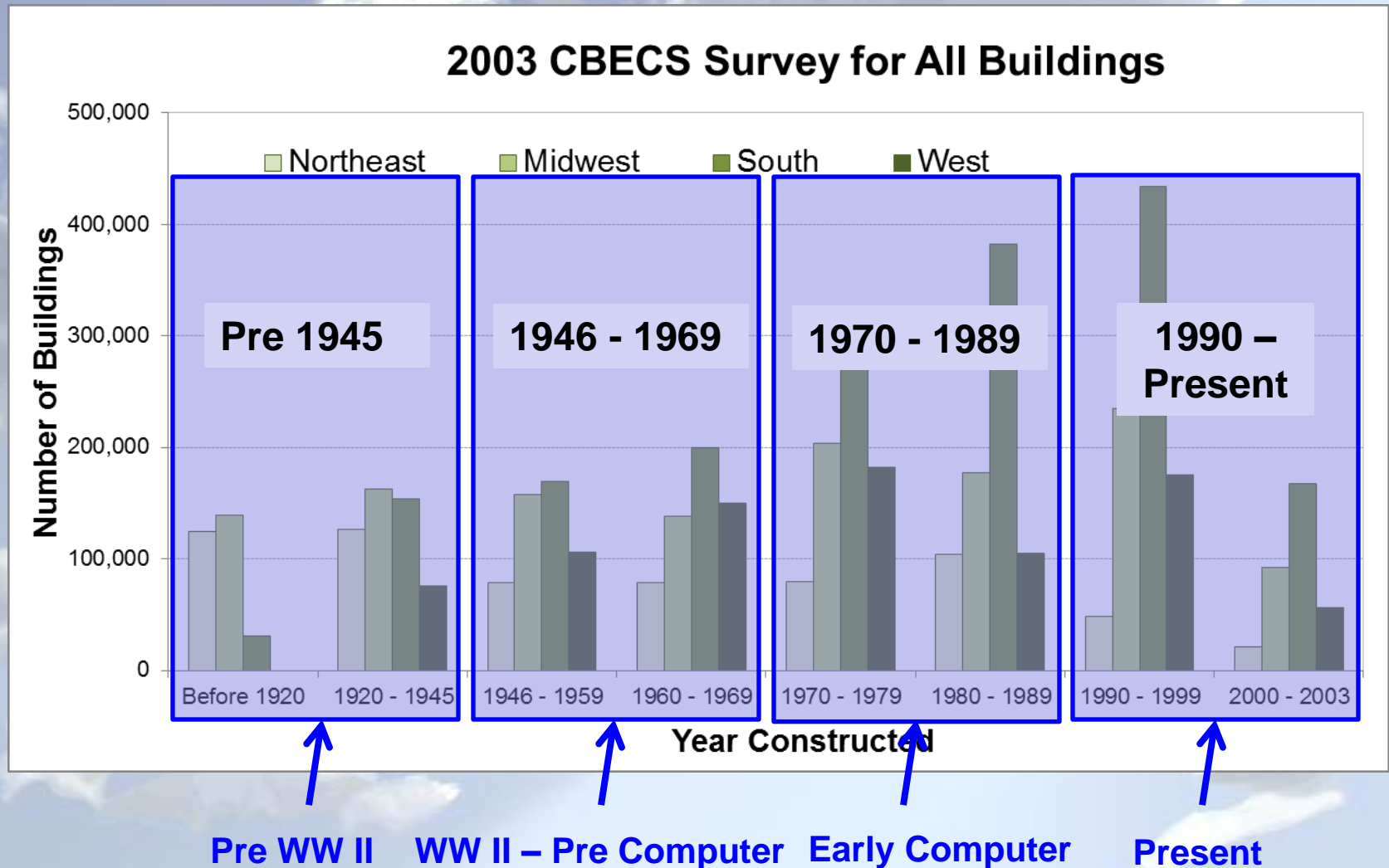
# Distribution/Age of U.S. Commercial Buildings

## CBECS Survey Summary

2003 CBECS Survey for All Buildings



# History: Building Energy Load Calculation Methods



# History: Pre 1945 – Guide Books

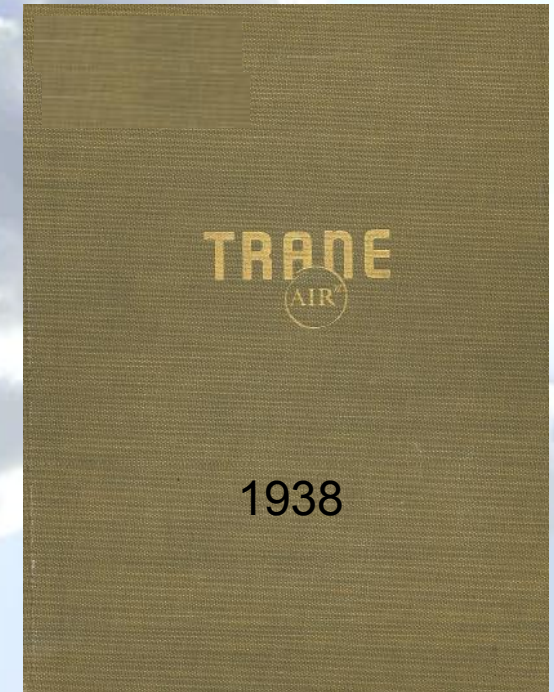
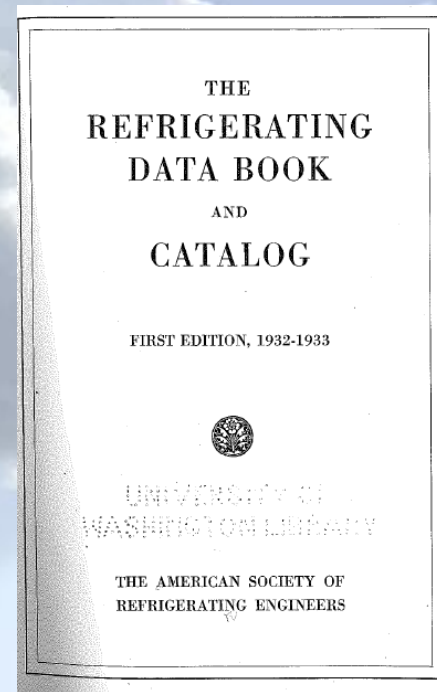
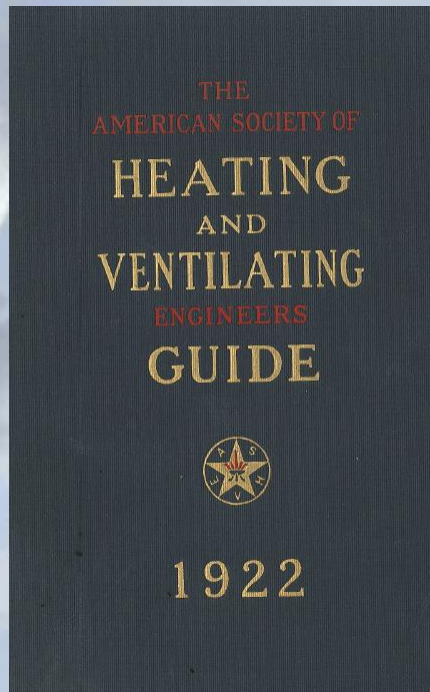
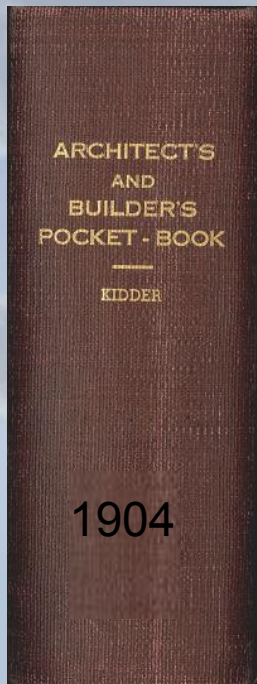
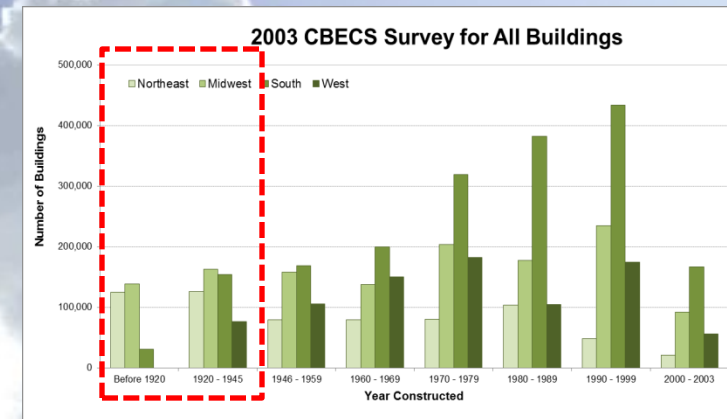
## Guide Books:

1904 Frank E. Kidder *Architect's and Builder's Handbook*

1922 ASHVE *Guide*

1932 *The Refrigerating Data Book* by ASRE

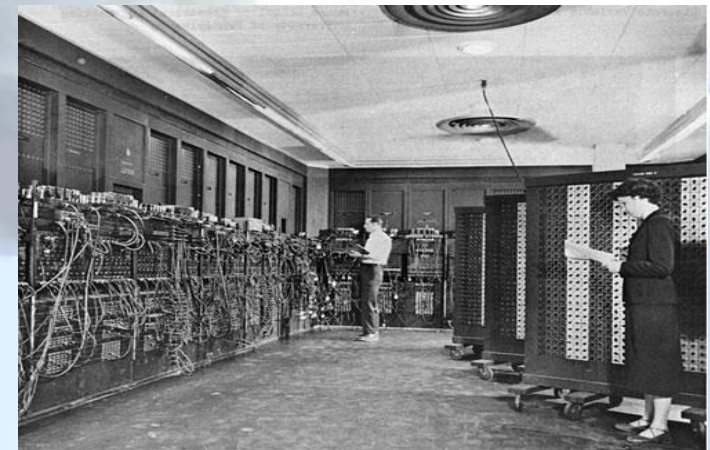
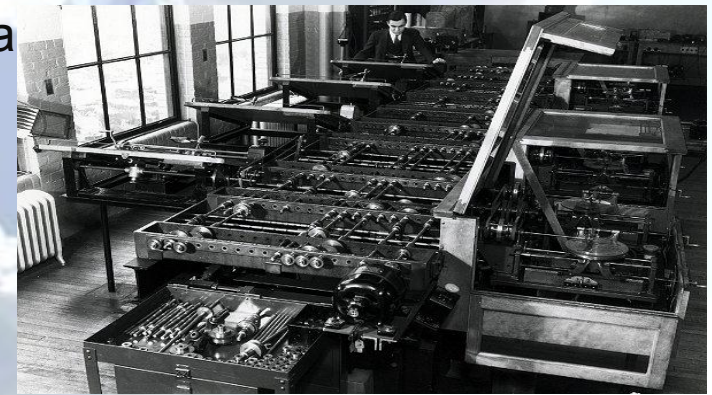
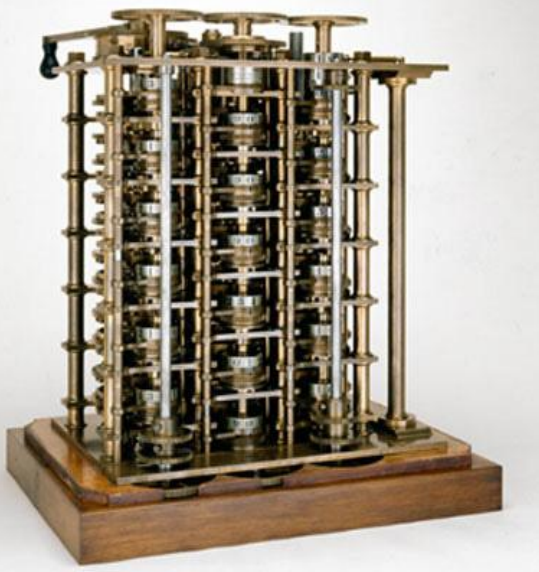
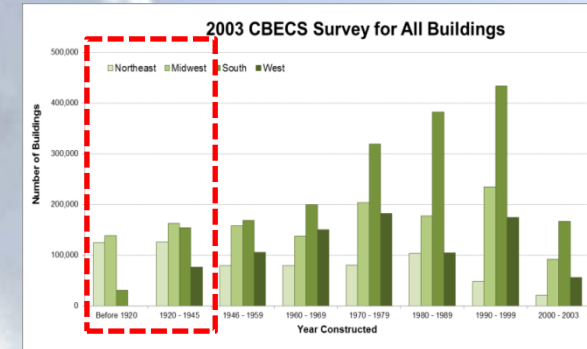
1938 *Trane Air Conditioning Manual*



# History: Pre 1945 – Guide Books

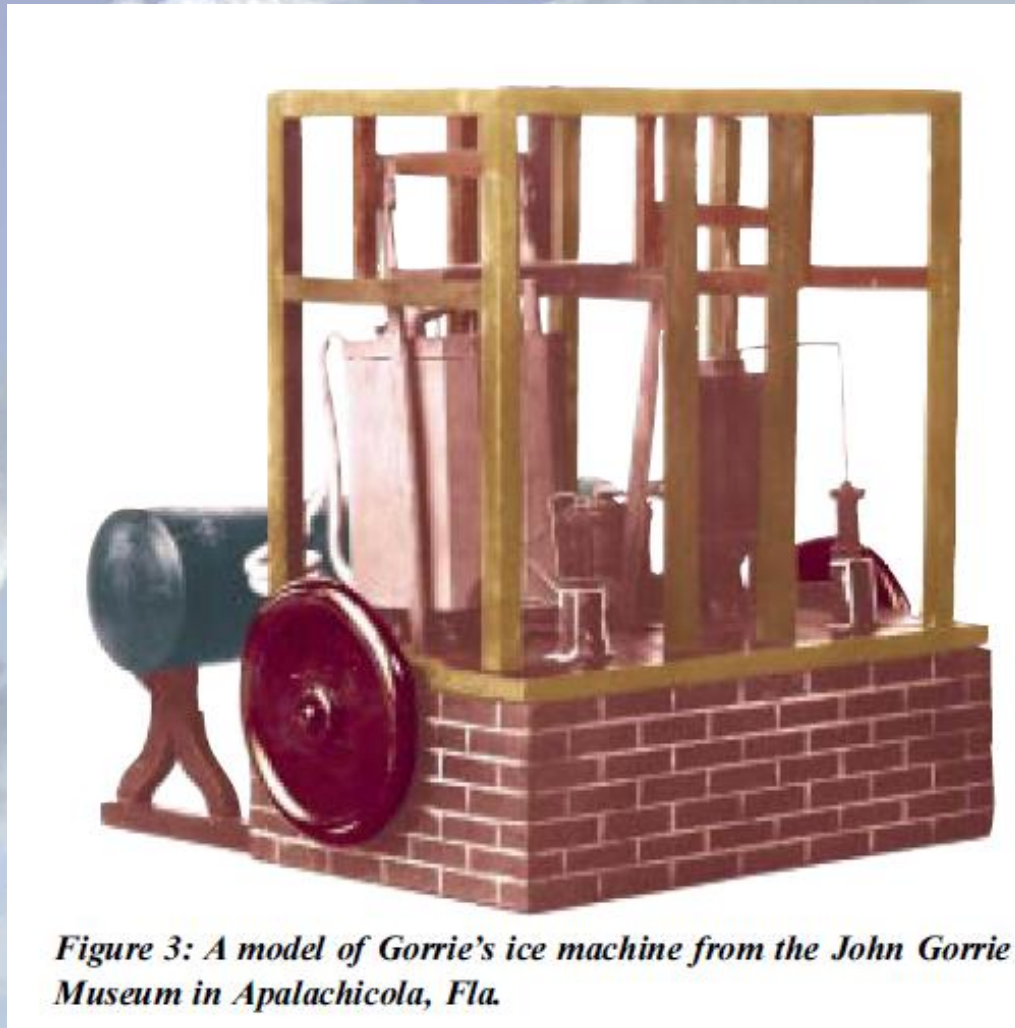
## Computer Development:

- ❑ 1822 - 1832 Charles Babbage and Joseph Clement  
Produced the first Difference Engine
- ❑ 1815-1852: first computer programmer: Ada Lovelace
- ❑ In 1930, differential analyzer available
- ❑ In 1946, first large scale electronic digital computer available - ENIAC



# History: Pre 1945 – Important Developments

In 1848, Dr. John Gorrie invented his “ice machine”



*Figure 3: A model of Gorrie's ice machine from the John Gorrie Museum in Apalachicola, Fla.*

# History: Pre 1945 – Important Developments

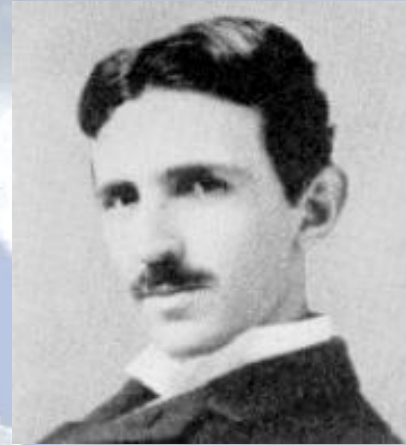
In the late 1880s, “War of the Currents” began between Edison and Tesla

**Thomas Edison**

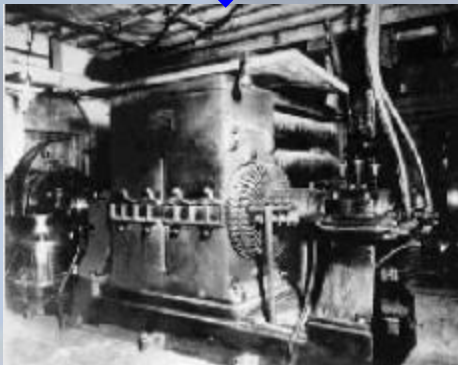


**V.S.**

**Nikola Tesla**



**DC motor**



**AC motor**



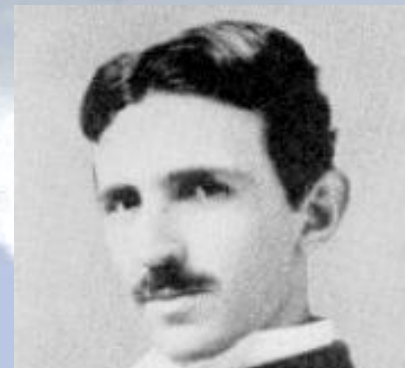
# History: Pre 1945 – Important Developments

In the late 1880s, “War of the Currents” began between Edison and Tesla

**Thomas Edison**

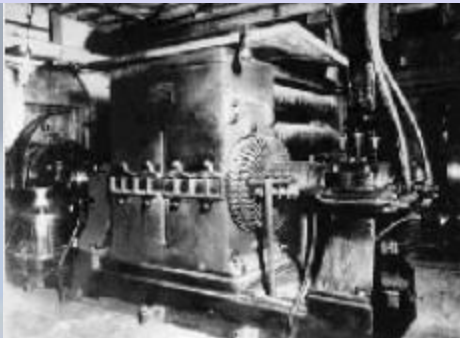


**Nikola Tesla**



**V.S.**

*Before that, air handling systems were steam-driven!*





# History: Pre 1945 – Heating Load Calculation

Frank E. Kidder Architect's and Builder's Handbook  
Peak Load Calculation:

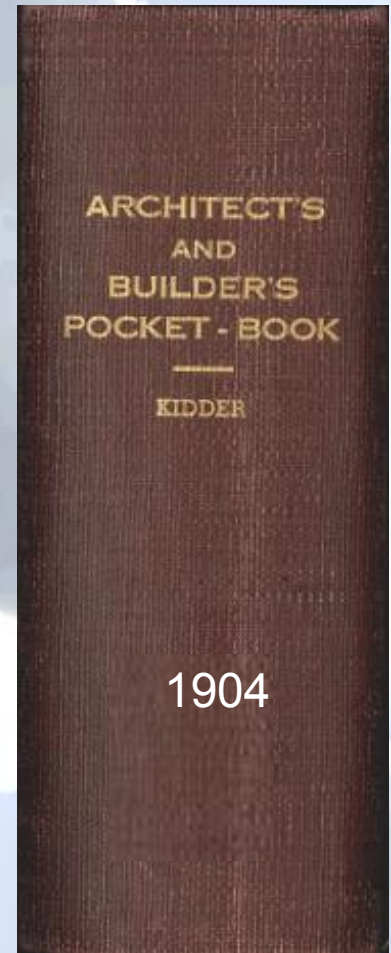
**Heat Loss Calculation**

In 1904, “There appears to be **no rule** by which the architect can determine the size of the furnace that should be used to heat a given building other than by **using the tables** given by the various manufacturers.....”

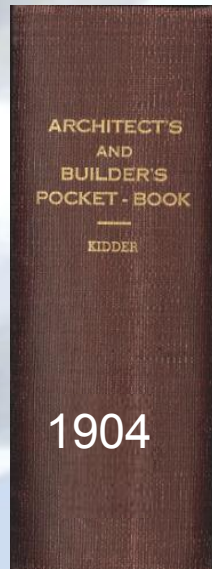
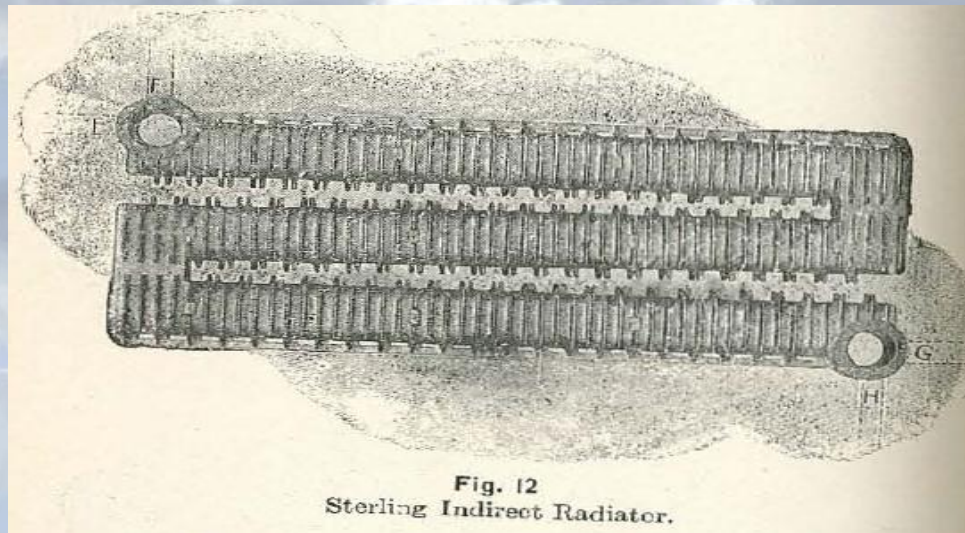
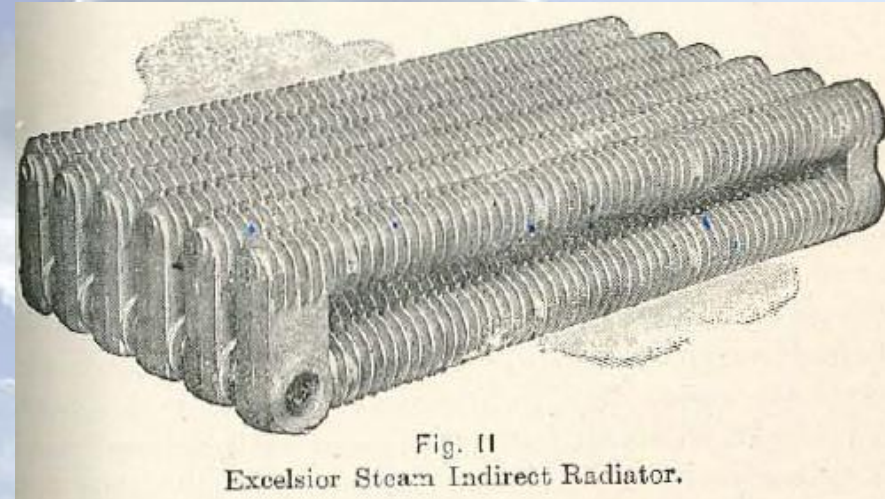
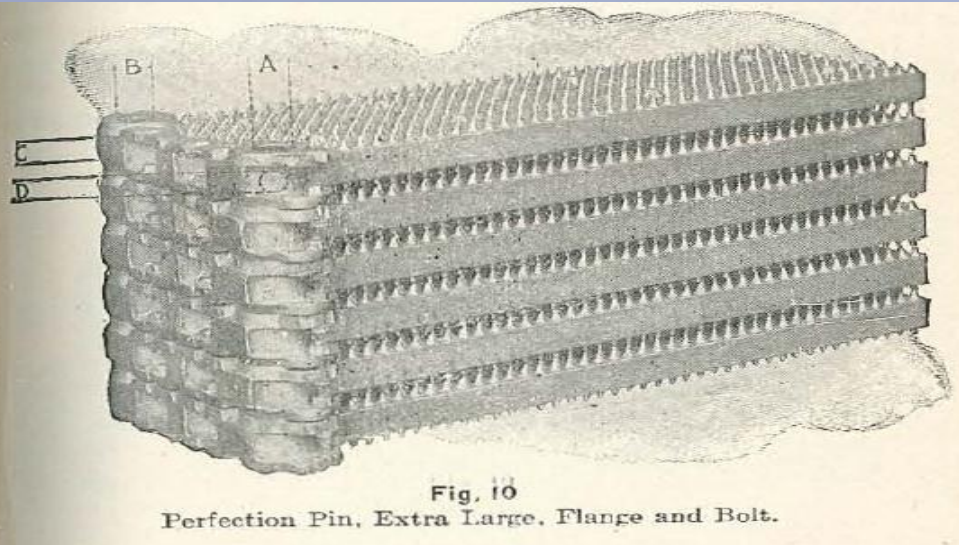
**1904:**

***There were no standardized annual building energy use calculations***

Source: Architect's and Builder's Handbook in 1904 by Frank E. Kidder



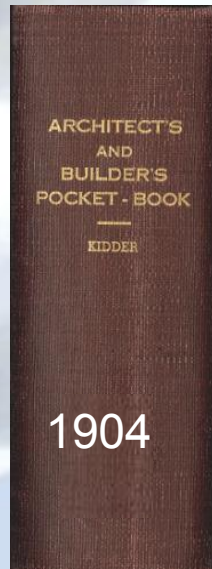
# History: Pre 1945 – Heating Load Calculation Radiators



# History: Pre 1945 – Heating Load Calculation Radiators

DATA FOR EXCELSIOR INDIRECT STEAM-RADIATORS.

Heating Surface.	Cold-air Supply.	Diameter of Duct if Round.	Hot-air Flue.	Size for Brick-work if Hot-air Flues.	Size of Register.	Ratio of 1 to 30.	Ratio of 1 to 35.	Ratio of 1 to 40.
Sq. Ft.	Sq. In.	Inches.	Sq. In.	Inches.	Inches.	Cu. Ft.	Cu. Ft.	Cu. Ft.
24	36	6.8	48	4×12	8×8	720	840	960
36	54	8.3	72	8×12	9×12	1080	1260	1440
48	72	9.6	96	8×12	10×14	1440	1680	1920
60	90	10.0	120	12×12	12×15	1800	2100	2400
72	108	11.7	144	12×12	12×19	2160	2520	2880
84	126	12.7	168	12×16	14×22	2520	2940	3360
96	144	13.5	192	12×16	14×24	2880	3360	3840
108	162	14.4	226	12×20	16×20	3240	3780	4320
120	180	15.2	240	12×20	16×24	3600	4200	4800
132	198	15.9	264	12×24	20×20	3960	4620	5280
144	216	16.6	288	12×24	20×24	4320	5040	5760



# History: Pre 1945 – Heating Load Calculation Radiators

DATA FOR EXCELSIOR INDIRECT STEAM-RADIATORS.

Heating Surface.	Cold-air Sup-	of	re.	ck-	lot-	is-	to	Ratio of 1 to 35.	Ratio of 1 to 40.
Sq. Ft.	Sq. In.	Inches.	Sq. In.	Inches.	Inches.	Cu. Ft.	Cu. Ft.	Cu. Ft.	
24	36	6.8	48	4×12	8×8	720	840	960	
36	54	8.3	72	8×12	9×12	1080	1260	1440	
48	72	9.6	96	8×12	10×14	1440	1680	1920	
60	90	10.0	120	12×12	12×15	1800	2100	2400	
72	108	11.7	144	12×12	12×19	2160	2520	2880	
84	126	12.7	168	12×16	14×22	2520	2940	3360	
96	144	13.5	192	12×16	14×24	2880	3360	3840	
108	162	14.4	226	12×20	16×20	3240	3780	4320	
120	180	15.2	240	12×20	16×24	3600	4200	4800	
132	198	15.9	264	12×24	20×20	3960	4620	5280	
144	216	16.6	288	12×24	20×24	4320	5040	5760	

Size of Room → Size of Radiators

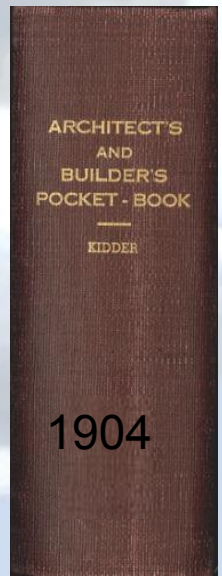
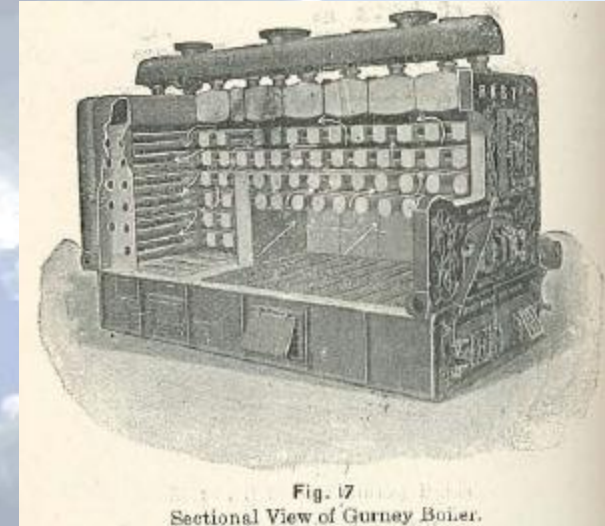
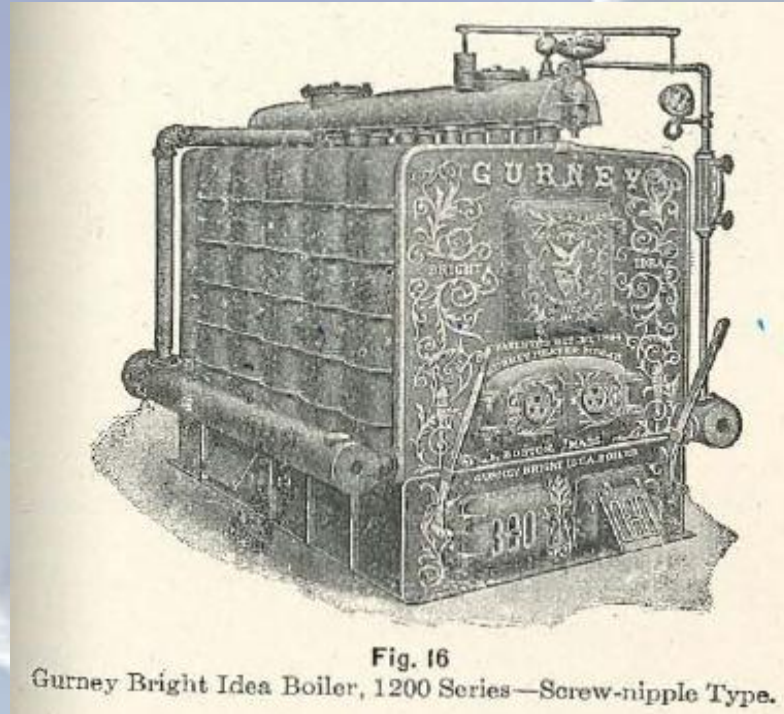
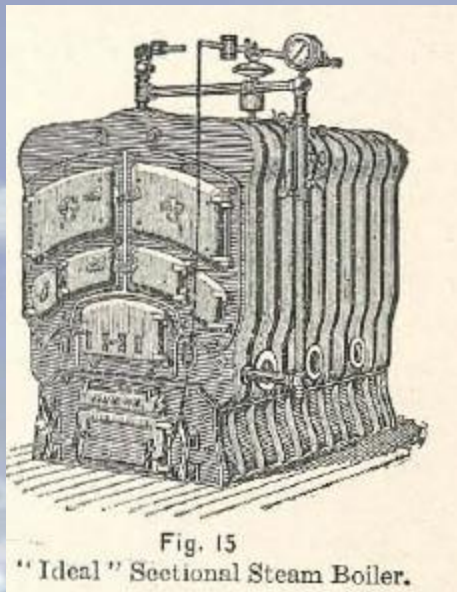
Fig. 12 Sterling Indirect Radiator.

ARCHITECT'S  
AND  
BUILDER'S  
POCKET-BOOK  
—  
KIDDER

1904

# History: Pre 1945 – Heating Load Calculation

## Boilers



# History: Pre 1945 – Heating Load Calculation

## Boilers

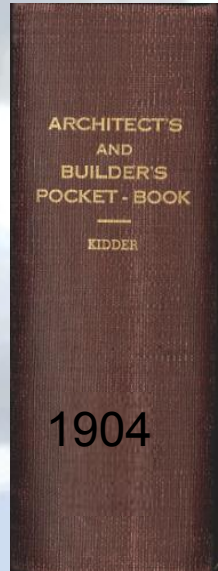
**HORIZONTAL TUBULAR BOILERS.**  
MANUFACTURED BY EDWARD KENDALL & SONS, CAMBRIDGE, MASS.\*

Diameter of Boiler.	Length of Boiler.	Number of Tubes.	Diameter of Tubes.	Length of Tubes.	Thickness of Shell.	Heating Surface.	Nominal Horse-power.	Approx. Weight of Boiler and Castings.	Square Feet of Grate Surface.†	Square Feet of Radiating Surface that Can be Supplied.‡
Ins.	Ft. Ins.		Ins.	Ft.	Ins.	Sq. Ft.				
30	6 0	36	2	5	1/4	114	7 1/2	3,600	5	684
"	7 0	"	"	6	"	137	9	3,750	5	822
"	8 0	"	"	7	"	160	10 1/2	3,900	6	990
"	9 0	"	"	8	"	182	12	4,050	8	1,092
36	8 0	34	2 1/2	7	"	189	12 1/2	4,390	8	1,124
"	9 0	"	"	8	"	216	14 1/2	4,600	8	1,296
"	10 0	"	"	9	"	243	16	4,810	10	1,458
"	11 0	"	"	10	"	270	18	5,090	10	1,620
"	12 0	"	"	11	"	297	20	5,300	12	1,782
"	13 0	28	3	12	"	321	21	5,510	12	1,926
42	10 0	45	2 1/2	9	"	315	21	6,610	12	1,890
"	11 0	"	"	10	"	350	23	7,030	12	2,100
"	12 0	"	"	11	"	384	26	7,300	14	2,304
"	13 0	"	"	12	"	420	28	7,660	14	2,520
"	12 0	38	3	11	"	389	26	7,320	14	2,334
"	13 0	"	"	12	"	425	28	7,680	14	2,550
"	14 0	"	"	13	"	460	31	7,950	16	2,760
"	15 0	"	"	14	"	495	33	8,220	16	2,970
48	12 2	69	2 1/2	11	5/16	566	38	9,750	18	3,396
"	13 2	"	"	12	"	617	41	10,150	18	3,702
"	15 2	49	3	14	"	626	42	10,685	18	3,756
"	16 2	"	"	15	"	671	45	11,035	18	4,026
"	17 2	"	"	16	"	716	48	11,485	20	4,296
"	17 2	38	3 1/2	16	"	658	44	12,085	20	3,948
"	18 2	"	"	17	"	700	47	12,535	20	4,200
54	15 2	60	3	14	1 1/16	759	51	14,015	24	4,554
"	16 2	72	"	15	"	954	63	15,074	26	5,724
"	17 2	"	"	16	"	1,018	68	15,584	28	6,108
"	18 2	"	"	17	"	1,082	72	16,094	28	6,492
"	17 2	54	3 1/2	16	"	905	60	15,458	26	5,430
"	18 2	"	"	17	"	961	64	15,960	26	5,766
"	19 2	"	"	18	"	1,018	68	16,552	28	6,108
60	18 2	92	3	17	3/8	1,364	91	19,000	34	8,284
"	18 2	64	3 1/2	17	"	1,133	76	18,468	30	6,798
"	19 2	"	"	18	"	1,200	80	19,227	32	7,200
66	18 2	110	3	17	"	1,615	108	22,430	40	9,690
"	18 2	82	3 1/2	17	"	1,426	95	22,190	36	8,556
72	18 2	130	3	17	7/16	1,900	127	26,036	48	11,400
"	18 2	100	3 1/2	17	"	1,721	115	25,980	44	10,326

\* Selected from 156 sizes listed by this firm. These boilers are made up to 96 ins. diam. and 21 ft. long.

† For hard coal or coke.

‡ Proportion 6 to 1. The last two columns added by the author.

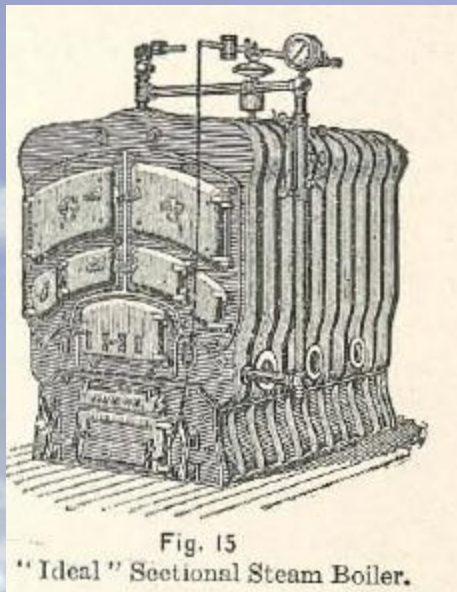


ARCHITECT'S  
AND  
BUILDER'S  
POCKET-BOOK  
—  
KIDDER

1904

# History: Pre 1945 – Heating Load Calculation

## Boilers



HORIZONTAL TUBULAR BOILERS.  
MANUFACTURED BY EDWARD KENDALL & SONS, CAMBRIDGE, MASS.\*

Diameter of Boiler.	Length of Boiler.	Number of Tubes.	Diameter of Tubes.	Length of Tubes.	Thickness of Shell.	Heating Surface.	Nominal Horse-power.	Approx. Weight of Boiler and Castings.	Square Feet of Grate Surface. †	Square Feet of Radiating Surface that can be Supplied. ‡
Ins.	Ft. Ins.		Ins.	Ft.	Ins.	Sq. Ft.				
30	6 0	36	2	5	1/4	114	7 3/4	3,600	5	684
"	7 0	"	"	6	"	137	9 3/8	3,750	5	822
"	8 0	"	"	7	"	160	10 3/8	3,900	6	990
"	9 0	"	"	8	"	182	12	4,050	8	1,092

No. of Radiators → Size of Boilers

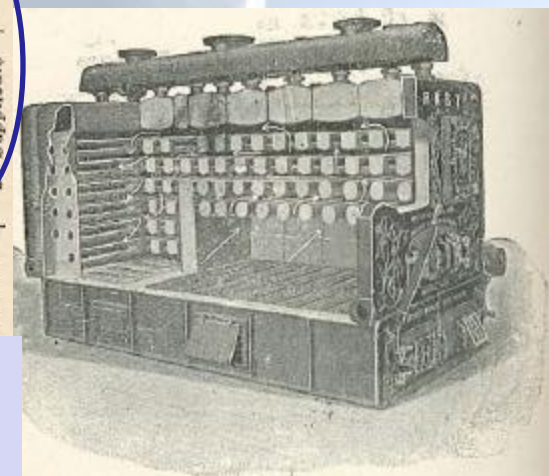
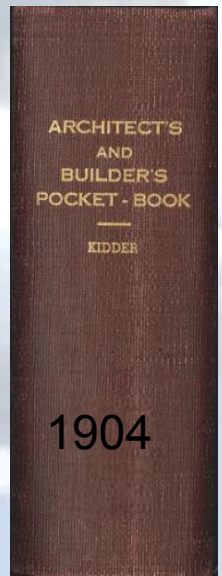


Fig. 17  
Sectional View of Gurney Boiler.

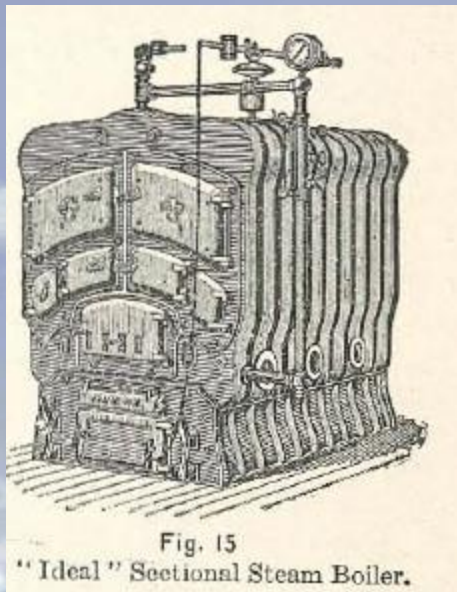
"	13 0	"	"	12	"	420	28	7,660	14	2,520
"	12 0	38	3	11	"	389	26	7,320	14	2,334
"	13 0	"	"	12	"	425	28	7,680	14	2,550
"	14 0	"	"	13	"	460	31	7,950	16	2,760
"	15 0	"	"	14	"	495	33	8,220	16	2,970
48	12 2	69	2 1/2	11	5/8	566	38	9,750	18	3,396
"	13 2	"	"	12	"	617	41	10,150	18	3,702
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"	18 2	"	"	17	"	700	47	12,535	20	4,200
54	15 2	60	3	14	1 1/2	759	51	14,015	24	4,554
"	16 2	72	"	15	"	954	63	15,074	26	5,724
"	17 2	"	"	16	"	1,018	68	15,584	28	6,108
"	18 2	"	"	17	"	1,082	72	16,094	28	6,492
"	17 2	54	3 1/2	16	"	905	60	15,458	26	5,430
"	18 2	"	"	17	"	961	64	15,960	26	5,766
"	19 2	"	"	18	"	1,018	68	16,552	28	6,108
60	18 2	92	3	17	3/8	1,364	91	19,000	34	8,284
"	18 2	64	3 1/2	17	"	1,133	76	18,468	30	6,798
"	19 2	"	"	18	"	1,200	80	19,227	32	7,200
66	18 2	110	3	17	"	1,615	108	22,430	40	9,690
"	18 2	82	3 1/2	17	"	1,426	95	22,190	36	8,556
72	18 2	130	3	17	1/2	1,900	127	26,036	48	11,400
"	18 2	100	3 1/2	17	"	1,721	115	25,980	44	10,326

\* Selected from 156 sizes listed by this firm. These boilers are made up to 96 ins. diam. and 21 ft. long.  
† For hard coal or coke.  
‡ Proportion 6 to 1. The last two columns added by the author.



# History: Pre 1945 – Heating Load Calculation

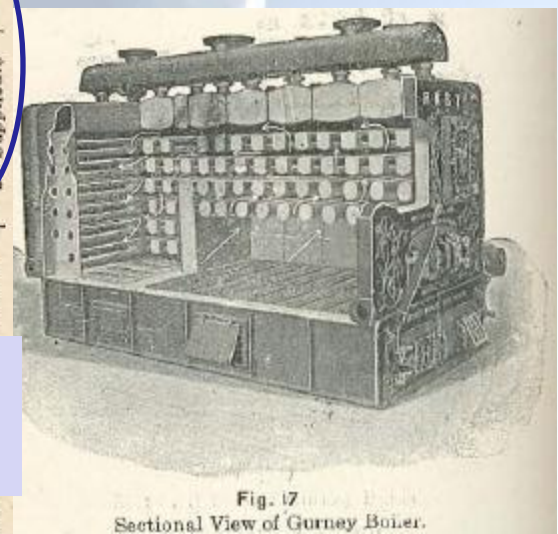
## Boilers



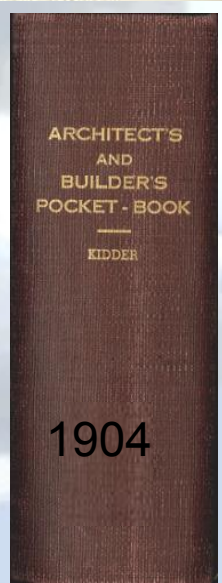
**HORIZONTAL TUBULAR BOILERS.**  
MANUFACTURED BY EDWARD KENDALL & SONS, CAMBRIDGE, MASS.\*

Diameter of Boiler.		Length of Boiler.	Number of Tubes.	Diameter of Tubes.	Length of Tubes.	Thickness of Shell.	Heating Surface.	Nominal Horse-power.	Approx. Weight of Boiler and Castings.	Square Feet of Radiating Surface.†	Square Feet of Radiating Surface that can be Supplied.‡
Ins.	Ft. Ins.	Ins.	Ft.	Ins.	Sq. Ft.	Ins.					
30	6 0	36	2	5 1/4	114	7/16	73	7 3/4	3,600	5	684
"	7 0	"	"	6	137	9/16	137	9 3/8	3,750	5	822
"	8 0	"	"	7	160	1 1/8	160	10 3/8	3,900	6	990
"	9 0	"	"	8	182	1 1/4	182	12 3/8	4,050	8	1,092
"	13 0	"	"	12	420	1 1/2	420	28	7,660	14	2,520
"	13 0	38	3	11	389	1 1/2	389	26	7,320	14	2,334
"	13 0	"	"	12	425	1 1/2	425	28	7,680	14	2,550
"	14 0	"	"	13	460	1 1/2	460	31	7,950	16	2,760
"	15 0	"	"	14	495	1 1/2	495	33	8,220	16	2,970

No. of Radiators → Size of Boilers



- 1904:**
- Method existed for sizing the steam radiator
  - Steam boilers were sized = number/type of radiators
  - Air conditioning had yet to be used commercially

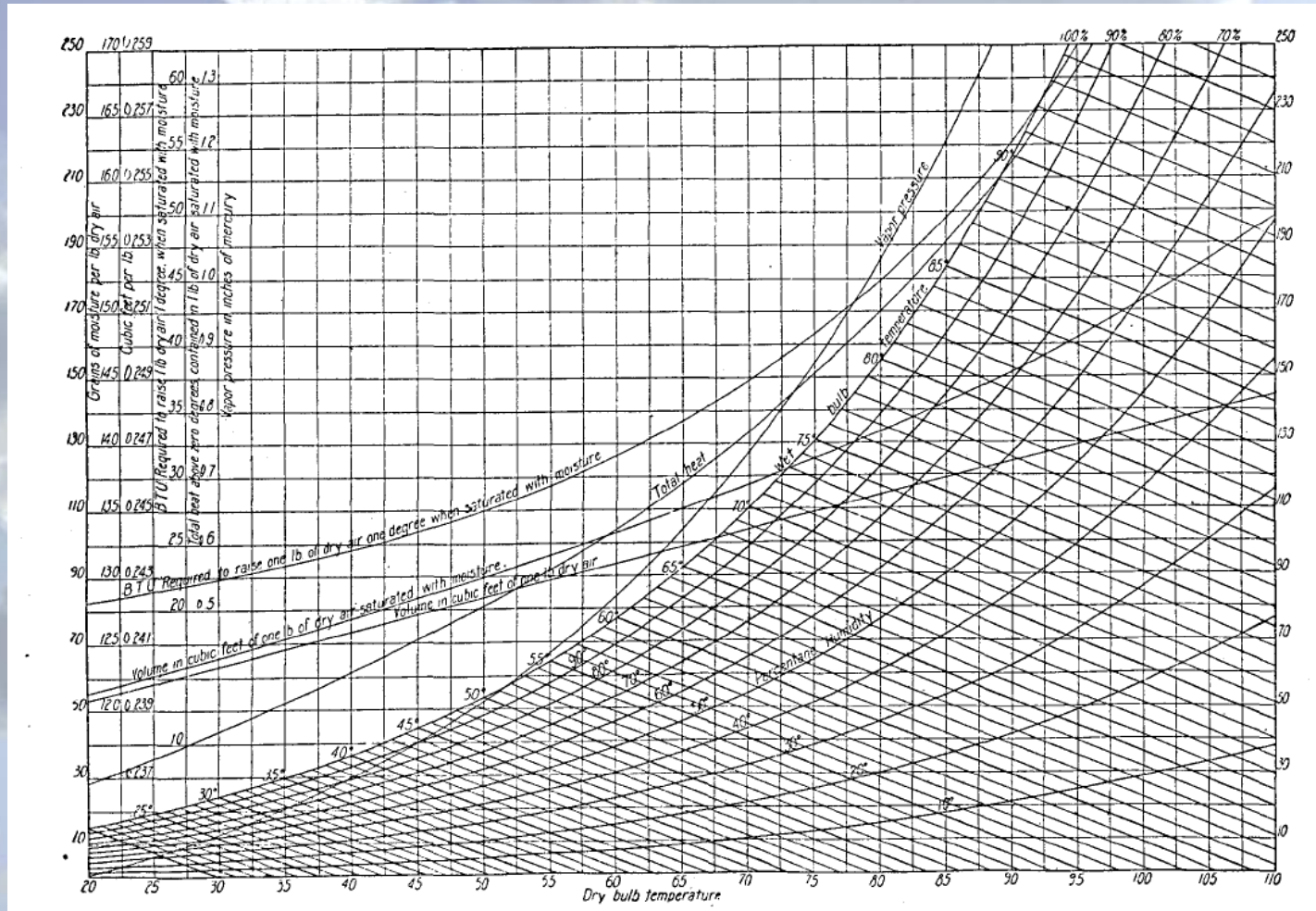


Source: Architects and Builders Handbook



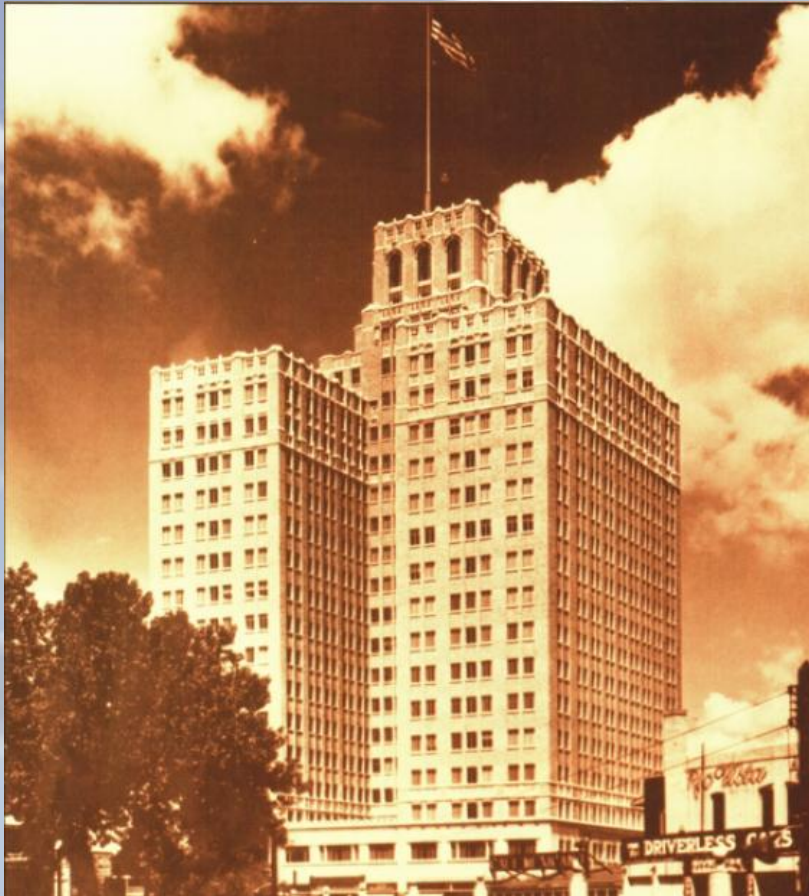
# History: Pre 1945 – Heating Load Calculation

In 1911, Willis Carrier developed his *Psychrometric chart*

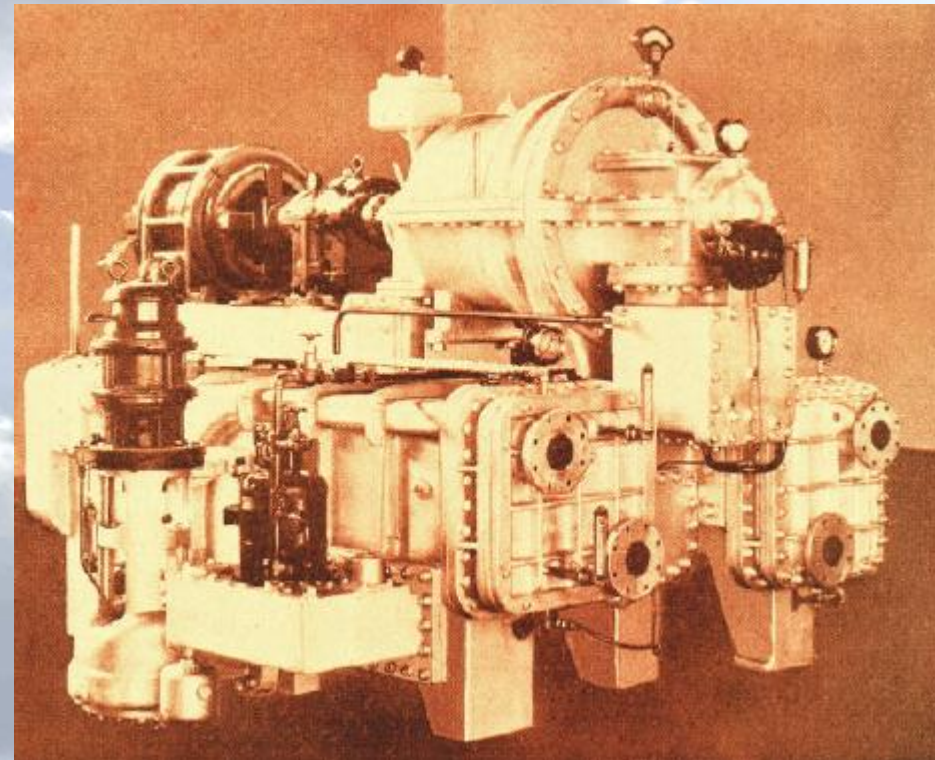


# History: Pre 1945 – Cooling Load Calculation

In 1928, the first high-rise air-conditioned office building in U.S. was built in San Antonio “The Milam Building”



The Milam Building



Original Carrier Centrifugal Refrigeration Unit

# History: Pre 1945 – Cooling Load Calculation

In 1928, the first high-rise air-conditioned office building in U.S. was built in San Antonio “The Milam Building”



The Milam Building

- ❑ Tallest Reinforced-Concrete High-Rise Office Building
- ❑ Air-Conditioning System was designed by Carrier Engineering Corporation
- ❑ 11 AHUs provided cooling, two Chillers with a Maximum 375-ton Capacity provided Chilled Water
- ❑ Radiant Heat was Absorbed by the Heavy Construction
- ❑ Venetian Blinds, Cloth Window Shades, Duct dampers were Added to Solve the Problem

# History: Pre 1945 – Cooling Load Calculation

Until 1938, TRANE Company Published its first design manual, called “TRANE Air-Conditioning Design Manual” and Provided a *load estimate sheet* for engineers to use.

1938

FORM NO. 100  
 PREPARED BY: \_\_\_\_\_ PROPOSAL NO.: \_\_\_\_\_  
 DATE: \_\_\_\_\_ PLAN NO.: \_\_\_\_\_  
 DWT: \_\_\_\_\_ SHEET NO.: \_\_\_\_\_

**COOLING LOAD ESTIMATE SHEET**  
**THE TRANE COMPANY**  
 La Crosse, Wisconsin

JOB NAME: Acme Industrial Bldg. LOCATION: Chicago, Illinois  
 ROOM: Entire Bldg. SIZE: 75' x 180' HEIGHT: 12' FLOOR: First  
 FLOOR CEILING HEIGHTS: EXT. WALL: 95' VENTILATOR: 75' NEW POINT: 67' N. H. 39%  
 FLOOR AREA: 80' VENTILATOR: 67' NEW POINT: 80' N. H. 50%  
 TIME: A. M. 3 P. M. LAT: 40° WALL COLOR: \_\_\_\_\_ DARK  LIGHT  MISCEL.   
 WINDOWS: \_\_\_\_\_ SHADES  AVOIDS  MATT  ROOF COLOR: \_\_\_\_\_ MAKE  LIST  MISCEL.

ROOM	NO.	AREA (SQ. FT.)	U	D	UNITS PER HOUR
<b>CONDUCTION HEAT GAINS</b>					
1	OUTER WALL BRICK	325x7x18	5400	**	*****
2	OUTER WALL PLUS	56x5x7 plus	2x7x7	3058	1.3 15 24,000
3	OUTER WALL SET		3342	0.3 15	15,000
4	PAINT ON SET				
5	GLASS IN WINDOW				
6	FLOOR				
7	CEILING OF FLOOR				
8	ROOF	150x75	11,250	0.4 19	87,500
9	MISC.				
<b>TOTAL CONDUCTION HEAT GAINS</b> ***** ** ** 112,500					
<b>EXCESS SOLAR HEAT GAINS</b>					
10	WALLS NORTH				
11	WALLS SOUTH				
12	WALLS EAST	(No solar heat gain - See table 3-28)			
13	WALLS WEST	75x12 minus 10x7x5	550	0.5 9	1,490
14	ROOF NORTH				
15	ROOF WEST	150x12 minus 18x7x5+49	1181	0.3 8	3,890
16	ROOF SOUTH				
17	ROOF EAST	150x75	11,250	0.4 63	283,500
18	GLASS FAN IN				
19	WINDSHIELD				
20	DOOR	(No solar heat gain - See table 3-29)			
21	BATHROOM				
22	BOLING	10x7x5	350	1.1 8	3,090
23	BOILER ROOM				
24	REST	7x7 plus 18x7x5	879	1.1 99	57,510
25	RESTROOM				
26	RESTROOM				
27	MISC.				
<b>TOTAL EXCESS SOLAR HEAT GAINS</b> ***** ** ** 247,200					
<b>DUCT HEAT GAINS</b>					
28	AIR-RAID BATT.				
29	NON-INSULATED DUCTS				
30	TOTAL DUCT HEAT GAINS				

ITEM NO.	DESCRIPTION	NO. OF PEOPLE	LOAD	TOTAL
31	BODY HEAT GAINS	75	2.00	15,000
32	LAMP (WET)	25	1.80	4,500
33	LAMP (DRY)	50	1.80	22,500
34	TOTAL BODY HEAT GAINS			42,000
<b>EQUIPMENT HEAT GAINS</b>				
35	ENGINE HEAT	3500	3.33	11,650
36	SPACE HEATING SYSTEMS	50	3000	150,000
37	LABORATORY EQUIPMENT			
38	OTHER EQUIPMENT			
39	NO. OF PEOPLE			
40	NO. OF LAMP			
41	NO. OF ENGINE			
42	NO. OF SPACE HEAT.			
43	NO. OF LABORATORY			
44	NO. OF OTHER			
<b>TOTAL EQUIPMENT HEAT GAINS</b> 161,650				
<b>INFILTRATION HEAT GAINS (SEE TABLE 3-28)</b> ***** ** **				
<b>MISCELLANEOUS HEAT GAINS</b>				
<b>TOTAL MISCELLANEOUS HEAT GAINS</b>				
<b>SUMMARY OF HEAT GAINS</b>				
45	CONDUCTION			112,500
46	EXCESS SOLAR			247,200
47	WIND LOAD			16,870
48	PEOPLE LOAD			42,000
49	EQUIPMENT LOAD			161,650
50	MISCELLANEOUS			
51	TOTAL REVERSIBLE HEAT GAINS			580,220
52	TOTAL LATENT HEAT GAINS			25,050
53	TOTAL HEAT GAINS - (ITEM 51 + ITEM 52)			605,270
54	DESIRABLE HEAT LOSS - (ITEM 45 - 49) - (ITEM 52) =			542,330
55	DESIRABLE HEAT LOSS - (ITEM 53) =			580,410
56	DESIRABLE HEAT LOSS - (ITEM 54) =			63,960
57	DESIRABLE HEAT LOSS - (ITEM 55) =			63,960
58	DESIRABLE HEAT LOSS - (ITEM 56) =			63,960
59	DESIRABLE HEAT LOSS - (ITEM 57) =			63,960
60	TOTAL AIR SUPPLY - (ITEM 56) - (ITEM 57) =			38,450
<b>HEAT LOAD OF VENTILATION AIR</b>				
61	NO. OF PEOPLE	75	3.00	225,000
62	NO. OF SPACE HEAT.	50	3000	150,000
<b>TOTAL COOLING LOAD ON COILS AND REFRIGERATING APPARATUS</b>				
63	TOTAL COOLING LOAD B.T.U. PER HOUR			375,000
64	TONNAGE EQUIVALENT OF COOLING LOAD - (ITEM 63) / 12,000 =			31.25 TONS

UNITS SELECTED

FIGURE 3-H

**Solar Temperature Differences for Walls and Roofs**  
 To be Used in Calculating Excess Solar Heat Gains  
 30 Degree Latitude

TIME	DIRECTION WALL FACES							
	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	ROOFS
8 A.M.	6	7						9
9	26	32	15					23
10	32	44	26					45
11	34	49	28					55
12	12	27	24	1				65
1 P.M.		11	16	5				69
2			2	6	2			66
3				5	14	11		59
4				1	24	27	13	59
5					28	40	24	46
6					25	44	32	29
7					15	32	26	9
8						7	6	

**DARK COLORS**  
BLACK, DARK GREEN

TIME	DIRECTION WALL FACES							
	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	ROOFS
8 A.M.	1	2						3
9	14	17	7					17
10	18	29	15					27
11	19	23	16					36
12	8	16	13					49
1 P.M.		8	7	7				49
2				1				40
3					3	16	9	36
4					16	23	13	27
5					15	26	18	17
6					7	17	14	3
7						2	1	

**MEDIUM COLORS**  
RED, BROWN, LIGHT GREEN

TIME	DIRECTION WALL FACES							
	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	ROOFS
8 A.M.								
9	6	8	2					7
10	8	13	6					14
11	5	11	7					19
12		7	5					22
1 P.M.				1				23
2								22
3					1			19
4					6	7		14
5					7	11	5	14
6					6	13	8	7
7						2	8	6
8								

**LIGHT COLORS**  
ON DARK SURFACES  
WHITE, ALUMINUM

# History: Pre 1945 – Load Estimate Sheet

## TRANE Air-Conditioning Manual

FORM NO. 1		COOLING LOAD ESTIMATE SHEET		THE TRANE COMPANY		La Crosse, Wisconsin	
DESIGNED BY _____	PROPOSAL NO. _____						
DRAWN BY _____	PLAN NO. _____						
JOB NAME: <b>Anne Industrial Corp.</b>		LOCATION: <b>Chicago, Illinois</b>		FLOOR: <b>First</b>			
Entire bldg.				W. W. <b>50%</b>			
OUTSIDE DESIGN CONDITIONS: DRY-BULB <b>80°</b>				W. W. <b>50%</b>			
INDOOR DESIGN CONDITIONS: DRY-BULB <b>75°</b>				W. W. <b>50%</b>			
WIND: <b>3 M.P.H.</b>		LAT: <b>40°</b>		WIND COLOR: <b>DIRTY</b>		LIGHT: <b>0</b>	
WIND DIRECTION: <b>SW</b>		WIND VELOCITY: <b>3</b>		WIND COLOR: <b>DIRTY</b>		WIND COLOR: <b>DIRTY</b>	

ITEM	DESCRIPTION	AREA	U-Factor	Correction Factor	Heat Gain
<b>CONDUCTION HEAT GAINS</b>					
1	EXTERIOR WALL				34,000
2	EXTERIOR GLAZING				18,000
3	EXTERIOR ROOF				
4	INTERIOR WALL				
5	INTERIOR GLAZING				
6	FLOOR				
7	CEILING ON ROOF	180x75	11,250	0.4	15
8	ROOF				67,500
<b>EXCESS SOLAR HEAT GAINS</b>					
9	WALLS EXPOSED				155,500
10	ROOF EXPOSED				
11	EAST				
12	SOUTH				
13	WEST				
14	ROOF				1,400
15	WIND				
16	ADJACENT BUILDING	10x75	1125	0.3	5
17	ROOF	18x75	11,250	0.4	63
Solar gain - See table 3-29					
18	10x7x5		350	1.1	8
19	18x7x5		870	1.1	77
20	NORTHWEST				
21	SOUTH				
22	WIND				
<b>DUCT HEAT GAINS</b>					
23	INSULATED DUCTS				
24	NON-INSULATED DUCTS				
25	TOTAL DUCT HEAT GAIN				

ITEM	DESCRIPTION	Heat Gain
26	<b>Body Heat Gains</b>	18,870
27	<b>Equipment Heat Gains</b>	11,900
28	<b>Infiltration Heat Gains</b>	
29	<b>Miscellaneous Heat Gains</b>	
30	<b>Summary of Heat Gains</b>	26,890
31	<b>Heat Load of Ventilation Air</b>	50x155=7750
32	<b>Total Cooling Load on Coils</b>	

Design Data

Conduction Heat Gains

Excess Solar Heat Gains

Solar Temperature Difference Method

Duct Heat Gains

Body Heat Gains

Equipment Heat Gains

Infiltration Heat Gains

Miscellaneous Heat Gains

Summary of Heat Gains

Heat Load of Ventilation Air

Total Cooling Load on Coils

FIGURE 3-H

# History: Pre 1945 – Load Estimate Sheet

## TRANE Air-Conditioning Manual

**COOLING LOAD ESTIMATE SHEET**  
THE TRANE COMPANY  
La Crosse, Wisconsin

PROPOSAL NO. \_\_\_\_\_  
PLAN NO. \_\_\_\_\_

DESIGNED BY \_\_\_\_\_  
DATE \_\_\_\_\_

JOB NAME: Auto Industrial Corp. LOCATION: Chicago, Illinois  
Entire bldg. First FLOOR AREA: 39%  
OUTSIDE DESIGN CONDITION: DRY BULB 95 F. W. 50%  
WIND DIRECTION: DRY BULB WIND VELOCITY: 40 MPH. WIND COLOR:  DARK  LIGHT  MEDIUM

ITEM	DESCRIPTION	AREA	UNIT	LOAD	REMARKS
1	CONDUCTION HEAT GAINS			34,000	
2	EXCESS SOLAR HEAT GAINS			1,490	
3	DUCT HEAT GAINS				
4	EQUIPMENT HEAT GAINS			11,900	
5	INFILTRATION HEAT GAINS			283,500	
6	BODY HEAT GAINS			18,870	
7	TOTAL HEAT GAINS			459,760	

**Summary of Heat Gains**

ITEM	DESCRIPTION	LOAD
1	CONDUCTION HEAT GAINS	34,000
2	EXCESS SOLAR HEAT GAINS	1,490
3	DUCT HEAT GAINS	
4	EQUIPMENT HEAT GAINS	11,900
5	INFILTRATION HEAT GAINS	283,500
6	BODY HEAT GAINS	18,870
7	TOTAL HEAT GAINS	459,760

**Heat Load of Ventilation Air**

**Total Cooling Load on Coils**

FIGURE 3-H

Design Data

Conduction Heat Gains

Body Heat Gains

Equipment Heat Gains

Infiltration Heat Gains

No direct treatment of thermal mass

Excess Solar Heat Gains

Solar Temperature Difference Method

Summary of Heat Gains

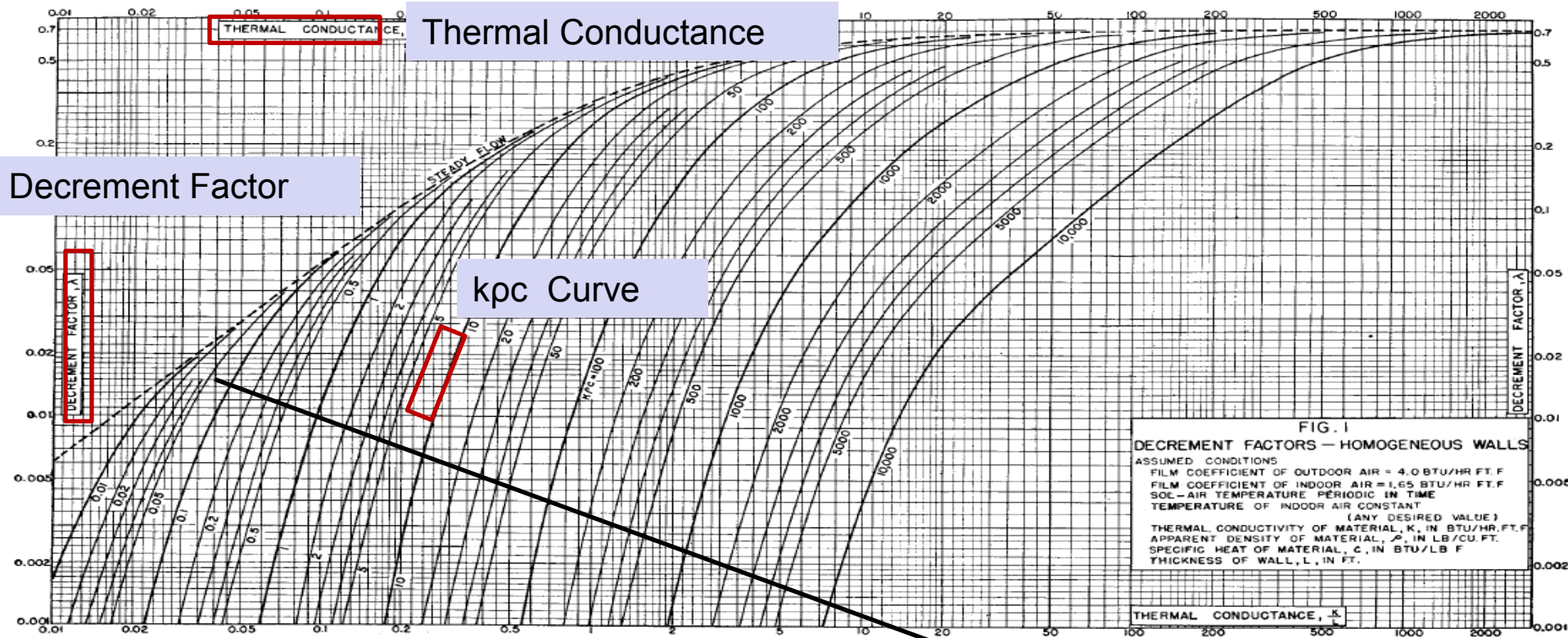
Heat Load of Ventilation Air

Duct Heat Gains

Total Cooling Load on Coils

# History: Pre 1945 – Cooling Load Calculation

In 1944, Mackey and Wright developed Sol-Air Temperature Method which was published by ASHVE



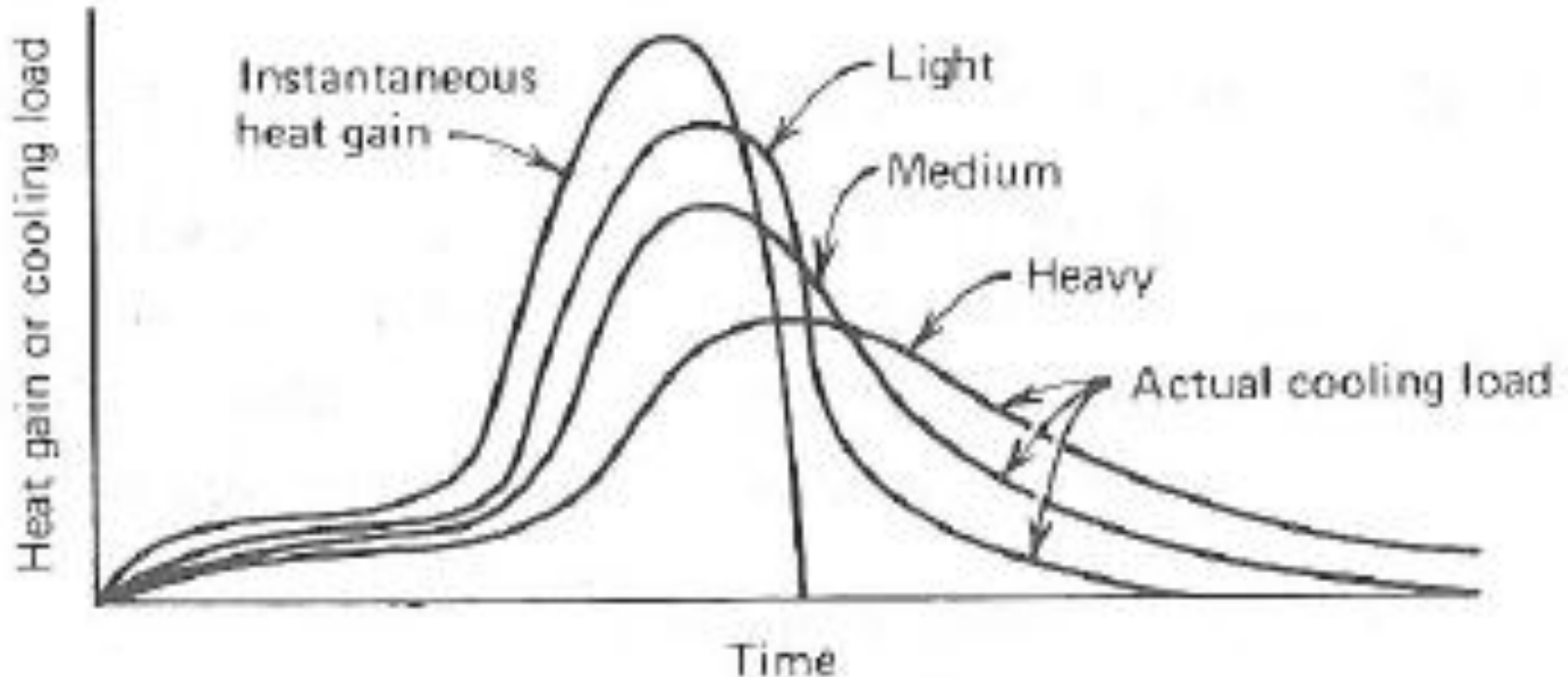
Inside Surface Temperature

$$t_o = t_i + \frac{0.606(t_m - t_i)}{0.856 + L/k} + \sum_{n=1}^{\infty} \lambda_n t_n \cos(15n\theta - \alpha_n - \phi_n)$$

There is time lag for the peak and a reduction in amplitude.

# History: Pre 1945 – Cooling Load Calculation

In 1944, Mackey and Wright developed Sol-Air Temperature Method which was published by ASHVE



Inside Surface Temperature

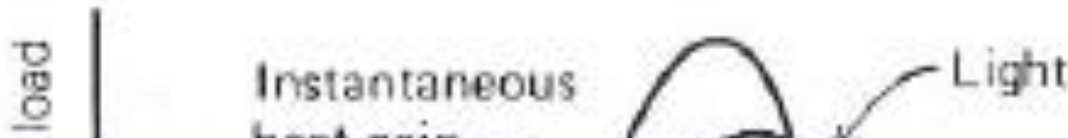
$$t_o = t_i + \frac{0.606(t_m - t_i)}{0.856 + L/k} + \sum_{n=1}^{\infty} \lambda_n t_n \cos(15n\theta - \alpha_n - \phi_n)$$

There is time lag for the peak and a reduction in amplitude.



# History: Pre 1945 – Cooling Load Calculation

In 1944, Mackey and Wright developed Sol-Air Temperature Method which was published by ASHVE



*Effect of thermal mass could be calculated !*



Inside Surface Temperature

$$t_o = t_i + \frac{0.606(t_m - t_i)}{0.856 + L/k} + \sum_{n=1}^{\infty} \lambda_n t_n \cos(15n\theta - \alpha_n - \phi_n)$$

There is time lag for the peak and a reduction in amplitude.

# History: Pre 1945 – Cooling Load Calculation

## Sol-Air Temperature Method:

Later in 1961, sol-air temperature method was tabulated in the *ASHRAE Guide and Data Book – Fundamentals and Equipment*

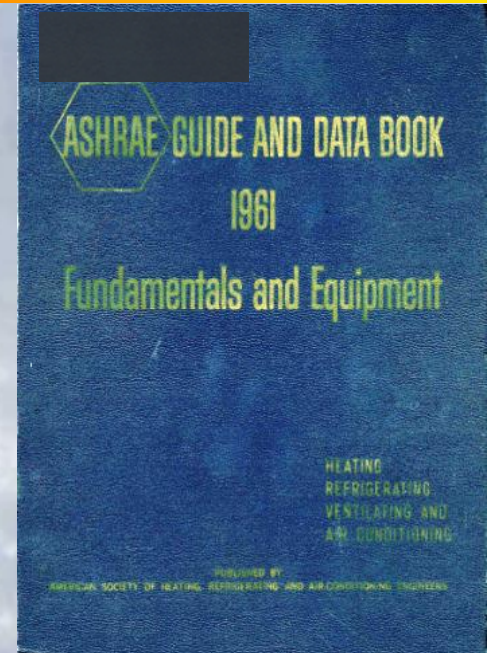


Table 8 . . . Summer Design Sol-Air Temperatures Used for Tables 9 and 10

Mean Sun Time	Sol-Air Temperature $t_s$ , Fahrenheit Degrees								
	Any Surface <sup>b</sup>	Horiz.	North	East		South		West	
Ratio <sup>a</sup> : $\frac{\alpha}{f_{co}}$	0	0.225	0	0.225	0.125	0.225	0.125	0.225	0.125
12 Midnight	77	77	77	77	77	77	77	77	77
1 AM	76	76	76	76	76	76	76	76	76
2	76	76	76	76	76	76	76	76	76
3	75	75	75	75	75	75	75	75	75
4	74	74	74	74	74	74	74	74	74
5	74	74	74	75	80	74	74	74	74
6	74	76	74	110	93	74	74	74	74
7	75	91	75	123	100	75	75	74	74
8	77	106	77	126	103	82	78	77	77
9	80	119	80	125	104	93	86	80	80
10	83	129	83	117	100	102	93	83	83
11	87	137	87	108	96	110	99	89	87
12 Noon	90	142	90	92	92	114	104	96	92
1 PM	93	144	93	93	93	115	105	110	102
2	94	140	94	95	94	111	104	124	111
3	95	132	95	95	95	104	100	135	119
4	94	120	94	94	94	99	96	141	120
5	93	107	93	93	93	95	94	139	118
6	91	96	91	91	91	91	91	125	111
7	87	90	87	87	87	88	87	103	94
8	85	85	85	85	85	85	85	85	85
9	83	83	83	83	83	83	83	83	83
10	81	81	81	81	81	81	81	81	81
11	79	79	79	79	79	79	79	79	79
24 Hr Avg. $t_m$	83.1	100.5	83.1	93.0	88.4	89.0	86.2	93.0	88.4

<sup>a</sup>  $\alpha$  = surface absorptivity, dimensionless, roof = 0.9; dark walls = 0.9, and light walls = 0.5.  $f_{co}$  = unit convective conductance = 4.0 Btu per (hr) (F deg).  
<sup>b</sup> Values in this column are magnitudes of  $t_o$ , the outdoor air temperature.

# History: Pre 1945 – Cooling Load Calculation

1961 ASHRAE Guide and Data Book – Fundamentals and Equipment – **Total Equivalent Temperature Difference** tabulated in the Handbook

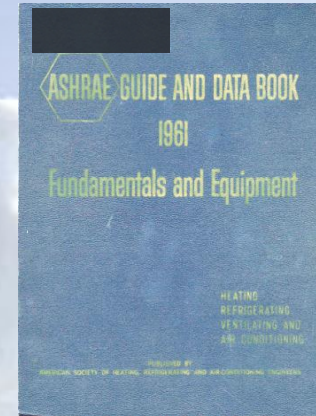
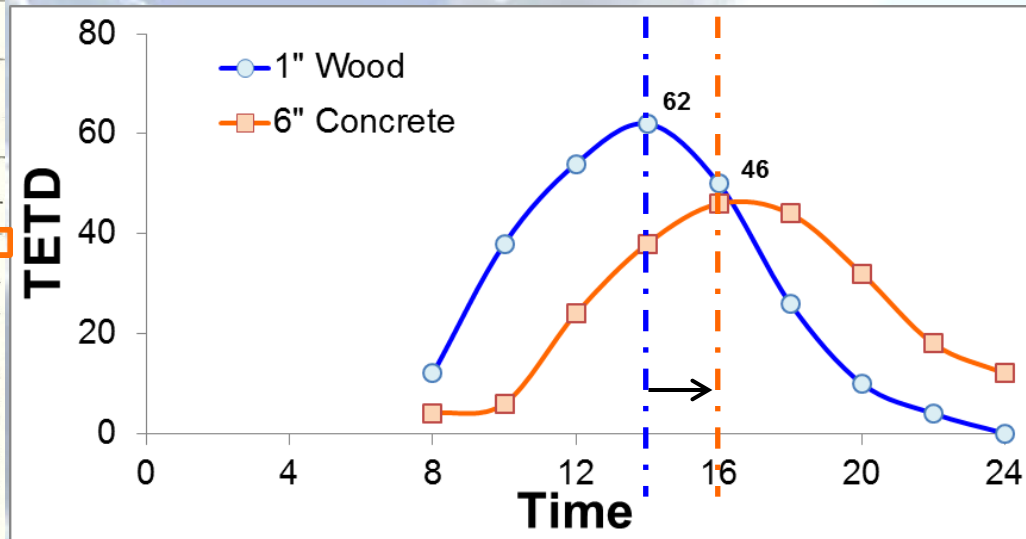


Table 9... Total Equivalent Temperature Differentials for Calculating Heat Gain Through Sunlit and Shaded Roofs

Description of Roof Construction <sup>a</sup>	Sun Time								
	A.M.			P.M.					
	8	10	12	2	4	6	8	10	12
<b>Light Construction Roofs—Exposed to Sun</b>									
1" Wood <sup>b</sup> or 1" Wood <sup>b</sup> + 1" or 2" insulation	12	38	54	62	50	26	10	4	0
<b>Medium Construction Roofs—Exposed to Sun</b>									
2" Concrete or 2" Concrete + 1" or 2" insulation or 2" Wood <sup>b</sup>	6	30	48	58	50	32	14	6	2
2" Gypsum or 2" Gypsum + 1" insulation 1" Wood <sup>b</sup> or 2" Wood <sup>b</sup> or 2" Concrete or 2" Concrete + 4" rock wool or in furred ceiling 2" Gypsum	0	20	40	52	54	42	20	10	6
4" Concrete or 4" Concrete with 2" insulation	0	20	38	50	52	40	22	12	6
<b>Heavy Construction Roofs—Exposed to Sun</b>									
3" Concrete or 3" Concrete + 2" insulation	4	6	24	38	46	44	32	18	12
5" Concrete or 5" Concrete + 2" insulation	0	0	20	32	40	44	34	20	14
<b>Roofs Covered with Water—Exposed to Sun</b>									
Light construction roof with 1" water	0	4	16	22	18	14	10	2	0
Heavy construction roof with 1" water	-2	-2	-4	10	14	16	14	10	6
Any roof with 6" water	-2	0	0	6	10	10	8	4	0
<b>Roofs with Roof Sprays—Exposed to Sun</b>									
Light construction	0	4	12	18	16	14	10	2	0
Heavy construction	-2	-2	2	8	12	14	12	10	6
<b>Roofs in Shade</b>									
Light construction	-4	0	6	12	14	12	8	2	0
Medium construction	-4	-2	2	8	12	12	10	6	2
Heavy construction	-2	-2	0	4	8	10	10	8	4



There is time lag for the peak and a reduction in amplitude.

# History: Pre 1945 – Cooling Load Calculation

1961 ASHRAE Guide and Data Book – Fundamentals and Equipment – **Total Equivalent Temperature Difference** tabulated in the Handbook

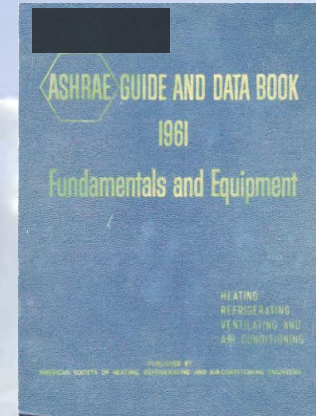
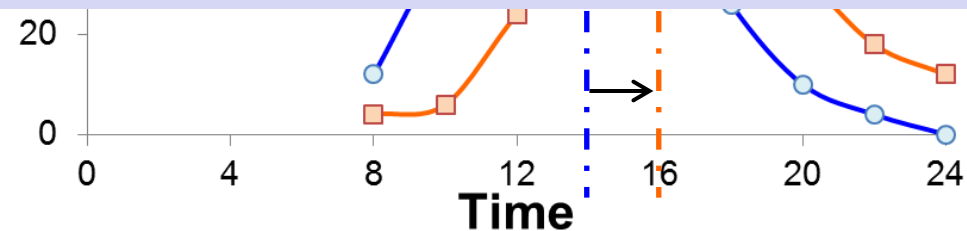


Table 9... Total Equivalent Temperature Differentials for Calculating Heat Gain Through Sunlit and Shaded Roofs

Description of Roof Construction*	Sun Time									
	A.M.					P.M.				
	8	10	12	2	4	6	8	10	12	
<b>Light Construction Roofs—Exposed to Sun</b>										
1" Wood <sup>b</sup> or 1" Wood <sup>b</sup> + 1" or 2" insulation	12	38	54	62	50	26	10	4	0	
<b>Medium Construction Roofs—Exposed to Sun</b>										
2" Concrete or 2" Concrete + 1" or 2" insulation										

**The curves shown in Mackey and Wright and ASHRAE original test data were finally tabulated in the ASHRAE Guide and Data Book**

Light construction roof with 1" water	0	4	16	22	18	14	10	2	0	
Heavy construction roof with 1" water	-2	-2	-4	10	14	16	14	10	6	
Any roof with 6" water	-2	0	0	6	10	10	8	4	0	
<b>Roofs with Roof Sprays—Exposed to Sun</b>										
Light construction	0	4	12	18	16	14	10	2	0	
Heavy construction	-2	-2	2	8	12	14	12	10	6	
<b>Roofs in Shade</b>										
Light construction	-4	0	6	12	14	12	8	2	0	
Medium construction	-4	-2	2	8	12	12	10	6	2	
Heavy construction	-2	-2	0	4	8	10	10	8	4	



There is time lag for the peak and a reduction in amplitude.

# History: Pre 1945 – Cooling Load Calculation

In the 1967 ASHRAE Handbook, the Sol-Air Temperature table was further modified:

A heat balance at a sunlit surface gives:

$$q / A = \alpha I_t + h_o (t_o - t_s) - \epsilon \Delta R$$

In terms of the sol-air temperature,  $t_e$

$$q / A = h_o (t_e - t_s)$$

where,

$$t_e = t_o + \alpha I_t / h_o - \epsilon \Delta R / h_o$$

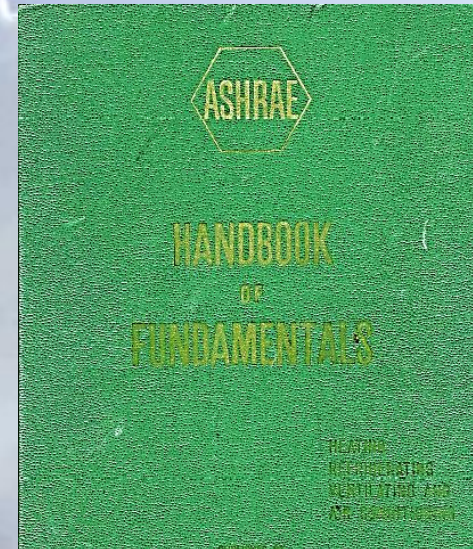


Table 25 ... Sol-Air Temperatures for July 21, 40 deg North Latitude

Time	Air Temp, F	$\alpha/h_o = 0.15$									
		N	NE	E	SE	S	SW	W	NW	Hor	
1	76	76	76	76	76	76	76	76	76	76	69
2	76	76	76	76	76	76	76	76	76	76	69
3	75	76	75	75	75	75	75	75	75	75	68
4	74	74	74	74	74	74	74	74	74	74	67
5	74	74	74	74	74	74	74	74	74	74	67
6	74	82	95	97	86	78	75	75	75	75	74
7											
8											
9											
10											
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Table 26 ... Total Equivalent Temperature Differentials for Calculating Heat Gain Through Roofs

Description of Roof Construction <sup>a</sup>	Sun Time												$\lambda$	
	A.M.						P.M.							
	2	4	6	8	10	12	2	4	6	8	10	12		
Light Construction Roofs—Exposed to Sun														
1" Wood <sup>b</sup>	-5	-6	-6	16	52	81	94	84	56	20	5	-4	0.95	2
2" Insulating board + 1" wood <sup>b</sup>	-2	-3	-6	-1	50	50	75	86	77	53	20	7	0.82	4
2" Concrete or 2" gypsum Plank	-2	-5	-6	11	41	69	85	83	63	32	13	1	0.83	3
2" Wood <sup>b</sup>	1	-3	-0	1	24	54	77	85	75	48	23	6	0.82	3
Medium Construction Roofs—Exposed to Sun														
2" Insulating board + 2" concrete or 2" gypsum Plank	10	3	-1	-1	13	36	-69	75	75	60	28	19	0.69	5
2" Gypsum or 2" concrete + 4" rock wool + 1/2" plaster	13	5	0	-1	9	30	54	71	75	64	43	22	0.46	5
2" Wood <sup>b</sup> + 4" rock wool + 1/2" plaster	20	19	12	6	7	16	32	49	61	63	64	39	0.48	7
Heavy Construction Roofs—Exposed to Sun														
4" Concrete	9	3	-1	5	23	46	65	74	68	49	31	15	0.64	4
4" Concrete	20	12	7	6	16	32	49	74	63	54	40	28	0.48	5
2" Insulating board + 4" concrete	27	19	14	10	14	25	39	51	57	54	45	32	0.38	6
2" Insulating board + 0" concrete	32	27	22	18	17	23	31	41	47	48	44	35	0.26	7
Roofs Covered with Water—Exposed to Sun														
Light Construction	60	3	-1	-4	-6	-6	-1	6	13	17	17	13	7	
		1	-6	-9	-11	-12	-6	4	15	21	22	17	8	0
70	6	7	4	1	-1	0	4	11	18	21	21	17	12	5
		1	0	-3	-5	-5	0	10	19	25	26	21	12	5
Heavy Construction	60	6	3	-1	-3	-4	-1	4	9	13	15	13	10	
		1	1	-3	-6	-8	-6	1	8	16	18	17	11	6
70	6	11	8	5	2	2	4	9	14	18	20	18	15	
		1	3	0	-2	0	6	14	20	23	21	16	11	11
Roofs Covered with Water—Exposed to Sun														
Light Construction	60	6	3	0	-2	0	6	14	20	23	21	16	11	11
		1	5	1	-1	-2	1	8	16	21	23	21	15	9
Heavy Construction	60	6	3	0	-2	0	6	14	20	23	21	16	11	11
		1	5	1	-1	-2	1	8	16	21	23	21	15	9

<sup>a</sup> Includes 1 in. felt roofing with or without sng. May also be used for shingle roof. <sup>b</sup> Nominal thickness of the wood.

# History: 1946 – 1969 Guide Books

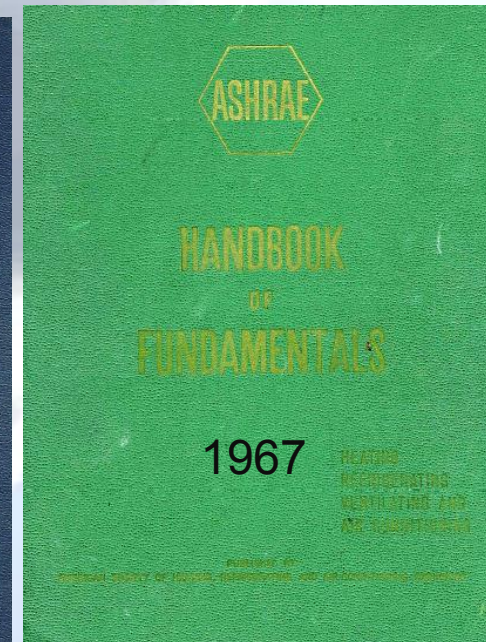
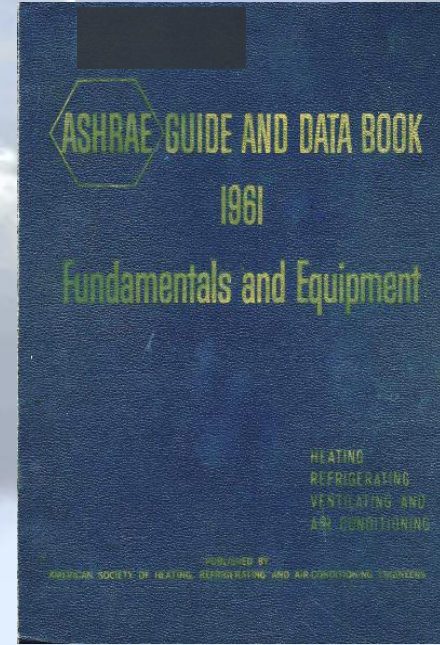
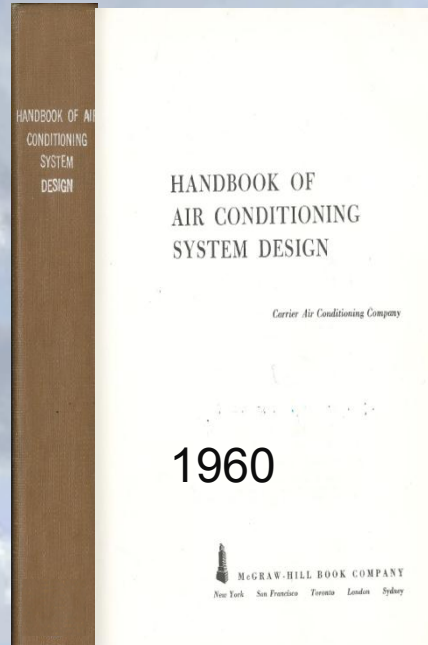
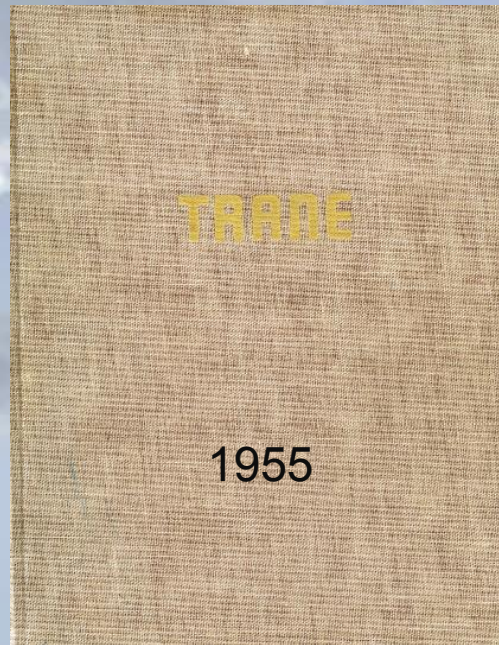
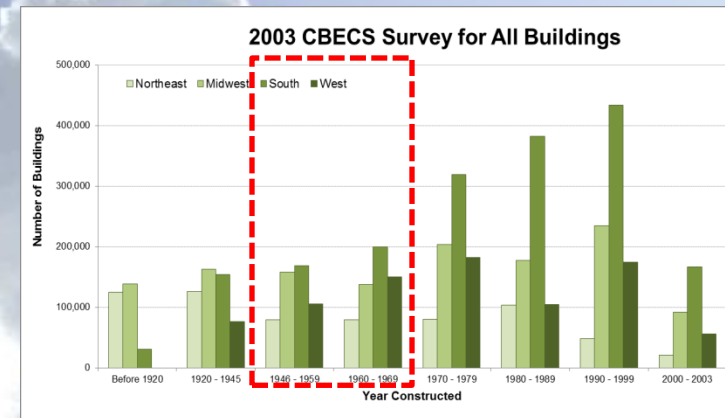
## Guide Books:

1955 *TRANE Air Conditioning Design Manual*

1960 *Handbook of Air Conditioning System Design by Carrier*

1961 *ASHRAE Guide and Data Book*

1967 *ASHRAE Handbook of Fundamentals*

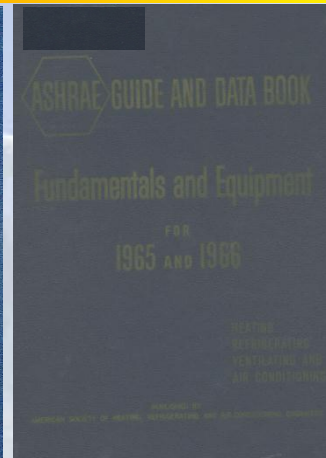
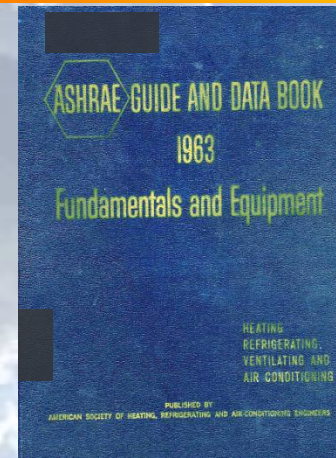
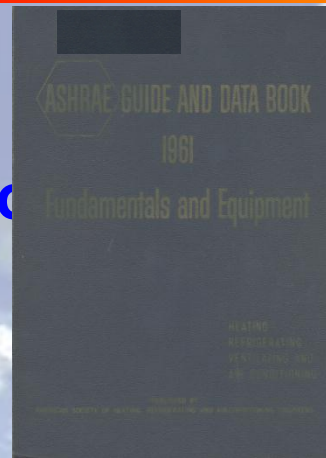


# History: 1946 – 1969 Cooling Load Calculation

## Peak Cooling Load Calculation

❑ 1961 TETD/TA Method:

- ✓ Total Equivalent Temperature Difference/Time Averaging Method
- ✓ Original Outlined by Stewart in 1948
- ✓ TETD table added to **ASHRAE Guide and Data Book** in 1961



Basic heat gain equation for exterior surface:

$$q = UA(TETD)$$



Thermal mass is in the TETD

Source: 1961 ASHRAE Guide and Data Book- Fundamentals and Equipment

Table 9... Total Equivalent Temperature Differentials for Calculating Heat Gain Through Sunlit and Shaded Roofs

Description of Roof Construction*	Sun Time								
	A.M.			P.M.					
	8	10	12	2	4	6	8	10	12
<i>Light Construction Roofs—Exposed to Sun</i>									
1" Wood <sup>b</sup> or 1" Wood <sup>b</sup> + 1" or 2" insulation	12	38	54	62	50	26	10	4	0
<i>Medium Construction Roofs—Exposed to Sun</i>									
2" Concrete or 2" Concrete + 1" or 2" insulation or 2" Wood <sup>b</sup>	6	30	48	58	50	32	14	6	2
2" Gypsum or 2" Gypsum + 1" insulation	0	20	40	52	54	42	30	10	6
1" Wood <sup>b</sup> or 2" Wood <sup>b</sup> or 1" + 4" rock wool	0	20	40	52	54	42	30	10	6
2" Concrete or 1" in furred ceiling	0	20	40	52	54	42	30	10	6
2" Gypsum	0	20	40	52	54	42	30	10	6
4" Concrete or 4" Concrete with 2" insulation	0	20	38	50	52	40	22	12	6
<i>Heavy Construction Roofs—Exposed to Sun</i>									
6" Concrete	4	6	24	38	46	44	32	18	12
6" Concrete + 2" insulation	6	6	20	34	42	44	34	20	14
<i>Roofs Covered with Water—Exposed to Sun</i>									
Light construction roof with 1" water	0	4	10	22	18	14	10	2	0
Heavy construction roof with 1" water	-2	-2	-4	10	14	16	14	10	6
Any roof with 6" water	-2	0	0	6	10	10	8	4	0
<i>Roofs with Roof Sprays—Exposed to Sun</i>									
Light construction	0	4	12	18	16	14	10	2	0
Heavy construction	-2	-2	2	8	12	14	12	10	6
<i>Roofs in Shade</i>									
Light construction	-4	0	6	12	14	12	8	2	0
Medium construction	-4	-2	2	8	12	12	10	6	2
Heavy construction	-2	-2	0	4	8	10	10	8	4

\* Includes 3/8 in. felt roofing with or without slag. May also be used for shingle roof.  
<sup>b</sup> Nominal thickness of the wood.  
 Notes for Table 9  
 Explanation:  $\frac{\text{Total heat transmission from solar radiation and temperature difference between outdoor and room air, Btu (or kWh) per sq ft (or m<sup>2</sup>) of roof area}}{\text{Equivalent temperature difference from above}} \times \left\{ \begin{array}{l} \text{Heat transmission coefficient for area} \\ \text{(see Btu, or kWh, per ft<sup>2</sup> or m<sup>2</sup>)} \\ \text{of 1 ft (or 1 m) of wall} \end{array} \right\}$   
 1. Shaded. Calculated by Mackay and Wright method (see reference list) and adjusted for studying ASHRAE's original test data. Estimated for short August 1st at 80 deg north latitude. For air or temperatures used in calculations see Table 8. For typical design day where the maximum outdoor temperature is 95 F and minimum is 60 deg north which absorbs 90 percent of solar radiation, and reflects only 10 percent.  
 2. Application. Those values may be used for all normal air conditioning installations, usually without correction, in latitude 0 deg to 90 deg north or south when the load is calculated for the hottest weather. Note 8 explains how to adjust the temperature differential for other room and outdoor temperatures.  
 3. Peaked Roofs. If the roof is peaked and the heat gain is primarily due to solar radiation, use for the area of the roof, the area projected on a horizontal plane.  
 4. Area. If the ceiling is insulated and if a fan is used in the attic for positive ventilation, the total temperature differential for a roof exposed to the sun may be decreased 25 percent.  
 5. Correction. For temperatures of 95 deg or when outdoor maximum design temperature minus room is 40 deg or less. If the outdoor design temperature minus room temperature is different from the above of 15 deg, correction follows: When the difference is greater (or less) than 15 deg add the excess to (or subtract the deficiency from) the above differential.  
 For outdoor daily range of temperature other than 40 deg. If the daily range of temperature is less than 50 deg, add 1 deg for every 2 deg lower daily range; if the daily range is greater than 50 deg, subtract 1 deg for every 4 deg higher daily range. For example, the daily range in Miami, Florida is 12 deg or 9 deg less than 40 deg. There fore, the correction is +1 deg at all hours of the day.

# History: 1970 – 1989 Cooling Load Calculation

In 1977 TETD/TA replaced with CLTD/CLF Method:

- ✓ Firstly developed by Rudoy and Duran in 1974 and published by *ASHRAE Transactions*
- ✓ Later appeared in **1977 ASHRAE handbook**

**Table 1 Procedure for Calculating Space Design Cooling Load—Summary of Load Sources and Equations**

Load Source	Equation	Reference, Table, Description
External		Chapter 22—Design Heat Transfer Coefficients—Tables 3 and 4 Area Calculated from Architectural Plans
Roof	$q = U \times A \times CLTD$	Table 5—Cooling Load Temperature Difference at Base Conditions for Roofs Note 4—Correction for Color of Exterior Surface Note 2—Correction for Outside Dry Bulb Temperature and Daily Range Note 2—Correction for Inside Dry Bulb Temperature Note 1 & 5—Application for Latitude and Month
Walls	$q = U \times A \times CLTD$	Chapter 22—Design Heat Transmission Coefficients—Tables 3 and 4 Area Calculated from Architectural Plans Table 6—Wall Construction Group Description Table 7—Cooling Load Temperature Difference at Base Conditions for Wall Group Note 3—Correction for Color of Exterior Surface Note 2—Correction for Outside Dry Bulb Temperature and Daily Range Note 2—Correction for Inside Dry Bulb Temperature Note 1 & 4 Application for Latitude and Month
Glass	$q = U \times A \times CLTD$	Chapter 22 or Chapter 26—Type of Glass and Interior Shading if Used Area—Net Glass Area Calculated from Plans Table 9—Cooling Load Temperature Difference for Conduction Load Through Glass Note 1—Correction for Inside Dry Bulb Temperature
Conduction	$q = U \times A \times CLTD$	Area—Net Glass Area Calculated from Plans Chapter 26—Tables 28, 33, 34, 35, 36, 38, and 40 Shading Coefficients for Combination of Type of Glass and Type of Shading Table 10—Maximum Solar Heat Gain Factor for Specific Orientation of Surface, Latitude and Month
Solar	$q = A \times SC \times SHGF \times CLF$	Table 11—Cooling Load Factor with No Interior Shading Table 12—Cooling Load Factor if Interior Shading is Used
Partitions, Ceilings, Floors	$q = U \times A \times TD$	Chapter 22—Design Heat Transmission Coefficients—Tables 3 and 4 Area Calculated from Architectural Plans Section 5.0—Design Temperature Difference
Internal Lights	$q = INPUT \times CLF$	Input Rating from Electrical Plans or Lighting Fixture Data Tables 13 & 14—Coefficients “a” and classification “b” for Type of Fixture, Installation, Air Supply and Return and Room Furnishings and Construction Table 15—Cooling Load Factor Based on Total Hours of Operation and Time Note 1—Correction for Schedule of Operation of Cooling System
People		Number of People in Space Table 16 or Chapter 8—Sensible Heat Gain from Occupants Table 17—Cooling Load Factor for People—Based on Duration of Occupancy and Time from Entry
Sensible	$q_s = No \times Sens. H.G. \times CLF$	Note 1—Correction for Density of Occupants Table 16 or Chapter 8—Latent Heat Gain from Occupants
Latent	$q_l = No \times Lat. H.G.$	Table 16 or Chapter 8—Latent Heat Gain from Occupants
Appliances		Tables 18 & 19—Recommended Rate of Heat Gain—Sensible Heat Table 20—For Use with Hood Table 21—For Use without Hood
Sensible	$q_s = HEAT GAIN \times CLF$	Tables 18 & 19—Recommended Rate of Heat Gain—Latent Heat (Without Hood) Set Equal to Zero When Hood is Used Over Appliances
Latent	$q_l = HEAT GAIN$	Tables 18 & 19—Recommended Rate of Heat Gain—Latent Heat (Without Hood) Set Equal to Zero When Hood is Used Over Appliances
Power	$q = HEAT GAIN \times CLF$	Eq 21, 22, or 23 using Tables 22 and 23 or Manufacturer’s Data Table 21
Ventilation & Infiltration Air		Ventilation and Infiltration Air, Standard CFM Inside-Outside Air Temperature Difference, deg F
Sensible	$q_s = 1.10 \times CFM \times \Delta t$	
Latent	$q_l = 4840 \times CFM \times \Delta W$	Inside-Outside Air Humidity Ratio Difference, lb H <sub>2</sub> O/lb Dry Air
Total	$q = 4.5 \times CFM \times \Delta h$	Inside-Outside Air Enthalpy Difference, Btu/lb of Dry Air
Adjustment Factor		Fraction of Input Energy Lost to the Surroundings; Applied to all External and Internal Loads Except Ventilation and Infiltration Air. Eq 31
	$F_e = 1 - 0.02 K_1$	

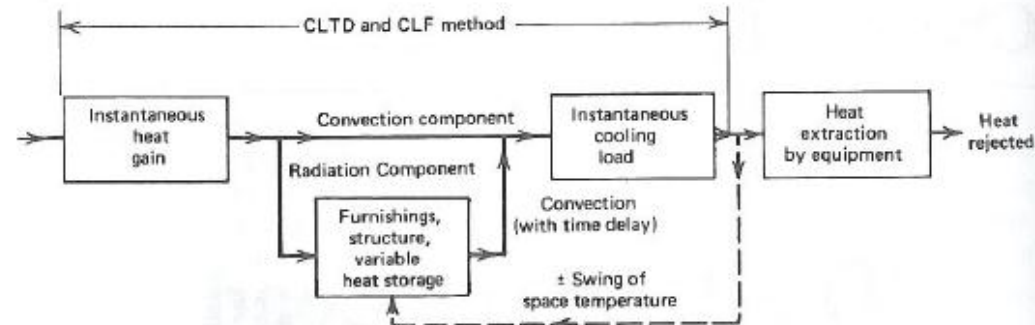


Figure 8-1 Schematic relation of heat gain to cooling load.

Roof, Wall, Glass:  $q = UA(CLTD)$

Solar:

$$q = A \times SC \times SHGF \times CLF$$

Internal Lights:

$$q = INPUT \times CLF$$

People:

$$q = No. \times Sens.H.G. \times CLF$$





# History: 1946 – 1969 Cooling Load Calculation

## Other Developments:

### *Finite Difference /Finite Element Method :*

- ✓ FDM/FEM became available in 1960
- ✓ Mainly used as a basis for a computer algorithm

### Chartered Institution of Building Services Engineers (CIBSE) Admittance Method:

- ✓ Original developed by Loudon in 1968
- ✓ Standard method in UK
- ✓ The concept of *thermal admittance* was first introduced by Institution of Heating and Ventilating Engineers (IHVE) Guide in 1970
- ✓ Later selected by CIBSE Guide A



# History: 1946 – 1969 Annual Energy Use

## Annual Building Energy Use Calculation:

### Heating Degree-Day Method:

- ✓ Degree Days first used to predict snow melt.
- ✓ Manual method was adopted in mid 1960s
- ✓ Later appeared in **1981 ASHRAE Handbook**

### Equivalent Full Load Hours Method :

- ✓ Manual method was adopted in the mid-1960s
- ✓ Cooling energy requirement calculation
- ✓ Later appeared in **1981 ASHRAE Handbook**

### Classic Heating Degree-Day Method:

$$E = \frac{H_L \cdot D \cdot 24}{\Delta t \cdot k \cdot V} \cdot C_D$$

Where,

$E$ : fuel or energy consumption for the estimate period, Btu  
 $H_L$ : design heat loss, including infiltration and ventilation, Btu/h.  
 $D$ : number of 65°F degree days in the estimation period  
 $\Delta t$ : design temperature difference, °F  
 $k$ : a correction factor that includes the effects of rated full load efficiency, part load performance, oversizing and energy conservation devices  
 $V$ : heating value of fuel, units consistent with  $H_L$  and  $E$   
 $C_D$ : empirical correction factor for heating effect versus 65°F degree-days

### Cooling Season Power:

$$P_C = \frac{0.746(bhp)_t(T)H_e}{E}$$

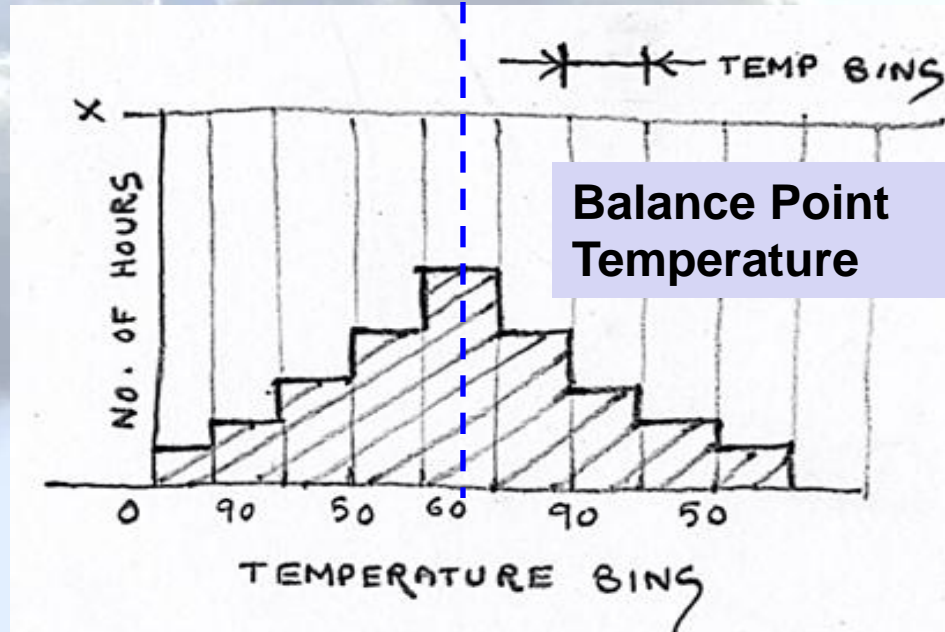
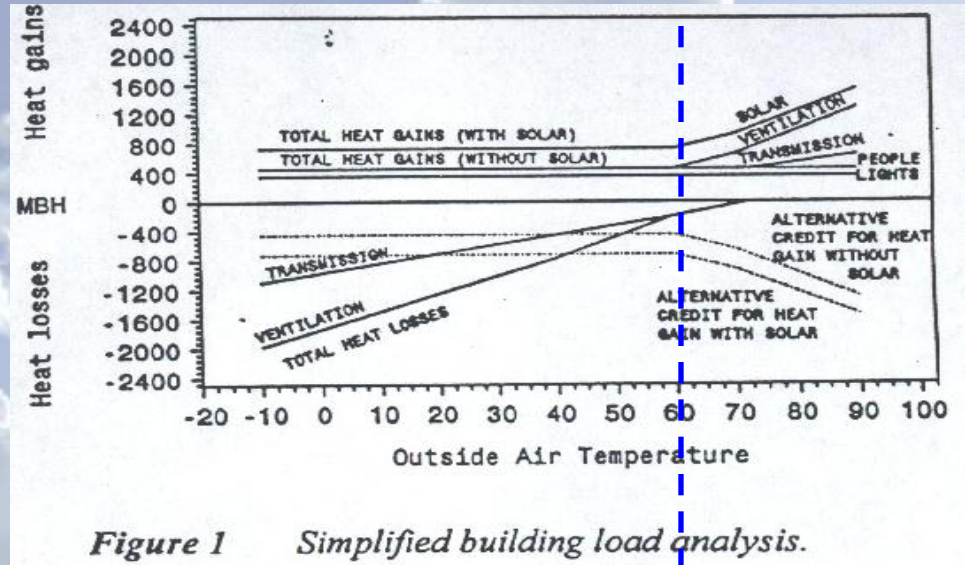
Where,

$P_C$ : cooling season power (kWh)  
 $(bhp)_t$ : brake horsepower per ton  
 $T$ : maximum refrigeration design load (tons)  
 $H_e$ : equivalent full-load refrigeration operating time (h)  
 $E$ : motor efficiency at average load(decimal)

# History: 1946 – 1969 Annual Energy Use

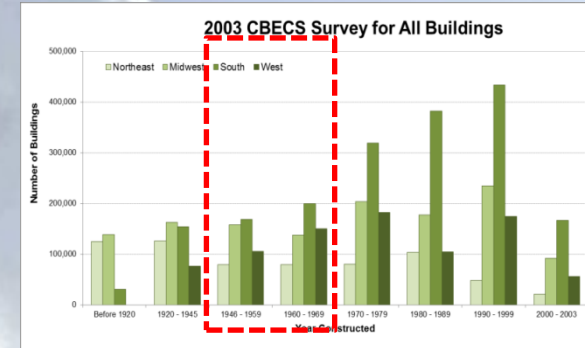
## Bin Method:

- ✓ Manual method was adopted in the mid-1960s
- ✓ Heating and Cooling
- ✓ Energy Calculation
- ✓ Later appeared in **1981 ASHRAE Handbook**

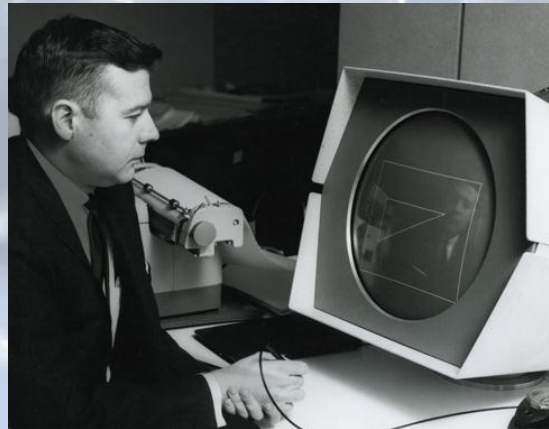


# History : 1946 – 1969 Computer Developments

- ❑ In 1957, FORTRAN I compiler was developed by John Backus and colleagues at IBM
- ❑ During 1958 – Present, FORTRAN II, III, IV, FORTRAN 66, FORTRAN 77, Fortran 90, Fortran 95, Fortran 2003, Fortran 2008 are available
- ❑ In 1960, PDP-1, the first commercial mini computer was available
- ❑ In 1964, BASIC programming was available



IBM Mainframe Computer 704 Series



PDP-1 Mini Computer



IBM PC 5150

**Today, most whole building simulation programs are still using FORTRAN**

# History: 1946 – 1969 Annual Energy Use

## Thermal Network Method:

- ✓ Thermal Network Model varies
- ✓ Refinement of the Heat balance method
- ✓ Thermal network model was available in 1958
- ✓ Later appeared into **1997 ASHRAE Handbook**

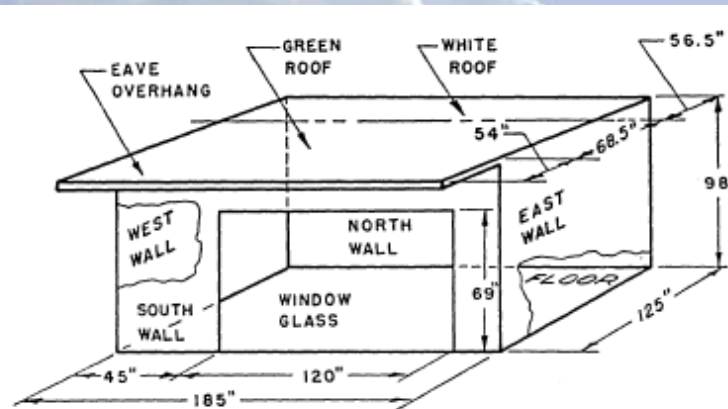


FIG. 1—SCHEMATIC DIAGRAM OF TEST HOUSE

# History: 1946 – 1969 Annual Energy Use

## Thermal Network Method:

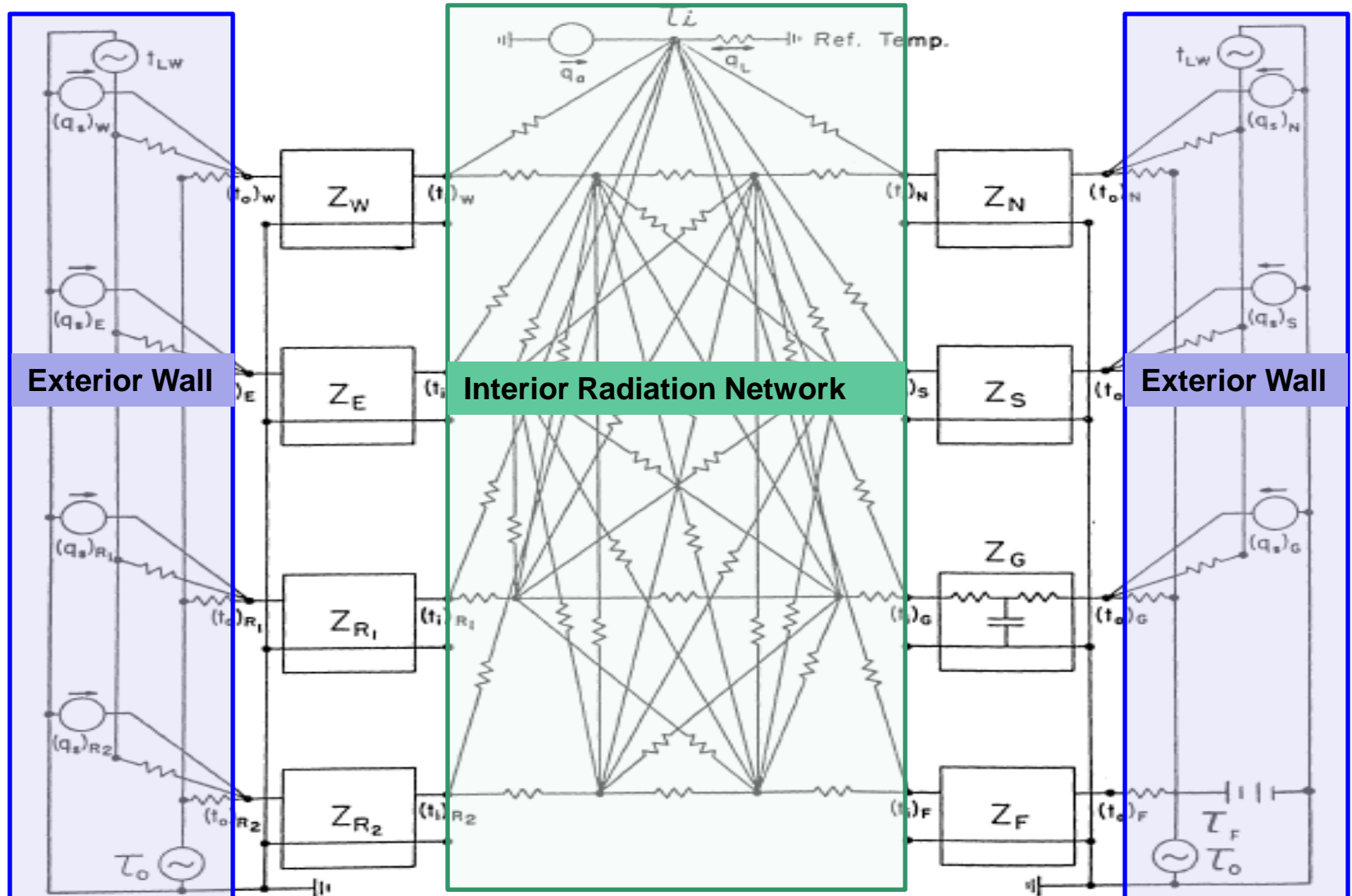
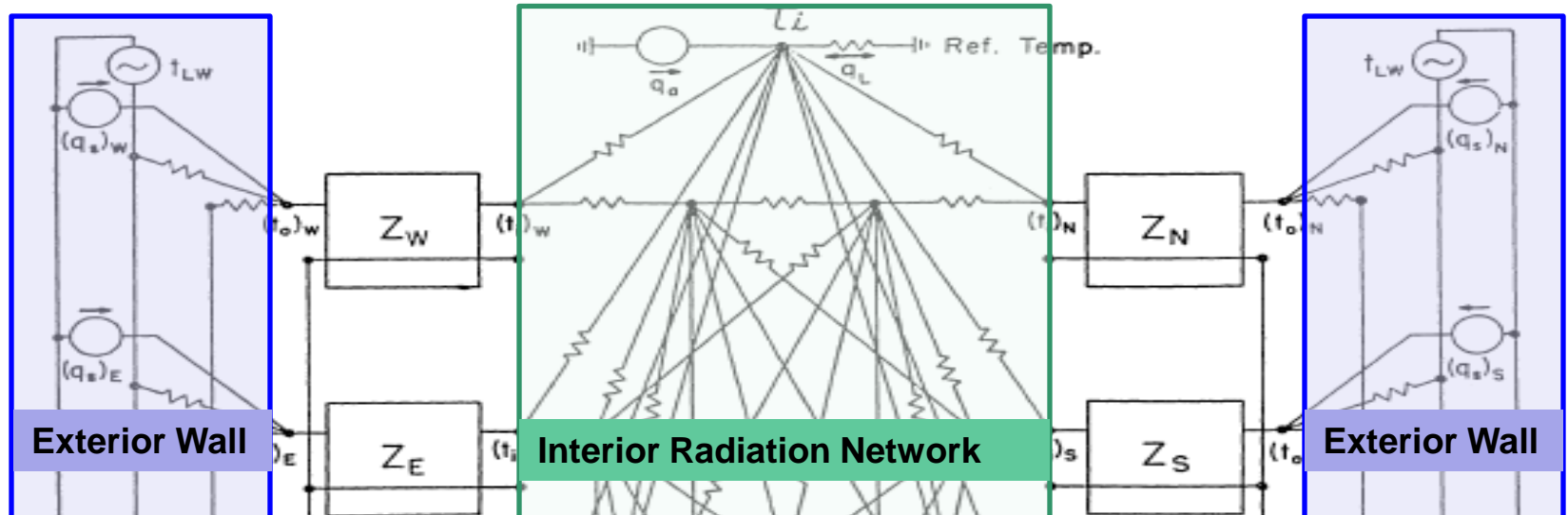


FIG. 2—BASIC THERMAL NETWORK REPRESENTING THE IDEALIZED TEST HOUSE

# History: 1946 – 1969 Annual Energy Use

## Thermal Network Method:



*Thermal mass was represented by an electrical RC network*

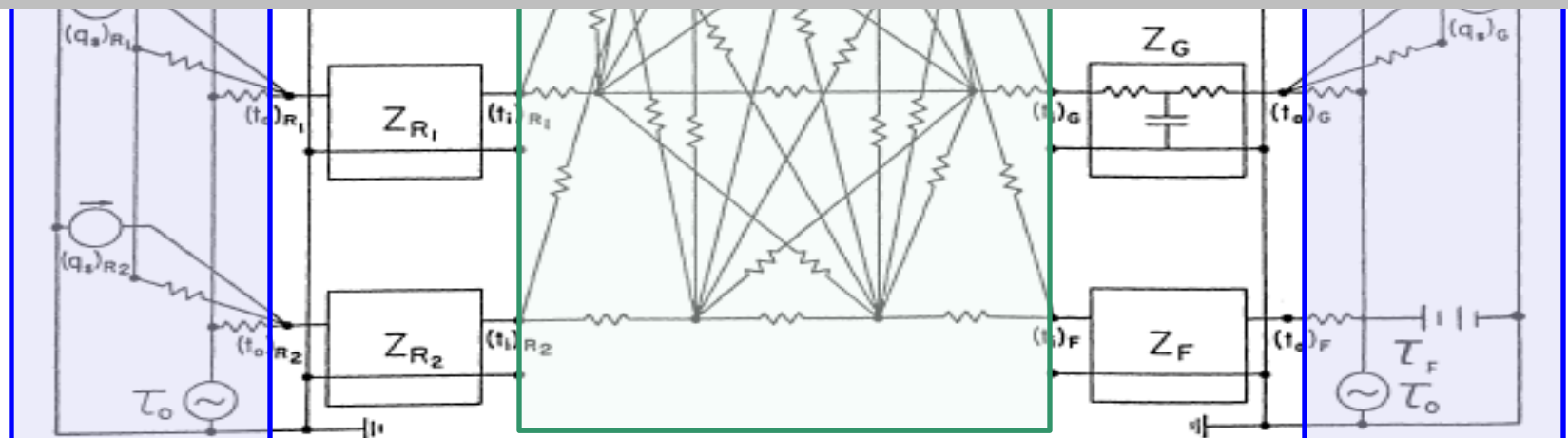


FIG. 2—BASIC THERMAL NETWORK REPRESENTING THE IDEALIZED TEST HOUSE



# History: 1946 – 1969 Annual Energy Use

## Thermal Network Method:

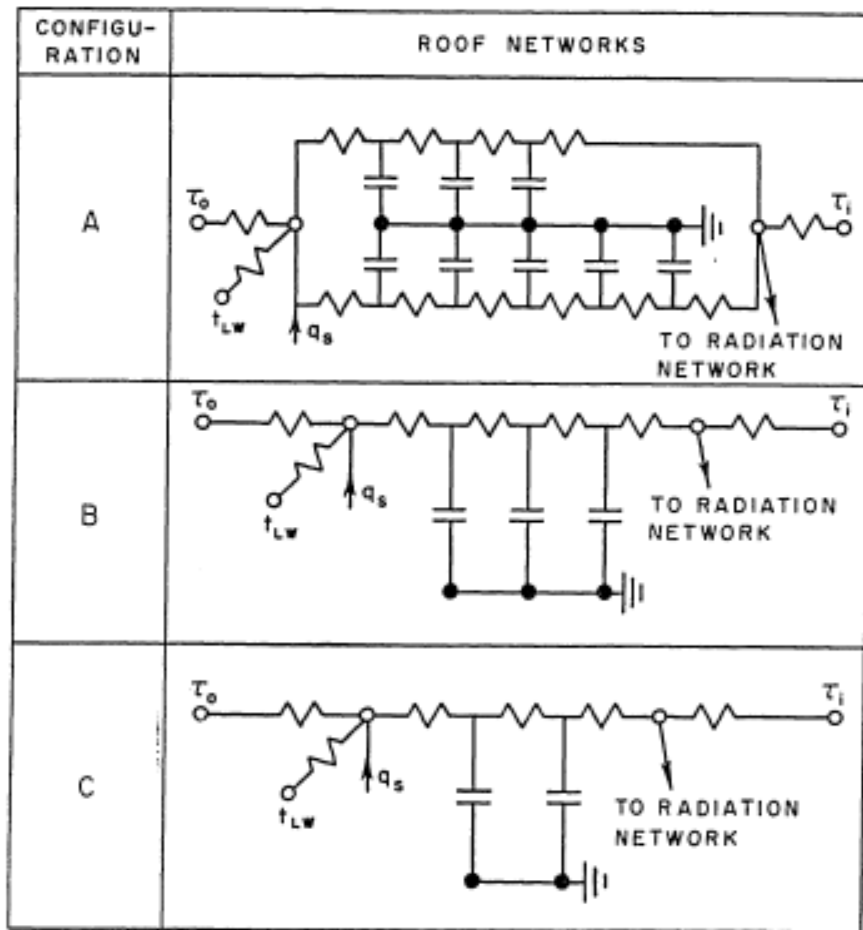


TABLE A—MAGNITUDE OF DECREMENT FACTORS

	$\lambda_2$	$\lambda_3$	ADD. TIME LAG
A. Solar radiation transmitted through north glass ref. D.....	0.54	0.95	3 hrs
B. Solar radiation transmitted through south glass ref. E 2 in. floor.....	0.66	1.00	1 hr, approx.
6 in. floor.....	0.47	1.00	1 hr, approx.
C. Southwest wall ref. F.....	0.93	0.92	0 hr
D. Roof problem.....	0.34	0.83	3 hr

- RC Network allowed for layered walls, roofs.
- RC Network allowed for nodal temperatures to be determined.

# History : 1946 – 1969 Annual Energy Use

## Computer Algorithms:

### *Thermal Response Factor Method:*

- ✓ First developed by Stephenson and Mitalas in 1967
- ✓ Later appeared as *Weighting Factor Method* in **1981 ASHRAE Handbook**

### Heat Gain Weighting Factors: $v_0, v_1, v_2, \dots, w_1, w_2, \dots$

For each type of heat gain  $q_\theta$ , cooling load for  $Q_\theta$ :

$$Q_\theta = v_0 q_\theta + v_1 q_{\theta-1} + \dots - w_1 Q_{\theta-1} - w_2 Q_{\theta-2} - \dots$$

### Air Temperature Weighting Factors: $g_0, g_1, g_2, \dots, P_1, P_2, \dots$

# History: 1946 – 1969 Annual Energy Use

## Computer Algorithms:

### Thermal Mass: Transfer Function Method:

- ✓ Firstly introduced by 1972 ASHRAE Handbook of Fundamentals
- ✓ Associated Sol-Air Temperature

Heat gain through a wall or roof:

$$q_{e,r} = A \left[ \sum_{n=0} b_n (t_{e,\tau-n\Delta}) - \sum_{n=1} d_n \left( \frac{q_{e,r} - n\Delta}{A} \right) - t_{rc} \sum_{n=0} c_n \right]$$

where,

$$b_n \quad c_n \quad d_n$$

Transfer function coefficients

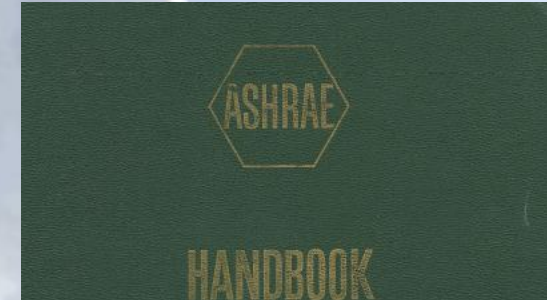


Table 39 ... Transfer Function Coefficients for Exterior Walls  
(Time Interval = 1.0 hr)

No.	Construction [Note 1]	Code Numbers	Coefficients $b_n$ and $d_n$ [Note 2]						$t_{rc}$	$\sum_{n=0}^{\infty} c_n$	
			$n=0$	$n=1$	$n=2$	$n=3$	$n=4$	$n=5$			$n=6$
1	2" face brick, 2" insulation, and 4" low-concrete block	AB, A2, B2, C2, B2, B2	0.0000	0.0096	0.0023	0.0152	0.0010	0.0000	-0.0001	0.102	0.00637
2	4" l.w. concrete	AB, C14, B1, B2	0.0014	-0.0209	0.0118	0.0034	0.0000	0.0000	0.0000	0.0000	0.0000
3	2" face brick, air space, and 2" common brick	A0, A2, B1, C2, B1, B2	0.0000	0.0000	0.0007	0.0098	0.0008	0.0013	0.0001	0.0000	0.00018
4	2" face brick, air space, and 2" l.w. concrete block	A0, A2, B1, C2, B1, B2	0.0000	0.0000	-0.0024	0.0144	0.0004	0.0004	0.0004	0.0000	0.00018
5	4" face brick, air space, and 2" l.w. concrete block	A0, A2, B1, C2, B1, B2	0.0000	0.0000	-0.0024	0.0144	0.0004	0.0004	0.0004	0.0000	0.00018
6	2" face brick, air space, and 2" l.w. concrete	A0, A2, B1, C2, B1, B2	0.0000	0.0000	0.0000	0.0124	0.0007	0.0011	0.0000	0.0000	0.00004
7	4" face brick, air space, and 2" l.w. concrete	A0, A2, B1, C2, B1, B2	0.0000	0.0000	0.0000	0.0124	0.0007	0.0011	0.0000	0.0000	0.00004
8	2" face brick, air space, and 2" common brick	AB, A2, B1, C2, B1, B2	0.0000	0.0000	0.0000	0.0078	0.0000	0.0001	0.0000	0.0000	0.00000
9	4" face brick, air space, and 4" l.w. concrete block	AB, A2, B1, C2, B1, B2	0.0000	0.0000	0.0000	0.0118	0.0000	0.0000	0.0000	0.0000	0.00000
10	2" face brick, air space, and 4" l.w. concrete block	AB, A2, B1, C2, B1, B2	0.0000	0.0000	0.0000	0.0098	0.0000	0.0000	0.0000	0.0000	0.00000
11	2" l.w. concrete	AB, A2, B1, C2, B1, B2	0.0000	0.0000	0.0000	0.0018	0.0000	0.0000	0.0000	0.0000	0.00000
12	2" l.w. concrete with 2" insulation	AB, A2, B1, C2, B1, B2	0.0000	0.0000	0.0000	0.0018	0.0000	0.0000	0.0000	0.0000	0.00000
13	4" l.w. concrete with 2" insulation	AB, A2, B1, C2, B1, B2	0.0000	0.0000	0.0000	0.0018	0.0000	0.0000	0.0000	0.0000	0.00000
14	2" face brick with air space	AB, A1, C16, B1, B2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00000
15	4" face brick with air space	AB, A1, C16, B1, B2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00000
16	2" face brick, 2" common brick with 2" insulation	AB, A2, B2, C2, B2, B2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00000
17	4" face brick, 2" common brick with 2" insulation	AB, A2, B2, C2, B2, B2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00000
18	Wall with 4" face brick, air space	AB, A2, B1, C2, B1, B2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00000

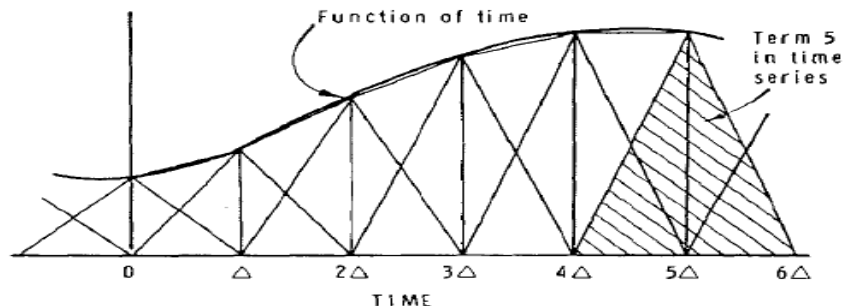


Fig. 1 Time-series representation of a continuous function

# History: 1946 – 1969 Cooling Load Calculation

## Computer Algorithms:

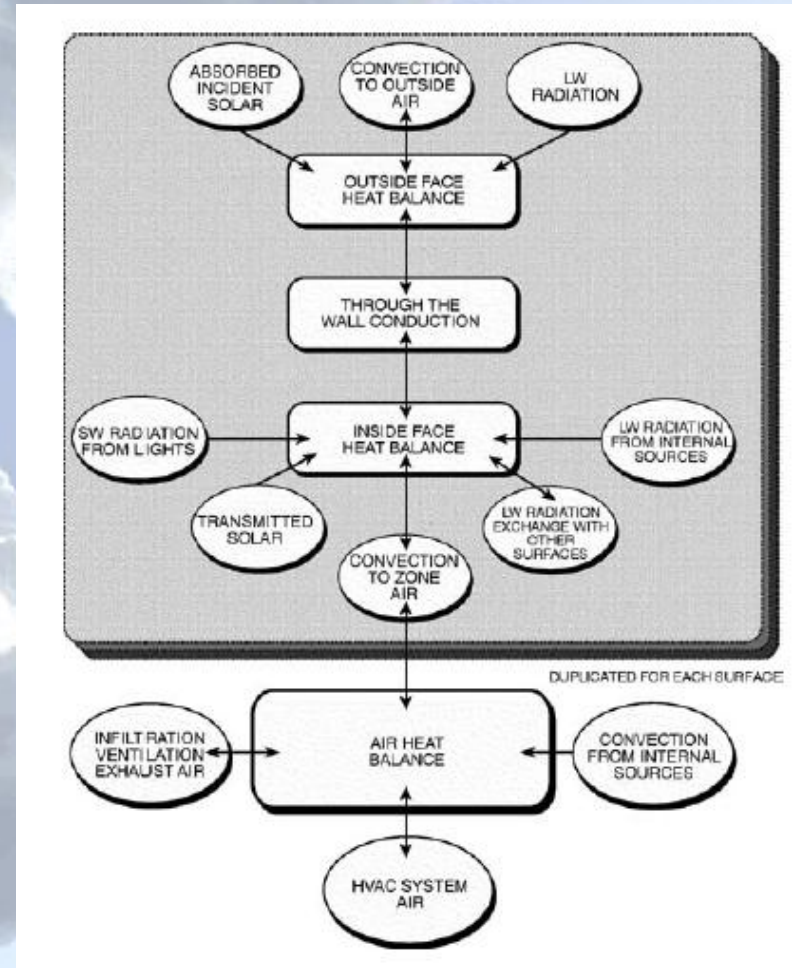
### Heat Balance Method:

- ✓ Early used for general thermal modeling in aerospace and other industries
- ✓ Detailed calculation procedures by Buchberg in 1958
- ✓ Later appeared in **1981 ASHRAE handbook**

System Heat Transfer:  $q_{sys_j} = a + bt_{a_j}$

where,

$$t_{a_j} = \frac{a + \sum_{i=1}^N A_i h_{ci} t_{si,j} + \rho c V_{infil_f} t_{o_j} + q_{c,int_j}}{-b + \sum_{i=1}^N A_i h_{ci} + \rho c V_{infil_j} + \rho c V_{vent_j}}$$

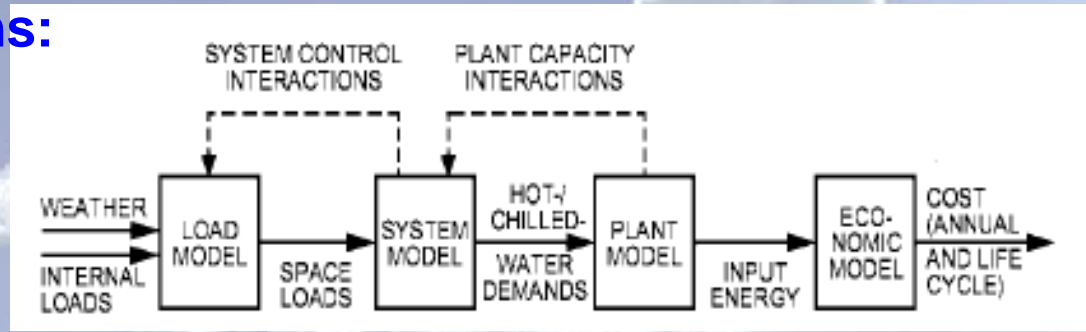


Schematic of Heat Balance Processes in Zone  
(Source: 2009 ASHRAE Handbook)

# History: 1970 – 1989 Annual Energy Use

## Computer Algorithms:

DOE-2  
(Weighting Factor Method)



## Complete Set of ASHRAE Algorithms

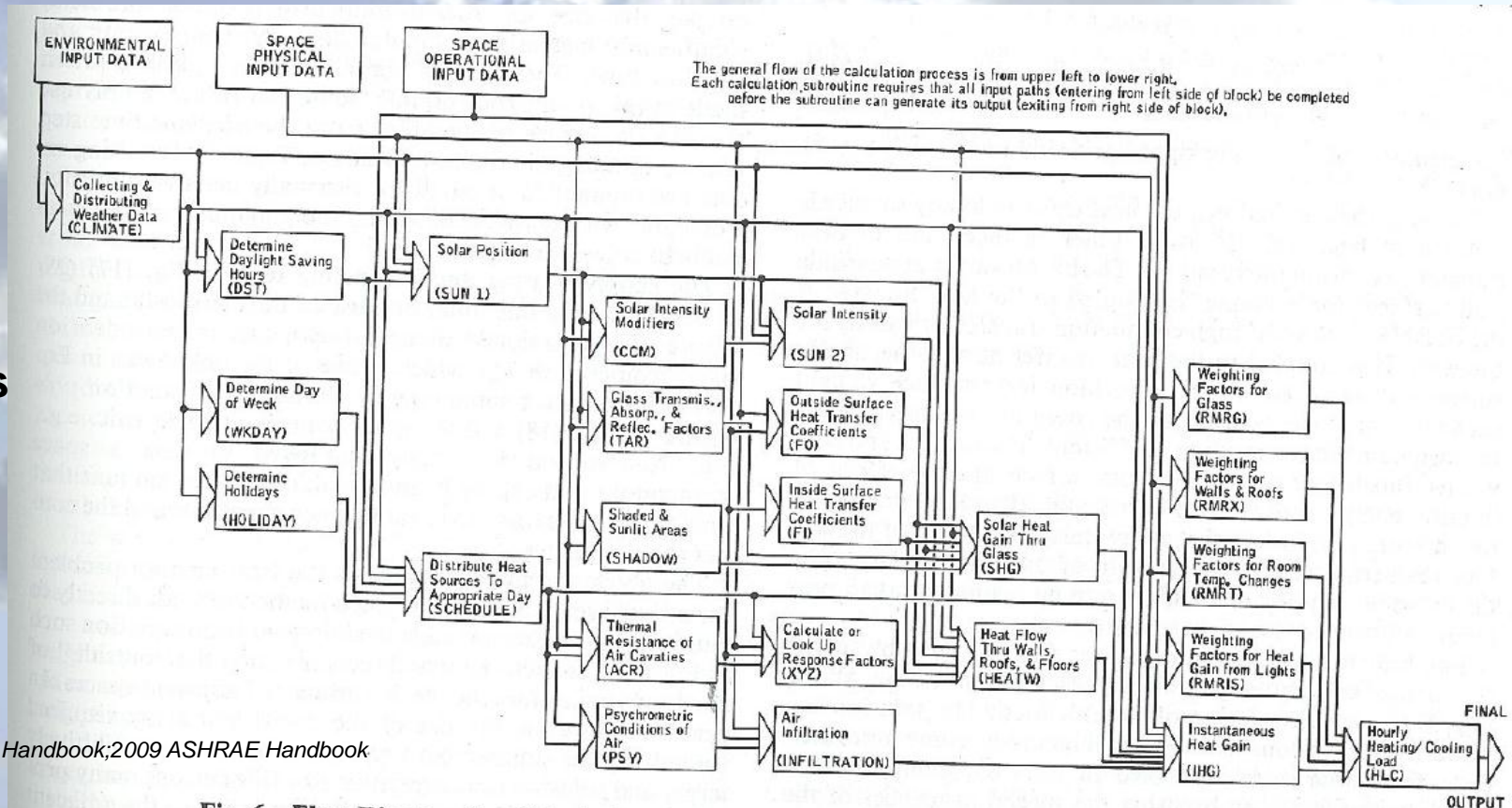


Fig. 6 Flow Diagram For Calculation of Hourly Heating Cooling Loads Using ASHRAE Algorithms

Source: 1985 ASHRAE Handbook; 2009 ASHRAE Handbook

# History: 1970 – 1989 Guide Books

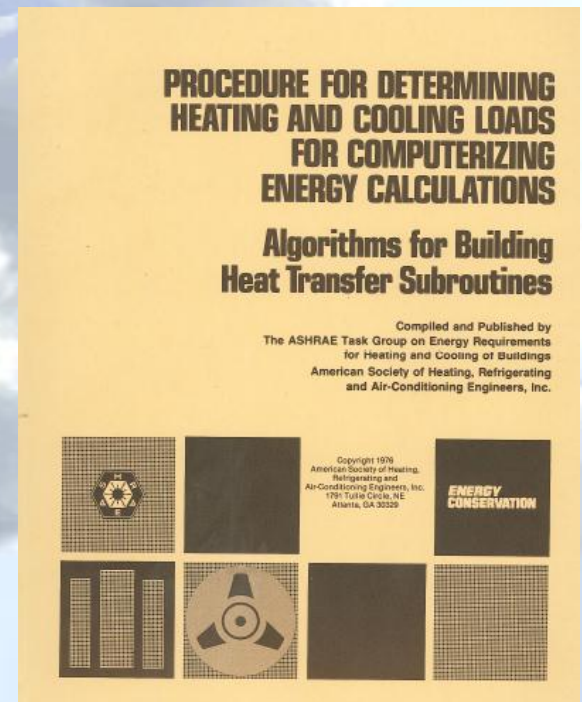
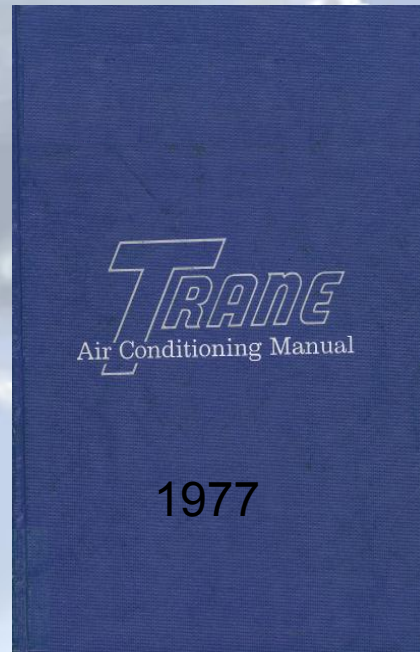
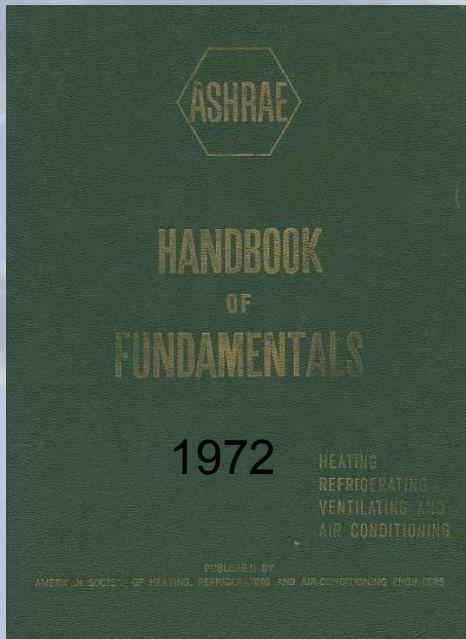
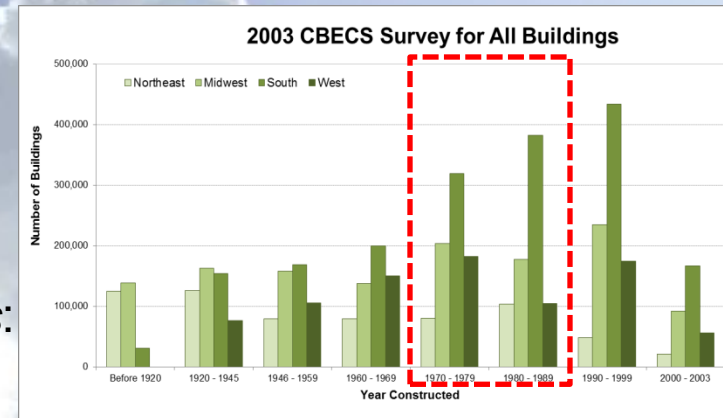
## Guide Books:

1972 ASHRAE Handbook of Fundamentals

1977 TRANE Air Conditioning Manual

1975 ASHRAE Task Group on Energy Requirements:

Procedure for Determining Heating and Cooling Loads for Computerizing Energy Calculations

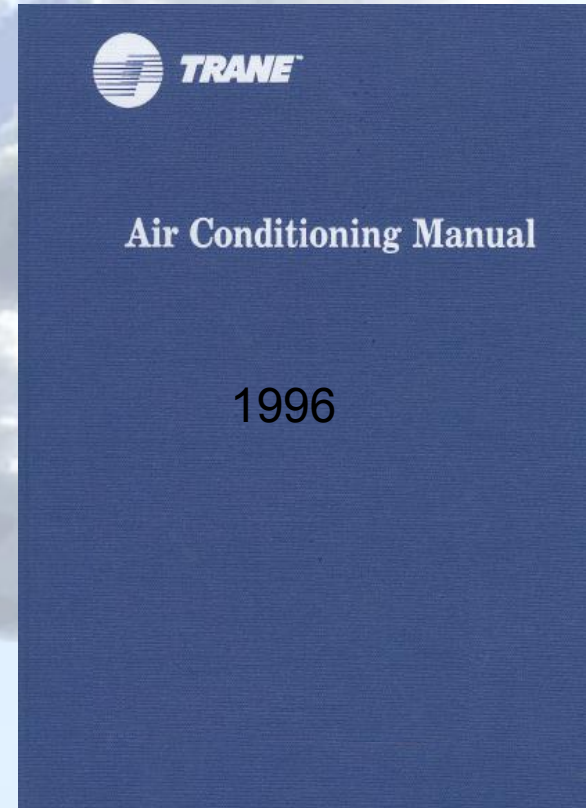
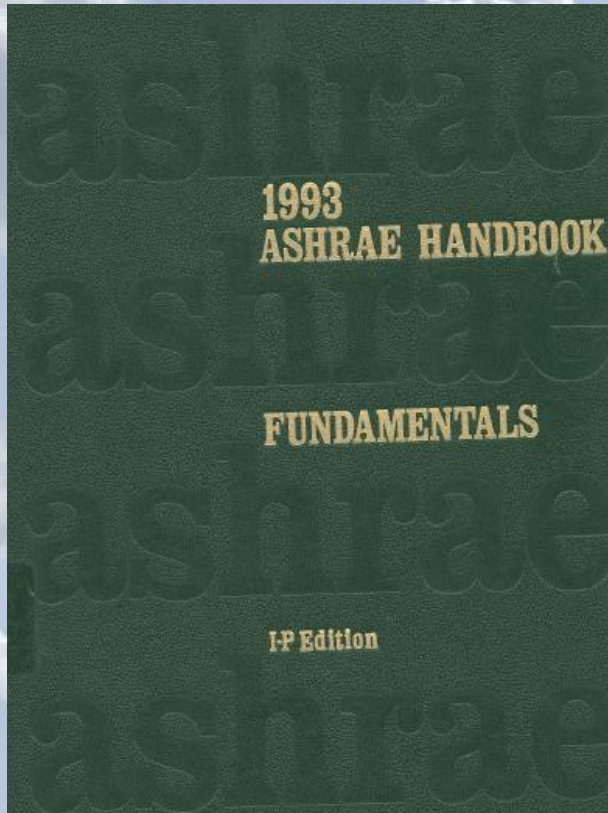
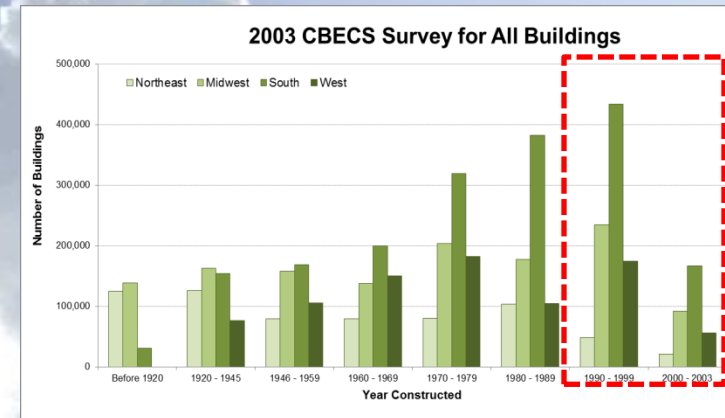


# History: 1990 – Present Guide Books

## Guide Books:

1993 *ASHRAE Handbook of Fundamentals*

1996 *TRANE Air Conditioning Manual*



# History: 1990 – Present Cooling Load Calculation

## Computer Algorithms:

### Radiant Time Series Method:

- ✓ First proposed by Spitler, Fisher and Pedersen in 1997
- ✓ Later appeared in **2001 ASHRAE Handbook of Fundamentals**

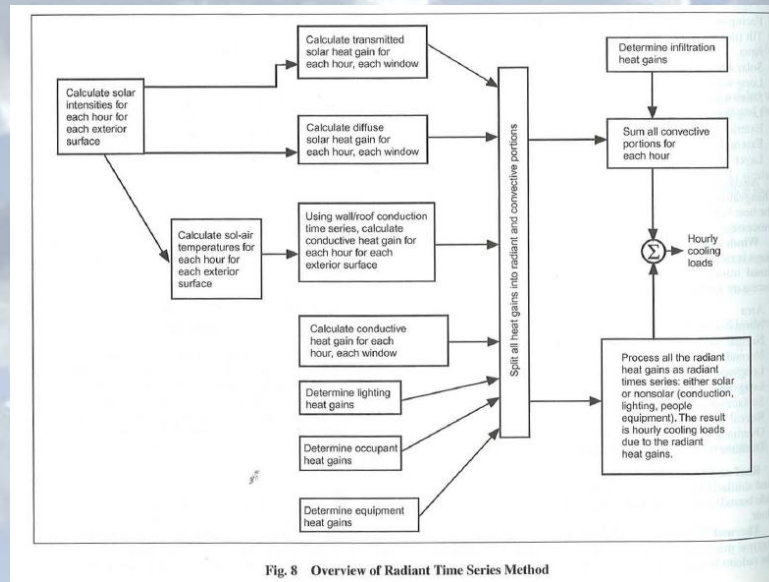


Fig. 8 Overview of Radiant Time Series Method

Source: 2001 ASHRAE Handbook of Fundamentals

2001 ASHRAE FUNDAMENTALS EXAMPLE 11P UNITS						REV 2008.05.25	28 Nov-11
110202 Bardell Engineering Associates						George P. Bardell, P.E., Baltimore, MD	
ROOM NO./NAME 106 Modular Office Block Load							
Length	204	feet	Area	41720	sq feet	Infiltration cfm	Heating
Width	200	feet	Volume	83440	cubic feet	2000	2000
Ceiling Height	9	feet					
INTERNAL LOADS							
# People	0	250	9	0	0	DB, F	75
Over-ride Room Inset	0	0	0	0	0	Refr	60%
Default	400	Latest	0232	17350	Heating	DB, F	72
Use	400	200	0232	17350	Outside Cooling Weather		
EXPOSURES						cfs - 10 - BALTIMORE BLDG ASSOCIATES INC. - 6%	
North	0	0	0	0	Heating 99.6% F		12.3
Removal Adjunct	-180	0	-90	90	Supply Cooling F		07
Actual Adjunct	-180	0	-90	90	Air Heating F		180
South	0	0	0	0	Frame with EPS		
East	0	0	0	0	Frame with EPS		
West	0	0	0	0	Dir glazd, low-E, bronze		
Type 1 Wall Area, sf	5712	5712	3020	3020	Dir glaz, low-E, bronze		
No. Type 1 Windows	0	0	0	0	Dir glaz, low-E, bronze		
No. Type 2 Windows	0	0	0	0	Dir glaz, low-E, bronze		
Roof Area, sf	20568	6%	= Roof % to RA	6%	= Lights % to RA		
ROOM LOADS							
Peak Rm Occurs	7	Per Unit	Sensible	Sensible	Room	Room	Room
Month	18	Cooling	Cooling	Cooling	Cooling	Cooling	Heating
INTERNAL LOADS							
People	No. People	347	160.776	81.600			
Lighting	watts	212,300					
Equipment	171,300	10.2	608.832				
ENVELOPE LOADS							
ROOF							
0.90 U factor	28,560	0%	28,544			94,309	
WALLS							
0.90 U factor							
North	5712	1.8	10,227			27,006	
South	5712	0.2	12,289			27,006	
East	3020	1.3	7,181			18,534	
West	3020	3.3	12,627			18,534	
WINDOWS							
Window Type 1: Dir glazd, low-E, bronze							
1-ft window	North	0	0.0				
20% SHGF (S)	South	0	0.0				
0.40 U factor	East	0	0.0				
74% IAC	West	0	0.0				
Window Type 2: Dir glaz, low-E, bronze							
1-ft window	North	0	0.0				
20% SHGF (S)	South	0	0.0				
0.40 U factor	East	0	0.0				
74% IAC	West	0	0.0				
INFILTRATION LOADS							
Cooling	Sensible	1000	12.50			12,540	
Cooling	Latent	1000	24.8			24,813	
Heating	2000	65.0					130,029
ROOM LOAD TOTALS							
			984,206	-	106,413	305,495	
			49,707			9,919	
BLOCK LOADS							
TOTAL ROOM SENS-RA-LATENT =						1,074,190	ROOM HTG: 305,495
Peak Block Load Occurs: OUTSIDE AIR: OA Sensible						231,690	OA Heating: 812,623
Month:	7	OA cfm =	12590	OA Latent:	531,979		
Hour:	15	FAN HEAT:	90	HP to S. Air:	127,395	TOT HEATING JWBH:	1,118,120
		PUMP HEAT:	6	HP to CHW:		Heating Inhibit =	19.6
TOTAL BLOCK COOLING LOAD, sens						1,765,074	147.1 388

Source: Steven F. Bruning 2012 ASHRAE Journal



# History: 1990 – Present Cooling Load Calculation

## Residential Heat Balance (RHB) and Residential Load Factor (RLF) Methods:

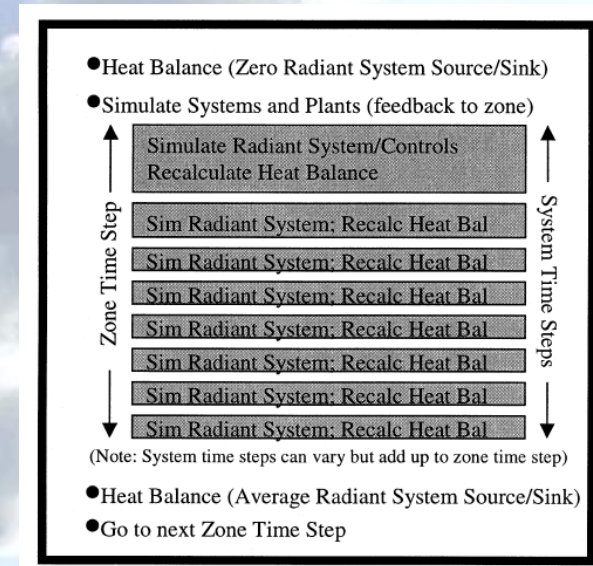
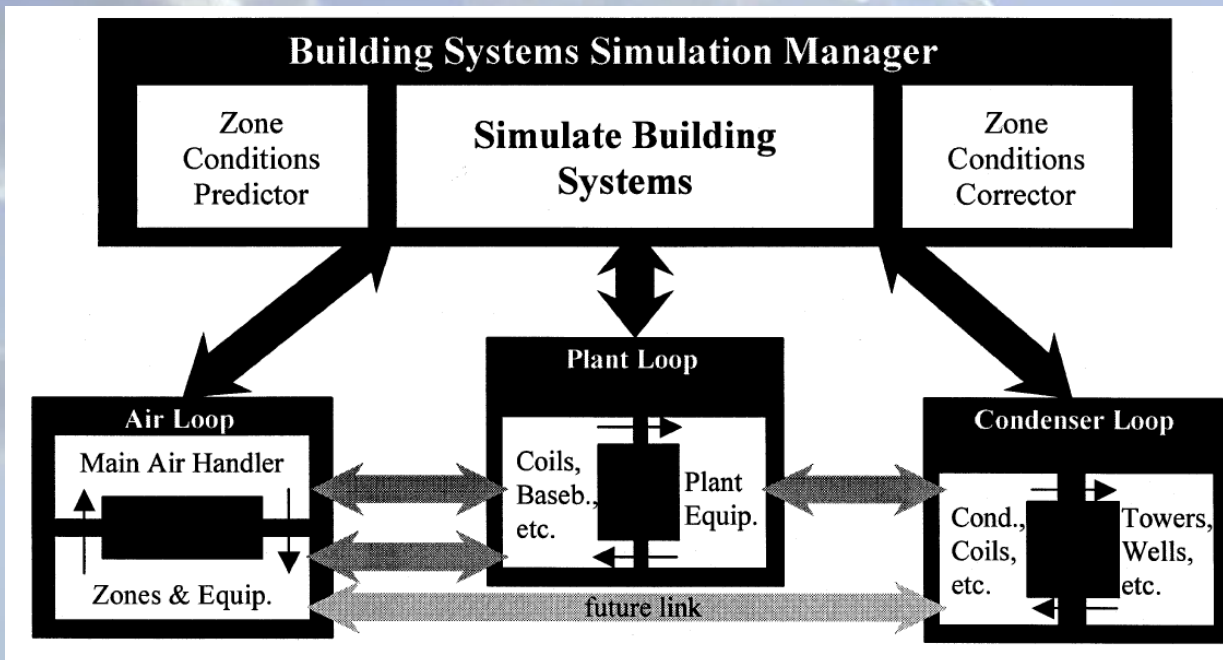
- ✓ First introduced by Barnaby, Spitler and Xiao in 2004 ASHRAE Final Report
- ✓ Both methods used for residential calculations
- ✓ Later appeared in **2005 ASHRAE Handbook of Fundamentals**

Item	Valid Range	Notes
Latitude	20 to 60°N	Also approximately valid for 20 to 60°S with N and S orientations reversed for southern hemisphere.
Date	July 21	Application must be summer peaking. Buildings in mild climates with significant SE/SW glazing may experience maximum cooling load in fall or even winter. Use RHB if local experience indicates this is a possibility.
Elevation	Less than 2000 m	RLF factors assume 50 m elevation. With elevation-corrected $C_p$ , method is acceptably accurate except at very high elevations.
Climate	Warm/hot	Design-day average outdoor temperature assumed to be above indoor design temperature.
Construction	Lightweight residential construction (wood or metal framing, wood or stucco siding)	May be applied to masonry veneer over frame construction; results are conservative. Use RHB for structural masonry or unconventional construction.
Fenestration area	0 to 15% of floor area on any façade, 0 to 30% of floor area total	Spaces with high fenestration fraction should be analyzed with RHB.
Fenestration tilt	Vertical or horizontal	Skylights with tilt less than 30° can be treated as horizontal. Buildings with significant sloped glazing areas should be analyzed with RHB.
Occupancy	Residential	Applications with high internal gains and/or high occupant density should be analyzed with RHB or nonresidential procedures.
Temperature swing	1.7 K	
Distribution losses	Typical	Applications with extensive duct runs in unconditioned spaces should be analyzed with RHB.

# History: 1990 – Present Cooling Load Calculation

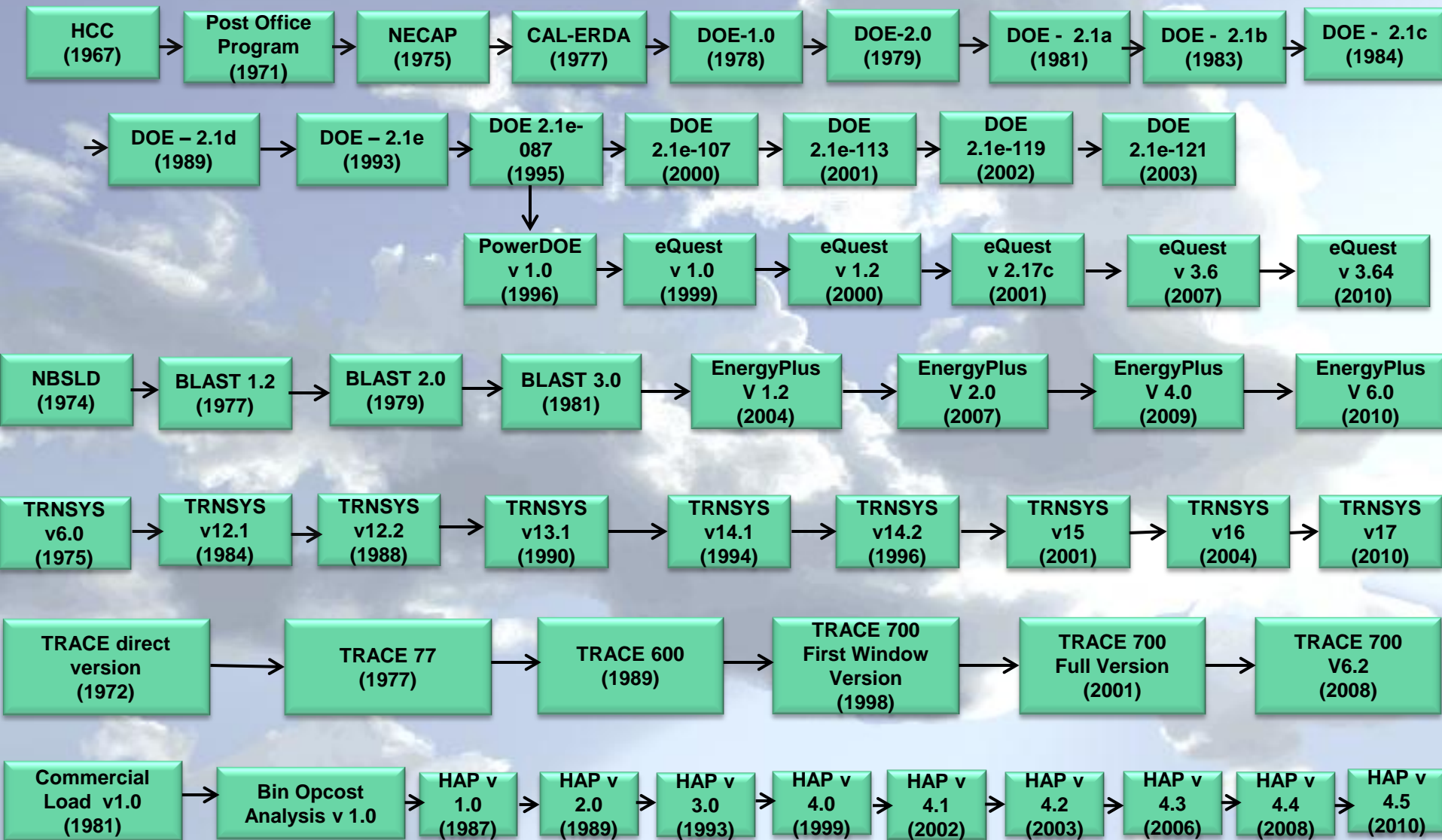
## Modeling Radiant Systems Using a Heat Balance Simulation:

- ✓ First studied by Strand & Pedersen in 1994.
- ✓ First published by Strand in 2001 thesis.
- ✓ Required the development of new type of transfer functions.
- ✓ Now a module in the EnergyPlus program



# History: 1960 – Present Annual Energy Use

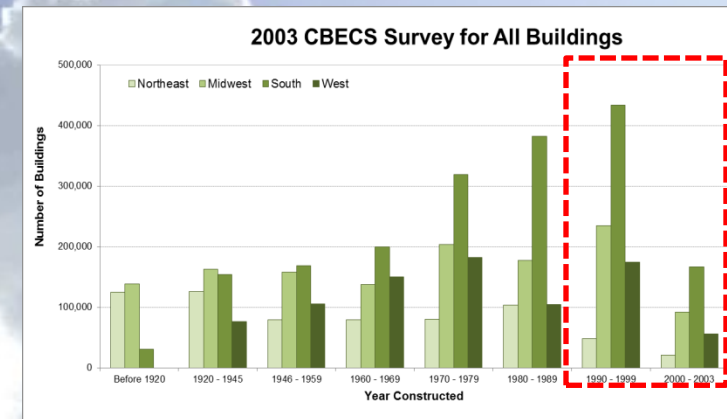
## Building Energy Modeling Programs:



# History: 1990 – Present Summary

## Thermal Mass Studies (Examples):

- ❑ *Thermal structure factors* proposed by Kossecka in 1992
- ❑ *Thermal mass factors* introduced by ISO Standards 9869 in 1994
- ❑ *Radiant Floor Heating and Cooling systems* (Olesen 1997, 2002)



Structure Factors for Walls with Cores Composed of Heavyweight Concrete and Insulation, Shown in Figure 1

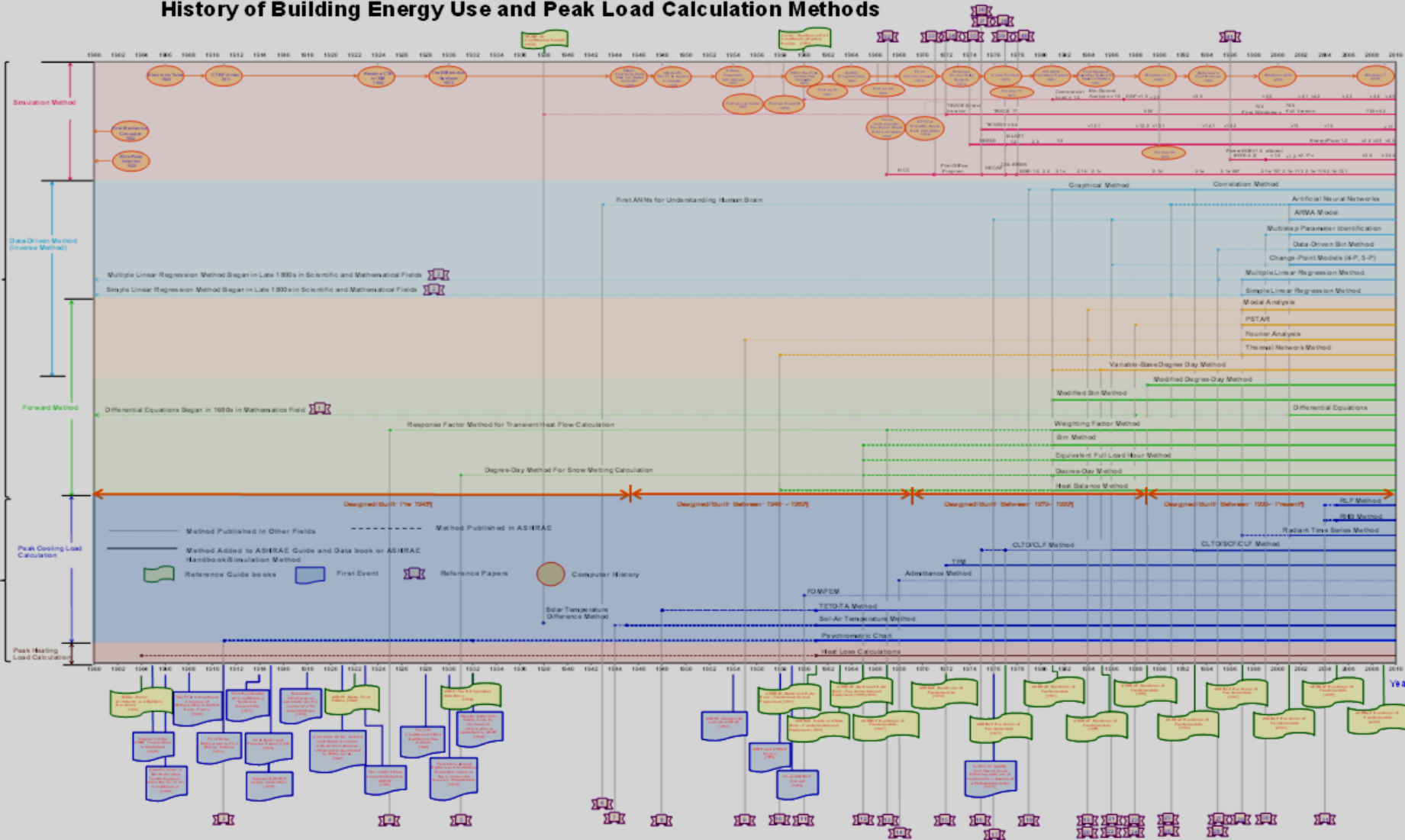
Structure No.	Layer thicknesses (in.)	$\Psi_{ii}$	$\Psi_{ie}$	$\Psi_{ee}$
<b>Gypsum - Heavyweight Concrete - Insulation - Heavyweight Concrete - Stucco</b>				
1	1/2 - 3 - 4 - 3 - 3/4	0.408	0.048	0.496
2	1/2 - 4 - 4 - 2 - 3/4	0.530	0.053	0.363
3	1/2 - 6 - 4 - 0 - 3/4	0.770	0.068	0.094
<b>Gypsum - Insulation - Heavyweight Concrete - Insulation - Stucco</b>				
4	1/2 - 4 - 6 - 0 - 3/4	0.034	0.040	0.885
5	1/2 - 1 - 6 - 3 - 3/4	0.460	0.187	0.167
6	1/2 - 2 - 6 - 2 - 3/4	0.234	0.222	0.322
Homogeneous Core	1/2 - 10 - 3/4	0.294	0.162	0.382

Decrement Factors, Amplitudes, and Time Shifts of the Transmittance and Admittance Response for Walls with Cores Composed of Heavyweight Concrete and Insulation, Shown in Figure 1

Wall No	$\Phi_{ii}/\Phi_{ie}$	1/B Response			D/B Response	
		DF	Amplitude Btu/h-ft <sup>2</sup> -°F	$\tau_{ij}$ (h)	Amplitude Btu/h-ft <sup>2</sup> -°F	$\tau_{ij}$ (h)
<b>Gypsum - Heavyweight Concrete - Insulation - Heavyweight Concrete - Stucco</b>						
1	0.048/0.408	0.270	0.0148	-8.831	0.758	1.565
2	0.053/0.530	0.251	0.0138	-8.524	0.764	1.231
3	0.068/0.770	0.205	0.0112	-7.478	0.746	0.908
<b>Gypsum - Insulation - Heavyweight Concrete - Insulation - Stucco</b>						
4	0.040/0.034	0.356	0.0196	-6.761	0.153	4.072
5	0.187/0.460	0.070	0.0038	-8.237	0.226	1.905
6	0.222/0.234	0.059	0.0032	-8.288	0.171	2.998
Homogen. Core	0.162/0.294	0.039	0.0021	-20.548	0.398	2.386

# History: Overview Chart 1900 - Present

## History of Building Energy Use and Peak Load Calculation Methods



# Summary:

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- Important to consider age of building stock in the U.S. 1900 to present
- History of building load calculation methods tied to:
  - The development of ASHVE, ASRE, ASHAE, ASHRAE.
  - The development of computers, programming language.
- 1904 – 1938 no direct consideration of thermal mass in building heat load calculation.

# Summary

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- Other considerations:
  - 1848 - Invention of refrigeration
  - Late 1800s – resolution of A.C. vs D.C. for electric motors
  - 1911 – psychrometric chart (Willis Carrier)
  - 1928 – first air-conditioned office building (Milam Building, San Antonio, TX)
- 1944 – First use of thermal mass: Mackey and Wright develop sol-air temperature with decrement factor. 1961 adopted into ASHRAE Guide and Data Book
- 1961 – Total Equivalent Temperature Difference/Time Average (TETD/TA) Method

# Summary

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- 1977 – TETD/TA replaced with Cooling Load Temperature Difference/Cooling Load Factor (CLTD/CLF) Method
- Annual Calculation Methods: 1960s - heating degree days, equivalent full load hours, bin method.
- 1958 – thermal network models created based on electrical RC circuits.



# Summary

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- Computer Algorithms (1960 – present):
  - Thermal response factors,
  - transfer functions,
  - weighting factors,
  - heat balance method,
  - radiant time series,
  - residential heat balance, residential load factors
  - new transfer functions for radiant heating
- Examples of Thermal Mass Studies: thermal mass structural factors, thermal mass factors, radiant floor systems

**Questions?**

