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The Art of Thermal Mass Modeling for Energy Conservation in Buildings, Part 1

ACI Spring 2012 Convention
March 18 – 21, Dallas, TX

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Thermal Mass Provisions in ASHRAE Standard 90.1 and the IECC

ACI Spring Conference
ACI Committee 122
March 19, 2012

Stephen V. Skalko, P.E.
Portland Cement Association

Energy Codes and Standards

OBJECTIVES

- Review development history of Standard 90.1 & IECC (formerly (MEC)
- Examine format of prescriptive thermal mass provisions
- Application of thermal mass requirements

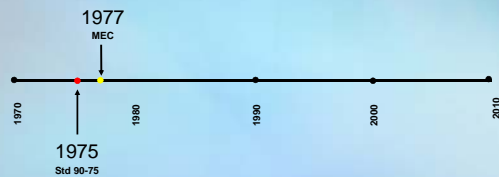
Energy Codes and Standards

- ASHRAE develops the 1st energy standard
- Criteria based on best practices



Timeline

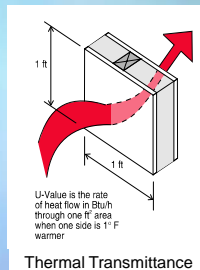
Energy Codes and Standards



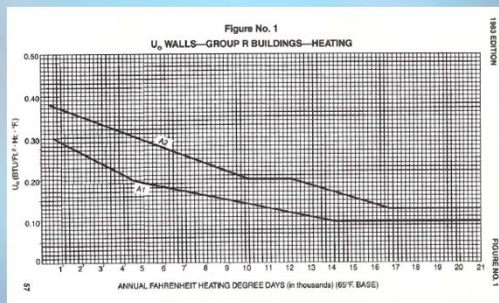
Timeline

Energy Codes and Standards

- The Standard had U-factor criteria for
 - Roofs
 - Walls
 - Floors
 - Windows
 - Skylights
- The smaller the number the better energy conservation



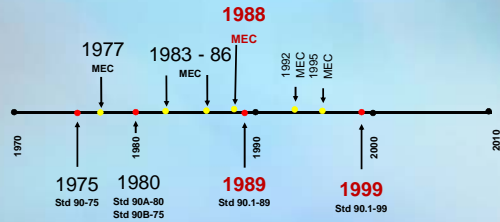
Energy Codes and Standards



Energy Codes and Standards

MAXIMUM WALL U-VALUE (Uw) Mason Walls					
UFD Range	NC Range		Interior Insulation	Exterior Insulation	
15	5.0 - 9.9	10.0 - 14.9	0.17	0.24	0.31
71	5.0 - 9.9	10.0 - 14.9	0.17	0.24	0.30
13	5.0 - 9.9	10.0 - 14.9	0.17	0.24	0.33
71	5.0 - 9.9	10.0 - 14.9	0.17	0.24	0.31
10	5.0 - 9.9	10.0 - 14.9	0.17	0.24	0.31
49	5.0 - 9.9	10.0 - 14.9	0.17	0.24	0.31

Energy Codes and Standards



Timeline

Building envelope revisions to Standard 90.1

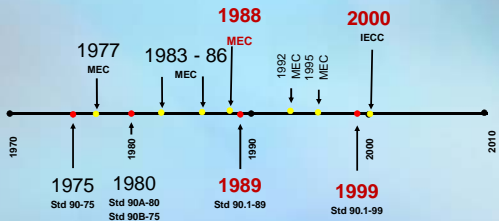
Energy Codes and Standards

TABLE 5.1 Example Building Envelope Requirements (Values can be found in the appropriate tables in Normative Appendix B)												
Opaque Element	Climate Zone 1		Climate Zone 2		Climate Zone 3		Climate Zone 4		Climate Zone 5		Climate Zone 6	
	U-value	R-value	U-value	R-value	U-value	R-value	U-value	R-value	U-value	R-value	U-value	R-value
Roof	0.05	20	0.05	20	0.05	20	0.05	20	0.05	20	0.05	20
Walls, Above Grade	0.09	11	0.09	11	0.09	11	0.09	11	0.09	11	0.09	11
Walls, Below Grade	0.15	6.7	0.15	6.7	0.15	6.7	0.15	6.7	0.15	6.7	0.15	6.7
Floors	0.18	5.6	0.18	5.6	0.18	5.6	0.18	5.6	0.18	5.6	0.18	5.6
Doors	0.35	2.8	0.35	2.8	0.35	2.8	0.35	2.8	0.35	2.8	0.35	2.8
Windows	0.30	3.3	0.30	3.3	0.30	3.3	0.30	3.3	0.30	3.3	0.30	3.3

Energy Codes and Standards

TABLE 5.3 Example Building Envelope Requirements (Values can be found in the appropriate tables in Normative Appendix B)						
Opaque Element	Climate Zone 1		Climate Zone 2		Climate Zone 3	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
Roof	U-0.05	R-20	U-0.05	R-20	U-0.05	R-20
Walls, Above Grade	U-0.09	R-11	U-0.09	R-11	U-0.09	R-11
Walls, Below Grade	U-0.15	R-6.7	U-0.15	R-6.7	U-0.15	R-6.7
Floors	U-0.18	R-5.6	U-0.18	R-5.6	U-0.18	R-5.6
Doors	U-0.35	R-2.8	U-0.35	R-2.8	U-0.35	R-2.8
Windows	U-0.30	R-3.3	U-0.30	R-3.3	U-0.30	R-3.3

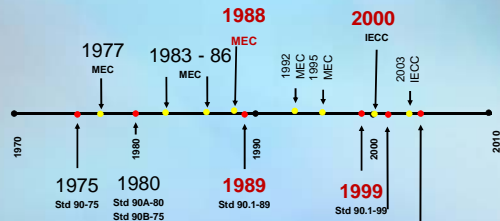
Energy Codes and Standards



Timeline

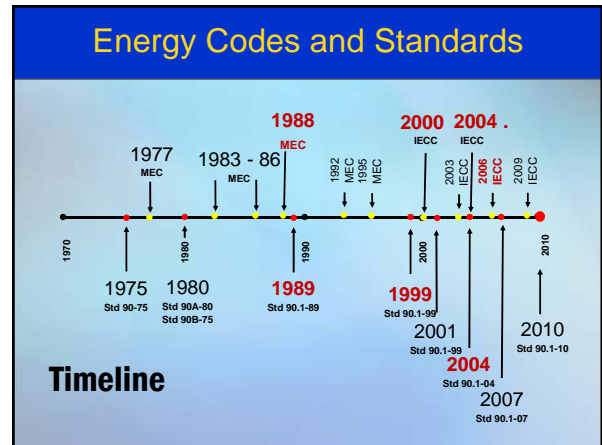
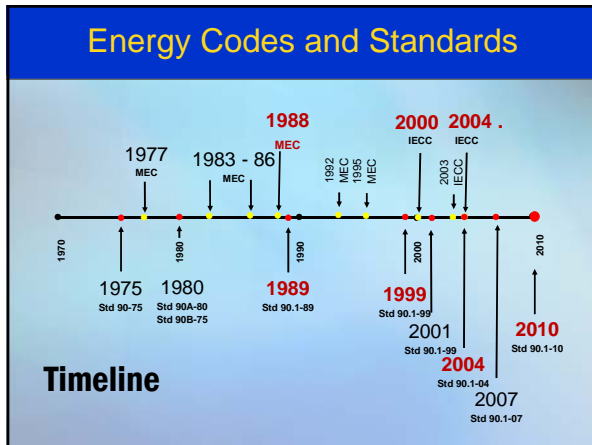
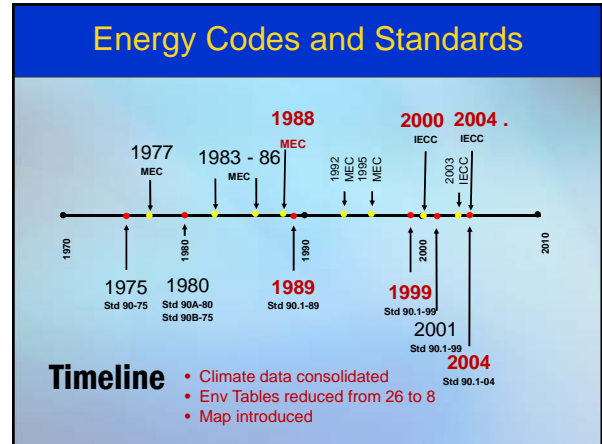
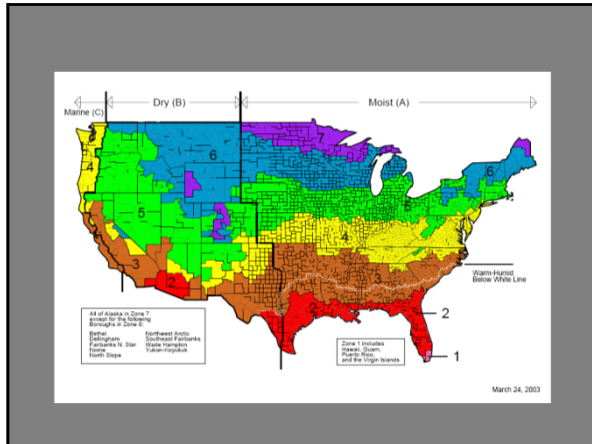
Model Energy Code (MEC) becomes International Energy Conservation Code (IECC)

Energy Codes and Standards



Timeline

- Climate data consolidated
- Env Tables reduced from 26 to 8
- Map introduced



ASHRAE Standard 90-2010

TABLE 5.5-3 Building Envelope Requirements for Climate Zone 3 (A, B, C)

Opaque Elements	Nonresidential		Residential		Semiretired	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
Roof						
→ Insulation Entirely above Deck	U-0.048	R-20.0 ± 1	U-0.048	R-20.0 ± 1	U-0.175	R-5.0 ± 1
Metal Building ^a	U-0.055	R-13.0 ± 13.0	U-0.055	R-13.0 ± 13.0	U-0.097	R-10.0
Attic and Other	U-0.027	R-38.0	U-0.027	R-38.0	U-0.053	R-19.0
Walls, Above-Grade						
→ Mass	U-0.123	R-7.6 ± 1	U-0.104	R-6.5 ± 1	U-0.580	NR
Metal Building ^a	U-0.084	R-19.0	U-0.084	R-19.0	U-0.113	R-13.0
Steel-Framed	U-0.084	R-13.0 + R-3.8 ± 1	U-0.064	R-13.0 + R-7.5 ± 1	U-0.124	R-13.0
Wood-Framed and Other	U-0.089	R-13.0	U-0.089	R-13.0	U-0.089	R-13.0
Walls, Below-Grade						
→ Below-Grade Wall	C-1.140	NR	C-1.140	NR	C-1.140	NR
Floors						
→ Mass	U-0.107	R-6.4 ± 1	U-0.087	R-6.3 ± 1	U-0.322	NR
Steel-Joint	U-0.082	R-19.0	U-0.082	R-19.0	U-0.069	R-13.0
Wood-Framed and Other	U-0.051	R-19.0	U-0.033	R-30.0	U-0.066	R-13.0
Slab-On-Grade Floors						
→ Unheated	F-0.730	NR	F-0.730	NR	F-0.730	NR
Heated	F-0.900	R-10 for 24 in.	F-0.900	R-10 for 24 in.	F-1.020	R-7.5 for 12 in.

IECC 2009 All other (90.1)

TABLE 602.201 BUILDING ENVELOPE REQUIREMENTS - OPaque ASSEMBLIES

CLIMATE ZONE	1		2		3		4		5		6		7		8		
	All other	Group II	All other	Group II	All other	Group II	All other	Group II	All other	Group II	All other	Group II	All other	Group II	All other	Group II	
Roof																	
→ Insulation entirely above Deck	R-15a	R-20a	R-20a	R-20a	R-20a	R-20a	R-20a	R-20a	R-20a	R-20a	R-20a	R-20a	R-20a	R-20a	R-20a	R-20a	R-20a
→ Insulation below Deck	R-19	R-19	R-13 ± R-13	R-13 ± R-13	R-13	R-13	R-19	R-13 ± R-13	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19
→ Insulation on Deck	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30
Walls, Above-Grade																	
→ Mass	NR	R-7.6a	R-7.6a	R-7.6a	R-7.6a	R-7.6a	R-7.6a	R-7.6a	R-7.6a	R-7.6a	R-7.6a	R-7.6a	R-7.6a	R-7.6a	R-7.6a	R-7.6a	R-7.6a
Metal Building ^a	R-16	R-16	R-16	R-16	R-19	R-19	R-19	R-13 ± R-13	R-13 ± R-13	R-13 ± R-13	R-13 ± R-13	R-13 ± R-13	R-13 ± R-13	R-13 ± R-13	R-13 ± R-13	R-13 ± R-13	R-13 ± R-13
Steel-Framed	R-13	R-13	R-13	R-13	R-13	R-13	R-13	R-13 ± R-13	R-13 ± R-13	R-13 ± R-13	R-13 ± R-13	R-13 ± R-13	R-13 ± R-13	R-13 ± R-13	R-13 ± R-13	R-13 ± R-13	R-13 ± R-13
Wood-Framed and Other	R-13	R-13	R-13	R-13	R-13	R-13	R-13	R-13 ± R-13	R-13 ± R-13	R-13 ± R-13	R-13 ± R-13	R-13 ± R-13	R-13 ± R-13	R-13 ± R-13	R-13 ± R-13	R-13 ± R-13	R-13 ± R-13
Walls, Below-Grade																	
→ Below-Grade Wall	NR	NR	NR	NR	NR	NR	NR	R-7.5a	R-7.5a	R-7.5a	R-7.5a	R-7.5a	R-7.5a	R-7.5a	R-7.5a	R-7.5a	R-7.5a
Floors																	
→ Mass	NR	NR	R-6.3a	R-6.3a	R-6.3a	R-6.3a	R-6.3a	R-6.3a	R-6.3a	R-6.3a	R-6.3a	R-6.3a	R-6.3a	R-6.3a	R-6.3a	R-6.3a	R-6.3a
Steel-Joint	NR	NR	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19
Wood-Framed and Other	NR	NR	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19
Slab-On-Grade Floors																	
→ Unheated slabs	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
→ Heated slabs	R-7.5a	R-7.5a	R-7.5a	R-7.5a	R-7.5a	R-7.5a	R-7.5a	R-7.5a	R-7.5a	R-7.5a	R-7.5a	R-7.5a	R-7.5a	R-7.5a	R-7.5a	R-7.5a	R-7.5a

IECC 2009 Low Rise Residential

TABLE 402.1.1
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT*

CLIMATE ZONE	FENESTRATION U-FACTOR ¹	SKYLIGHT ² U-FACTOR	GLAZED FENESTRATION SHGC ^{3,4}	CEILING R-VALUE	WOOD FRAME WALL R-VALUE	MASS WALL R-VALUE	FLOOR R-VALUE	BASEMENT WALL R-VALUE	SLAB ⁵ R-VALUE & DEPTH	CEILING SPACE ⁶ WALL R-VALUE
1	1.2	0.75	0.30	30	13	3/4	13	0	0	0
2	0.65 ⁷	0.75	0.30	30	13	4/6	13	0	0	0
3	0.50 ⁷	0.65	0.30	30	13	5/8	19	5/12 ⁸	0	5/13
4 except Marine	0.35	0.60	NR	38	13	5/10	19	10/13	10, 2 R	10/13
5 and Marine 4	0.35	0.60	NR	38	20 or 13+ ⁹	13/17	30 ⁸	10/13	10, 2 R	10/13
6	0.35	0.60	NR	49	20 or 13+ ⁹	15/19	30 ⁸	15/19	10, 4 R	10/13
7 and 8	0.35	0.60	NR	49	21	10/21	38 ⁸	15/19	10, 4 R	10/13

Mass Walls – The second value applies when more than half of the insulation is on the interior of the wall.



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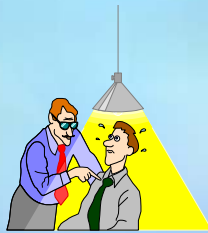
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Questions?