A Commercial Building Energy Standard for Mexico

Joe Huang, Jeffrey L. Warner, and Stephen Wiel, LBNL, Berkeley, California
Alejandro Rivas, RAMPA, Naucalpan, Mexico
Odon de Buen, CONAE, Mexico City, Mexico

ABSTRACT

Beginning in 1992, the Comisión Nacional de Ahorro de Energía (CONAE), or Mexican National Commission for Energy Conservation, developed a national energy standard for commercial buildings, with assistance from USAID and LBNL. The first complete draft of the standard was released for public review in mid-1995. To promote public acceptance of the standard, CONAE held advisory meetings with architects, engineers, and utility representatives, and organized public workshops presented by the authors, with support from USAID. In response to industry comments, the standard was revised in late 1997 and is currently under review by CONAE. It is anticipated that the revised draft will be released again for final public comments in the summer of 1998. The standard will become law one year after it is finalized by CONAE and published in the federal government record.

Since Mexico consists of cooling-dominated climates, the standard emphasizes energy-efficient envelope design to control solar and conductive heat gains. We extended DOE-2 simulation results for four climates to all of Mexico through regression analysis. Based on these results, we developed a simplified custom budget calculation approach. To facilitate the method's use, a calculation template was devised in a spreadsheet program and distributed to the public. CONAE anticipates that local engineering associations will use this spreadsheet to administer code compliance.

History of Mexican Building Energy Standards

The Mexican federal government began to recognize the economic and environmental benefits of energy efficiency in the early 1980's. Initial Mexican efforts to develop energy standards involved simplified analytical approaches with nominal goals. For example, the federal government first addressed the issue of high cooling energy consumption in northwest Mexican housing in a 1985 study (de Buen 1987). The study concluded that roof insulation was the most effective energy conservation measure in such buildings. Four years later, the government implemented a roof insulation program in the residential sector of Mexicali, Baja California. This successful program became a benchmark for efforts to reduce space-conditioning energy consumption in Mexico. The program also generated greater interest in issues related to energy consumption in buildings and led to a discussion about drafting a building energy efficiency standard.

Mexico's federal administration changed in December 1988, resulting in a drive toward national modernization. This change in government provided a new opportunity for the enactment of energy efficiency standards. Ten months after he took office in September 1989, President Carlos Salinas de Gortari signed a bill that created the Comisión Nacional de Ahorro de Energía (CONAE), or National Commission for Energy Conservation, making energy efficiency a national priority.

In August 1991, the Mexican government proposed the first building energy standard and commissioned a review of the building codes of 23 cities and seven states in northern Mexico. In this hot, dry region, building envelope characteristics greatly influence energy consumption. Based on the review, government engineers drafted a standard recommending materials and construction types for residential buildings, with a particular emphasis on wall and roof insulation and window shading devices. However, this effort failed to produce the intended changes in construction codes, primarily because the proposed standard contained no clear indication of the economic benefits of the recommended measures.

In July 1992, the Mexican Congress passed a law requiring all federal government ministries to produce standards for their jurisdictions, participate in national standardization efforts, and organize consulting committees for these purposes. The standards produced under this structure are called Normas

Oficiales Mexicanas (NOMs), or Official Mexican Standards. The objective of the NOMs is to establish standard specifications for products, processes, and services that would otherwise represent security risks, affect the health of humans, animals, or plants, disrupt the general or labor environment, or affect the preservation of natural resources (Bello 1994). CONAE directed efforts to produce NOMs and invited the participation of other government institutions, materials and equipment manufacturers, chambers of commerce and industry, research and educational institutions, and professional associations. By 1997, CONAE had an ambitious program of 19 enacted and proposed energy efficiency NOMs covering everything from building mechanical systems to agricultural pumps. Standards were proposed for envelopes and lighting systems for both commercial and residential buildings.

CONAE contracted Alejandro Rivas, a co-author of this paper, to develop the commercial building envelope standard in 1993. CONAE also sought and received support from the U.S. Agency for International Development (USAID). Through USAID, Lawrence Berkeley National Laboratory (LBNL) and other U.S. institutions began to provide technical assistance to CONAE and Rivas in 1994. Hampered by the limited data on weather and building characteristics and the lack of building energy simulation capabilities, Rivas used manual calculations based on peak design temperatures to develop a draft standard. He derived prescriptive values for wall and roof insulation from a cost-benefit analysis that compared calculated energy savings to the expected costs of conservation measures. Concurrently, LBNL obtained detailed weather data for three Mexican cities and contracted Pacific Northwest National Laboratory (PNNL) to use the DOE-2 program to analyze various energy efficiency options in Mexican commercial buildings (Halverson et al. 1994).

In late 1994, LBNL reviewed Rivas' draft standard and devised a plan to strengthen it technically. LBNL researchers recognized the benefits of a design calculation methodology familiar to Mexican engineers and architects, but cautioned that a standard based on peak temperatures would magnify the importance of insulation at the expense of solar control measures. Joe Huang, another co-author of this paper, proposed that the standard retain its calculation approach, but that the peak temperatures be replaced with temperatures more representative of average cooling season conditions. LBNL agreed to provide CONAE and Rivas with average Equivalent Temperatures (T_{eq}) and Solar Heat Gains through windows and skylights (I_s), derived from DOE-2 simulations of a prototypical office building in four Mexican cities.

Technical Basis for the Proposed Standard

DOE-2 Analysis

We performed our analysis for the proposed building standard using DOE-2.1E, a detailed hourly building energy simulation program developed at LBNL (Winkelmann et al. 1993). DOE-2 is used widely in the United States and abroad to analyze building energy performance and set building standards. The program uses response factors to calculate heat flows across building surfaces, and weighting factors to model the dynamic thermal behavior of a space or building in response to varying heat gains and losses. These two related techniques, particularly the use of "custom" weighting factors, allow DOE-2 to simulate the effects of thermal mass on heat conduction and cooling loads. Studies have shown DOE-2 to be accurate in predicting indoor conditions in buildings of both lightweight and heavy construction (Lomas et al. 1994; Meldem & Winkelmann 1998).

We simulated the varying envelope heat flows over the cooling season in a prototypical office building in four representative Mexican locations: Mexico City (a mild central plateau), Merida (a hot, humid location), Monterrey (a hot, dry location), and Mexicali (an extremely hot, dry location). Weather data for the first three locations were obtained from the U.S. National Climatic Data Center, while a California Energy Commission weather file for El Centro, California, was used to represent nearby Mexicali.

Our analysis drew on the previous PNNL study in defining a prototypical Mexican office building for simulation. Table 1 lists our assumptions for various building characteristics. The four sides of the building faced in the cardinal directions. We accounted for the generally taller commercial buildings in Mexico City. Both steel-frame and masonry wall construction types were examined in each location. The typical operating conditions were defined in consultation with CONAE engineers.

We performed parametric DOE-2 simulations for varying window and skylight area, glazing conductance, shading coefficient, overhang length, wall and roof insulation, absorptance, and emittance. We tabulated the net heat flows through the different building envelope components during business hours from April through October, the cooling season in most regions of Mexico. Conductive and solar heat flows were tabulated separately for windows and skylights. To enhance accuracy, the heat flows were corrected according to the zone temperatures seen by the cooling system. We then derived average hourly Equivalent Temperatures (T_{eq}) by dividing each heat flow by the conductance and area of the respective building component (i.e., a wall, roof, window, or skylight) and the cooling system operating hours:

$$T_{eq} = T_{in} + Q_c / (U \cdot A \cdot t), \qquad (1)$$

where

T_{eq} = average hourly cooling seasonal Equivalent Temperature for the building component, in °C;

T_{in} = interior cooling setpoint temperature, 25°C;

Q_c = total cooling seasonal load calculated by DOE-2 for the building component, in W·h;

U = conductance of the building component, in $W/m^2 \cdot K$;

A = surface area of the building component, in m^2; and

t = cooling system seasonal operating time, in h.

For opaque building components, the Equivalent Temperature is the average hourly *sol-air* temperature, due to both the ambient temperature and solar radiation, at the exterior surface over the cooling season. For windows and skylights, it is simply the average hourly ambient temperature at the exterior surface. Because of the influences of solar heat gains and thermal lag, Equivalent Temperatures differ by orientation and wall construction type. Since the Equivalent Temperatures are derived from DOE-2 results, using them in the design calculation in the proposed standard would recreate the DOE-2-computed cooling loads.

For solar gains through windows and skylights, we used a similar procedure to derive average hourly Solar Heat Gains per unit area of glazing by dividing the total solar heat flow by the solar aperture of the glazing and the cooling system operating hours:

$$I_s = Q_s / (C_s \cdot A \cdot t), \qquad (2)$$

where

I_s = average hourly cooling seasonal Solar Heat Gain through a clear, single-pane glazing, in W/m^2;

Q_s = total cooling seasonal solar load calculated by DOE-2 for the glazing, in W·h;

C_s = shading coefficient of the glazing;

A = glazing area, in m^2; and

t = cooling system seasonal operating time, in h.

Extrapolation of DOE-2-Derived Equivalent Temperatures to Other Climates

After deriving the Equivalent Temperatures from the DOE-2 simulation results for the four cities, we compared them to such monthly weather statistics as average and peak temperatures, temperature ranges, etc., and found the best correlation with average monthly dry-bulb temperatures. Figures 1 and 2 show the regression results for north-facing masonry walls and concrete roofs, respectively. We applied these regression equations to weather data from the Mexican National Meteorological Service to produce a table of Equivalent Temperatures for 65 major Mexican cities, part of which is shown in columns F through T of Table 2.

Because of the uncertainty in the solar radiation data in the weather files and the absence of suitable solar data in the monthly climate statistics we obtained, we did not attempt to extrapolate the average Solar Heat Gains for the four cities examined in the simulations to other locations. Instead, we simply assigned the average Solar Heat Gain for one of the four cities to each of the other 61 cities, based on general location and climate information.

Description of the Proposed Standard

The current draft of CONAE's proposed energy efficiency standard for non-residential buildings, NOM-008-ENER-1995, was completed in August 1997. The objective of the standard is to set the minimum requirements for the design and construction of building envelopes that will produce optimum energy consumption levels with properly designed and installed HVAC systems. When enacted, this standard will apply to public and private buildings, new construction and expansion or remodeling of existing buildings, and all buildings with cooling or ventilation systems and installed power demand of at least 20 kW. The standard contains an exhaustive list of occupancy types and will apply to virtually all commercial buildings, except special care areas in hospitals and clinics that require special air-conditioning systems, and buildings used primarily for manufacturing or agriculture.

Compliance Path

Although previous versions of the standard contained both Prescriptive and Performance Paths for compliance, the former was dropped in 1996 at the urging of an advisory group of architects. After presentations at three universities in Mexico City, Chihuahua, and Monterrey, these architects voiced the concern that the Prescriptive Path could lead to poor architectural designs by giving architects an easy solution that does not require them to evaluate or improve their designs. (This advisory group also proposed that the universities increase their efforts to introduce energy-efficient building design and prepare special post-graduate courses on this subject.) In response to their concern, CONAE eliminated the Predetermined Values by climate for window and skylight effective solar aperture and conductance, wall and roof conductance, and other mandatory requirements from the standard, leaving only the Performance Path. However, the Prescriptive requirements are still used in defining the Reference Building, to which the Proposed Building must be compared.

Performance Path for Evaluating the Energy Performance of the Building Envelope

A designer using the Performance Path to comply with the proposed standard must evaluate the energy performance of the Proposed Building using the simplified heat flow calculation method described above, and demonstrate that the average hourly heat flow through the building envelope does not exceed that in a Reference Building.

The Reference Building is defined as having the same orientation, gross envelope areas, zoning, and boundary conditions as the Proposed Building. However, the window area in the Reference Building is fixed at 40% of the gross exterior wall area on each orientation, the U-factor at 5.319 $W/m^2 \cdot K$, and the shading coefficient at 1.00. The skylight area is held at 5% of the gross exterior roof area in the Reference Building, the U-factor at 5.952 $W/m^2 \cdot K$, and the shading coefficient at 0.85. The U-factors of the walls and roof of the Reference Building vary by climate, as shown in columns C through E of Table 2. These U-factors are the same as the Predetermined Values or mandatory requirements of the abandoned Prescriptive Path. As in ASHRAE-90.1 (ASHRAE 1989) and other building energy standards, the Predetermined Values define base-case conservation levels determined to be most cost-effective. The Performance Path allows other building configurations to comply with the standard as long as the total heat gains through the envelope are equivalent, without regard to the cost effectiveness of the conservation measures specified.

Figure 3 is a map showing the geographic distribution of the Predetermined Values for roof insulation. This map is not part of the standard, but demonstrates clearly the cost-effective roof insulation levels implicit in the standard. The standard itself lists the Predetermined Values for roof conductance in the 65 locations.

Calculation Method

The proposed standard prescribes that the average cooling seasonal heat flow (Q_p) due to conduction and solar radiation through the conditioned envelope of the Proposed Building be no greater than the average heat flow (Q_r) through that of the Reference Building. The standard incorporates the simplified Equivalent Temperature (T_{eq}) calculation method described above to calculate this average heat flow. This technique is analogous to ASHRAE's Cooling Load Temperature Difference Method, and was selected because of its similarity to the design cooling load calculations familiar to Mexican engineers and HVAC contractors.

The calculation of the total cooling load uses the building envelope characteristics (i.e., conductance, shading coefficient, and surface area) and the Equivalent Temperatures and Solar Heat Gains shown in Table 2 in the reverse process of that used to derive them from the DOE-2 results:

$$
\begin{aligned}
Q_{total} = {} & U_{roof} \cdot A_{roof} \cdot (T_{eq,roof} - T_{in}) && \text{(roofs)} \\
& + \sum_{i=1}^{4} U_{wall,i} \cdot A_{wall,i} \cdot (T_{eq,wall,i} - T_{in}) && \text{(walls)} \\
& + \sum_{i=1}^{4} U_{window,i} \cdot A_{window,i} \cdot (T_{eq,window,i} - T_{in}) && \text{(window conduction)} \\
& + U_{skylight} \cdot A_{skylight} \cdot (T_{eq,skylight} - T_{in}) && \text{(skylight conduction)} \\
& + \sum_{i=1}^{4} I_{s,vertical,i} \cdot C_{s,window,i} \cdot SE_i \cdot A_{window,i} && \text{(window solar)} \\
& + I_{s,horizontal} \cdot C_{s,skylight} \cdot A_{skylight} && \text{(skylight solar)} \qquad (3)
\end{aligned}
$$

where

Q_{total} = total cooling seasonal load for the Proposed Building envelope, in W;

U_i = conductance of each building component on each orientation (i) of the Proposed Building, in $W/m^2 \cdot K$;

A_i = surface area of each building component on each orientation (i) of the Proposed Building, in m^2;

$T_{eq,i}$ = average cooling seasonal Equivalent Temperature for each building component on each orientation (i) of the Proposed Building, in °C, tabulated for each location, as in Table 2;

T_{in} = assumed interior cooling setpoint temperature, 25°C;

$I_{s,i}$ = average cooling seasonal Solar Heat Gain for each glazing on each orientation (i) of the Proposed Building, in W/m^2, tabulated for each location, as in Table 2;

$C_{s,i}$ = shading coefficient of each glazing on each orientation (i) of the Proposed Building; and

SE_i = exterior shading correction factor for each glazing on each orientation (i) of the Proposed Building, listed in an appendix to the standard.

Although these calculations can be performed manually, Rivas created a template in a commercial spreadsheet program to automate the process. A user need enter only the dimensions and thermal characteristics of the Proposed Building; the spreadsheet program automatically calculates the cooling loads of both the Proposed and Reference Buildings. Figure 4 shows the first page of the spreadsheet template for entering the dimensions and thermal characteristics of the building envelope. Figure 5 shows the second page with results of an example comparative heat flow calculation for the Proposed (*Proyecto*) and Reference (*Referencia*) Buildings. In this example, the Proposed Building uses 54.5% of the energy consumed in the Reference Building and easily complies with the standard.

Verification of the Standard

After CONAE released the draft standard for public comment in 1995, Huang repeated the analysis to determine how well the standard would promote the use of cost-effective energy efficiency measures. He used DOE-2 simulations to assess (1) the cost effectiveness of the Predetermined Values in the standard and (2) the accuracy of the standard's Simplified Calculation Method. He drew the following conclusions.

1) The Predetermined Values in the standard are reasonable in light of the considerable uncertainties in the costs of building materials and energy.
2) The Simplified Calculation Method is consistent with the DOE-2 program in showing the trends for various energy efficiency measures, particularly the tradeoffs between window area and shading and wall and roof insulation, for the prototypical buildings examined. As with other energy efficiency standards, idealized building operating conditions were assumed in the analysis. It is unclear how well the results apply to buildings with very different operating characteristics.
3) With an annual discount rate of 18% and a 10-year horizon, the standard should produce incremental construction costs of N\$16/m^2 of conditioned floor area, annual electricity savings of N\$14/m^2, and a net present value of N\$48/m^2 (US\$8/m^2 at early 1996 exchange rates) for the average new office building. The net present values comprising this national average range from N\$16/m^2 for a masonry building in Mexico City to N\$114/m^2 for a masonry building in Mexicali. These savings are due solely to reduced cooling energy consumption; even greater savings should be captured through reductions in HVAC system size and fan energy consumption in many buildings. The Mexican economy has undergone much turmoil since this verification analysis was performed in 1995, but the general conclusion of cost effectiveness remains valid, assuming that the ratio of energy to construction costs has not decreased.

Current Status of the Standard

The revised draft standard with the modified calculation method was completed and released for public comment in April 1995. During the following two years, CONAE invited building materials manufacturers and suppliers, engineers, architects, builders, and utility representatives to public meetings and workshops on the purpose and methodology of the new building standard. Three co-authors of this paper, Huang, Rivas, and de Buen, presented the standard to a group of HVAC engineers in Mexico City in April 1996. In January and February 1997, the Institute of International Energy Education, a USAID-funded educational organization in the United States, collaborated with CONAE in organizing two week-long workshops on the standard in Mexico City and Monterrey, with Huang, Rivas, and Jeff Johnson of PNNL as the instructors. More than 60 utility representatives, architects, engineers, and others attended each workshop and voiced support for the standard, but stressed the need for continued education about energy-efficient building design.

CONAE and Rivas continue to respond to public comments, their most recent effort being the deletion of the Prescriptive Path from the standard in August 1997 at the recommendation of numerous architects, as explained above. The revised draft is under both internal review at CONAE and public review. CONAE intends to finalize the standard during the summer of 1998, after which there must be a 90-day grace period for final comments. If no objections are raised, the standard may be published in the federal government record as early as the fall of 1998, becoming mandatory one year later. Concurrently, Mexican federal, state, and municipal government officials are developing permit, certification, and enforcement procedures for building professionals. Mexico's Energy Department faces a potential obstacle in the Commerce Department's policy of eliminating regulations to facilitate an open market.

While the energy efficiency standard proceeds through the legislative process, CONAE and Rivas are developing plans for dissemination, training, and enforcement of the standard. CONAE intends to put the standard and the compliance calculation tool developed by Rivas on the World Wide Web in 1998. Although the plans are not final, the compliance process will likely be carried out by engineers trained and certified by CONAE, in much the same manner that structural and mechanical design are already performed by licensed engineers.

Concluding Observations

We have developed a new method for estimating building energy consumption with limited climatic data and information on building characteristics. Our methodology is well suited to an energy efficiency standard for a nation in which building professionals are relatively unfamiliar with energy calculation methods and simulation tools. It is our belief that the calculation procedure is basically sound and ready for use by the Mexican government. Enhancements to the standard will inevitably occur over time as additional information is gathered and analyses are performed. For example, the building prototype can be improved with measured data; the simulations can be extended to different building types to yield different Equivalent Temperatures; weather, particularly solar, data can be refined in quality and expanded to other locations; and the Equivalent Temperature calculation can be extended from heat flows to system loads.

The current standard should be regarded not so much as a completed effort, but as a step in promoting more energy-efficient and economical building practices in Mexico. In the future, the process will surely evolve beyond this specific building standard to the distribution of building energy analysis tools and training throughout Mexico.

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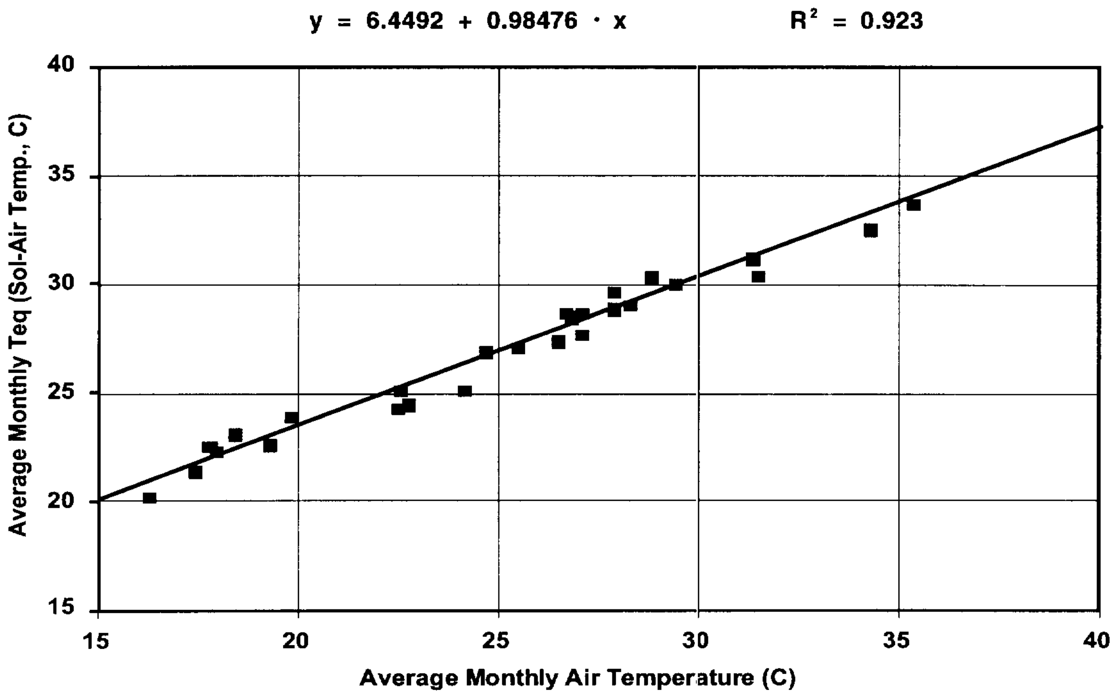


Figure 1. Regression Analysis to Derive T_{eq} for North-Facing Masonry Walls

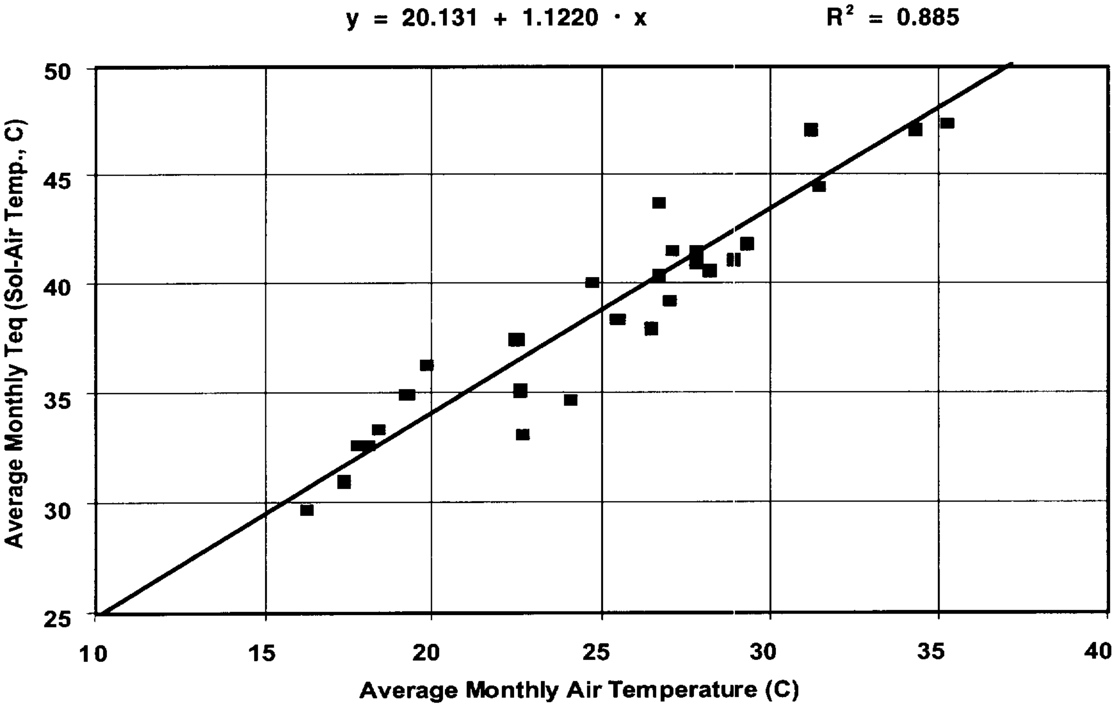


Figure 2. Regression Analysis to Derive T_{eq} for Concrete Roofs

Table 2. Values for Calculating the Average Heat Flow Through the Building Envelope
(Translated from original in Spanish)

STATE	City	CONDUCTION																	SOLAR RADIATION					
		OPAQUE PORTION												TRANSPARENT					TRANSPARENT PORTION					
		Reference U-Factor			AVERAGE EQUIVALENT TEMPERATURE Teq (C)														AVERAGE SOLAR HEAT GAIN					
		Roof	Walls		Roof	Heavy Mass Walls				Lightweight Walls				Windows					IN (W/M^2)					
			Heavy	Light		N	E	S	W	N	E	S	W	Hor.	N	E	S	W	Hor.	N	E	S	W	Avg.
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(R)	(S)	(T)	(U)	(V)	(W)	(X)	(Y)	(Z)
AGUASCALIENTES	Aguacalientes	0.517	2.381	0.826	36	23	26	25	25	29	32	31	31	21	23	23	23	24	274.0	91.2	137.3	117.9	145.9	123.1
BAJA CALIF. SUR	La Paz	0.345	0.803	0.475	43	29	33	31	31	35	39	37	38	25	26	27	28	28	322.0	70.3	159.3	131.1	163.7	131.1
	Cabo S. Lucas	0.391	1.371	0.629	39	26	29	27	27	31	35	34	34	23	24	25	25	25	322.0	70.3	159.3	131.1	163.7	131.1
BAJA CALIIFORNIA	Ensenada	0.535	2.381	1.068	34	21	23	23	22	27	30	29	29	20	21	22	22	22	322.0	70.3	159.3	131.1	163.7	131.1
	Mexicali	0.302	0.603	0.408	46	32	36	34	34	37	42	39	41	27	28	29	30	30	322.0	70.3	159.3	131.1	163.7	131.1
	Tijuana	0.453	1.513	0.673	38	25	28	27	27	31	34	33	33	22	24	25	25	25	322.0	70.3	159.3	131.1	163.7	131.1
CAMPECHE	Campeche	0.296	0.689	0.446	45	31	34	32	33	36	40	38	39	26	27	28	29	29	283.5	95.2	151.5	118.8	132.7	122.8
	Cd. Carmen.	0.296	0.689	0.446	45	31	34	32	33	36	40	38	39	26	27	28	29	29	283.5	95.2	151.5	118.8	132.7	122.8
COAHUILA	Monclova	0.345	0.803	0.475	43	29	33	31	31	35	39	37	38	25	26	27	28	28	322.0	70.3	159.3	131.1	163.7	131.1
	Piedras Negras	0.345	0.781	0.475	43	30	33	31	31	35	39	37	38	25	27	28	28	28	322.0	70.3	159.3	131.1	163.7	131.1
	Saltillo	0.483	2.201	0.741	37	24	27	25	25	30	33	32	32	22	23	24	24	24	322.0	70.3	159.3	131.1	163.7	131.1
	Torreon	0.362	0.875	0.508	42	29	32	30	30	34	38	36	37	25	26	27	27	27	322.0	70.3	159.3	131.1	163.7	131.1
COLIMA	Colima	0.362	0.931	0.517	42	28	31	30	30	34	37	36	37	24	26	27	27	27	274.0	91.2	137.3	117.9	145.9	123.1
	Manzanillo	0.308	0.723	0.46	44	30	34	32	32	35	39	38	39	25	27	28	28	28	274.0	91.2	137.3	117.9	145.9	123.1
CHIAPAS	Arriaga	0.296	0.657	0.426	45	31	35	33	33	36	41	39	40	26	28	29	29	29	272.3	102.1	139.9	113.8	133.7	122.4
	Comitan	0.535	2.381	0.962	34	22	24	23	23	28	30	30	30	20	22	22	22	22	272.3	102.1	139.9	113.8	133.7	122.4
	San Cristobal	0.687	2.381	1.793	31	18	20	20	19	24	27	27	26	18	19	20	20	20	272.3	102.1	139.9	113.8	133.7	122.4
	Tapachula	0.322	0.803	0.475	43	29	33	31	31	35	39	37	38	25	26	27	28	28	272.3	102.1	139.9	113.8	133.7	122.4
	Tuxtla Gutierrez	0.337	0.931	0.517	42	28	31	30	30	34	37	36	37	24	26	27	27	27	272.3	102.1	139.9	113.8	133.7	122.4
CHIHUAHUA	Casas Grandes	0.453	1.689	0.689	38	25	28	26	26	30	34	33	33	22	24	24	24	25	272.3	102.1	139.9	113.8	133.7	122.4
	Chihuahua	0.426	1.371	0.629	39	26	29	27	27	31	35	34	34	23	24	25	25	25	322.0	70.3	159.3	131.1	163.7	131.1
	Cd. Juarez	0.345	0.781	0.475	43	30	33	31	31	35	39	37	38	25	26	27	28	28	322.0	70.3	159.3	131.1	163.7	131.1
	H. del Parral	0.603	2.381	1.068	34	21	23	22	22	27	30	29	29	20	21	21	22	22	322.0	70.3	159.3	131.1	163.7	131.1
D. F.	Mexico (a)	0.723	2.381	1.371	32	20	22	21	21	26	28	28	27	19	20	21	21	21	322.0	70.3	159.3	131.1	163.7	131.1
DURANGO	Durango	0.517	2.381	0.826	36	23	26	25	25	29	32	31	31	21	23	23	23	24	322.0	70.3	159.3	131.1	163.7	131.1
	Lerdo	0.362	0.931	0.517	42	28	31	30	30	34	37	36	37	24	26	27	27	27	322.0	70.3	159.3	131.1	163.7	131.1
GUANAJUATO	Guanajuato	0.557	2.381	0.931	35	22	25	24	23	28	31	30	30	21	22	22	23	23	274.0	91.2	137.3	117.9	145.9	123.1
	Leon (b)	0.483	1.911	0.741	37	24	27	26	26	30	33	32	32	22	23	24	24	24	274.0	91.2	137.3	117.9	145.9	123.1
GUERRERO	Acapulco	0.296	0.673	0.439	45	31	35	32	33	36	40	38	40	26	27	29	29	29	274.0	91.2	137.3	117.9	145.9	123.1
	Chilpancingo	0.413	1.793	0.689	38	25	27	26	26	30	34	33	33	22	23	24	24	25	274.0	91.2	137.3	117.9	145.9	123.1
	Zihuatanejo	0.296	0.673	0.439	45	31	35	32	33	36	40	38	40	26	27	29	29	29	274.0	91.2	137.3	117.9	145.9	123.1
HIDALGO	Pachuca	0.902	2.381	2.201	30	18	20	20	19	24	26	26	25	18	19	19	19	20	272.3	102.1	139.9	113.8	133.7	122.4
	Tulancingo	0.687	2.381	1.689	31	19	21	20	20	25	27	27	26	18	20	20	20	20	272.3	102.1	139.9	113.8	133.7	122.4

Table 1. Prototypical Office Building Characteristics

Building Characteristic	Value
Aspect ratio	1:1
Number of stories	12 in Mexico City; three in other cities
Floor-to-floor height	4 m
Floor area per story	669 m^2 (7,200 ft^2)
Wall construction type	Steel-frame; masonry
Lighting power density	16 W/m^2 (1.5 W/ft^2)
Plug loads	8 W/m^2 (0.75 W/ft^2)
Occupant density	5 m^2/person in core zones; 14 m^2/person in perimeter zones
Cooling setpoint temperature	25°C (77°F)
Cooling equipment efficiency	8.5 EER
Ventilation rate	0.46 m^3/min·m^2 (0.14 cfm/ft^2)
Economizer usage	Yes

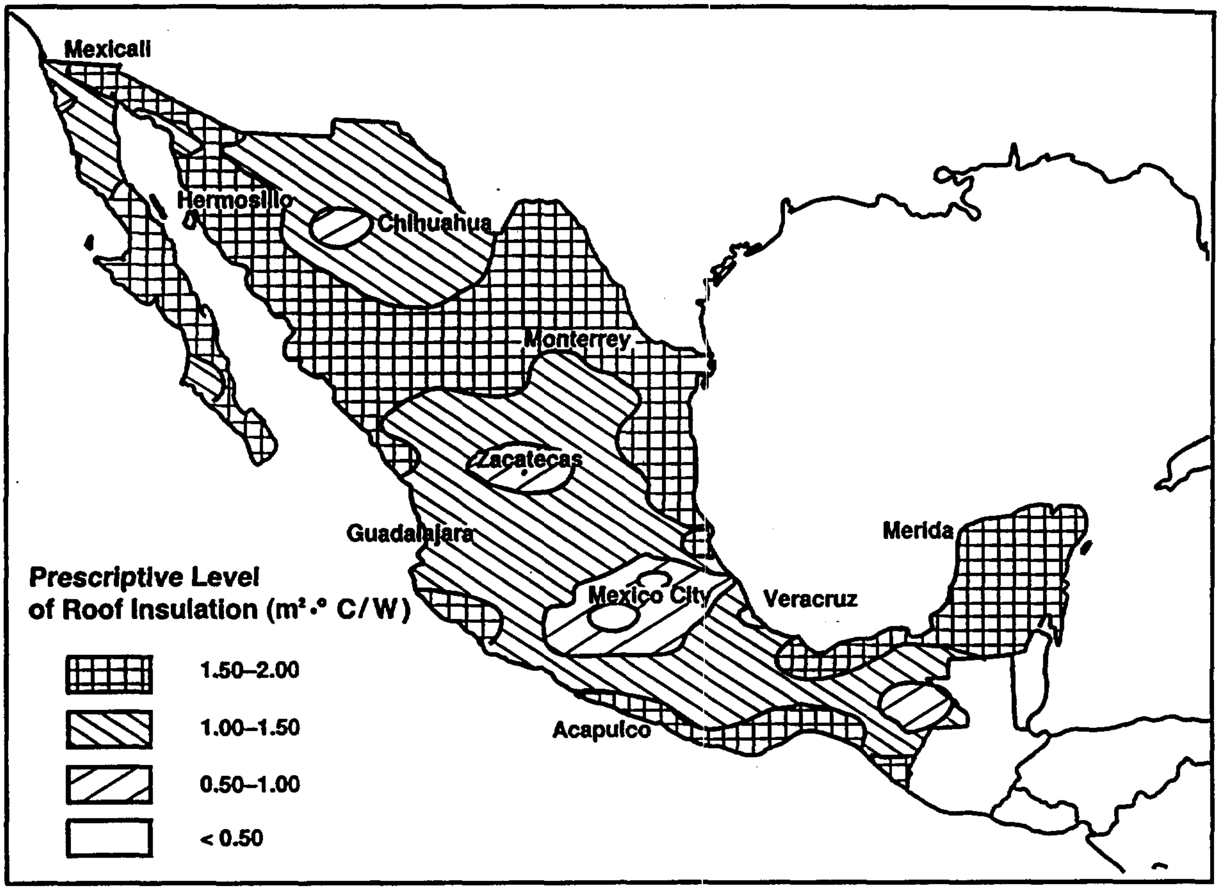
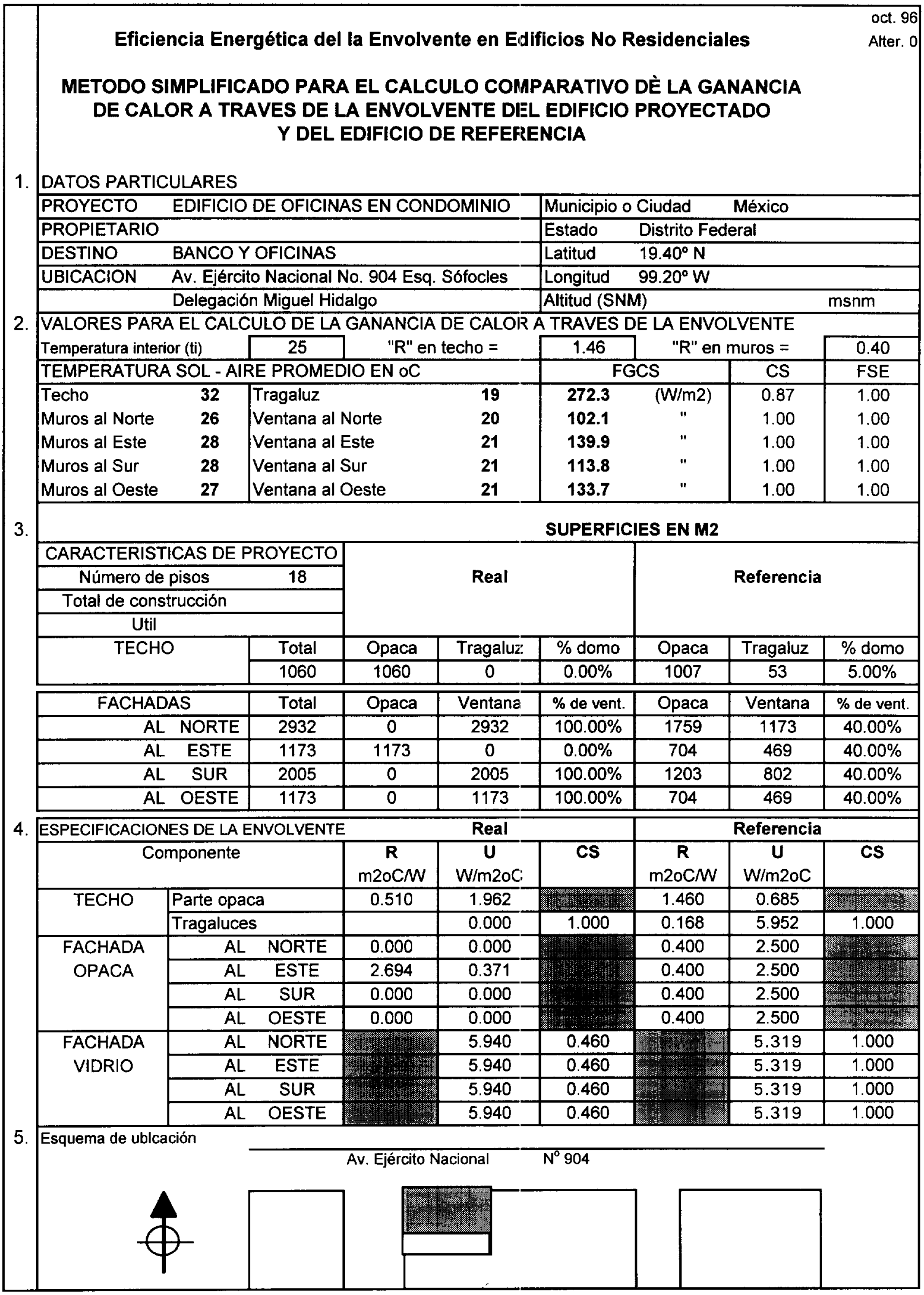


Figure 3. Map of Predetermined Values for Concrete Roof Insulation



oct. 96
Alter. 0

Eficiencia Energética del la Envolvente en Edificios No Residenciales

METODO SIMPLIFICADO PARA EL CALCULO COMPARATIVO DÈ LA GANANCIA DE CALOR A TRAVES DE LA ENVOLVENTE DEL EDIFICIO PROYECTADO Y DEL EDIFICIO DE REFERENCIA

1. DATOS PARTICULARES

PROYECTO	EDIFICIO DE OFICINAS EN CONDOMINIO	Municipio o Ciudad	México
PROPIETARIO		Estado	Distrito Federal
DESTINO	BANCO Y OFICINAS	Latitud	19.40° N
UBICACION	Av. Ejército Nacional No. 904 Esq. Sófocles	Longitud	99.20° W
	Delegación Miguel Hidalgo	Altitud (SNM)	msnm

2. VALORES PARA EL CALCULO DE LA GANANCIA DE CALOR A TRAVES DE LA ENVOLVENTE

Temperatura interior (ti)	25	"R" en techo =	1.46	"R" en muros =	0.40

TEMPERATURA SOL - AIRE PROMEDIO EN oC				FGCS		CS	FSE
Techo	**32**	Tragaluz	**19**	**272.3**	(W/m2)	0.87	1.00
Muros al Norte	**26**	Ventana al Norte	**20**	**102.1**	"	1.00	1.00
Muros al Este	**28**	Ventana al Este	**21**	**139.9**	"	1.00	1.00
Muros al Sur	**28**	Ventana al Sur	**21**	**113.8**	"	1.00	1.00
Muros al Oeste	**27**	Ventana al Oeste	**21**	**133.7**	"	1.00	1.00

3. **SUPERFICIES EN M2**

CARACTERISTICAS DE PROYECTO		**Real**			**Referencia**		
Número de pisos	18						
Total de construcción							
Util							
TECHO	Total	Opaca	Tragaluz	% domo	Opaca	Tragaluz	% domo
	1060	1060	0	0.00%	1007	53	5.00%

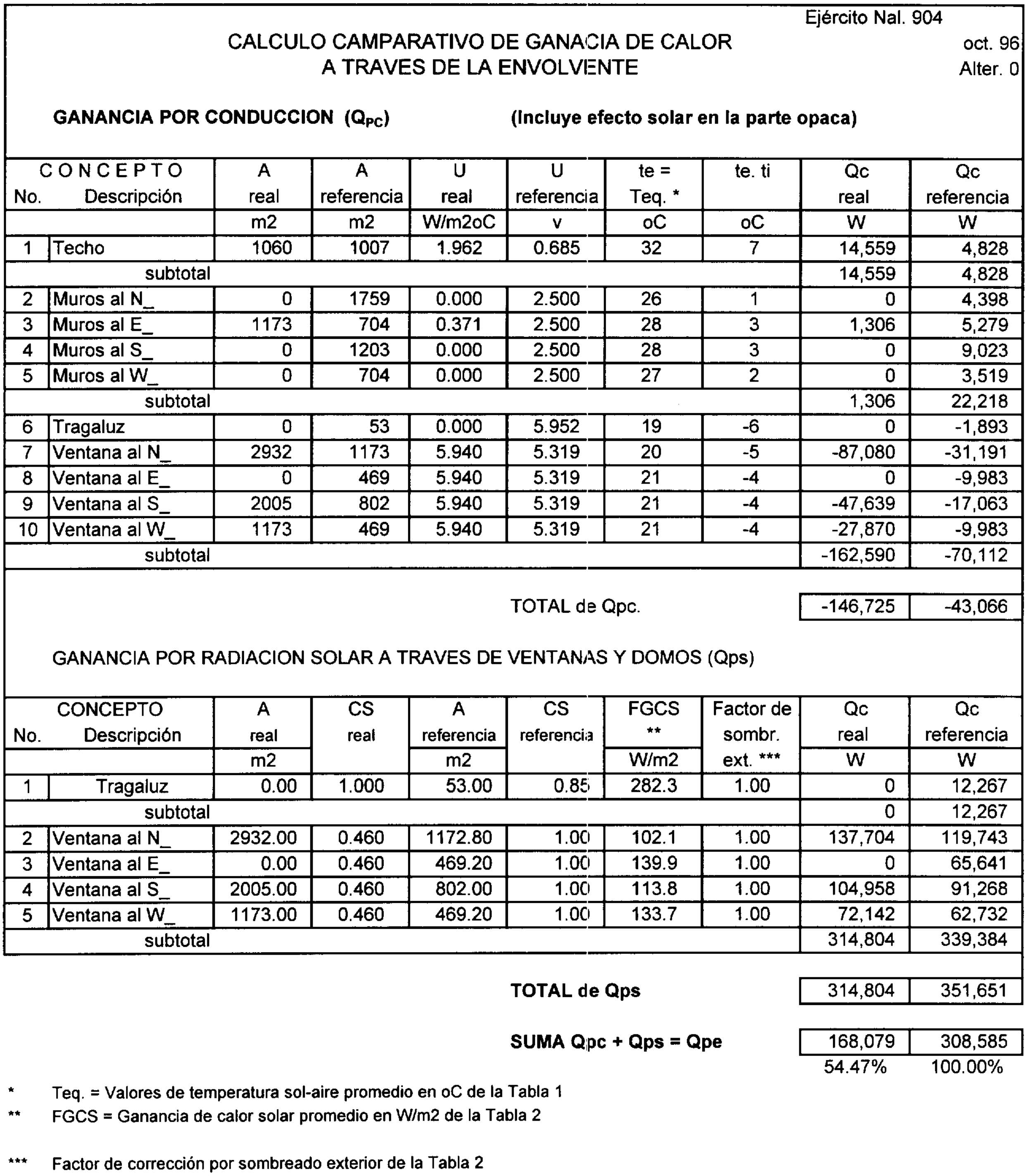
FACHADAS	Total	Opaca	Ventana	% de vent.	Opaca	Ventana	% de vent.
AL NORTE	2932	0	2932	100.00%	1759	1173	40.00%
AL ESTE	1173	1173	0	0.00%	704	469	40.00%
AL SUR	2005	0	2005	100.00%	1203	802	40.00%
AL OESTE	1173	0	1173	100.00%	704	469	40.00%

4. ESPECIFICACIONES DE LA ENVOLVENTE

		Real			**Referencia**		
Componente		**R** m2oC/W	**U** W/m2oC	**CS**	**R** m2oC/W	**U** W/m2oC	**CS**
TECHO	Parte opaca	0.510	1.962	▨	1.460	0.685	▨
	Tragaluces		0.000	1.000	0.168	5.952	1.000
FACHADA OPACA	AL NORTE	0.000	0.000	▨	0.400	2.500	▨
	AL ESTE	2.694	0.371	▨	0.400	2.500	▨
	AL SUR	0.000	0.000	▨	0.400	2.500	▨
	AL OESTE	0.000	0.000	▨	0.400	2.500	▨
FACHADA VIDRIO	AL NORTE	▨	5.940	0.460	▨	5.319	1.000
	AL ESTE	▨	5.940	0.460	▨	5.319	1.000
	AL SUR	▨	5.940	0.460	▨	5.319	1.000
	AL OESTE	▨	5.940	0.460	▨	5.319	1.000

5. Esquema de ubicación

Figure 4. First Page of Spreadsheet Template for Compliance Calculation



Ejército Nal. 904

CALCULO CAMPARATIVO DE GANACIA DE CALOR
A TRAVES DE LA ENVOLVENTE

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GANANCIA POR CONDUCCION (Q_{PC}) **(Incluye efecto solar en la parte opaca)**

CONCEPTO No.	Descripción	A real	A referencia	U real	U referencia	te = Teq. *	te. ti	Qc real	Qc referencia
		m2	m2	W/m2oC	v	oC	oC	W	W
1	Techo	1060	1007	1.962	0.685	32	7	14,559	4,828
subtotal								14,559	4,828
2	Muros al N_	0	1759	0.000	2.500	26	1	0	4,398
3	Muros al E_	1173	704	0.371	2.500	28	3	1,306	5,279
4	Muros al S_	0	1203	0.000	2.500	28	3	0	9,023
5	Muros al W_	0	704	0.000	2.500	27	2	0	3,519
subtotal								1,306	22,218
6	Tragaluz	0	53	0.000	5.952	19	-6	0	-1,893
7	Ventana al N_	2932	1173	5.940	5.319	20	-5	-87,080	-31,191
8	Ventana al E_	0	469	5.940	5.319	21	-4	0	-9,983
9	Ventana al S_	2005	802	5.940	5.319	21	-4	-47,639	-17,063
10	Ventana al W_	1173	469	5.940	5.319	21	-4	-27,870	-9,983
subtotal								-162,590	-70,112
						TOTAL de Qpc.		-146,725	-43,066

GANANCIA POR RADIACION SOLAR A TRAVES DE VENTANAS Y DOMOS (Qps)

CONCEPTO No.	Descripción	A real	CS real	A referencia	CS referencia	FGCS **	Factor de sombr. ext. ***	Qc real	Qc referencia
		m2		m2		W/m2		W	W
1	Tragaluz	0.00	1.000	53.00	0.85	282.3	1.00	0	12,267
subtotal								0	12,267
2	Ventana al N_	2932.00	0.460	1172.80	1.00	102.1	1.00	137,704	119,743
3	Ventana al E_	0.00	0.460	469.20	1.00	139.9	1.00	0	65,641
4	Ventana al S_	2005.00	0.460	802.00	1.00	113.8	1.00	104,958	91,268
5	Ventana al W_	1173.00	0.460	469.20	1.00	133.7	1.00	72,142	62,732
subtotal								314,804	339,384
						TOTAL de Qps		314,804	351,651
						SUMA Qpc + Qps = Qpe		168,079	308,585
								54.47%	100.00%

* Teq. = Valores de temperatura sol-aire promedio en oC de la Tabla 1

** FGCS = Ganancia de calor solar promedio en W/m2 de la Tabla 2

*** Factor de corrección por sombreado exterior de la Tabla 2

Figure 5. Second Page of Spreadsheet Template for Compliance Calculation