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Residential Cooling Load Calculation Methods Analysis

Prepared for:
Pacific Gas and Electric Company
Department of Products and Services

Final Report
January 18, 1995
Updated March 20, 1996

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Abstract

In 1994, Pacific Gas and Electric Company (PG&E) undertook a study entitled, "Residential Cooling Load Calculation and Air Conditioner Selection Methods Analysis". This study was the outgrowth of concern over the coincident peak effect of residential air conditioners. Residential AC coincident peak load depends on (among other factors) the size of the unit. In 1994, PG&E began requiring a cooling load calculation as a condition for residential AC rebates.

An air conditioner selection process consists of two stages. First the building sensible and latent load at the design conditions is calculated and then an equipment selection method is applied to choose a particular unit from the manufacturer's catalog. If errors occur in either one of these stages the units would be sized improperly.

The two parts of the study mirrored the two stages of equipment selection. In Part One, forty-one cooling load calculation methods submitted by over fifty contractors and distributors were compared against ACCA Manual J, an industry accepted standard. As submitted, ten of the methods calculated loads within 20% of Manual J. With revisions, another ten methods came within 20% of Manual J.

In the second part of the study, equipment selection methodologies were compared based on how they actually sized units to the expected indoor design conditions. A method of predicting indoor conditions specific to each piece of equipment was developed. Existing equipment selection methodologies can oversize units on houses in hot dry climates by 50% or more.

I. Executive Summary

Various research projects and field testing performed for Pacific Gas and Electric Company by Proctor Engineering Group and others have indicated that residential air conditioners are substantially oversized (Lucas 1992, PG&E RACER 1992, Florida Solar Energy Center 1994). HVAC contractors often size air conditioners by rules of thumb that have developed over the years. This leads to substantial over sizing and a higher diversified electric peak load (Neal et al. 1992, Proctor et al. 1992).

In order to solve this problem the AC sizing should be performed in two stages. First, an accurate cooling load calculation method should be used to estimate design sensible and latent loads. Second, an equipment selection method should be applied to choose a particular unit from the manufacturer's catalog that just meets these loads. If errors occur on either one of these stages, or if the load calculation and sizing methodologies make different assumptions, the units could be sized improperly.

In 1994, concerned about the high coincident electric load of residential air conditioners PG&E's Products and Services Department began requiring a cooling load calculation as a condition for residential AC rebates. At the same time, PG&E commissioned an investigation which had the following primary goal:

- To determine which load calculation and equipment selection methods could be used within the PG&E's service territory to obtain proper equipment sizing.

In the first part of the study contractors submitted load calculations These methods were compared against a liberal criterion, the method must not produce loads differing from Manual J estimated loads by over 20%. The analysis of these submissions is summarized in Figure 1-1. By the end of the process, half of the methods were approved (one quarter as submitted, one quarter with revisions).

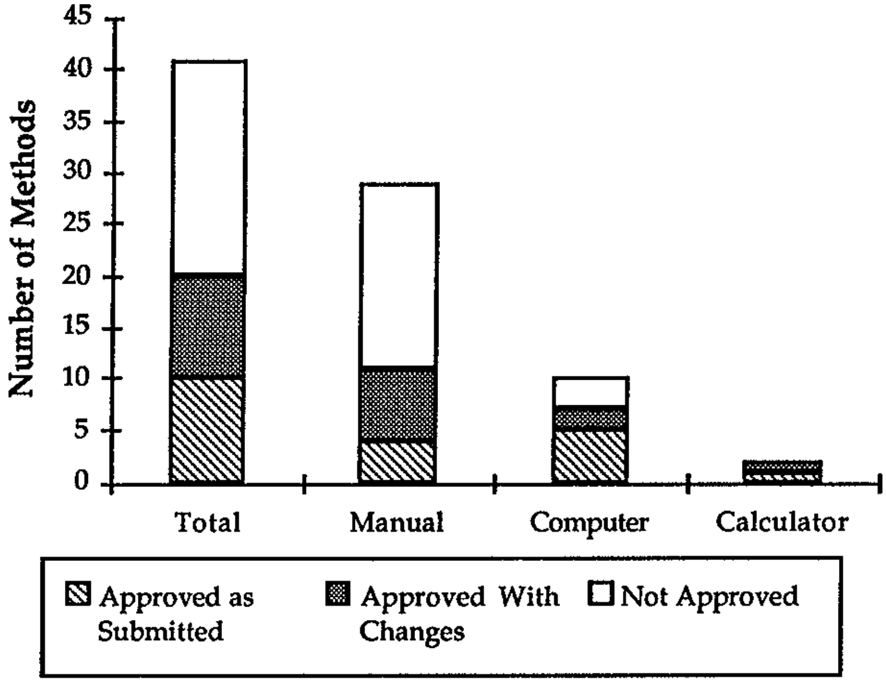


Figure 1-1. Cooling Load Calculation Approvals

The objective of the second part of the study was to analyze different equipment selection methodologies based on residential building load calculations within PG&E service territory. For this purpose the air conditioners for prototype building/climate combinations were selected using different equipment selection methods. None of the existing methods could be used as a benchmark for the comparison since they assume standard 50% design indoor relative humidity which is not the case in PG&E's service territory. A methodology of determining the expected indoor conditions was developed to make the comparison possible. The indoor humidity depends on internal gains, the humidity ratio of the outdoor air, house infiltration and sensible heat ratio of the equipment, and is unique for any particular climate-building-air conditioner combination.

The equipment selected by the tested methodologies was analyzed for the expected indoor conditions. The air conditioner capacity under the expected indoor conditions and design outdoor conditions was compared to the loads from Manual J. The results are shown in Figure 1-2

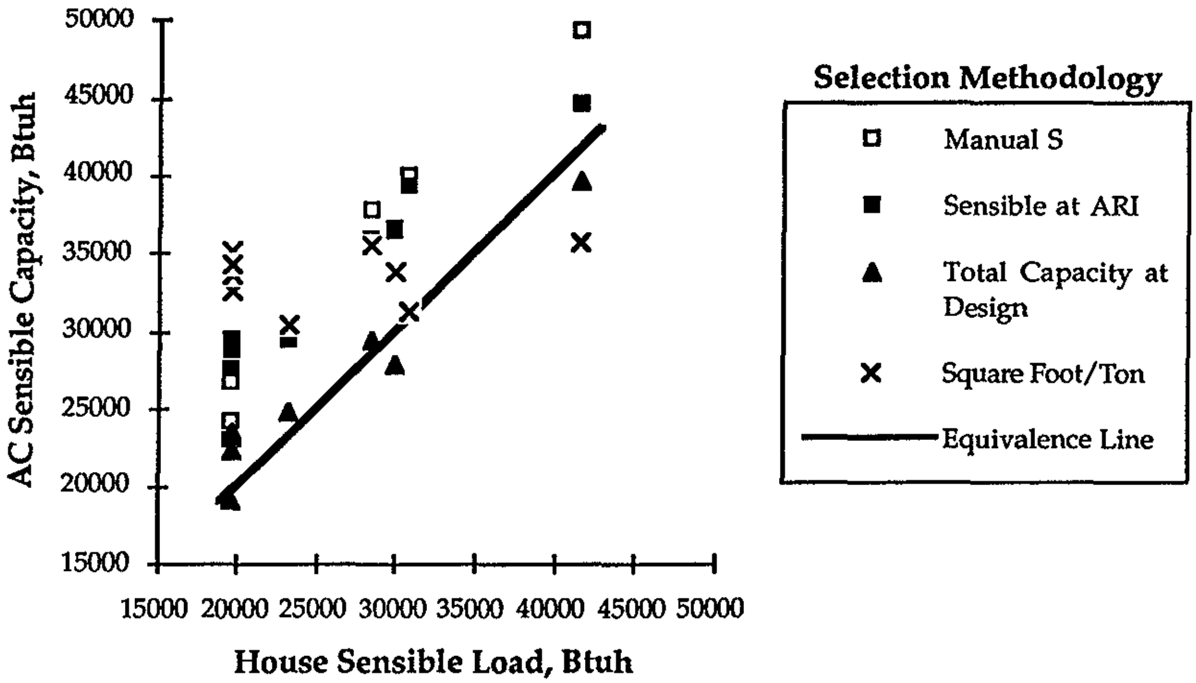


Figure 1-2. Equipment Selection Results (Capacity vs. Load)

Based on this investigation Proctor Engineering Group concludes:

- A majority of the existing design load calculation methods that are commonly used produce estimates of cooling load that exceed Manual J by over 20%.
- Submitted load estimation methodologies showed a number of common shortcomings: no error checking procedure, insufficient data for load calculation through windows and opaque surfaces, lack of consideration for actual indoor conditions, oversimplified procedures for duct load, infiltration, and latent load, as well as insufficient data for interior and exterior shading.
- Four of the most popular equipment selection methods result in equipment specification from 14% undersized to 79% oversized compared to the building Manual J loads.
- Manual S selects units that are oversized by approximately 20% for PG&E's service territory beyond any over sizing that might be inherent in Manual J.
- All evidence known to the authors indicates that when Manual J (without any added safety factors) is used to estimate the cooling load and Manual S is used to select equipment, air conditioners in PG&E's service territory will be oversized. That combination of methodologies is conservative. Only a field investigation would verify the actual operation of units sized in this manner.
- Air conditioner manufacturers do not present sufficient performance data for proper sizing in hot/dry conditions similar to those in PG&E's service territory.

Based on this investigation, Proctor Engineering Group makes the following recommendations:

- A baseline load calculation and sizing methodology should be verified by field testing (submetering) of known size units with documented performance data, in houses with known physical characteristics.
- Load calculations should be required on all air conditioners that are going to be installed with utility assistance. Only independently reviewed load calculations that fall within an acceptable range around a verified methodology should be used for the PG&E rebate program.
- The load calculation documentation should be reviewed to ensure that approved methods were used correctly for the particular buildings.
- If control of over sizing is to be accomplished, the capacity of the installed equipment should be verified.

- Pacific Gas and Electric Company and other utilities should work with manufacturers to obtain a consistent presentation of air conditioner performance data appropriate to hot dry climates.

II. Introduction

In 1994, PG&E undertook a study entitled, "Residential Cooling Load Calculation and Air Conditioner Selection Methods Analysis" in conjunction with their air conditioner rebate program. The primary goal was to assist the HVAC contractors in the PG&E service territory in using appropriate cooling load calculation and equipment selection methods. This would help prevent AC over sizing and consequently would reduce PG&E's peak electric load.

Sizing is a two stage procedure. First the building design load is calculated and then equipment is selected. If errors occur in either one of these stages or they contain inconsistent assumptions the units may be sized improperly.

There are many load calculation methods used by HVAC contractors and engineers, ranging from single page manual worksheets to computer software packages. Different methods often yield different results for the same buildings. In the PG&E rebate program, all calculations must be performed using an approved method in order to qualify for the rebate.

The two manual methods generally accepted by the industry are the ACCA Manual J method (Manual J 1986), and the ASHRAE CLTD/CLF method (ASHRAE Fundamentals 1993). Both methods are based on significant modeling assumptions and have limitations, but are traditionally considered to be sufficiently accurate for normal use.

Part 1 of this study collected, analyzed and compared 41 cooling load calculation methods to Manual J.

In Part 2 of this study, four equipment selection methods were analyzed. Air conditioners were selected from major manufacturers' catalogs while using different load calculation and equipment selection methods. A methodology for determining the expected house indoor conditions for a particular climate-building-air conditioner combination was developed. Based on this methodology over sizing margins for the selected units were calculated.

III. Methodology, Part 1 Load Calculations

The load calculation comparison methodology included the following steps:

- Seven prototype building/climate combinations were created,
- Benchmark loads were calculated using Manual J and ASHRAE methods,
- Load calculation methods submitted by the HVAC contractors were used to estimate cooling load and the results were compared to Manual J loads.

PROTOTYPE BUILDING/CLIMATE DESCRIPTIONS

Four prototype building designs were created for this study. They are "Typical", "Old", "New", and "Massive". The "Typical" building represents construction in compliance with 1988 California Energy Efficiency Standards for second generation residential buildings. The "Old" building construction is leaky and poorly insulated. Both "New" and "Massive" buildings comply with 1992 California Energy Efficiency Standards. They have the same level of insulation and window type, but the Massive building has more glazing area and thermal mass than the New building.

The following factors are main contributors to residential building and HVAC system cooling load:

- Location, including daily temperature range, degrees latitude and summer outside design conditions;
- Inside design conditions;
- Assembly type and area of exterior walls, roofs, floors, windows and partitions;
- Window orientation, exterior and interior shading;
- Infiltration;
- Number of people and their activity;
- Internal gains from appliances and lighting;
- Mechanical ventilation;
- Duct location, leakage and insulation level.

Two Northern California cities, Fresno and Petaluma were used as the prototype locations. Fresno is a hot dry Central Valley location with a climate similar to that in which most of the PG&E residential air conditioners are located. Petaluma has more moderate design conditions.

Details of these buildings are given in Appendix H.

LOAD ESTIMATION

Two manual HVAC load estimation methods are generally accepted by the industry: Manual J and ASHRAE CLTD/CLF. These methods calculate cooling load at 2.5% design conditions which is considered sufficient for residential HVAC applications. Two point five percent design conditions are outdoor temperatures that are exceeded 2.5% of the total summer hours (June through September). Indoor design conditions are 75°F dry bulb with 50% relative humidity.

The load calculated with Manual J is usually larger and this method was selected as a benchmark for this study. The loads calculated by both methods for the prototype buildings are contained in Appendix I

ACCA Manual J

Manual J was developed by the Air Conditioning Contractors of America and the Air-Conditioning and Refrigeration Institute (Manual J, 1986). It estimates the cooling load of a residence at design conditions.

The total building heat gain is calculated as a sum of the heat gains through the building envelope and internal gains. Envelope gains include solar radiation, outdoor/indoor temperature difference, infiltration, and ventilation. Internal gains are from people and appliances. These gains are calculated through twenty four hour average heat transfer multipliers and equivalent temperature differences. Time of day and building heat storage capacity effects are bundled in these multipliers.

ASHRAE CLTD/CLF

The Cooling Load Temperature Difference/Cooling Load Factors method (CLTD/CLF) is described in ASHRAE Fundamentals, 1993. It considers the same heat gain sources as Manual J and yields approximately the same calculated building envelope sensible load. However the treatment of latent gains and gains through ducts is different between Manual J and ASHRAE (ASHRAE estimates smaller duct gains).

Contractor Submissions

Forty one different methods were submitted by HVAC contractors and distributors for review. They included manual worksheets (29 submissions), computer software (10 submissions), and pre-programmed calculators (2 submissions). Each method was used to calculate load for the prototype building/climate combinations and was analyzed for any shortcomings.

IV. Discussion, Part 1 Load Calculations

Forty one different methods were submitted for review, including 29 manual worksheets, 10 programs for IBM compatible computers and 2 programs for hand held calculators. Manual methods are the most popular among the contractors because they require less time to learn and are easiest to use. However they are less reliable since every input is open to errors. Computer programs usually offer comprehensive libraries of location data, assemblies, materials, glazing and shading types. On the other hand they sometimes contain "bugs" and tempt the user to enter the default values which do not fit every situation.

The following method shortcomings were the most frequently found.

1. No appropriate error checking procedure. This applies to all manual methods. Most computer programs have some checking procedures, but all fall short of the error checking potential of computers. One computer program calculated an incorrect load after the initial input and thus required a manual check to find errors. The program authors released a new version of the software after discussions with PEG.

2. Insufficient location data. Many methods show design outdoor parameters for a very limited number of geographical locations or show data other than that in Manual J and ASHRAE. Daily temperature range is often not considered.

3. No consideration given to actual indoor wet bulb temperature. The expected wet bulb temperature at design outdoor conditions is a primary parameter for determination of equipment cooling capacity, but none of the methods provide a procedure for its calculation.

4. Duct load calculations are oversimplified or not addressed. Several methods do not calculate the duct load and several others recommend the same default multiplier without considering duct location and level of insulation. In other cases it is assumed that all ducts were in the same location and had the same level of insulation, which is often specified in terms of thickness without a reference to R-value. Duct leakage is not considered in any of the methods.

5. Insufficient data for load calculation through opaque surfaces. Many methods provide data for very limited amount of construction assemblies. Worksheets often do not specify the cooling load multipliers for R-13 walls, R-19 floors, or R-30 ceilings. In some cases the recommended multiplier selection is based on the criteria such as "two inches of insulation or more". Partitions and knee walls that separate a conditioned space from an unconditioned space like attic or garage are often considered as exterior sunlit walls or ignored.

6. Insufficient data for windows and doors. Window type, material and frame were often not taken into account. In extreme cases it means that the calculated load is the same for clear single glazed sliding window with metal frame and an energy efficient low-e double pane window with thermal break. Skylights are often ignored. Doors are sometimes considered as exterior walls or glazing.

7. Insufficient data for interior shading. Interior shading device type and color are not considered. For example, one model assumes that dark drapes have the same shading effect as light venetian blinds.

8. Insufficient data for exterior shading. In many cases there are neither instructions on overhang shading effect calculation nor are the specific dimensions such as window height, overhang length and distance to the top of the window taken into account.

9. Infiltration load is not specifically addressed or it is calculated with an oversimplified procedure. It is often assumed that the infiltration rate is constant or depends only on the conditioned floor area. Manual J recommends different rates depending on the construction quality and floor area. ASHRAE rates depend on the outdoor design temperature and building air tightness type defined as tight, medium or loose.

10. Latent load is not calculated. Many methods estimate the design latent load to be equal to 30% of the sensible load and this is not the case for a California-type climate. The latent load should be calculated based on the number of people and the outdoor humidity ratio.

11. Ventilation load is not considered. Most methods do not provide the procedure to determine ventilation requirements and load.

Initial method shortcomings are summarized in Table 4-1.

Table 4-1. Method Shortcomings	
Shortcoming	% with problem
No appropriate error checking procedure	86
Insufficient location data	64
No consideration for actual indoor wet bulb temperature	100
Duct load calculations are oversimplified or not addressed	92
Insufficient data for load calculation through opaque surfaces	69
Insufficient data for windows and doors	72
Insufficient data for interior shading	61
Insufficient data for exterior shading	61
Infiltration load calculations are oversimplified	56
Latent load is not calculated.	64
Ventilation load is not considered	64

INVESTIGATION OBSERVATIONS

In the course of the investigation the following items were observed:

- Most applicants were unaware of any method shortcomings and referred to their long positive experience with their AC sizing method, "I have never had a complaint".
- Some applicants used outdated methods published in the 1950s. Others used cooling factors based on old typed of construction ignoring the latest development in building insulation, window types and materials, and air tightness.

PREVIOUS STUDIES

A number of previous studies have been conducted on residential air conditioner sizing. Included are studies by Lucas, Neal and O'Neal, and Florida Solar Energy Center.

Lucas

Lucas analyzed monitored data collected during the past 7 years from residences in the Pacific Northwest to determine whether residential air conditioners have been sized properly. Both the sizing recommendation based on Manual J and peak monitored loads were compared to the capacity of the installed equipment for each site.

Lucas concluded:

- In sixty homes air conditioners were oversized an average of 43% relative to Manual J. About half the units were oversized by more than 25% and about one-sixth were undersized.
- Monitored cooling energy data revealed that the air conditioners in 13 of 75 sites (17%) operated frequently at full cooling capacity during the summer. The indoor temperature measurements in these houses were an average of 2.3°F higher relative to other sites compared to Manual J. Most of the AC were undersized or properly sized, however, 4 of them appeared to be oversized.
- The data indicated a reasonable average down sizing of 20% was available from existing cooling capacities.

Neal and O'Neal

The study examined the impacts of air conditioner sizing, efficiency, and refrigerant charge on the utility peak demand from steady-state operation of residential central air conditioners. The analysis was based on the results of laboratory tests of a three-ton, capillary tube expansion, split-system air conditioner, and assumptions about relative sizing of the equipment to the cooling load of the residence.

Neal and O'Neal concluded:

- Proper sizing of the unit was the largest factor affecting energy demand of the three factors (sizing, charging, and efficiency). For example, the utility peak demand for a SEER 10 unit could be reduced by 23% if a 75% oversized unit was replaced by the properly sized unit. The authors used the 75% as a "normal existing true oversizing", referring to multiple sources which showed that typical oversizing of central residential air conditioners was in the range of 60% to 80%. They suggested that the bigger portion of normal oversizing resulted from installers who did no load calculations but used outdated, overly conservative, "rules-of-thumb", such as 400 sq.ft. per ton and then went up in equipment size "just to be sure".

- Very little was gained by size reduction until the size of the equipment is reduced below 26% above the true proper size[1]. Because the authors thought that ACCA/ASHRAE calculations produced conservative results that cause oversizing of approximately 25% , they suggested that the dealer should not be allowed to exceed Manual J results and should be encouraged to select the next smaller capacity unit.

Florida Solar Energy Center

Florida Solar Energy Center (FSEC) has studied the issue of residential air conditioning sizing methods in Florida. Four hundred and eighty nine contractors were surveyed.

The authors concluded:

Air conditioning sizing was accomplished by using Manual-J procedure by 33% of the respondents, software by about 34.4% of the respondents, square-footage by 24.2% and other procedures by about 8.4%. At the same time FSEC thought that respondents might have a built-in bias self selecting those most concerned about the issue.

- Thirty eight point five percent (38.5%) of respondents said they had at times purposely oversized units.
- FSEC suggested that the consequence of oversizing are typically greater initial cost and greater energy use.
- There was no consensus between contractors that use square-footage method. They used different numbers of square feet per ton.

[1] This conclusion was for units controlled by a constant thermostat setting.

V. Results, Part 1 Load Calculations

Only ten of the methodologies were within 20% of Manual J as submitted. The most common cause for initial rejection was the treatment of latent loads. Many methods assume latent load is 30% of sensible load. Other methods overstate sensible loads by 30 to 150% often based on simplifications that may have been accurate when buildings were less insulated.

The approval process was interactive and, with revisions, an additional 10 methods were approved. Figure 5-1 illustrates the proportion of methods approved by method type.

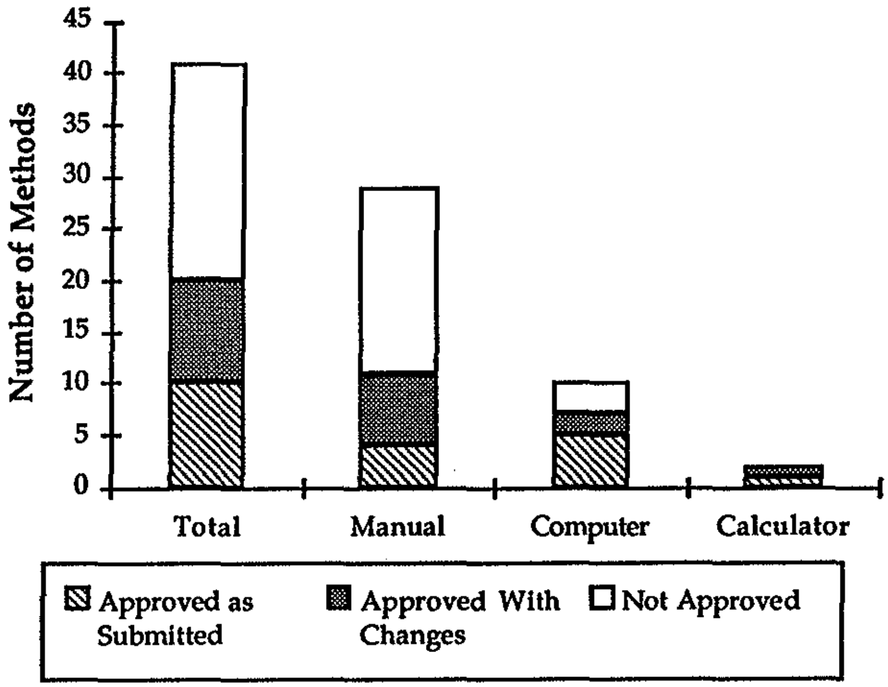


Figure 5-1. Cooling Load Calculation Approvals

VI. Methodology, Part 2 Equipment Selection

Proper equipment sizing is a two part process. The design cooling load is estimated and then the equipment is selected. The objective of the second part of this study was to analyze different equipment selection methodologies.

In many cases, different equipment selection methods lead to a different unit being selected for the same house. In this study, the air conditioners from four major manufacturers participating in the PG&E rebate program were selected for six different houses using the four most popular methods. The selection methods are:

- ACCA Manual S
- Design Sensible Load at ARI Indoor Conditions
- Design Total Load
- Square Feet per Ton "Rules of Thumb"

The cooling load for the houses was calculated using four previously approved methods:

- ACCA Manual J
- Trane Worksheet #22-8018-1 P. I. revise 03/16/94
- Comply-24 computer program for load and Title 24 compliance analysis
- Lennox Worksheet # CL 841-L7.

METHOD DESCRIPTIONS

ACCA Manual S

This method consists of four basic steps:

1. Based on the sensible heat ratio, a CFM is initially determined. For dry climates this is 650 cfm per ton of sensible load.
2. Initially select a specific AC unit from the manufacturer's application data based on the cooling CFM and design sensible capacity.
3. Compare the selected unit's sensible and latent capacities against the corresponding building Manual J loads. The unit is considered correct if at the design outdoor temperature, 75°F indoor dry bulb temperature, and 62°F indoor wet bulb temperature its sensible capacity is at least equal but not more than 15% greater than the sensible load, and the latent capacity is at least equal to the calculated latent load.

4A. If the unit is slightly short of sensible or latent capacity, the same unit with a different blower speed is checked for compliance. If still short, the unit of the next larger sized unit is tried with the blower operating at nominal speed.

4B. If the unit sensible capacity exceeds oversize limitations the next smaller unit size is checked with nominal blower speed.

Sensible Load at ARI Indoor Conditions

According to this method, the unit is selected based on its sensible capacity at design outdoor conditions and indoor conditions of 80°F dry bulb/67°F wet bulb temperature. The correctly sized unit has a sensible capacity within 0 to 15% larger than the sensible load and a latent capacity which is equal to or greater than the building latent load.

Total Load

According to this method, the unit is selected based on its total capacity at design outdoor conditions and indoor conditions of 75°F dry bulb/62°F wet bulb temperature. The total capacity of the unit at the design indoor and outdoor conditions must be 100% to 115% of the total load. No effort is made to determine that either the sensible or latent load of the house will be met by the sensible or latent capacity of the unit, only that the total load of the house will be met by the total capacity of the equipment.

Square Feet/Ton, "Rules of Thumb"

Contractors often use a "Rule of Thumb" methodology for selecting equipment. This methodology does not require calculation of the cooling load of the house. Based on the contractors mental categorization of a low, average, or high cooling load, a nominal air conditioner size is selected. One source of these values is the check numbers from the ASHRAE Cooling and Heating Load Calculation Manual.

According to this method, the unit is selected by using 700 Square Foot/Ton for a low load house, 550 Square Foot/Ton for a average load house, and 400 Square Foot/Ton for a high load house.

CALCULATING AIR CONDITIONER OVER SIZING MARGINS

None of the existing equipment selection methods could be used as a benchmark for proper sizing at design since they all imply that the design indoor relative humidity is 50% independent of the infiltration rate, outdoor air humidity ratio, number of people, and unit latent capacity. In the hot and dry climate zones typical of PG&E's service territory, the design indoor relative humidity will be closer to 35%-40% at an indoor temperature of 75°F. A methodology of determining the expected indoor conditions and unit performance at these conditions was necessary. A methodology based on Equilibrium Sensible Heat Ratios was developed for the comparison.

Determining the Expected Indoor Conditions at Design (Equilibrium SHR Method)

The indoor design conditions are uniquely determined for a given thermostat setting, climate, building, air conditioner combination. These are the conditions that exist when the air conditioner sensible heat ratio equals the building load sensible heat ratio. At that point the moisture entering the building is balanced by the moisture removed by the air conditioner.

This equilibrium is automatic. For example if the SHR of the air conditioner is any higher than that of the load (excess sensible capacity relative to latent capacity) the amount of moisture in the air will increase and the SHR of the air conditioner will fall back to equilibrium.

A two step process was used, calculating potential house Sensible Heat Ratios and AC Sensible Heat Ratios then finding the indoor conditions where they match.

Building SHRs were calculated at 75°F indoor dry bulb temperature and a series of potential wet bulb temperatures as follows:

- The indoor humidity ratio in grains of moisture per pound of dry air was calculated for the assumed indoor wet bulb temperature.
- The infiltration latent load in Btu/hr is calculated based on the calculated infiltration rate and the difference between the moisture content of the indoor and outdoor air
- The building design latent load is determined as a sum of the infiltration load and internal gains.
- Sensible load is calculated in accordance with the load calculation method being tested.
- Total load is calculated as a sum of the sensible and latent loads, and the SHR is determined as a ratio of sensible load to total load.

Table 6-1 shows an example of these calculations for the "New" building located in Fresno, California.

Table 6-1. Example - Expected Building Loads and Sensible Heat Ratios					
SHR	Heat Gains, MBtuh				Indoor Wet Bulb °F
	Total	Sensible	Latent	Inf. Latent	
0.893	31.7	28.4	3.4	2.0	49
0.902	31.4	28.4	3,1	1.7	51
0.911	31.1	28.4	2,8	1.3	53
0.921	30.8	28.4	2.4	1.0	55
0.932	30.4	28.4	2.1	.7	57
0.943	30.1	28.4	1.7	.3	59
0.944	**30.03**	**28.36**	**1.67**	**.29**	**59.2**
0.949	29.9	28.4	1.5	.1	60

Air conditioner SHR at various indoor wet bulb temperatures was determined by adjustment of the manufacturer catalog data. In this example it was done by interpolation between the data at 59°F w.b. and 63°F w.b. as shown in Table 6-2.

Table 6-2. Example - Expected AC Capacities and Sensible Heat Ratios (Trane TTR042C w TXC060C5 @ 1600 CFM and 100°F Outside)				
SHR	Capacities, MBtuh			Indoor Wet Bulb (°F)
	Total	Sensible	Latent	
0.95	37.7	35.9	1.8	59
0.94	**37.85**	**35.63**	**2.22**	**59.2**
0.75	40.7	30.5	10.2	63
0.56	43.9	24.4	19.5	67
0.39	47.2	18.3	28.9	71

Equipment Capacity vs. House Load

When the house load and AC capacity reach equilibrium, the sensible heat ratio of the house will match the sensible heat ratio of the AC equipment. For example, a Trane TTR042C outdoor section with TXC060C5 indoor was first selected for this building using the Manual J load calculation method and the Manual S selection method. Manual S methodology resulted in a unit selection 12% oversized.

The SHR method establishes an expected design indoor wet bulb temperature of 59.2°F. This results in an actual oversizing of 26% as shown in Table 6-3.

Table 6-3. Example - Capacity/Load Comparison and Over Sizing Margins

House Load @ Design Conditions[2]			AC Capacities, @Design Conditions[3]			SHR AC	SHR bldg.	Over sizing, %		
Total	Sens.	Lat.	Total	Sens.	Lat.			Total	Sens.	Lat.
30029	28358	1671	37850	35630	2220	0.94	0.94	26	26	33

[2]Manual J adjusted to equilibrium conditions

[3]Manufacturers data adjusted to equilibrium conditions

VII. Discussion, Part 2 Equipment Selection

All the equipment selection methods evaluated except for the "rule of thumb" method require initial load calculation. Most selection methods also require substantial interpretation of manufacturers' data. This presents a challenge to the individual contractor. The required steps are summarized in Table 7-1. Samples of these manufacturers' data are contained in Appendix J.

Table 7-1 Equipment Selection Methodology Iterations with Manufacturers' Data			
Manual S Step 1) Select based on target air flow, sensible capacity, and indoor 75db/62wb			
Carrier Requires calculation to change from 80°F db	**Trane** Can be read directly from data	**York** Can be read directly from data	**Lennox** Requires calculation of sensible capacity from total and SHR
Manual S Step 2) Compare sensible and latent capacities of equipment to calculated loads			
Carrier Requires calculation to change from 80°F db and subtraction to get latent	**Trane** Requires subtraction to get latent	**York** Requires subtraction to get latent	**Lennox** Requires calculation from total and SHR
Manual S Step 3) Check alternative blower speeds if necessary			
Carrier Alternative air flows are listed but the above calculations must be repeated	**Trane** Requires calculation for alternative air flows	**York** Requires calculation for alternative air flows	**Lennox** Alternative air flows are listed but the above calculations must be repeated
Design Sensible Load at ARI Indoor Conditions Select based on sensible capacity at an indoor 80db/67wb			
Carrier Can be read directly from data	**Trane** Can be read directly from data	**York** Can be read directly from data	**Lennox** Requires calculation from total and SHR

Table 7-1 Continued			
Total Load Select based on total capacity at an indoor 75db/62wb			
Carrier Requires calculation to change from 80°F db	**Trane** Can be read directly from data	**York** Can be read directly from data	**Lennox** Can be read directly from data
Square Foot/Ton Select based on square footage of home and manufacturer's data for design conditions (indoor 75db/62wb)			
Carrier Requires calculation to change from 80°F db	**Trane** Can be read directly from data	**York** Can be read directly from data	**Lennox** Can be read directly from data

None of these manufacturers provide information at the actual design conditions expected in PG&E's service territory. In addition there is no standardized methodology for presenting performance data. This makes the equipment selection process more difficult and increases the likelihood of errors.

VIII. Results, Part 2 Equipment Selection

Figure 8-1 compares air conditioner capacities to the building load for various equipment selection methods. This information is detailed in Appendix D.

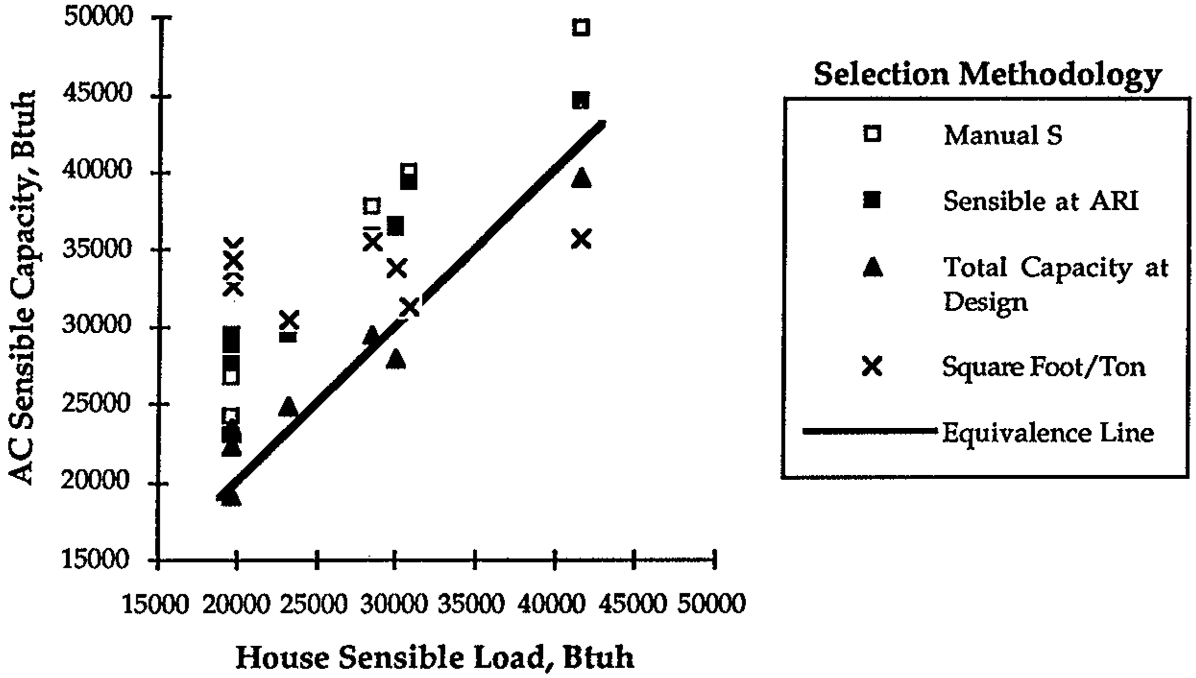


Figure 8-1. Equipment Selection Results (Capacity vs. Load)

Figures 8-2 through 8-5 show how well individual selection methods matched the equipment to the load.

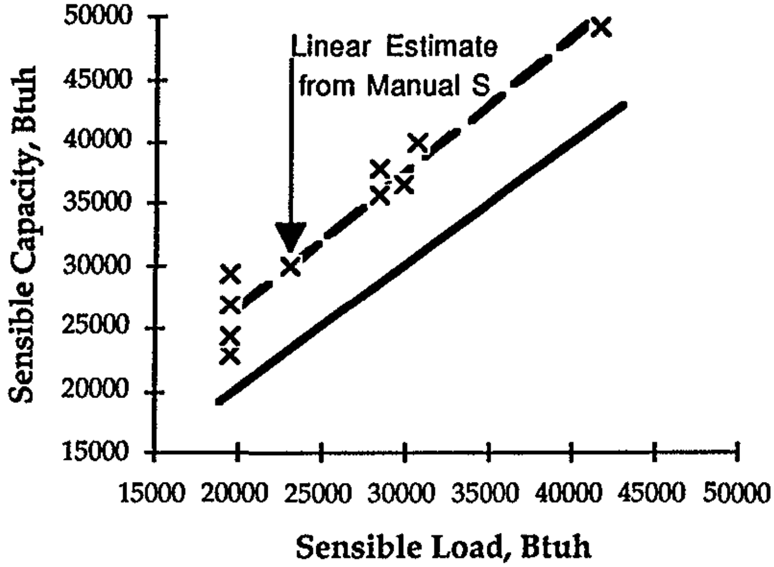


Figure 8-2 Manual S Sizing

MANUAL S

Manual S is based on a design inside wet bulb temperature of 62°F. The actual wet bulb temperature experienced in most of PG&E's service territory is much closer to 58°F at design. Manual S also only restricts oversizing the sensible capacity. In hot/dry climates this will lead to air conditioner oversizing.

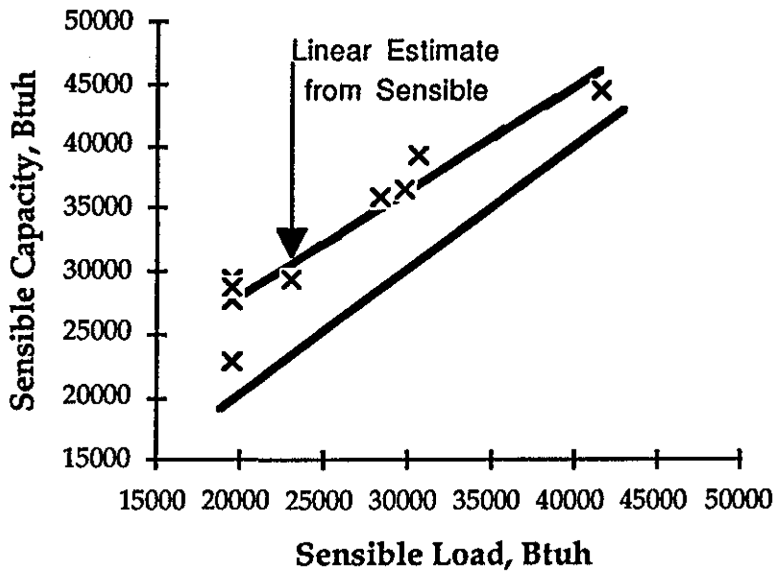


Figure 8-3 Sensible Load Sizing

DESIGN SENSIBLE LOAD AT 80/67

Air conditioner capacity at standard conditions of 80°F dry bulb and 67°F wet bulb temperature for air entering the indoor coil are often used for AC selection. This methodology selects units with sensible capacities and sensible heat ratios approximately the same as those selected with Manual S. With this method units will be oversized similar to Manual S.

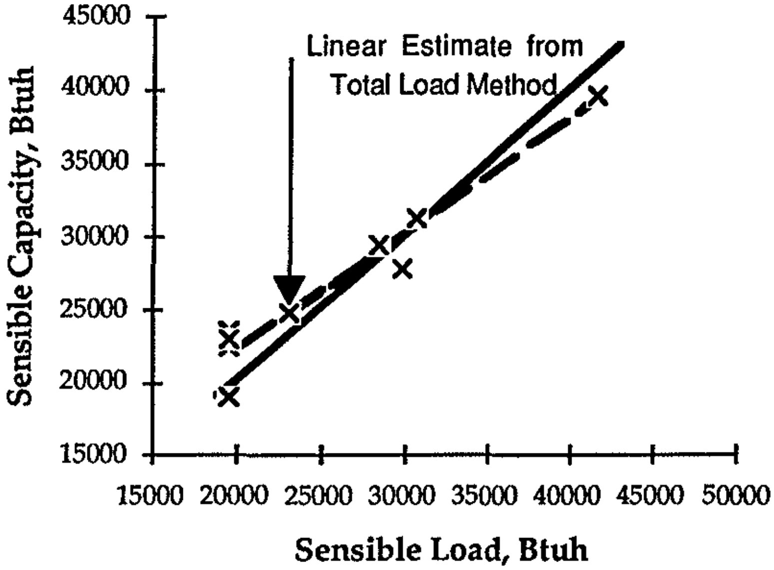


Figure 8-4 Total Load Sizing

DESIGN TOTAL LOAD AT 75/62

Many of the load calculation methods analyzed in this project show the total capacity as the final number for the AC selection.

In PG&E's service territory selecting the equipment based on a correctly calculated total load (that doesn't overestimate latent load) results in equipment selection that closely matches the actual load at the dryer indoor conditions.

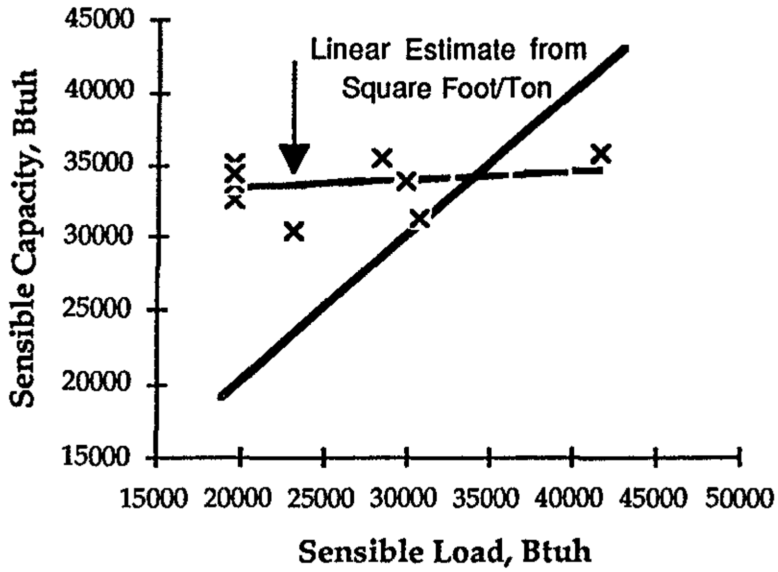


Figure 8-5 Rule of Thumb Sizing

SQUARE FOOT PER TON

Rules of thumb are easy to apply but very subjective. In this analysis 700 ft^2/ton was used for the "New" building in Petaluma; 550 ft^2/ton for the "Typical" building in Petaluma, "New" building in Fresno, and "Massive" building in Fresno; 400 ft^2/ton for the "Old" building in Petaluma and Fresno. In this analysis the equipment sized by this method was vastly oversized for homes with small cooling loads and undersized for homes with large cooling loads.

DISCUSSIONS WITH ACCA - AC SELECTION FOR HOT/DRY CLIMATES

Mr. Hank Rutkowski, P.E., the Technical Director of ACCA, was contacted and the results of this study discussed. The discussion included the following:

- Mr. Rutkowski noted that Manual J was based on conservative assumptions and no special safety factors should be used with it. In the 14 years that the method has been published he has not heard any complaints about insufficient capacity of installed units selected by Manual J.
- He agreed with the study results that most of the load calculation methods used by HVAC contractors over predict the building load when compared to Manual J.
- Mr. Rutkowski was made aware of the study results which indicate that units in PG&E's service territory would be oversized approximately 20% even if all the procedures recommended by the ACCA Manual J and Manual S were followed. He agreed that the Manuals could be improved for dry and hot climates.

- He agreed with the study methodology of equipment selection at expected design conditions. At the same time he said that procedures must be simplified in order to be used by contractors in the field. He suggested that based on this methodology the Manual J and Manual S tables may be expanded by changing the load calculation and AC selection recommendations for dry and hot climate zones.
- Mr. Rutkowski recommended that PEG generate the necessary factors for Manual J and Manual S. He indicated an interest in publishing an ACCA Technical Bulletin as a first step to implementing changes.

IX. Conclusions and Recommendations

This study investigated the residential building cooling load calculation and equipment selection methods used by HVAC contractors in PG&E's service territory.

CONCLUSIONS

- A majority of the existing design load calculation methods that are commonly used produce estimates of cooling load that exceed Manual J by over 20%.
- Submitted load estimation methodologies showed a number of common shortcomings: no error checking procedure, insufficient data for load calculation through windows and opaque surfaces, lack of consideration for actual indoor conditions, oversimplified procedures for duct load, infiltration, and latent load, as well as insufficient data for interior and exterior shading.
- Four of the most popular equipment selection methods result in equipment specification from 14% undersized to 79% oversized compared to the building Manual J loads.
- Manual S selects units that are oversized by approximately 20% for PG&E's service territory beyond any over sizing that might be inherent in Manual J.
- All evidence known to the authors indicates that when Manual J (without any added safety factors) is used to estimate the cooling load and Manual S is used to select equipment, air conditioners in PG&E's service territory will be oversized. That combination of methodologies is conservative. Only a field investigation would verify the actual operation of units sized in this manner.
- Air conditioner manufacturers do not present sufficient performance data for proper sizing in hot/dry conditions similar to those in PG&E's service territory.

RECOMMENDATIONS

Based on this investigation, Proctor Engineering Group makes the following recommendations:

- A baseline load calculation and sizing methodology should be verified by field testing (submetering) of known size units with documented performance data, in houses with known physical characteristics.
- Load calculations should be required on all air conditioners that are going to be installed with utility assistance. Only independently reviewed load

calculations that fall within an acceptable range around a verified methodology should be used for the PG&E rebate program.

- The load calculation documentation should be reviewed to ensure that approved methods were used correctly for the particular buildings.
- If control of over sizing is to be accomplished, the capacity of the installed equipment should be verified.
- Pacific Gas and Electric Company and other utilities should work with manufacturers to obtain a consistent presentation of air conditioner performance data appropriate to hot dry climates.

Appendix A
References and Bibliography

ACCA, 1986. Manual J. Seventh Edition. Load Calculation for Residential Winter and Summer Air Conditioning, Air Conditioning Contractors of America, 1513 16th Street, N.W., Washington, D.C. 20036.

ACCA, 1992. Manual S. Residential Equipment Selection, Air Conditioning Contractors of America, 1513 16th Street, N.W., Washington, D.C. 20036.

ASHRAE, 1993. Fundamentals, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329.

ASHRAE, 1978. Cooling and Heating Load Calculation Manual, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329.

Carrier Corp., 1993. Book One. Unitary Products, Carrier Corporation, Syracuse, NY 13221.

Florida Solar Energy Center, 1994. Residential Air Conditioning Sizing Methodology Draft Final Report, Department of Community Affairs, Florida Energy Office, 2740 Centerview Drive, Tallahassee, Florida 32399.

Lennox Company, 1992. HS23 Series Condensing Units Engineering Data, Bulletin No. 480191, The Lennox Industries, Inc.

Lucas, R., 1992. "Analysis of Historical Residential Air-Conditioning Equipment Sizing Using Monitored Data," Proceedings of the ACEEE 1992 Summer Study on Energy Efficiency in Buildings, American Council for an Energy Efficient Economy, Washington, D.C.

Neal, L., O'Neal, D., 1992. "The Impact of Residential Air Conditioner Charging and Sizing on Peak Electrical Demand," Proceedings of the ACEEE 1992 Summer Study on Energy Efficiency in Buildings, American Council for an Energy Efficient Economy, Washington, D.C.

Proctor, J., and Pernick R., 1992. "Getting It Right the Second Time: Measured Savings and Peak Reduction from Duct and Appliance Repairs," Proceedings of the ACEEE 1992 Summer Study on Energy Efficiency in Buildings, American Council for an Energy Efficient Economy, Washington, D.C.

PG&E Model Energy Communities Project, RACER, 1992. Pacific Gas and Electric Company, San Francisco, California.

Trane Company, 1993. Residential Products Guide, The Trane Company, Unitary Products Group, Troup Highway, Tyler, TX 75707

York Company, 1993. Stellar 2000™ Split-System Air Conditioning Application Data, Publication No. 550.34-AD1Y (792), The York International Corporation, P.O. Box 1592, York, PA 17405-1592.

Appendix B
Analysis Initiation Letter to HVAC Contractors

Memorandum

TO: All Interested Parties

SUBJECT: Approved Design Cooling Load Calculation Methods

FROM: Zinoviy Katsnelson, Proctor Engineering Group

DATE: March 7 1994

As of today two methods are approved for use in the PG&E AC rebate program. These methods are generally accepted by the industry and will be taken as the baseline for acceptance of other methods. The two currently accepted methods are:

- ACCA Manual J Seventh Edition (manual version)
- ASHRAE method described in 1993 ASHRAE Handbook of Fundamentals, Chapter #25

These methods like all methods have some shortcomings. These shortcomings are listed in the method summaries.

Many methods used in the field are based on these two. This should make approval of many other methods a short process. There are also more sophisticated methods than these two. In order to approve any particular method Proctor Engineering Group will need for each submittal:

1) All forms used in the calculation
2) All explanatory manuals and reference tables
3) The name and phone number of your contact with the developer of the method.

In the case of a software program, Proctor Engineering Group will also need:

4) An evaluation copy of the software.

TO:

DATE:

Thank you for your submission of a design cooling load calculation for use in the PG&E AC rebate program. In order to evaluate your method for inclusion in the program we will need the items below. We have highlighted the items which were not received with your initial submittal.

1) All forms used in the calculation
2) All explanatory manuals and reference tables
3) The name and phone number of your contact with the developer of the method.

In the case of a software program, Proctor Engineering Group will also need:

4) An evaluation copy of the software.

Please send these items to us and we will evaluate your method as soon as possible. Thank you for your cooperation.

Our address is:

Proctor Engineering Group
5725 Paradise Drive, Suite 820
Corte Madera, CA 94925

Sincerely,

Zinoviy Katsnelson
Senior Energy Analyst

Attachment

Appendix C Approved Method Summaries

Status Report 11/09/94 - Load Calculations

As of 10/18/94, the following methods have been approved for use in the 1994 PG&E rebate program:

NOTE THAT THESE METHODS SHOULD USE OUTDOOR CONDITIONS FROM MANUAL J, OR ASHRAE FUNDAMENTALS 1993 CHAPTER 24.

Worksheets approved as received:

Name	Comments
ID 0 Manual J	Available through ACCA; t.: (202) 483-9370
ID 11 Proprietary Worksheet	
ID 12 REZ-1 (Cat. No. 794-101) Carrier	Available through E.B.Ward & Co.; t.: (415) 873-1660
ID 21 Manual J simplified worksheet	Used with standard Manual J Tables and instructions.
ID 35 Manual J simplified worksheet	Used with standard Manual J Tables and instructions. Available from EGIA; t.: (800) 652-1080
ID 50 Manual J simplified worksheet	Used with standard Manual J Tables and instructions.

Worksheets approved with changes:

NOTE THAT THESE METHODS CAN BE USED ONLY WITH THE NOTED CHANGES.

Name	Changes
ID 1, 53 Pub. No. 22-8018-1 P.I. (L) Trane	1) Eliminated latent capacity multiplier and specified Manual J latent calculation. 2) Recommends that equipment be selected based on calculated sensible capacity, under local design conditions, with latent capacity checked to ensure it is sufficient. Available through Trane Co.; t.: (916) 929-3319
ID 3 Pub. No. CL 841-L7 Lennox	1) Specified source of weather data including the use of 0 grains difference for most parts of California. 2) A sizing methodology in line with the Manual J Available through Lennox Co.; t.: (916) 447-7503
ID 6 Proprietary Worksheet	1) Window and door cooling factors changed as of April, 1994
ID 13 Pub. No. 34-4018 General Electric Worksheet	1) Eliminated latent capacity multiplier and specified Manual J latent calculation. 2) Recommends that equipment be selected based on calculated sensible capacity, under local design conditions, with latent capacity checked to ensure it is sufficient.
ID 26 Proprietary Worksheet	1) Added overhang effect 2) Reduced infiltration assumptions 3) Added variable duct gain multiplier
ID 32 and ID 14 AIM MISC.000.2.6	1) Eliminate latent capacity multiplier (Line D). 2) Line C is now your total sensible load. 3) Calculate the latent load as 230 btu per person. 4) Manual J recommends that: ""Cooling Only" equipment should be selected so that its sensible capacity is not less than calculated total sensible load or not more than 115 percent of this calculated load (allowing for the standard steps in capacity provided by the manufacturers product line). In addition, the corresponding latent capacity should not be less than the calculated latent load."

Status Report 11/09/94 - Load Calculations

Computer programs approved:

Name	Comments
ID 20 Elite Software RHVAC v.5.0	Only this version has been tested and approved. Available through Elite Co.; t.: (409) 846-2340
ID 23 Right J v. 1.72 and 1.74	Only these versions have been tested and approved. Available through Wright Associates Co.; t.: (617) 862-8719
ID 33 Lennox Logic 1000, 1993	Only this version has been tested and approved. Available through Lennox Co.; t.: (916) 447-7503
ID 31 Lennox Logic Junior LJR-851-L5	This version is older than ID 44
ID 47 Comply-24, v. 4.11, 1993	Available through Gabel Dodd Associates Co.; t.: (510) 428-0803
ID 51 MC2, RL5M v. 4.1	Available through MC2 Software Co.; t.: (305) 665-0100

Computer programs approved with caveats:

NOTE THAT THESE METHODS CAN BE USED ONLY WITH THE NOTED INPUTS.

Name	Required Inputs
ID 7 Micropas 4.0	1) "Latent Fraction" in "HVAC Sizing" set to 0% 2) Manually calculate latent load as 230 btu per person Available through Enercomp Co.; t.: (916) 568-2485
ID 19 Carrier E20-II	1) "Latent Factor" in "Weather Information" set to 0% 2) Manually calculate latent load as 230 btu per person Available through E.B.Ward & Co.; t.: (415) 873-1660
ID 44 Lennox Logic Junior III	1) Must use design conditions, duct multiplier, and grains humidity from Manual J 2) Must select equipment based on sensible load and check for latent Available through AAA Enterprises Co.; t.: (404) 938-1717

Status Report - Load Calculations

As of 10/18/94 (with revisions made 3/20/96), the following methods have been approved for use in the 1994 PG&E rebate program:

NOTE THAT THESE METHODS SHOULD USE OUTDOOR CONDITIONS FROM MANUAL J, OR ASHRAE FUNDAMENTALS 1993 CHAPTER 24.

Worksheets approved as received:

Name	Comments
ID 0 Manual J	Available through ACCA; t.: (202) 483-9370
ID 11 Proprietary Worksheet	
ID 12 REZ-1 (Cat. No. 794-101) Carrier	Available through E.B.Ward & Co.; @: (415) 873-1660
ID 21 Manual J simplified worksheet	Used with standard Manual J Tables and instructions.
ID 35 Manual J simplified worksheet	Used with standard Manual J Tables and instructions. Available from EGIA; @: (800) 652-1080
ID 50 Manual J simplified worksheet	Used with standard Manual J Tables and instructions.

Worksheets approved with changes:

NOTE THAT THESE METHODS CAN BE USED ONLY WITH THE NOTED CHANGES.

Name	Changes
ID 1, 53 Pub. No. 22-8018-1 P.I. (L) Trane	1) Eliminated latent capacity multiplier and specified Manual J latent calculation. 2) Recommends that equipment be selected based on calculated sensible capacity, under local design conditions, with latent capacity checked to ensure it is sufficient. Available through Trane Co.; @.: (916) 929-3319
ID 3 Pub. No. CL 841-L7 Lennox	1) Specified source of weather data including the use of 0 grains difference for most parts of California. 2) A sizing methodology in line with the Manual J Available through Lennox Co.; @: (916) 447-7503
ID 6 Proprietary Worksheet	1) Window and door cooling factors changed as of April, 1994
ID 13 Pub. No. 34-4018 General Electric Worksheet	1) Eliminated latent capacity multiplier and specified Manual J latent calculation. 2) Recommends that equipment be selected based on calculated sensible capacity, under local design conditions, with latent capacity checked to ensure it is sufficient.
ID 26 Proprietary Worksheet	1) Added overhang effect 2) Reduced infiltration assumptions 3) Added variable duct gain multiplier
ID 32 and ID 14 AIM MISC.000.2.6	1) Eliminate latent capacity multiplier (Line D). 2) Line C is now your total sensible load. 3) Calculate the latent load as 230 btu per person. 4) Manual J recommends that: ""Cooling Only" equipment should be selected so that its sensible capacity is not less than calculated total sensible load or not more than 115 percent of this calculated load (allowing for the standard steps in capacity provided by the manufacturers product line). In addition, the corresponding latent capacity should not be less than the calculated latent load."

Status Report - Load Calculations

Computer programs approved:

Name	Comments
ID 20 Elite Software RHVAC v.5.0	Only this version has been tested and approved. Available through Elite Co.; @: (409) 846-2340
ID 23 Right J v. 1.72 and 1.74	Only these versions have been tested and approved. Available through Wright Associates Co.; @.: (617) 862-8719
ID 33 Lennox Logic 1000, 1993	Only this version has been tested and approved. Available through Lennox Co.; @.: (916) 447-7503
ID 31 Lennox Logic Junior LJR-851-L5	This version is older than ID 44
ID 47 Comply-24, v. 4.11, 1993	Available through Gabel Dodd Associates Co.; @: (510) 428-0803
ID 51 MC2, RL5M v. 4.1	Available through MC2 Software Co.; @.: (305) 665-0100
Added 3/20/96	
Carrier REZCALC v. 2.0	Only this version has been tested and approved. Available through MAC Consulting, Marianne Catrambone @ (315) 677-0243

Computer programs approved with caveats:

NOTE THAT THESE METHODS CAN BE USED ONLY WITH THE NOTED INPUTS.

Name	Required Inputs
ID 7 Micropas 4.0	1) "Latent Fraction" in "HVAC Sizing" set to 0% 2) Manually calculate latent load as 230 btu per person Available through Enercomp Co.; @.: (916) 568-2485
ID 19 Carrier E20-II	1) "Latent Factor" in "Weather Information" set to 0% 2) Manually calculate latent load as 230 btu per person Available through E.B.Ward & Co.; @.: (415) 873-1660
ID 44 Lennox Logic Junior III	1) Must use design conditions, duct multiplier, and grains humidity from Manual J 2) Must select equipment based on sensible load and check for latent Available through AAA Enterprises Co.; @: (404) 938-1717

Appendix D
Air Conditioners Selected From the Major Manufacturer's Catalogs Using Different Selection Methods

A. Various Sizing Methods Comparison. Load per Manual J. Carrier Air Conditioners.

Separate oversizing safety factor was not used for any unit.

1. Equipment Selection per Manual S* (or ASHRAE). Load per Manual-J

	Carrier Design CFM =SL/(1.1*TD)	Selection Outdoor Model	Indoor Coil	Performance @ Closest Avail. Cond. (75/62/90 Pet., 75/62/100 Frsno.) Adjusted per manufacturer's recommendations Sensible	Latent	Total	Watt	EER	% Sens. oversiz.
	It is not the actual unit CFM								
1. Typical, Petaluma, W	1238.28877	38CK036	Stndrd. CD5A036	25690	5910	31600	3455	9.1	11
2. Old, Petaluma, N	1598.074866	38CK048-32	Stndrd. CD5A048	32520	8330	40850	4465	9.1	9
3. Old, Fresno, N	2224.705882	*38CK060-32 (SEER 10.8)	Stndrd. CD5A060	41606	10144	51750	6160	8.4	0
4. New, Petaluma, N	1049.893048	38CK030 @ 1000CFM	Stndrd. CD5A030	20525	5575	26100	2965	8.8	5
5. New, Fresno, E	1516.470588	38CK042	Stndrd. CD5A042	29274	6626	35900	4285	8.4	3
6. Massive, Fresno, N	1642.673797	38CK048	Stndrd. CD5A048-31	32520	8330	40850	5060	8.1	6

B. Various Sizing Methods Comparison. Load per Trane #22-8018-1 P.I. (Revised 03/16/94). Trane Air Conditioners.

1. Equipment Selection per Manual S* (or ASHRAE). Load per Trane

	Trane Design CFM =SL/(1.1*TD)	Selection Outdoor Model	Indoor Coil	Performance @ Closest Avail. Cond. (75/62/90 Pet., 75/62/100 Frsno.) Adjusted per manufacturer's recommendations Sensible	Latent	Total	Watt	EER	% Sens. oversiz.
	It is not the actual unit CFM								
1. Typical, Petaluma, W	1326.417112	TTR036C	TXA043C4 @ 1400CFM	27700	6550	34250	3709.5	9.2	12
2. Old, Petaluma, N	1549.73262	TTR042C	TXA049C4 @ 1600CFM	32238	9538	41775	4549	9.2	11
3. Old, Fresno, N	2185.347594	TTR060C	TXH060S5 @ 2000CFM	43600	10775	54375	6312	8.6	7
4. New, Petaluma, N	1144.224599	TTR036C	TXA031C4 @ 1100CFM	23388	8488	31875	3510	9.1	9
5. New, Fresno, E	1655.935829	TTR042C	TXC060C5 @ 1600CFM	31850	8100	39950	4859	8.2	3
6. Massive, Fresno, N	1727.112299	TTR042C	TXH060S5 @ 1600CFM	34575	7313	41888	4946	8.5	7

C. Various Sizing Methods Comparison. Load per Comply-24. York Air Conditioners.

1. Equipment Selection per Manual S* (or ASHRAE). Load per Comply-24

	York Design CFM =SL/(1.1*TD)	Selection Outdoor Model	Indoor Coil	Performance @ Closest Avail. Cond. (75/62/90 Pet., 75/62/100 Frsno.) Adjusted per manufacturer's recommendations Sensible	Latent	Total	Watt	EER	% Sens. oversiz.
	It is not the actual unit CFM								
1. Typical, Petaluma, W	1466.737968	H1DA036	G3UA048 @ 1290 CFM	29100	5450	34550	3340	10.3	6
2. Old, Petaluma, N	1773.101604	H1DA048	G3UA060 @ 1600 CFM	36900	10600	47500	4450	10.7	11
3. Old, Fresno, N	2345.668449	H1DA060	G3UA061 @ 1900 CFM	44050	9600	53650	5975	9.0	0
4. New, Petaluma, N	1253.957219	H1DA036	M3CF044 @ 1290 CFM	25750	8250	34000	3365	10.1	10
5. New, Fresno, E	1698.983957	H1DA048	G3UA060 @ 1600 CFM	35850	7700	43550	4850	9.0	13
6. Massive, Fresno, N	1797.754011	H1DA048	G3UA060 @ 1600 CFM	35850	7700	43550	4850	9.0	7

D. Various Sizing Methods Comparison. Load per Lennox Pub. CL 841-L7. Lennox Air Conditioners.

Separate oversizing safety factor was not used for any unit.

***1. Equipment Selection per Manual S* (or ASHRAE). Load per Lennox

	**Lennox (SEER 10-11.6) Design CFM =SL/(1.1*TD)	Selection Outdoor Model	Indoor Coil	Performance @ Closest Avail. Cond. (75/62/90 Pet., 75/62/100 Frsno.) Adjusted per manufacturer's recommendations Sensible	Latent	Total	Watt	EER	% Sens. oversiz.
	It is not the actual unit CFM								
1. Typical, Petaluma, W	1297	*See following sheets for specific calculations*							
2. Old, Petaluma, N	1512								
3. Old, Fresno, N	2010								
4. New, Petaluma, N	1245								
5. New, Fresno, E	1807								
6. Massive, Fresno, N	1909								

2. Equipment Selection at Standard Design Indoor Conditions. *Load per Manual-J*
Performance @ Stand. Indoor Cond. 80/67 (Outdoor 90°F Pet., 100°F Frsn.)

CFM	Selection Outdoor Mo	Indoor Coil	Sensible	Latent	Total	Watt	EER	% Sens. oversiz.
1200	38CK036	Stndrd. CD5A036	25550	9400	34950	3580	9.8	10
1600	38CK048	Stndrd. CD5A048-32	32450	12400	44850	5060	8.9	9
2250	*38CK060	Stndrd. CD5A060-31	42100	13900	56000	6610	8.5	1
1000	38CK030	Stndrd. CD5A030	20600	8350	28950	3080	9.4	5
1575	38CK042	Stndrd. CD5A042	30450	8800	39250	4420	8.9	7
1600	38CK048	Stndrd. CD5A048-31	32450	12400	44850	5060	8.9	6

2. Equipment Selection at Standard Design Indoor Conditions. *Load per Trane*
Performance @ Stand. Indoor Cond. 80/67 (Outdoor 90°F Pet., 100°F Frsn.)

CFM	Selection Outdoor Mo	Indoor Coil	Sensible	Latent	Total	Watt	EER	% Sens. oversiz.
1200	TTR036C	TXA037E5	25700	11800	37500	3722	10.1	4
1600	TTR042C	TWE060A	32100	14000	46100	4496	10.3	11
2000	TTR060C	TWE060P15-C	41800	15900	57700	6729	8.6	2
1100	TTR036C	TXA031E5	23900	12100	36000	3630	9.9	12
1300	TTR042C	TWV039E15-C	31800	12600	44400	4806	9.2	3
1600	TTR042C	TWH064P15-C	36300	10300	46600	5176	9.0	12

2. Equipment Selection at Standard Design Indoor Conditions. *Load per Comply-24*
Performance @ Stand. Indoor Cond. 80/67 (Outdoor 90°F Pet., 100°F Frsn.)

CFM	Selection *Outdoor Mc	Indoor Coil	Sensible	Latent	Total	Watt	EER	% Sens. oversiz.
1290	H1DA036	G3UA048	28850	8600	37450	3580	10.5	5
1600	H1DA048	G3UA060	36550	14950	51500	4775	10.8	10
1900	H1DA060	M3HD060	50250	5450	55700	6700	8.3	15
1290	H1DA036	M3CF044	25500	11300	36800	3610	10.2	9
1600	H1DA048	G3UA060	35450	12050	47500	5225	9.1	12
1600	H1DA048	G3UA060	35450	12050	47500	5225	9.1	5

*Units have SEER 10.2-10.5

2. Equipment Selection at Standard Design Indoor Conditions. *Load per Lennox*
Performance @ Stand. Indoor Cond. 80/67 (Outdoor 90°F Pet., 100°F Frsn.)

CFM	Selection Outdoor Mo	Indoor Coil	Sensible	Latent	Total	Watt	EER	% Sens. oversiz.
1000	HS23-411	C16-41	25818	11342	37160	3410	10.9	6
1200	HS23-411	C16-51	29002	10500	39501	3615	10.9	3
1800	*HS23-511	C24-51	38132	14203	52335	5786	9.0	1
1000	HS23-411	C16-41	25818	11342	37160	3410	10.9	11
1700	HS23-461	C16-46	34249	8964	43213	4498	9.6	1
1800	*HS23-511	C24-51	38132	14203	52335	5786	9.0	7

3. Equipment Selection Based on Total Capacity. *Load per Manual-J*

Carrier

Performance @ Closest Available Cond. (75/62/90 Pet., 75/62/100 Frsno.)
Adjusted per manufacturer's recommendations

Calculated Total Btuh	Selection Outdoor Model	Indoor Coil	CFM	Sensible	Latent	Total	Watt	EER	%Total oversiz.
24536	38CK030	Stndrd. CD5A030	1000	20525	5575	26100	2965	8.8	6
31264	38CK036	Stndrd. CD5A036	1350	26464	5836	32300	3540	9.1	3
42982	*38CK060-32	Stndrd. CD5A060	1750	37594	11506	49100	5955	8.2	14
21013	38CK024	Stndrd. CD5A024	900	17093	4208	21300	2385	8.9	1
29738	38CK042	Stndrd. CD5A042	1225	27286	6964	34250	4075	8.4	15
32098	38CK042	Stndrd. CD5A042-30	1225	27286	6964	34250	4075	8.4	7

3. Equipment Selection Based on Total Capacity. *Load per Trane*

Trane

Performance @ Closest Available Cond. (75/62/90 Pet., 75/62/100 Frsno.)
Adjusted per manufacturer's recommendations

Calculated Total Btuh	Selection Outdoor Model	Indoor Coil	CFM	Sensible	Latent	Total	Watt	EER	%Latent	%Total oversiz.
26184	TTR030C	TXC043C4	1100	22388	5838	28225	3091.5	9.1	323	8
30360	TTR036C	TWE036C14	1200	24150	8500	32650	3589.5	9.1	516	8
42246	TTR042C	TWV064P15-C	1600	36525	6075	42600	4996	8.5	340	1
22777	*TTR030C	TWE030C14	1000	19875	6450	26325	2934	9.0	367	16
32346	TTR036C	TXC049C4	1400	26875	5700	32575	3969.5	8.2	313	1
33677	TTR042C	TXC036F4	1200	26850	10100	36950	4541	8.1	632	10

3. Equipment Selection Based on Total Capacity. *Load per Comply-24*

York

Performance @ Closest Available Cond. (75/62/90 Pet., 75/62/100 Frsno.)
Adjusted per manufacturer's recommendations

Calculated Total Btuh	Selection Outdoor Model	Indoor Coil	CFM	Sensible	Latent	Total	Watt	EER	%Total oversiz.
28328	H1DA030	G3UA037	1060	23550	4850	28400	2735	10.4	0
34165	H1DA036	G3UA048	1290	29100	5450	34550	3340	10.3	1
45304	H1DA060	G3SN060	1900	37800	13250	51050	5725	8.9	13
24351	H1DA030	M3UF032	1060	20700	6350	27050	2680	10.1	11
33459	H1DA042	M3UF044	1500	31350	5600	36950	4445	8.3	10
35177	H1DA042	M3UF044	1500	31350	5600	36950	4445	8.3	5

3. Equipment Selection Based on Total Capacity. *Load per Lennox*

Lennox

*Performance @ Closest Available Cond. (75/63/90 Pet., 75/63/100 Frsno.)
Adjusted per manufacturer's recommendations

Calculated Total Btuh	Selection Outdoor Model	Indoor Coil	CFM	Sensible	Latent	Total	Watt	EER	%Total oversiz.
25628	**HS23-261	C22-31	1050	20457	5147	25604	2485	10.3	0
29662	**HS23-311	CB19-41	1025	23873	6381	30254	2915	10.4	2
38962	HS23-461	C16-41	1500	30903	10353	41256	4388	9.4	6
24663	**HS23-261	C22-31	1050	20457	5147	25604	2485	10.3	4
35179	HS23-411	C16-51	1400	29532	6761	36293	4024	9.0	3
37079	HS23-461	C16-41	1500	30903	10353	41256	4388	9.4	11

4. Equipment Selection Based on "Rules of Thumb" Method.

Carrier

Perf. @ Closest Avail. Cond. (75/62/90 Pet., 75/62/100 Frsno.)
Adjusted per manufacturer's recommendations

Calculated Total Btuh	Selection Outdoor Model	Indoor Coil	CFM	Sensible	Latent	Total	Watt	EER	%Total oversiz.
34036	38CK042	Stndrd. CD5A042	1225	28436	8064	36500	3865	9.44	7
36000	38CK042	Stndrd. CD5A042	1225	28436	8064	36500	3865	9.44	1
36000	38CK048	Stndrd. CD5A048	1400	31055	8995	40050	4955	8.08	11
37286	38CK042	Stndrd. CD5A042	1400	29955	7395	37350	3965	9.42	0
37286	38CK048	Stndrd. CD5A048	1400	31055	8995	40050	4955	8.08	7
33000	38CK042	Stndrd. CD5A042-30	1400	28605	6445	35050	4180	8.39	6

4. Equipment Selection Based on "Rules of Thumb" Method.

Trane

Perf. @ Closest Avail. Cond. (75/62/90 Pet., 75/62/100 Frsno.)
Adjusted per manufacturer's recommendations

Calculated Total Btuh	Selection Outdoor Model	Indoor Coil	CFM	Sensible	Latent	Total	Watt	EER	%Total oversiz.
34036.36	TTR036C	TXC048C4	1400	27713	6638	34350	3720	9.2	1
36000	TTR042C	TWE042C14	1400	29325	10675	40000	4411	9.1	11
36000	TTR042C	TWE060A	1600	31675	8275	39950	4639	8.6	11
37285.71	TTR042C	TWE042C14	1400	29325	10675	40000	4411	9.1	7
37285.71	TTR042C	TWE060A	1600	31675	8275	39950	4639	8.6	7
33000	TTR042C	TXC036F4	1200	26850	10100	36950	4541	8.1	12

4. Equipment Selection Based on "Rules of Thumb" Method.

Perf. @ Closest Avail. Cond. (75/62/90 Pet., 75/62/100 Frsno.)
Adjusted per manufacturer's recommendations

Calculated Total Btuh	Selection Outdoor Model	Indoor Coil	CFM	Sensible	Latent	Total	Watt	EER	%Total oversiz.
34036.36	H1DA036	G3UA048	1290	29100	5450	34550	3340	10.3	2
36000	H1DA042	M3UF044	1500	32300	8000	40300	4075	9.9	12
36000	H1DA042	M3UF044	1500	31350	5600	36950	4445	8.3	3
37285.71	H1DA042	M3UF044	1500	32300	8000	40300	4075	9.9	8
37285.71	H1DA042	G3UA061	1500	34950	4650	39600	4655	8.5	6
33000	H1DA042	M3UF044	1500	31350	5600	36950	4445	8.3	12

4. Equipment Selection Based on "Rules of Thumb" Method.

*Perf. @ Closest Avail. Cond. (75/63/90 Pet., 75/63/100 Frsno.)
Adjusted per manufacturer's recommendations

Calculated Total Btuh	Selection Outdoor Model	Indoor Coil	CFM	Sensible	Latent	Total	Watt	EER	%Total oversiz.
34036	HS23-411	C16-46	1250	30755.8	6482.4	37238	3585	10.4	9
36000	HS23-411	C16-46	1500	30755.8	7751	38507	3948	9.8	7
36000	HS23-411	C16-46	1500	29725.8	6581	36307	4163	8.7	1
37286	HS23-411	C16-46	1500	30755.8	7751	38507	3948	9.8	3
37286	HS23-461	C16-41	1500	30903.4	10353	41256	4388	9.4	11
33000	HS23-411	C16-51	1400	29532.5	6760.5	36293	4024	9.0	10

Appendix E
Expected AC Performance at Various Indoor Humidity Conditions

1. TRANE Co.

Trane TTR036 w TXA036C4 @ 1200CFM — Rate of change per F/1000 CFM

O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Comp Watt decr.
90	*58.2*	*30.990*	*27.445*	*2.035*	*0.886*	*2.862*				
	58.3	*31.054*	*28.861*	*2.193*	*0.929*	*2.864*	*531*	*786*	*1318*	*19*
	59	31.5	28.2	3.3	0.90	2.88	542	833	1375	19
	63	34.1	24.2	9.9	0.71	2.97	562	927	1490	19
	67	36.8	19.75	17.05	0.54	3.06	583	958	1542	21
	71	39.6	15.15	24.45	0.38	3.16	na	na	na	na

Trane TTR030C w TXA043C4 @ 1100CFM — Rate of change per F/1000 CFM

O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Comp Watt decr.
90	*57*	*25.375*	*26.975*	*-1.600*	*1.063*	*2.343*				
	58.1	*25.994*	*25.999*	*-0.005*	*1.000*	*2.369*	*511*	*807*	*1318*	*22*
	59	26.5	25.2	1.3	0.951	2.39	523	852	1375	*20*
	59.4	*26.73*	*24.825*	*1.905*	*0.929*	*2.399*	*523*	*852*	*1375*	*20*
	63	28.8	21.45	7.35	0.745	2.48	545	943	1489	18
	67	31.2	17.3	13.9	0.554	2.56	545	966	1511	20
	71	33.6	13.05	20.55	0.388	2.65	na	na	na	na

Trane TTR036C w TXC049C @ 1400CFM — Rate of change per F/1000 CFM

O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Comp Watt decr.
100	*57*	*29.450*	*32.300*	*-2.850*	*1.097*	*3.065*				
	58.7	*30.513*	*30.558*	*-0.045*	*1.001*	*3.103*	*446*	*732*	*1179*	*16*
	59	30.7	30.25	0.45	0.985	3.11	446	804	1250	16
	59.7	*31.1375*	*29.4625*	*1.675*	*0.946*	*3.12575*	*446*	*804*	*1250*	*16*
	63	33.2	25.75	7.45	0.776	3.2	446	946	1393	16
	67	35.7	20.45	15.25	0.573	3.29	464	973	1437	16
	71	38.3	15	23.3	0.392	3.38	na	na	na	na

Trane TTR036C w TWE036C14 @ 1200CFM — Rate of change per F/1000 CFM

O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Comp Watt decr.
90	*57*	*29.425*	*28.788*	*0.638*	*0.978*	*2.725*				
	58	*30.063*	*27.894*	*2.169*	*0.928*	*2.748*	*531*	*745*	*1276*	*19*
	59	30.7	27	3.7	0.879	2.77	542	792	1333	19
	59.6	*31.09*	*26.43*	*4.66*	*0.850*	*2.7835*	*542*	*792*	*1333*	*19*
	63	33.3	23.2	10.1	0.697	2.86	563	885	1448	19
	67	36	18.95	17.05	0.526	2.95	563	906	1469	21
	71	38.7	14.6	24.1	0.377	3.05	na	na	na	na

Trane TTR030C w TWE030C14 @ 1000CFM						Rate of change per F/1000 CFM				
O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Compr Watt decr.
90	57	23.450	23.650	-0.200	1.009	2.273				
	58.7	24.428	22.418	2.010	0.918	2.304	575	725	1300	19
	59	24.6	22.2	2.4	0.902	2.31	575	775	1350	20
	59.6	24.945	21.735	3.21	0.871	2.322	575	775	1350	20
	63	26.9	19.1	7.8	0.710	2.39	575	875	1450	22
	67	29.2	15.6	13.6	0.534	2.48	600	900	1500	20
	71	31.6	12	19.6	0.380	2.56	na	na	na	na

Trane TTR036C w TXA048C4 @ 1400CFM						Rate of change per F/1000 CFM				
O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Compr Watt decr.
90	57	31.150	33.650	-2.500	1.080	2.815				
	58	31.775	32.500	-0.725	1.023	2.838	446	821	1268	16
	59	32.4	31.35	1.05	0.968	2.86	464	866	1330	16
	59.7	32.855	30.5013	2.35375	0.928	2.87575	464	866	1330	16
	63	35	26.5	8.5	0.757	2.95	500	955	1455	16
	67	37.8	21.15	16.65	0.560	3.04	500	964	1464	18
	71	40.6	15.75	24.85	0.388	3.14	na	na	na	na

Trane TTR060 w TWE048C14 @ 1800CFM						Rate of change per F/1000 CFM				
O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Compr Watt decr.
100	57	45.775	44.287	1.488	0.967					
	57.5	46.231	43.578	2.654	0.943	4.975				
	57.8	46.505	43.152	3.353	0.928		507	788	1295	24
	59	47.6	41.45	6.15	0.871	5.04	514	826	1340	25
	63	51.3	35.5	15.8	0.692	5.22	528	903	1431	26
	67	55.1	29	26.1	0.526	5.41	556	944	1500	28
	71	59.1	22.2	36.9	0.376	5.61	na	na	na	na

Trane TTR030C w TXC030C4 @ 1000CFM						Rate of change per F/1000 CFM				
O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Compr Watt decr.
90	57	24.025	21.625	2.400	0.900	2.290				
	58	24.563	20.913	3.650	0.851	2.310	537	713	1250	20
	59	25.1	20.2	4.9	0.805	2.33	550	750	1300	20
	63	27.3	17.2	10.1	0.630	2.41	575	825	1400	20
	67	29.6	13.9	15.7	0.470	2.49	625	863	1488	22
	71	32.1	10.45	21.65	0.326	2.58	na	na	na	na

Trane TTR030C w TXC036F4 @ 1100CFM						Rate of change per F/1000 CFM				
O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Comp Watt decr.
90	*57*	*24.975*	*26.513*	*-1.537*	*1.062*	*2.333*				
	58.1	*25.594*	*25.543*	*0.051*	*0.998*	*2.353*	*511*	*801*	*1312*	*17*
	59	26.1	24.75	1.35	0.948	2.37	523	841	1364	*18*
	59.5	*26.3875*	*24.2875*	*2.1*	*0.920*	*2.38*	*523*	*841*	*1364*	*18*
	63	28.4	21.05	7.35	0.741	2.45	545	920	1466	20
	67	30.8	17	13.8	0.552	2.54	545	943	1489	20
	71	33.2	12.85	20.35	0.387	2.63	na	na	na	na

Trane TTR060C w TXH060S5 @ 2000CFM						Rate of change per F/1000 CFM				
O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Comp Watt decr.
100	*57*	*49.775*	*52.913*	*-3.137*	*1.063*	*5.075*				
	58.8	*51.418*	*49.661*	*1.756*	*0.966*	*5.161*	*456*	*903*	*1359*	*24*
	59	51.6	49.3	2.3	0.955	5.17	462	950	1412	*24*
	59.4	*51.97*	*48.54*	*3.43*	*0.934*	*5.189*	*462*	*950*	*1412*	*24*
	63	55.3	41.7	13.6	0.754	5.36	475	1044	1519	24
	67	59.1	33.35	25.75	0.564	5.55	500	1056	1556	25
	71	63.1	24.9	38.2	0.395	5.75	na	na	na	na

Trane TTR042C w TXA049C4 @ 1600CFM						Rate of change per F/1000 CFM				
O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Comp Watt decr.
90	*57*	*37.675*	*38.788*	*-1.113*	*1.030*	*3.555*				
	58.8	*39.138*	*36.504*	*2.634*	*0.933*	*3.623*	*508*	*793*	*1301*	*23*
	59	39.3	36.25	3.05	0.922	3.63	516	836	1352	23
	59.4	*39.63*	*35.715*	*3.915*	*0.901*	*3.645*	*516*	*836*	*1352*	*23*
	63	42.6	30.9	11.7	0.725	3.78	531	922	1453	23
	67	46	25	21	0.543	3.93	547	945	1492	25
	71	49.5	18.95	30.55	0.383	4.09	na	na	na	na

Trane TTR042C w TXC060C5 @ 1600CFM						Rate of change per F/1000 CFM				
O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Comp Watt decr.
100	*57*	*36.250*	*38.425*	*-2.175*	*1.060*	*3.868*				
	58.8	*37.555*	*36.153*	*1.403*	*0.963*	*3.933*	*453*	*789*	*1242*	*23*
	59	37.7	35.9	1.8	0.952	3.94	469	844	1313	23
	59.2	*37.85*	*35.63*	*2.22*	*0.941*	*3.9475*	*469*	*844*	*1313*	*23*
	63	40.7	30.5	10.2	0.749	4.09	500	953	1453	25
	67	43.9	24.4	19.5	0.556	4.25	516	953	1469	25
	71	47.2	18.3	28.9	0.388	4.41	na	na	na	na

Trane TTR042C w TXC036F4 @ 1200CFM							Rate of change per F/1000 CFM			
O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Compr Watt decr.
100	*57.2*	*33.373*	*31.560*	*1.813*	*0.946*	*3.699*				
	57.5	*33.594*	*31.275*	*2.319*	*0.931*	*3.709*				
	57.4	*33.520*	*31.370*	*2.150*	*0.936*	*3.706*				
	58	*33.963*	*30.800*	*3.163*	*0.907*	*3.726*	*615*		*792*	*1406*
	59	34.7	29.85	4.85	0.860	3.76	625		833	1458
	63	37.7	25.85	11.85	0.686	3.9	646		917	1562
	67	40.8	21.45	19.35	0.526	4.05	667		958	1625

Trane TTR036C w TXA031C4 @ 1100CFM							Rate of change per F/1000 CFM			
O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Compr Watt decr.
	90	*57*	*28.800*	*27.713*	*1.088*	*0.962*	*2.695*			
		58.1	*29.460*	*26.798*	*2.662*	*0.910*	*2.720*	*545*	*756*	*1301*
		59	30	26.05	3.95	0.868	2.74	568	807	1375
		59.4	*30.25*	*25.695*	*4.555*	*0.849*	*2.749*	*568*	*807*	*1375*
		63	32.5	22.5	10	0.692	2.83	614	909	1523
		67	35.2	18.5	16.7	0.526	2.92	614	920	1534
		71	37.9	14.45	23.45	0.381	3.02	na	na	na
	71	44	16.85	27.15	0.383	4.21	na		na	na

Trane TTR036C w TXA043C4 @ 1400CFM							Rate of change per F/1000 CFM			
O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Compr Watt decr.
90	*57*	*31.025*	*32.750*	*-1.725*	*1.056*	*2.805*				
	58	*31.663*	*31.675*	*-0.013*	*1.000*	*2.828*	*455*	*768*	*1223*	*16*
	59	32.3	30.6	1.7	0.947	2.85	464	821	1286	16
	59.4	*32.56*	*30.14*	*2.42*	*0.926*	*2.859*	*464*	*821*	*1286*	*16*
	63	34.9	26	8.9	0.745	2.94	482	929	1411	16
	67	37.6	20.8	16.8	0.553	3.03	518	929	1446	18
	71	40.5	15.6	24.9	0.385	3.13	na	na	na	na

Trane TTR042C w TXH060S5 @ 1600CFM							Rate of change per F/1000 CFM			
O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Compr Watt decr.
100	*57*	*37.975*	*41.438*	*-3.463*	*1.091*	*3.940*				
	57.4	*38.280*	*40.920*	*-2.640*	*1.069*	*3.956*	*477*	*809*	*1285*	*25*
	59	39.5	38.85	0.65	0.984	4.02	484	891	1375	25
	59.6	*39.965*	*37.995*	*1.97*	*0.951*	*4.044*	*484*	*891*	*1375*	*25*
	63	42.6	33.15	9.45	0.778	4.18	500	1055	1555	25
	67	45.8	26.4	19.4	0.576	4.34	516	1070	1586	25
	71	49.1	19.55	29.55	0.398	4.5	na	na	na	na

Trane TTR036C w TXA031E5 @ 1100CFM — Rate of change per F/1000 CFM

O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Comp Watt decr.
90	*57*	*29.600*	*28.725*	*0.875*	*0.970*	*2.705*				
	58.2	*30.320*	*27.660*	*2.660*	*0.912*	*2.732*	*545*	*807*	*1352*	*20*
	59	30.8	26.95	3.85	0.875	2.75	568	852	1420	20
	59.6	*31.175*	*26.3875*	*4.7875*	*0.846*	*2.7635*	*568*	*852*	*1420*	*20*
	63	33.3	23.2	10.1	0.697	2.84	614	943	1557	20
	67	36	19.05	16.95	0.529	2.93	614	955	1568	20
	71	38.7	14.85	23.85	0.384	3.02	na	na	na	na

Trane TTR036C w TXA037E5 @ 1200CFM — Rate of change per F/1000 CFM

O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Comp Watt decr.
90	*57*	*30.925*	*31.100*	*-0.175*	*1.006*	*2.755*				
	58.6	*31.945*	*29.500*	*2.445*	*0.923*	*2.791*	*531*	*833*	*1365*	*19*
	59	32.2	29.1	3.1	0.904	2.8	542	875	1417	19
	59.6	*32.59*	*28.47*	*4.12*	*0.874*	*2.8135*	*542*	*875*	*1417*	*19*
	63	34.8	24.9	9.9	0.716	2.89	563	958	1521	19
	67	37.5	20.3	17.2	0.541	2.98	583	990	1573	21
	71	40.3	15.55	24.75	0.386	3.08	na	na	na	na

Trane TTR060C w TWE060P15-C @ 2000CFM — Rate of change per F/1000 CFM

O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Comp Watt decr.
100	*57*	*45.950*	*46.400*	*-0.450*	*1.010*	*4.873*				
	58.2	*47.000*	*44.510*	*2.490*	*0.947*	*4.925*	*437*	*788*	*1225*	*22*
	59	47.7	43.25	4.45	0.907	4.96	450	831	1281	22
	59.6	*48.24*	*42.2525*	*5.9875*	*0.876*	*4.987*	*450*	*831*	*1281*	*22*
	63	51.3	36.6	14.7	0.713	5.14	475	919	1394	24
	67	55.1	29.25	25.85	0.531	5.33	475	938	1412	24
	71	58.9	21.75	37.15	0.369	5.52	na	na	na	na

Trane TTR042C w TWV039E15-C @ 1300CFM							Rate of change per F/1000 CFM			
O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Compr Watt decr.
100	*57*	*36.750*	*38.363*	*-1.613*	*1.044*	*3.848*				
	58.8	*38.055*	*36.191*	*1.864*	*0.951*	*3.913*	*558*	*928*	*1486*	*28*
	59	38.2	35.95	2.25	0.941	3.92	577	981	1558	29
	59.6	*38.65*	*35.185*	*3.465*	*0.910*	*3.9425*	*577*	*981*	*1558*	*29*
	63	41.2	30.85	10.35	0.749	4.07	615	1087	1702	31
	67	44.4	25.2	19.2	0.568	4.23	635	1106	1740	31
	71	47.7	19.45	28.25	0.408	4.39	na	na	na	na

Trane TTR042C w TWE060A @ 1600CFM							Rate of change per F/1000 CFM			
O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Compr Watt decr.
90	*57*	*37.950*	*38.800*	*-0.850*	*1.022*	*3.515*				
	58.8	*39.345*	*36.595*	*2.750*	*0.930*	*3.574*	*484*	*766*	*1250*	*20*
	59	39.5	36.35	3.15	0.920	3.58	500	813	1313	22
	59.6	*39.98*	*35.57*	*4.41*	*0.890*	*3.601*	*500*	*813*	*1313*	*22*
	63	42.7	31.15	11.55	0.730	3.72	531	906	1437	25
	67	46.1	25.35	20.75	0.550	3.88	547	938	1484	23
	71	49.6	19.35	30.25	0.390	4.03	na	na	na	na

Trane TTR042C w TWE060A @ 1600CFM							Rate of change per F/1000 CFM			
O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Compr Watt decr.
100	*57*	*36.250*	*38.175*	*-1.925*	*1.053*	*3.838*				
	58.9	*37.628*	*35.776*	*1.851*	*0.951*	*3.906*	*453*	*789*	*1242*	*23*
	59	37.7	35.65	2.05	0.946	3.91	469	828	1297	23
	59.1	*37.775*	*35.5175*	*2.2575*	*0.940*	*3.91375*	*469*	*828*	*1297*	*23*
	63	40.7	30.35	10.35	0.746	4.06	500	906	1406	25
	67	43.9	24.55	19.35	0.559	4.22	516	938	1453	25
	71	47.2	18.55	28.65	0.393	4.38	na	na	na	na

2. YORK Co.

York H1DA036 w M3CF044 @ 1290 CFM							Rate of change per F/1000 CFM			
O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Comp Watt decr.
90	57	31.15	31.15	0	1.000	3.12	*442*	*837*	*1279*	*38*
	58.6	*32.062*	*29.422*	*2.64*	*0.918*	*3.1984*	*438*	*849*	*1287*	*38*
	62	34	25.75	8.25	0.757	3.365	*434*	*860*	*1295*	*38*
	67	36.8	20.2	16.6	0.549	3.61	*442*	*na*	*na*	*38*
	72	39.65	No Data	No Data	No Data	3.855	*na*	*na*	*na*	*na*

York H1DA042 w M3UF044 @ 1500 CFM							Rate of change per F/1000 CFM			
O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Comp Watt decr.
90	57	36.95	36.95	0	1.000	3.78	*447*	*620*	*1067*	*39*
	58.9	*38.223*	*35.183*	*3.04*	*0.920*	*3.8921*	*450*	*773*	*1223*	*40*
	62	40.3	32.3	8	0.801	4.075	*453*	*927*	*1380*	*40*
	67	43.7	25.35	18.35	0.580	4.375	*447*	*na*	*na*	*39*
	72	47.05	No Data	No Data	No Data	4.67	*na*	*na*	*na*	*na*

York H1DA030 w M3UF032 @ 1060 CFM							Rate of change per F/1000 CFM			
O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Compr Watt decr.
90	57	24.8	24.8	0	1.000	2.485	*425*	*774*	*1198*	*37*
	58.6	*25.52*	*23.488*	*2.032*	*0.920*	*2.5474*	*429*	*802*	*1231*	*37*
	62	27.05	20.7	6.35	0.765	2.68	*434*	*830*	*1264*	*37*
	67	29.35	16.3	13.05	0.555	2.875	*425*	*na*	*na*	*37*
	72	31.6	No Data	No Data	No Data	3.07	*na*	*na*	*na*	*na*

3. CARRIER Co.

Carrier 38CK030 w CD5A030 @ 1000 CFM						Rate of change per F/1000 CFM				
O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Comp Watt decr.
90	57	23.7	23.7	0	1.000	2.875	*480*	*585*	*1065*	*18*
	59	*24.66*	*23.367*	*1.293*	*0.948*	*2.911*	*525*	*728*	*1253*	*21*
	59.5	*24.9*	*22.965*	*1.935*	*0.922*	*2.92*	*525*	*728*	*1253*	*21*
	62	26.1	20.777	5.323	0.796	2.965	*570*	*870*	*1440*	*23*
	67	28.95	16.425	12.525	0.567	3.08	*610*	*890*	*1500*	*24*
	72	32	11.975	20.025	0.374	3.2	*na*	*na*	*na*	*na*

Carrier 38CK042 w CD5A042 @ 1400 CFM						Rate of change per F/1000 CFM				
O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Comp Watt decr.
90	57	34.22	34.22	0	1	3.863	447	609	1056	15
	59	35.472	32.663	2.809	0.92	3.9038	506	733	1239	17
	59.5	35.785	32.242	3.543	0.90	3.914	506	733	1239	17
	62	37.35	29.955	7.395	0.80	3.965	564	857	1421	20
	67	41.3	23.955	17.345	0.58	4.105	607	936	1543	21
	72	45.55	17.405	28.145	0.38	4.255	na	na	na	na

Carrier 38CK024 w CD5A024 @ 900 CFM

O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Compr Watt decr.
90	57	19.42	19.42	0	1	2.32	418	401	818	14
	59	20.172	19.769	0.403	0.98	2.35	453	642	1095	18
	60	20.548	19.090	1.458	0.93	2.36	453	642	1095	18
	62	21.3	17.618	3.682	0.83	2.39	489	883	1372	21
	67	23.5	13.643	9.858	0.58	2.48	533	889	1422	22
	72	25.9	9.643	16.258	0.37	2.58	na	na	na	na

4. LENNOX Co.

Lennox HS23-411 w C16-41 @ 1000CFM

O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Comp Watt decr.
						Rate of change per F/1000 CFM				
90	*57*	*30564*	*30564*	0	1.00					
	58.9	*31350*	*28842*	2508	0.92	*3243*				
	59	*31699*	*28751*	2948	0.91	*3245*		*907*		*20*
	63	34934	25125	9809	0.72	3325	563	944	1507	21
	67	37184	21348	15836	0.57	3410	538	1020	1557	19
	71	39334	17270	22064	0.44	3485	na	na	na	na

* Assumptions about the SHR at 59F and 57F were made using Trane TTR030 w TWE030C14 @ 1000 CFM data

Lennox HS23-411 w C16-46 @ 1500CFM

O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Comp Watt decr.
						Rate of change per F/1000 CFM				
90	*59*	*36222*	*36222*	0	1.00	*3729*		*911*		*14*
	60.4	*37022*	*34309*	2713	*0.93*	*3758*				
	63	38507	30756	7751	0.80	3813	575	924	1307	14
	67	40807	25215	15592	0.62	3898	588	948	1340	13
	71	43157	19525	23632	0.45	3973	na	na	na	na

Lennox HS23-261 w C22-31 @ 1050CFM						Rate of change per F/1000 CFM				
O.D.B	I.W.B.	Total	Sens. @ 75	Lat @ 75	SHR	Compr KW	Total decr.	Sens incr.	Lat decr.	Compr Watt decr.
	90	*59*	*24533*	*24533*	0	1.00	*2451*		*971*	
		60.4	*24908*	*23107*	1801	*0.93*	*2464*			
		63	25604	20457	5147	0.80	2490	381	962	1343
		67	27204	16417	10787	0.60	2530	369	945	1314
		71	28754	12450	16304	0.43	2575	na	na	na

*** Assumptions about the SHR at 59F were made using Trane TTR030 w TWE043C14 @ 1100 CFM data**

Appendix F
Expected Building Sensible and Latent Load at Various Indoor Humidity Conditions

1. Typical House Manual J Load Adjustment (90 CFM Infiltration Effect, Petaluma)

SHR	Total	Sensible	Latent	Inf Latent	Indr W gr/lb	Indr.T w.b.
0.880	26322	23156	3166	1786	28.8	54.0
0.896	25830	23156	2674	1294	36.7	56.0
0.919	25189	23156	2033	653	47.0	58.5
0.920	25161	23156	2005	625	47.5	58.6
0.924	25052	23156	1896	516	49.2	59.0
0.927	24972	23156	1816	436	50.5	59.3
0.928	24947	23156	1791	411	50.9	59.4
0.929	24922	23156	1766	386	51.3	59.5
0.931	24866	23156	1710	330	52.2	59.7
0.934	24785	23156	1629	249	53.5	60.0
0.945	24511	23156	1355	-25	57.9	61.0

2. Old House Manual J Load Adjustment (121 CFM Infiltration Effect, Petaluma)

SHR	Total	Sensible	Latent	Inf Latent	Indr W gr/lb	Indr.T w.b.
0.896	33339	29884	3455	2075	32.7	55.0
0.905	33004	29884	3120	1740	36.7	56.0
0.915	32661	29884	2777	1397	40.8	57.0
0.920	32490	29884	2606	1226	42.8	57.5
0.922	32421	29884	2537	1157	43.7	57.7
0.924	32351	29884	2467	1087	44.5	57.9
0.925	32317	29884	2433	1053	44.9	58.0
0.926	32281	29884	2397	1017	45.3	58.1
0.933	32033	29884	2149	769	48.3	58.8
0.935	31958	29884	2074	694	49.2	59.0
0.937	31891	29884	2007	627	50.0	59.2
0.940	31783	29884	1899	519	51.3	59.5
0.942	31707	29884	1823	443	52.2	59.7
0.946	31599	29884	1715	335	53.5	60.0

3. Old House Manual J Load Adjustment (121 CFM Infiltration Effect, Fresno)

SHR	Total	Sensible	Latent	Inf Latent	Indr W gr/lb	Indr.T w.b.
0.888	46847	41602	5245	3865	10.5	49.0
0.899	46253	41602	4651	3271	17.6	51.0
0.912	45634	41602	4032	2652	25.0	53.0
0.925	44990	41602	3388	2008	32.7	55.0
0.939	44312	41602	2710	1330	40.8	57.0
0.942	44141	41602	2539	1159	42.8	57.5
0.946	43968	41602	2366	986	44.9	58.0
0.948	43897	41602	2295	915	45.8	58.2
0.953	43648	41602	2046	666	48.7	58.9
0.954	43609	41602	2007	627	49.2	59.0
0.958	43434	41602	1832	452	51.3	59.5
0.959	43358	41602	1756	376	52.2	59.7
0.960	43323	41602	1721	341	52.6	59.8
0.961	43287	41602	1685	305	53.1	59.9
0.962	43250	41602	1648	268	53.5	60.0

4. New House Manual J Load Adjustment (63 CFM Infiltration Effect, Petaluma)

SHR	Total	Sensible	Latent	Inf Latent	Indr W gr/lb	Indr.T w.b.
0.889	22093	19633	2460	1080	32.7	55.0
0.896	21919	19633	2286	906	36.7	56.0
0.903	21740	19633	2107	727	40.8	57.0
0.907	21652	19633	2019	639	42.8	57.5
0.910	21566	19633	1933	553	44.8	58.0
0.911	21543	19633	1910	530	45.3	58.1
0.912	21524	19633	1891	511	45.8	58.2
0.915	21450	19633	1817	437	47.5	58.6
0.916	21432	19633	1799	419	47.9	58.7
0.918	21395	19633	1762	382	48.7	58.9
0.919	21375	19633	1742	362	49.2	59.0
0.921	21318	19633	1685	305	50.5	59.3
0.922	21283	19633	1650	270	51.3	59.5
0.924	21244	19633	1611	231	52.2	59.7
0.927	21187	19633	1554	174	53.5	60.0

5. New House Manual J Load Adjustment (63 CFM Infiltration Effect, Fresno)

SHR	Total	Sensible	Latent	Inf Latent	Indr W gr/lb	Indr.T w.b.
0.893	31748	28358	3390	2010	10.5	49.0
0.902	31440	28358	3082	1702	17.6	51.0
0.911	31118	28358	2760	1380	25.0	53.0
0.921	30782	28358	2424	1044	32.7	55.0
0.932	30432	28358	2074	694	40.8	57.0
0.934	30360	28358	2002	622	42.4	57.4
0.937	30251	28358	1893	513	44.9	58.0
0.9391	30196	28358	1838	458	46.2	58.3
0.9397	30177	28358	1819	439	46.6	58.4
0.9403	30159	28358	1801	421	47.0	58.5
0.943	30066	28358	1708	328	49.2	59.0
0.944	30048	28358	1690	310	49.6	59.1
0.944	30029	28358	1671	291	50.0	59.2
0.947	29934	28358	1576	196	52.2	59.7
0.949	29878	28358	1520	140	53.5	60.0

6. Massive House Manual J Load Adjustment (81 CFM Infiltration Effect, Fresno)

SHR	Total	Sensible	Latent	Inf Latent	Indr W gr/lb	Indr.T w.b.
0.886	34685	30718	3967	2587	10.5	49.0
0.896	34288	30718	3570	2190	17.6	51.0
0.907	33873	30718	3155	1775	25.0	53.0
0.919	33442	30718	2724	1344	32.7	55.0
0.931	32988	30718	2270	890	40.8	57.0
0.932	32944	30718	2226	846	41.6	57.2
0.934	32874	30718	2156	776	42.8	57.5
0.945	32518	30718	1800	420	49.2	59.0
0.948	32400	30718	1682	302	51.3	59.5
0.949	32375	30718	1657	277	51.8	59.6
0.950	32350	30718	1632	252	52.2	59.7
0.952	32277	30718	1559	179	53.5	60.0
0.959	32031	30718	1313	-67	57.9	61.0

Appendix G
Oversizing Margins Calculated

1. Equipment Selection per Manual S* (or ASHRAE).

	SELECTION		Estimated Performance @ Real Cond. Adjusted per manufacturer's recommendations									Oversizing, %		
	Outdoor Model	Indoor Coil	Balance Point	Total	Sensible	Latent	Watt	EER	SHR ac	SHR hs	Total	Sens.	Latent
1. Typical, Petaluma, W	TTR036C	TXA043C4 @ 1400CFM	75/58.8/90	32560	30140	2420	3651	8.92	0.93	0.93	31	30	35
2. Old, Petaluma, N	TTR042C	TXA049C4 @ 1600CFM	75/59.4/90	39138	36504	2634	4429	8.84	0.93	0.93	22	22	23
3. Old, Fresno, N	TTR060C	TXH060S5 @ 2000CFM	75/59/100	51600	49300	2300	6169	8.36	0.955	0.954	18	19	15
4. M-JNew, Petaluma, N	38CK030	Stndrd. CD5A030	75/59.5/90	24900	22965	1935	2920	8.53	0.92	0.92	17	17	17
4. New, Petaluma, N	TTR036C	TXA031C4 @ 1100CFM	75/58.1/90	29460	26798	2662	3422	8.61	0.91	0.91	37	36	39
4. ComplyNew, Petaluma, N	H1DA036	M3CF044 @ 1290 CFM	75/58.6/90	32062	29422	2640	3198	10.02	0.92	0.92	49	50	45
4. LnxNew, Petaluma, N	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5. New, Fresno, E	TTR042C	TXC060C5 @ 1600CFM	75/59.2/100	37850	35630	2220	4754	7.96	0.94	0.94	26	26	33
6. Massive, Fresno, N	TTR042C	TXH060S5 @ 1600CFM	75/59.6/100	39965	37995	1970	4850	8.24	0.95	0.95	23	24	19

4. Equipment Selection Based on "Rules of Thumb" Method.

	SELECTION			Estimated Performance @ Real Cond. Adjusted per manufacturer's recommendations								**Oversizing, %**		
	Outdoor Model	Indoor Coil	CFM	Balance Point	Total	Sensible	Latent	Watt	EER	SHR ac	SHR hs	**Total**	**Sens.**	**Latent**
1. Typical, Petaluma, V	TTR036C	TXC048C4	1400	75/59.7/90	32855	30501	2354	3668	8.96	0.93	0.93	**32**	**32**	**38**
2. Old, Petaluma, N	TTR042C	TWE042C14	1400	75/57.9/90	36748	33869	2879	4270	8.61	0.92	0.92	**14**	**13**	**17**
3. Old, Fresno, N	TTR042C	TWE060A	1600	75/58.9/100	37628	35776	1851	4522	8.32	0.95	0.95	**-14**	**-14**	**-10**
4. M-JNew, Petaluma,	38CK042	Stndrd. CD5A042	1400	75/59/90	35472	32663	2809	3904	9.09	0.92	0.92	**66**	**66**	**61**
4. New, Petaluma, N	TTR042C	TWE042C14	1400	75/58.1/90	36903	33656	3246	4277	8.63	0.91	0.91	**71**	**71**	**70**
4. ComplyNew, Petalu	H1DA042	M3UF044	1500	75/58.9/90	38223	35183	3040	3892	9.82	0.92	0.92	**79**	**79**	**73**
4. LnxNew, Petaluma,	HS23-411	C16-46	1500	75/60.4/90	37022	34309	2713	3758	9.85	0.93	0.93	**75**	**75**	**84**
5. New, Fresno, E	TTR042C	TWE060A	1600	75/59.1/100	37775	35518	2258	4530	8.34	0.94	0.94	**26**	**25**	**34**
6. Massive, Fresno, N	TTR042C	TXC036F4	1200	75/57.5/100	33594	31275	2319	4385	7.66	0.93	0.93	**2**	**2**	**8**

2. Equipment Selection at Standard Design Indoor Conditions.

Load per Trane , unless noted differently

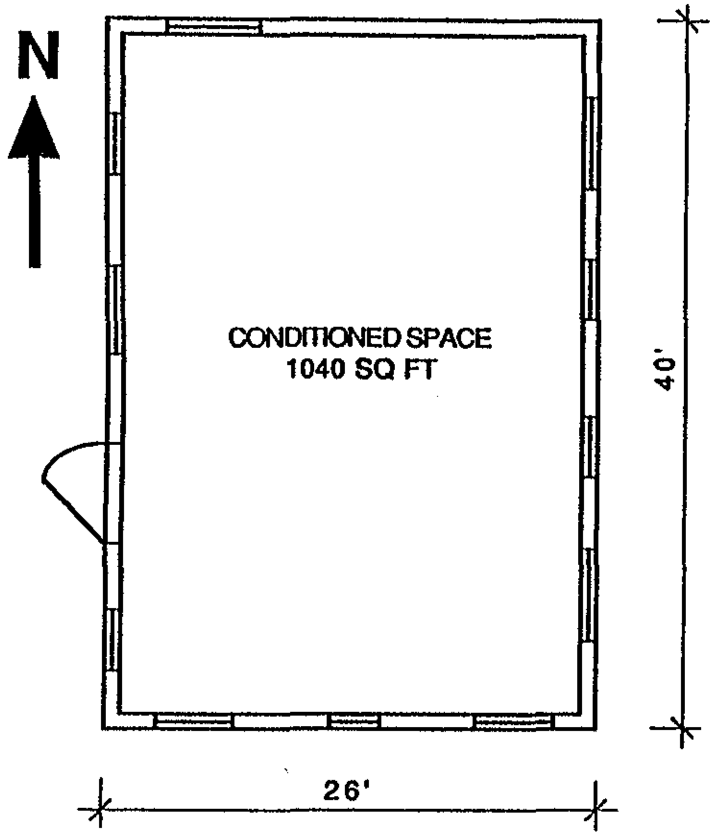
	SELECTION			Estimated Performance @ Real Cond. Adjusted per manufacturer's recommendations								Oversizing, %		
	CFM	Outdoor Model	Indoor Coil	Balance Point	Total	Sensible	Latent	Watt	EER	SHR ac	SHR hs	Total	Sens.	Latent
1. Typical, Petaluma, W	1200	TTR036C	TXA037E5	75/58.6/90	31945	29500	2445	3533	9.04	0.92	0.92	27	27	22
2. Old, Petaluma, N	1600	TTR042C	TWE060A	75/58.6/90	39345	36595	2750	4190	9.39	0.93	0.93	23	22	28
3. Old, Fresno, N	2000	TTR060C	TWE060P15-C	75/58.2/100	47000	44510	2490	6144	7.65	0.95	0.95	7	7	9
4. M-JNew, Petaluma, N	1000	38CK030	Stndrd. CD5A030	75/59.5/90	24900	22965	1935	2920	8.53	0.92	0.92	17	17	17
4. New, Petaluma, N	1100	TTR036C	TXA031E5	75/58.2/90	30320	27660	2660	3434	8.83	0.91	0.91	41	41	41
4. ComplyNew, Petaluma,	1290	H1DA036	M3CF044	75/58.6/90	32062	29422	2640	3198	10.02	0.92	0.92	49	50	45
4. LnxNew, Petaluma, N	1000	HS23-411	C16-41	75/58.9/90	31350	28842	2508	3243	9.67	0.92	0.92	47	47	42
5. New, Fresno, E	1300	TTR042C	TWV039E15-C	75/59/100	38200	35950	2250	4496	8.50	0.94	0.94	27	27	32
6. Massive, Fresno, N	1600	TTR042C	TWH064P15-C	75/60/100	41375	39312.5	2062.5	4904	8.44	0.95	0.95	28	28	32

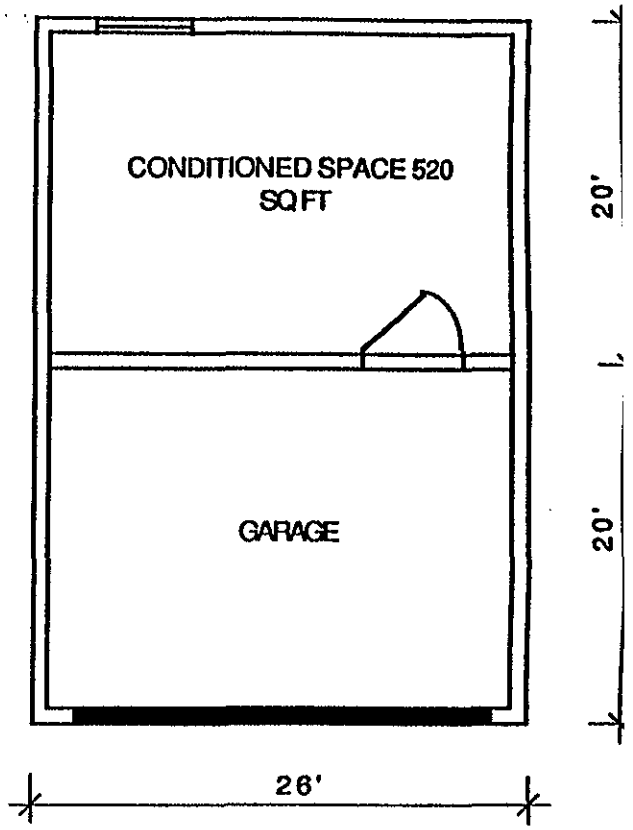
3. Equipment Selection Based on Total Capacity.

Load per Trane , unless noted differently

	SELECTION			Estimated Performance @ Real Cond. Adjusted per manufacturer's recommendations								**Oversizing, %**		
	Outdoor Model	Indoor Coil	CFM	Balance Point	Total	Sensible	Latent	Watt	EER	SHR ac	SHR hs	**Total**	**Sens.**	**Latent**
1. Typical, Petaluma, W	TTR030C	TXC043C4	1100	75/59.4/90	26730	24825	1905	3033	8.81	0.93	0.93	**7**	**7**	**6**
2. Old, Petaluma, N	TTR036C	TWE036C14	1200	75/58/90	30063	27894	2169	3500	8.59	0.93	0.93	**-7**	**-7**	**-11**
3. Old, Fresno, N	TTR042C	TWV064P15-C	1600	75/59.8/100	41240	39590	1650	4906	8.41	0.96	0.96	**-5**	**-5**	**-2**
4. M-JNew, Petaluma, N	38CK024	Stndrd. CD5A024	900	75/60/90	20548	19090	1458	2359	8.71	0.93	0.93	**-3**	**-3**	**-6**
4. New, Petaluma, N	TTR030C	TWE030C14	1000	75/58.7/90	24428	22418	2010	2868	8.52	0.92	0.92	**14**	**14**	**12**
4. ComplyNew, Petaluma,	H1DA030	M3UF032	1060	75/58.6/90	25520	23488	2032	2547	10.02	0.92	0.92	**19**	**20**	**12**
4. LnxNew, Petaluma, N	HS23-261	C22-31	1050	75/60.4/90	24908	23107	1801	2464	10.11	0.93	0.93	**18**	**18**	**22**
5. New, Fresno, E	TTR036C	TXC049C4	1400	75/59.7/100	31138	29463	1675	3918	7.95	0.95	0.95	**4**	**4**	**6**
6. Massive, Fresno, N	TTR042C	TXC036F4	1200	75/57.5/100	33594	31275	2319	4385	7.66	0.93	0.93	**2**	**2**	**8**

Appendix H Model Building Data





(2) **TYPICAL BUILDING**
Second Floor. Height 8 ft

(1) **TYPICAL BUILDING**
First Floor. Height10 ft

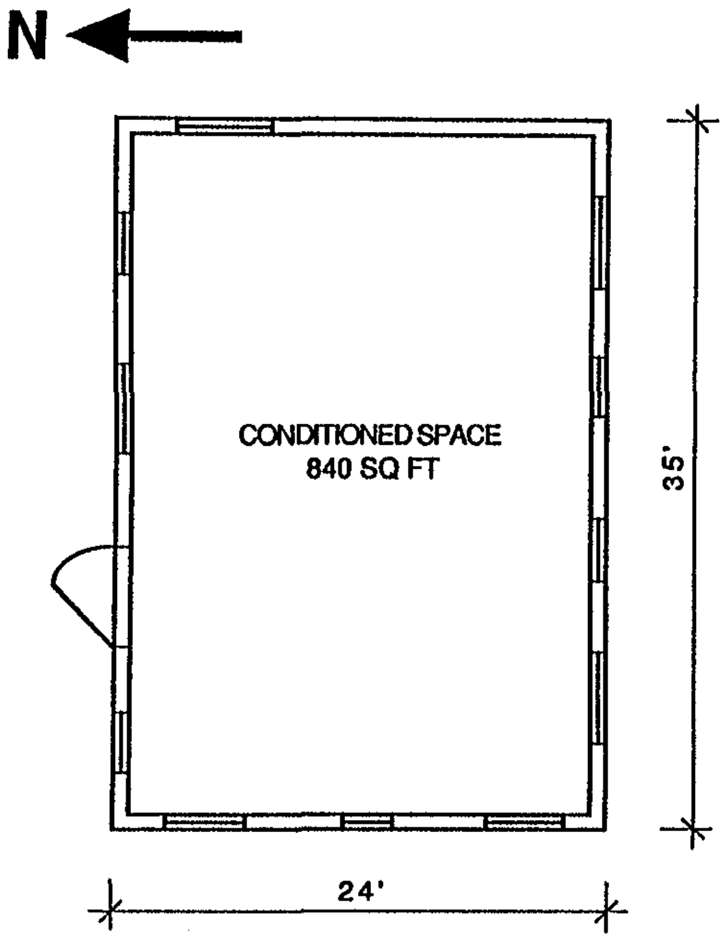
Table 1. Building Description. Typical Building

Building Characteristic	Description
Type	Residential, single family, detached
Location	Petaluma, CA and Fresno, CA
Orientation	Main Entrance faces West
Inside Design Conditions	75°F temperature, 50% RH
Number of Occupants	6
Ducts	In attic, R-2.1 insulation
Lights and Appliances	1200 (standard recommended)
Tightness	Average. Conventional construction. Door: Small perimeter gap having stop trim fitting properly around door and weather-stripped. Windows: Vertical sliding, weather-stripped. Certified to have a tested leak between 0.25 and 0.5 CFM per running foot of crack
Interior Mass	Normal
Roof/Ceiling	Dark roof over ventilated attic. R-19 ceiling insulation; 2-in x 8-in, 16-in on center joist
Wall	Wood frame, 2-in x 4-in, 16 on center. R-11 insulation, 0.85-in stucco, building paper, 0.5-in gyp board
Floor	R-11 insulation, 2-in x 6-in, 16-in on center, 0.625-in plywood, carpet and pad
Window	Clear, manufactured, single glazed, metal frame, sliding, no thermal. brake
Interior Shading	Light drapes
Exterior Shading	None
Door	Solid wood, no storm, 1.25-in

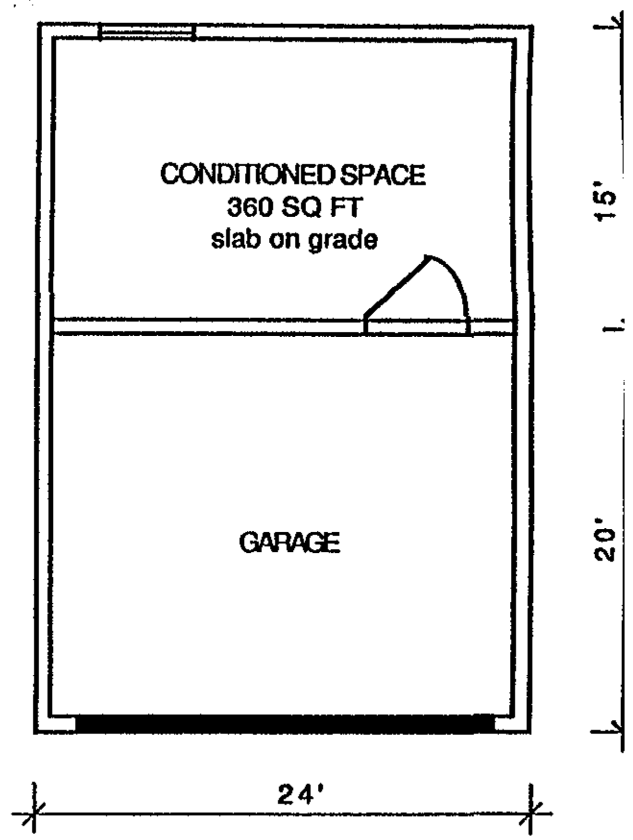
Table 1. Building Description (continued). Old Building

Building Characteristic	Description
Type	Residential, single family, detached
Location	Petaluma, CA and Fresno, CA
Orientation	Main Entrance faces North
Inside Design Conditions	75°F temperature, 50% RH
Number of Occupants	6
Ducts	In attic, No insulation
Lights and Appliances	1200 (standard recommended)
Tightness	Poor. Old building. Non-weather-stripped sliding windows
Interior Mass	Normal
Roof/Ceiling	Dark roof over ventilated attic. R-11 ceiling insulation; 2-in x 8-in, 16-in on center joist
Wall	Wood frame, 2-in x 4-in, 16 on center. No insulation, 0.85-in stucco, building paper, 0.5-in gyp board
Floor	No insulation, 2-in x 6-in, 16-in on center, 0.625-in plywood, carpet and pad
Window	Clear, manufactured, single glazed, metal frame, sliding, no thermal. brake
Interior Shading	None
Exterior Shading	None
Door	Solid wood, no storm, 1.25-in

94.127A

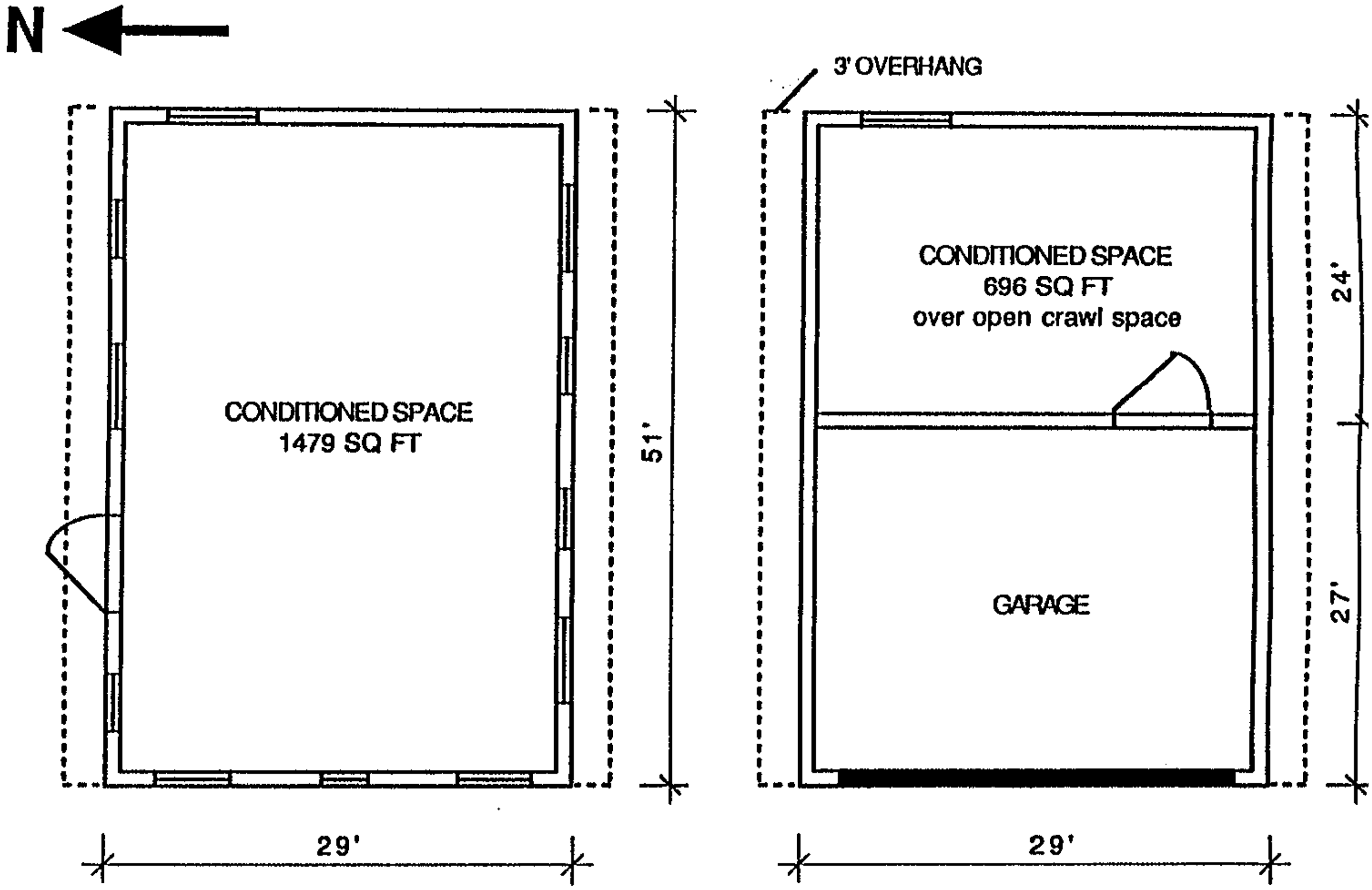


2 OLD BUILDING
Second Floor. Height 8 ft



1 OLD BUILDING
First Floor. Height10 ft

94.127A



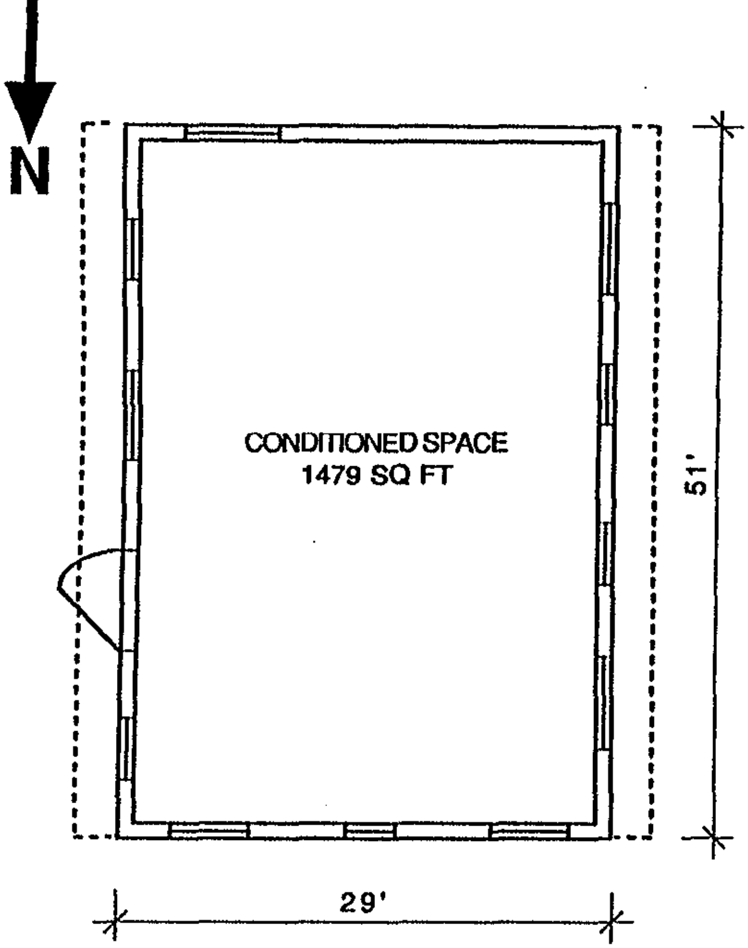
(2) NEW BUILDING, N
Second Floor. Height 8 ft

(1) NEW BUILDING, N
First Floor. Height10 ft

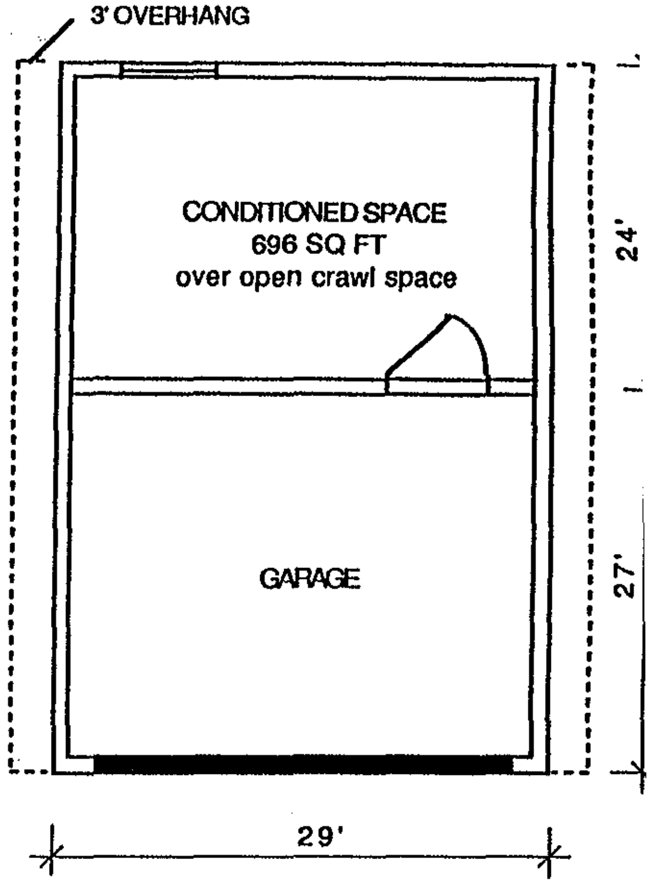
Table 1. Building Description (continued). New Building

Building Characteristic	Description
Type	Residential, single family, detached
Location	Petaluma, CA and Fresno, CA
Orientation	Main Entrance faces North in Petaluma, East in Fresno
Inside Design Conditions	75°F temperature, 50% RH
Number of Occupants	6
Ducts	In attic, R-4 insulation
Lights and Appliances	1200 (standard recommended)
Tightness	Tight. New construction. Wooden, weather stripped windows
Interior Mass	Normal
Roof/Ceiling	Dark roof over ventilated attic. R-30 ceiling insulation; 2-in x 8-in, 16-in on center joist
Wall	Wood frame, 2-in x 4-in, 16 on center. R-13 insulation, 0.85-in stucco, building paper, 0.5-in gyp board
Floor	R-19 insulation, 2-in x 6-in, 16-in on center, 0.625-in plywood, carpet and pad
Window	Clear, manufactured, double glazed, wooden frame, casement
Interior Shading	Light drapes
Exterior Shading	3' overhang 0.5' above 6' high windows on building long axes.
Door	Solid wood, no storm, 2-in

94127A



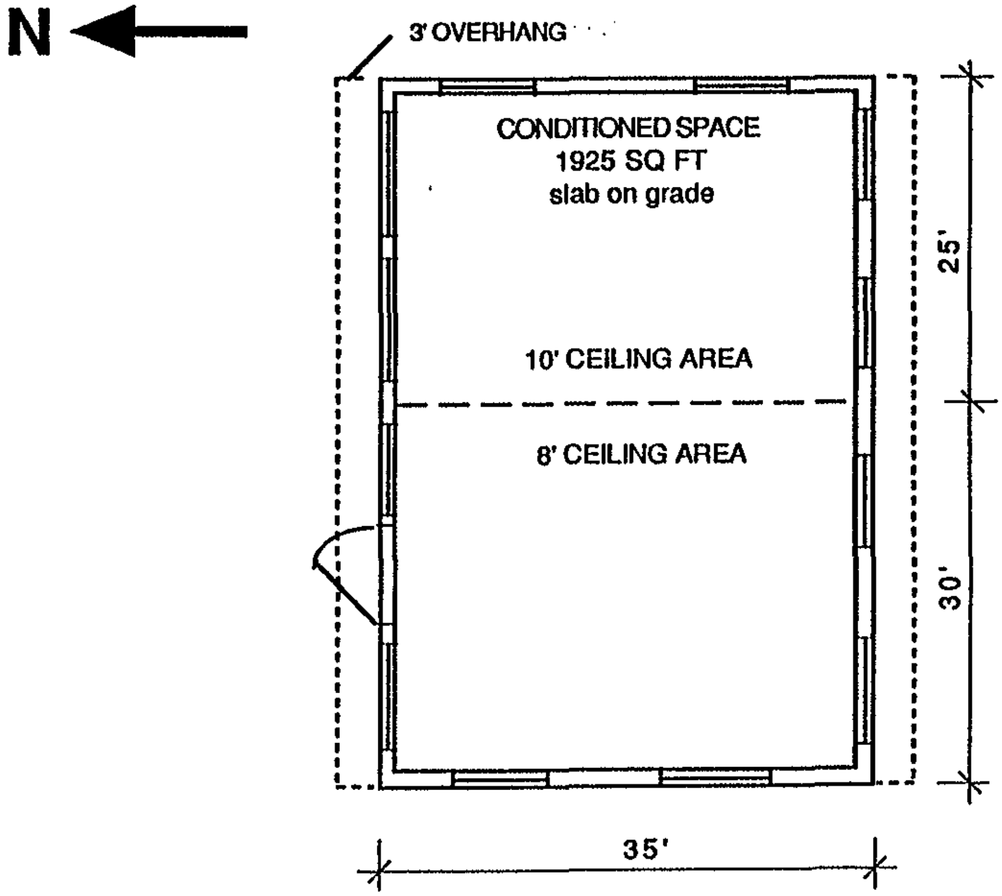
2 NEW BUILDING, E
Second Floor. Height 8 ft



1 NEW BUILDING, E
First Floor. Height10 ft

Table 1. Building Description (continued). Massive Building

Building Characteristic	Description
Type	Residential, single family, detached
Location	Fresno, CA
Orientation	Main Entrance faces North
Inside Design Conditions	75°F temperature, 50% RH
Number of Occupants	6
Ducts	In attic, R-4 insulation
Lights and Appliances	1200 (standard recommended)
Tightness	Tight. New construction. Wooden, weather stripped windows
Interior Mass	Floors covered by 0.5-in tile on mortar bed
Roof/Ceiling	Dark roof over ventilated attic. R-30 ceiling insulation; 2-in x 8-in, 16-in on center joist
Wall	Wood frame, 2-in x 4-in, 16 on center. R-13 insulation, 0.85-in stucco, building paper, 0.5-in gyp board
Floor	R-19 insulation, 2-in x 6-in, 16-in on center, 0.625-in plywood, carpet and pad
Window	Clear, manufactured, double glazed, wooden frame, casement
Interior Shading	Light drapes
Exterior Shading	3' overhang 0.5' above 6' high windows on building long axes.
Door	Solid wood, no storm, 2-in



1 MASSIVE BUILDING

Table 2. Building Dimensions

Building name	TYPICAL	OLD	NEW (North)	NEW (East)	MASSIVE
			Petaluma	Fresno	
Conditioned Floor Area, ft^2	1560	1200	2175	2175	1925
Conditioned Volume, ft^3	13520	10320	18792	18792	24150
Exterior Wall Area, ft^2					
North (0 Deg.)	468	430	648	232	690
South (180 Deg.)	208	430	648	522	690
West (90 Deg.)	520	192	232	648	630
East (270 Deg.)	520	432	522	648	630
Total	1716	1484	2050	2050	2640
Exterior Window Area, ft^2					
North (0 Deg.)	45	80	130	50	170
South (180 Deg.)	40	60	110	60	150
West (90 Deg.)	90	30	50	110	70
East (270 Deg.)	75	30	60	130	85
Total	250	200	350	350	475
Partition Area, ft^2	260	240	290	290	0
Exterior. Door Area, ft^2					
North (0 Deg.)		24	24	24	24
South (180 Deg.)					
West (90 Deg.)	24				
East (270 Deg.)					
Ceiling Area, ft^2	1040	840	1479	1479	1925
Ducts in attic	65%	65%	65%	65%	65%
Slab Floor Area, ft^2	0	360	0	0	1925
Slab perimeter, ft^2	0	78	0	0	180
Raised Floor Area, ft^2					
Over garage	520	480	783	783	0
Over open crawl space	520	0	696	696	0

Appendix I
Manual J and ASHRAE Prototype Building Loads

Manual J and ASHRAE CLTD/CLF methods were initially used to calculate loads for the prototype building/climate combinations. The load calculated with Manual J is usually larger and was selected as a benchmark for the comparisons in this study. Table I-1 summarizes the Manual J and ASHRAE prototype building loads.

Table I-1. Manual J and ASHRAE CLTD/CLF Loads

Building Name	Location	Manual J Load		ASHRAE Load	
		Sensible	Latent	Sensible	Latent
Typical	Petaluma	23156	1380	19904	0
Typical	Fresno	30316	1380	NA	NA
Old	Petaluma	29884	1380	25975	0
Old	Fresno	41602	1380	37584	0
New	Petaluma	19633	1380	18234	0
New	Fresno	28358	1380	26784	0
Massive	Fresno	30718	1380	30966	0

As shown in the table, ASHRAE latent load is 0 for the selected locations. ASHRAE (1993 Handbook of Fundamentals p. 25.4) estimates the total load by a multiplier to the sensible load. For locations with a humidity ratio of less than 0.01, the multiplier is 2 (net latent load = 0). Fresno and Petaluma have humidity ratios of 0.008 and 0.0082 respectively.

Appendix J
Presentation of Air Conditioner Performance Data by Major Manufacturers

Each manufacturer publishes air conditioner performance data in a different format. None of these manufacturers publish performance data for the actual conditions expected in PG&E's service territiory under design conditions.

CARRIER

The Carrier catalog shows data for each unit with the most common coil. Table J-1 illustrates the type of data given in the Carrier catalog. Multipliers are provided for determining the unit performance with other indoor coils.

Table J-1. Presentation of AC Performance Data by Carrier Co.

EVAPORATOR AIR		CONDENSER ENTERING AIR TEMPERATURES °F						
		75			85	95	105	115
CFM	Wet Bulb Temp.,°F	Capacity MBtuh		Total KW				
		Total	Sens.					
1000	72	33.0	16.5	3.10	Details Repeated @ Higher Temperatures			
	67	29.9	21.0	2.99	Details Repeated @ Higher Temperatures			
	62	27.0	25.2	2.88	Details Repeated @ Higher Temperatures			
	57	26.1	26.1	2.84	Details Repeated @ Higher Temperatures			
1125	72	Details Repeated @ Higher Air Flow Rate For All Indoor Wet Bulb Temperatures and All Outdoor Temperatures						
1350	72	Details Repeated @ Higher Air Flow Rate For All Indoor Wet Bulb Temperatures and All Outdoor Temperatures						

Data is shown for three different entering air flows and five condenser entering air temperatures from 75°F to 115°F in 10°F increments. Total and sensible capacities are net capacities with the blower heat subtracted. Sensible capacities are based on 80°F entering air at the indoor coil. The manufacturer recommends deducting 835 Btuh from the sensible capacity per 1000 CFM of indoor coil air for each degree below 80°F implying that the total capacity will be the same for the same wet bulb temperature.

The above adjustment is not applicable for sensible capacities at low wet bulb temperatures. Dry coil conditions require a different adjustment factor that is not stated in the catalog.

TRANE

Data in the Trane Co. catalog are presented for each combination of outdoor unit and indoor unit at nominal air flow. Multipliers are provided for the capacities and compressor kW at other airflows. The unit performance is shown for outdoor temperatures from 85°F to 115°F in 5°F increments, indoor dry bulb temperatures from 72°F to 80°F, and wet bulb temperatures from 59°F to 71°F. This is illustrated in Table J-2.

Table J-2. Presentation of AC Performance Data by Trane Co.

Outside D.B. Temp.	Inside W.B. Temp.	Total Cap.	Sens. Cap. at Entering D.B. Temp.					Compr. KW
			72	74	76	78	80	
85	59	42.0	33.5	36.4	39.2	42.2	43.3	3.21
	63	45.6	28.1	30.9	33.8	36.6	39.5	3.32
	67	49.4	22.0	24.8	27.7	30.5	33.4	3.44
90	71	All Details Repeated in 5°F Increments of Outdoor Temperature						

YORK

The York Co. catalog provides data for each outdoor unit/indoor coil combination at nominal airflow. Multipliers are provided for alternative airflows. Unit performance is shown for outdoor temperatures from 85°F to 115°F in 10°F increments, indoor dry bulb temperatures from 70°F to 85°F in 5°F increments, and wet bulb temperatures from 57°F to 72°F. This is illustrated in Table J-3.

Table J-3. Presentation of AC Performance Data by York Co.

	Evaporator Entering Conditions						
Outdoor D.B. Temp.	W.B. Temp.		Dry Bulb Temperature				System KW
			70	75	80	85	
		System Capacity, MBH					
		Total	Sensible				
95	72	58.0	NA	NA	28.3	36.1	4.9
	67	54.0	NA	28.7	36.5	43.6	4.6
	62	50.0	29.0	36.8	43.9	50.0	4.29
	57	46.0	37.2	46.0	46.0	46.0	3.99
105	72	All Details Repeated in 10°F Increments of Outdoor Temperature					

The numbers provided for the lower wet bulb temperatures are suspect. For example, at 95°F outdoor temperature and 57°F wet bulb temperature the sensible capacity of 46.0 MBH is shown to be the same at any indoor dry bulb temperature higher than 70°F. With a dry coil, the sensible capacity will be greater at higher indoor dry bulb temperatures. Additionally at dry coil conditions the unit performance is listed as strongly dependant on wet bulb temperature. For example, at 95°F outdoor temperature, 85°F indoor dry bulb, and 62°F wet bulb temperature the sensible capacity is shown as 50.0 MBH, while at 57°F wet bulb it is shown as 46.0 MBH. It is not likely that the capacity is effected by wet bulb temperatures once there is no latent capacity.

LENNOX

The Lennox Co. catalog shows data for each outdoor unit with the corresponding coil at different airflows. Unit performance is shown for outdoor temperatures from 85°F to 115°F in 10°F increments, indoor dry bulb temperatures from 75°F to 85°F, and wet bulb temperatures from 63°F to 71°F This is illustrated in Table J-4.

Table J-4. Presentation of AC Performance Data by Lennox Co.

Enter. Wet Bulb °F	Air Vol. CFM	Outdoor Air Temp. Entering Condenser, °F							
		85					95	105	115
		Total Cool. Cap.	Comp. Motor Watts	Sensible To Total Ratio					
				Dry Bulb Temp. °F					
				75	80	85			
63	1000	36700	2990	0.71	.85	.97	Details Repeated		
	1200	38300	3040	0.75	.89	1.00	Details Repeated		
	1400	39500	3080	.78	.94	1.00	Details Repeated		
67	Details Repeated								
71	Details Repeated								

Sensible and latent capacities are not shown in the catalog and are determined from the sensible to total ratio. All values are gross capacities and do not include evaporator blower motor heat deduction.