Process Loads and their impact on PHPP Calculations

Adam Cohen, *~ notes from the field ~*

A guiding goal of an energy modeler is to construct a realistic projection of the energy use of a building. When one is working on the energy model of a Passive House commercial building, there are many issues that confront an energy modeler. These issues potentially include such things as: diverse occupancy profiles, large scale diversity in zonal heat gain and loss, accurate prediction of occupant schedule and process load accounting. This article is intended to open a discussion on the latter; process loads and their impact on PHPP calculations.

For the energy modeler, the first and arguably most basic understanding of any energy modeling tool is to understand what it is doing “behind the curtain”. Luckily, the PHPP is transparent in that respect. Second, and probably the most important item to understand, are the limitations of the tools being used. Here the PHPP has some very real shortcomings. To start with, as a static program, the PHPP has only rudimentary ability to look at a schedule of loads. I find that the built in “non-dom” or commercial side of the PHPP is adequate for generalized prediction of loads of building types with very static use, such as office buildings and school classrooms, but as soon as one crosses the threshold to a more diverse usage in buildings such as churches, theaters, school cafeterias or medical clinics, supplementary calculations outside of the PHPP are required for accurate load prediction. These calculations become critical in understanding both the interior heat gains (IHG) and primary energy (PE) of the building being modeled.

There are quite a range of topics that can and should be discussed regarding these calculations, but this article is limited in scope to process loads, so those other discussions will be left for another time. The first issue is defining a process vs non-process load. ASHRAE provides only limited guidance on the definition of process loads, stating that it is *"the energy consumed in support of manufacturing, industrial or commercial processes not related to the comfort and amenities of the building's occupants."* Not a very precise definition. For further definition one can look into the LEED definition, *“The load on a building resulting from the consumption or release of process energy. (ASHRAE. (2010). ANSI/ASHRAE Standard 90.1-2010: Energy Standard for Buildings Except Low-Rise Residential Buildings. Atlanta, GA: American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc.)”*, once again not very informative.

For the purpose of this discussion, process energy is considered to include all energy used above base usage for a typical commercial building. For commercial construction, this includes but is not limited to; equipment beyond the scope of general office and general miscellaneous equipment, kitchen cooking, kitchen hood exhaust and refrigeration, laundry washing and drying, lighting beyond general space lighting (e.g., lighting integral to medical equipment), industrial equipment, medical equipment and other items related to the specialized usage of the building (e.g., water pumps for process water, etc.).

Non-process or base energy includes general lighting (such as for the interior, parking garage, surface parking, facade, or building grounds, except as noted above), HVAC (such as for ventilation, space heating, space cooling, fans, pumps, toilet exhaust, parking garage ventilation, etc.), service water heating for domestic or space heating purposes, general office and general miscellaneous equipment, computers, elevators and escalators, small break room type kitchen cooking and refrigeration and general plug loads for small auxiliary electric such as copiers, printers, task lighting, etc.

Now let's look at how process loads are defined in the PHPP. The PHPP energy definition is as follows:

> *"Total specific primary energy demand* ≤ 120 kWh/(m²yr)*
> ** The primary energy demand includes the energy demand for heating, cooling, hot water, ventilation, auxiliary electricity, lighting and **all other uses of electricity.** The limits set above for the specific useful cooling demand and the primary energy demand apply for schools and buildings with similar utilization patterns.*
> *These values are to be **used as a basis** but may need to be **adjusted** according to **building use**. In individual cases for which very high internal heat loads occur, **these values may also be exceeded** upon consultation with Passive House Institute. In such cases, proof of efficient electrical energy use is necessary."*

As far as PHPP is concerned, process loads are just another part of the overall energy load and the allowable amount of primary energy may be adjusted to account for the building type being certified. This definition has led to a prototype certification process, wherein best practices are defined by building type and each specific project type is examined on the basis of these best practices. While the certification criteria is an interesting philosophical discussion, as an energy modeler I want to know how to accurately predict the energy usage and heat gain implications of process load.

In assessing process load, the first step is to create an accurate use profile for the equipment. This means constructing a schedule for each piece of equipment which includes their time of use, the energy used during operation, an approximation of the interior heat gain characteristics of the equipment (i.e., a vacuum pump with dedicated intake and exhaust will have less impact on IHG than one that draws intake and exhausts to a mechanical room within the envelope or an LED lamp has much less percent of its energy as radiant heat than a halogen lamp).

Creating an accurate use profile can be simple or complex, the following are examples of initial occupancy schedules for a simple and complex building occupancy pattern.

	Opening		Treatment		Lunch		Treatment		Closing			
	7:30am - 8am		8am - 1pm		1pm - 2 pm		2pm - 5 pm		5pm - 5:30pm			
Hours	0.5		5		1		3		0.5			
Monday											10	Occupied Hours
	Office Staff	4	Office Staff	4	Office Staff	4	Office Staff	4	Office Staff	4		
	Doctors	3	Doctors	3	Doctors	3	Doctors	3	Doctors	3		
	Doctor's Assistant	3	Doctor's Assistant	3	Doctor's Assistant	3	Doctor's Assistant	3	Doctor's Assistant	3		
	Hygienists	4	Hygienists	4	Hygienists	4	Hygienists	4	Hygienists	4		
	Patients (treatment)	0	Patients (treatment)	7	Patients (treatment)	0	Patients (treatment)	7	Patients (treatment)	0		
	Patients (waiting)	0	Patients (waiting)	7	Patients (waiting)	0	Patients (waiting)	7	Patients (waiting)	0		
		14		28		14		28		14		
Teusday											10	Occupied Hours
	Office Staff	4	Office Staff	4	Office Staff	4	Office Staff	4	Office Staff	4		
	Doctors	3	Doctors	3	Doctors	3	Doctors	3	Doctors	3		
	Doctor's Assistant	3	Doctor's Assistant	3	Doctor's Assistant	3	Doctor's Assistant	3	Doctor's Assistant	3		
	Hygienists	5	Hygienists	5	Hygienists	5	Hygienists	5	Hygienists	5		
	Patients (treatment)	0	Patients (treatment)	8	Patients (treatment)	0	Patients (treatment)	8	Patients (treatment)	0		
	Patients (waiting)	0	Patients (waiting)	8	Patients (waiting)	0	Patients (waiting)	8	Patients (waiting)	0		
		15		31		15		31		15		
Wednesday											10	Occupied Hours
	Office Staff	4	Office Staff	4	Office Staff	4	Office Staff	4	Office Staff	4		
	Doctors	3	Doctors	3	Doctors	3	Doctors	3	Doctors	3		
	Doctor's Assistant	3	Doctor's Assistant	3	Doctor's Assistant	3	Doctor's Assistant	3	Doctor's Assistant	3		
	Hygienists	5	Hygienists	5	Hygienists	5	Hygienists	5	Hygienists	5		
	Patients (treatment)	0	Patients (treatment)	8	Patients (treatment)	0	Patients (treatment)	8	Patients (treatment)	0		
	Patients (waiting)	0	Patients (waiting)	8	Patients (waiting)	0	Patients (waiting)	8	Patients (waiting)	0		
		15		31		15		31		15		
Thursday											10	Occupied Hours
	Office Staff	4	Office Staff	4	Office Staff	4	Office Staff	4	Office Staff	4		
	Doctors	3	Doctors	3	Doctors	3	Doctors	3	Doctors	3		
	Doctor's Assistant	3	Doctor's Assistant	3	Doctor's Assistant	3	Doctor's Assistant	3	Doctor's Assistant	3		
	Hygienists	5	Hygienists	5	Hygienists	5	Hygienists	5	Hygienists	5		
	Patients (treatment)	0	Patients (treatment)	8	Patients (treatment)	0	Patients (treatment)	8	Patients (treatment)	0		
	Patients (waiting)	0	Patients (waiting)	8	Patients (waiting)	0	Patients (waiting)	8	Patients (waiting)	0		
		15		31		15		31		15		
Friday											6	Occupied Hours
	Office Staff	4	Office Staff	4	Office Staff	0	Office Staff	0	Office Staff	4		
	Doctors	2	Doctors	2	Doctors	0	Doctors	0	Doctors	2		
	Doctor's Assistant	2	Doctor's Assistant	2	Doctor's Assistant	0	Doctor's Assistant	0	Doctor's Assistant	2		
	Hygienists	1	Hygienists	1	Hygienists	0	Hygienists	0	Hygienists	1		
		9		15		0		0		9		
											46	Occupied Hours

Figure 1- Simple Occupancy Schedule for Medical Office

			Days							Time of Use						Usage Months													
Event	Event Type	Notes	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Open	Close	Hours / Day	Days / Week	# WEEKS	Total # HOURS	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Estimated # Occupants	Notes
SPRING SHOW	Auditions				x	x	x			6:00 PM	11:00 PM	5.00	3	1	15		x											65	Includes Staff
SPRING SHOW	Rehersal		x							2:00 PM	11:00 PM	9.00	1	6	54			x	x									65	Includes Staff
SPRING SHOW	Rehersal			x	x	x				7:00 PM	11:00 PM	4.00	3	6	72			x	x									65	Includes Staff
SPRING SHOW	Rehersal	Tech Week		x	x	x	x			6:00 PM	11:00 PM	5.00	4	1	20					x								90	Includes Staff + crew+cast
SPRING SHOW	Rehersal	Tech Week	x							10:00 AM	11:00 PM	13.00	1	1	13				x									97	Includes Staff +crew+band+cast
SPRING SHOW	Performance	1,2,3 Week	x							1:00 PM	6:00 PM	5.00	1	3	15					x								370	Audience, cast, Front of house, crew, band
SPRING SHOW	Performance	1st Week					x	x	x	6:00 PM	11:00 PM	5.00	3	1	15					x								370	Audience, cast, Front of house, crew, band
SPRING SHOW	Performance	2nd Week					x	x	x	6:00 PM	11:00 PM	5.00	3	1	15					x								370	Audience, cast, Front of house, crew, band
SPRING SHOW	Performance	3rd Week					x	x	x	6:00 PM	11:00 PM	5.00	3	1	15					x								370	Audience, cast, Front of house, crew, band
AFTER SCHOOL YOUTH THEATRE MUSICAL/WINTER	Auditions			x	x	x				6:00 PM	9:00 PM	3.00	3	1	9												x	55	Includes Staff
AFTER SCHOOL YOUTH THEATRE MUSICAL/WINTER	Rehersal			x	x	x	x			3:00 PM	7:00 PM	4.00	4	5	80	x											x	40	Includes Staff
AFTER SCHOOL YOUTH THEATRE MUSICAL/WINTER	Rehersal	Tech Week		x	x	x	x			6:00 PM	10:00 PM	4.00	4	1	16	x												65	Includes Staff+crew+cast
AFTER SCHOOL YOUTH THEATRE MUSICAL/WINTER	Performance	1,2 Week	x							1:30 PM	5:30 PM	4.00	1	2	8	x												325	Audiences and all other
AFTER SCHOOL YOUTH THEATRE MUSICAL/WINTER	Performance	1st Week						x	x	6:00 PM	10:00 PM	4.00	2	1	8	x												325	Audiences and all other
AFTER SCHOOL YOUTH THEATRE MUSICAL/WINTER	Performance	2nd Week						x	x	6:00 PM	10:00 PM	4.00	2	1	8		x											325	Audiences and all other
ANNUAL SUMMER YOUTH THEATRE	Auditions				x	x	x			6:00 PM	11:00 PM	5.00	3	1	15					x								65	Includes Staff
ANNUAL SUMMER YOUTH THEATRE	Rehersal		x							2:00 PM	11:00 PM	9.00	1	5	45						x	x						65	Includes Staff
ANNUAL SUMMER YOUTH THEATRE	Rehersal			x	x	x				7:00 PM	11:00 PM	4.00	3	6	72						x	x						65	Includes Staff
ANNUAL SUMMER YOUTH THEATRE	Rehersal	Tech Week		x	x	x	x			6:00 PM	11:00 PM	5.00	4	1	20							x						90	Includes Staff + crew+cast
ANNUAL SUMMER YOUTH THEATRE	Rehersal	Tech Week	x							10:00 AM	11:00 PM	13.00	1	1	13							x						97	Includes Staff +crew+band+cast
ANNUAL SUMMER YOUTH THEATRE	Performance	1,2,3 Week	x							1:00 PM	6:00 PM	5.00	1	3	15							x						370	Audience, cast, Front of house, crew, band
ANNUAL SUMMER YOUTH THEATRE	Performance	1st Week					x	x	x	6:00 PM	11:00 PM	5.00	3	1	15							x						370	Audience, cast, Front of house, crew, band
ANNUAL SUMMER YOUTH THEATRE	Performance	2nd Week					x	x	x	6:00 PM	11:00 PM	5.00	3	1	15							x						370	Audience, cast, Front of house, crew, band
ANNUAL SUMMER YOUTH THEATRE	Performance	3rd Week					x	x	x	6:00 PM	11:00 PM	5.00	3	1	15								x					370	Audience, cast, Front of house, crew, band
AFTER SCHOOL CHILDREN'S THEATRE MUSICAL/FALL	Auditions			x	x	x				6:00 PM	9:00 PM	3.00	3	1	9								x					55	Includes Staff
AFTER SCHOOL CHILDREN'S THEATRE MUSICAL/FALL	Rehersal			x	x	x	x			3:00 PM	7:00 PM	4.00	4	5	80								x					40	Includes Staff
AFTER SCHOOL CHILDREN'S THEATRE MUSICAL/FALL	Rehersal	Tech Week		x	x	x	x			6:00 PM	10:00 PM	4.00	4	1	16									x				65	Includes Staff & Crew
AFTER SCHOOL CHILDREN'S THEATRE MUSICAL/FALL	Performance	1,2 Week	x							1:30 PM	5:30 PM	4.00	1	2	8									x				325	Audiences and all other
AFTER SCHOOL CHILDREN'S THEATRE MUSICAL/FALL	Performance	1st Week						x	x	6:00 PM	10:00 PM	4.00	2	1	8									x				325	Audiences and all other
AFTER SCHOOL CHILDREN'S THEATRE MUSICAL/FALL	Performance	2nd Week						x	x	6:00 PM	10:00 PM	4.00	2	1	8									x				325	Audiences and all other
FALL INTERGENERATIONAL MUSICAL	Auditions				x	x	x			6:00 PM	11:00 PM	5.00	3	1	15								x					65	Includes Staff
FALL INTERGENERATIONAL MUSICAL	Rehersal		x							2:00 PM	11:00 PM	9.00	1	6	54									x	x	x		65	Includes Staff
FALL INTERGENERATIONAL MUSICAL	Rehersal			x	x	x				7:00 PM	11:00 PM	4.00	3	6	72									x	x	x		65	Includes Staff
FALL INTERGENERATIONAL MUSICAL	Rehersal	Tech Week		x	x	x	x			6:00 PM	11:00 PM	5.00	4	1	20											x		90	Includes Staff + crew+cast
FALL INTERGENERATIONAL MUSICAL	Rehersal	Tech Week	x							10:00 AM	11:00 PM	13.00	1	1	13											x		97	Includes Staff +crew+band+cast
FALL INTERGENERATIONAL MUSICAL	Performance	1,2,3 Week	x							1:00 PM	6:00 PM	5.00	1	3	15											x	x	370	Audience, cast, Front of house, crew, band
FALL INTERGENERATIONAL MUSICAL	Performance	1st Week					x	x	x	6:00 PM	11:00 PM	5.00	3	1	15											x		370	Audience, cast, Front of house, crew, band
FALL INTERGENERATIONAL MUSICAL	Performance	2nd Week					x	x	x	6:00 PM	11:00 PM	5.00	3	1	15											x		370	Audience, cast, Front of house, crew, band
FALL INTERGENERATIONAL MUSICAL	Performance	3rd Week					x	x	x	6:00 PM	11:00 PM	5.00	3	1	15												x	370	Audience, cast, Front of house, crew, band
ANNUAL BENEFIT EVENT	Rehersal		x	x		x		x		6:00 PM	10:00 PM	4.00	4	1	16		x											90	Includes Staff
ANNUAL BENEFIT EVENT	Rehersal								x	2:00 PM	6:00 PM	4.00	1	1	4		x											90	Includes Staff
ANNUAL BENEFIT EVENT	Performance								x	6:00 PM	10:00 PM	4.00	1	1	4		x											550	
TECHNICAL THEATER WORKSHOP SESSIONS	Workshop		x						x	10:00 AM	4:00 PM	6.00	2	7	84		x		x	x	x		x		x	x		15	Includes Staff
Production (Shop)	Production			x	x	x	x	x		8:00 AM	4:00 PM	8.00	5	48	1920	x	x	x	x	x	x	x	x	x	x	x	x	3	
Production Lighting (testing,hanging, dimmers, etc)	Production						x	x		10:00 AM	3:00 PM	5.00	2	25	250	x	x	x	x	x	x	x	x	x	x	x	x	2	
Office	Administration			x	x	x	x	x		8:00 AM	4:00 PM	8.00	5	50	2000	x	x	x	x	x	x	x	x	x	x	x	x	8	
Workshops, Night Kitchen, Coffeehouses	Expansion	Planned							x	6:00 PM	11:00 PM	5.00	1	26	130	x	x	x	x	x	x	x	x	x	x	x	x	100	
Performances of Projected Program Expansion	Expansion	Planned							x	6:00 PM	10:00 PM	4.00	1	26	104	x	x	x	x	x	x	x	x	x	x	x	x	125	

Figure 2 - Complex Occupancy Schedule for a Theatre

Determining the last two pieces of information, energy used during operation and an approximation of the interior heat gain characteristics can become challenging. Determining the actual energy usage of a piece of equipment can be a trying exercise in the real world. We have found that this is best accomplished through short term monitoring of similar equipment. Using name plate ratings will typically lead to overestimation of both energy and heat gain. Simple current transducers and mobile loggers make quick work of actual energy performance. The IHG of the equipment is a bit trickier. Because IHG depends on multiple factors including efficiency, process, sensible vs latent heat, etc. determining how much heat is released and how much of the heat release via radiant, convective or conductive heat there is a certain amount of "artistic finesse" in assessing IHG and assigning it appropriately to the building energy balance. For example, IHG in a commercial kitchen can be a challenge in the zone in which the kitchen is located, but in a 70,000 sq ft school with a 2,000 sq ft kitchen using the IHG from the kitchen to offset heat loss in an area far from the kitchen is a mistake without some means of actually capturing and moving that heat to another zone location. ASHRAE has some good general guidance for typical equipment IHG in the ASHRAE Handbook—Fundamentals. When one gets outside the 'typical' equipment, field determination of IHG becomes critical and more difficult.

(Please note for the following operations, it is best to work in the SI sheets of the PHPP, as the IP overlay for the PHPP 2007 (v12-10-09) in the "non-dom" tabs does not always tie to the SI sheet correctly and all the calculations are done in the SI sheets. You will have to unlock the sheets so that you can create the correct references between cells. You will also have to work in some of the white cells to get the information to report correctly. If you are not comfortable with this than please ask a more experienced modeler for assistance, because it is easy to make a mess if you are not careful. A number of bugs were fixed in the final IP version v06-02-10, but I haven't confirmed whether or not the non-dom issues were addressed.)

Using the schedule of equipment now becomes the basis for determining process load effect on both PE and IHG. For PE calculation, simple multiplication of hours use by wattage can be made and the sum of the equipment energy can be entered into the Aux sheet in one cell which one can label "process load". This will carry over to the electricity sheet and will be calculated in your PE tabulation. Please remember, if you have equipment that has different fuel sources than a separate tabulation will have to be made for these so that you can manually assign the appropriate fuel factors to the PE calculation.

Description	Usage	QTY	Existing?	Elec Size	Hours of usage / week	Utility Factor	Volts	Amps	Watts	Kilowatt Hours/ week	# Weeks	Annual Kilowatt Hours
Lab		3									50	
Electric Hand Piece	10 min/wk	3	Yes	120V, 30Vdc, 3W	0.16667				3	0.0005	50	0.025
Pencil Sharpener	10 min/wk	1	Yes	120v,2A	0.17		120	2	240	0.0408	50	2.04
Micro Abrader	10 min/wk	1	Yes	115V, 32W	0.17				32	0.00544	50	0.272
Polisher	3 min/wk	1	Yes	115V,26A, 1/4hp	0.05		115	26	2990	0.1495	50	7.475
"Suck down" Machine	10 min/wk	1	Yes	115V, 720W	0.17				720	0.1224	50	6.12
Model Trimmer	15 min/wk	1	Yes	115V, 7.2/3.6A, 1/2hp	0.25		115	7.2	828	0.207	50	10.35
Vibrator	30 min/wk	1	Yes	115V	0.5		115	2	230	0.115	50	5.75
OP #1 Doctor's												
Curing Light	1 hr/day	1	Yes	9V, 1.2A, 11W	5				11	0.055	50	2.75
Operating Light	4 hr/day	1	Yes	120V, 2.8A, 95W halogen	32		120	2.8	95	3.04	50	152
Chair	20 min/day	1	Yes	120V, 10A	1.66667		120	10	1200	2	50	100
Operatory Unit	30 min/day	1	Yes	120V, 3.1A,2.8A,1.4A	2.5		120	3.1	372	0.93	50	46.5
Amalgamator	3 min/day	1	Yes	120V,155W	0.25				155	0.03875	50	1.9375
X-Ray	30 sec/day	1	Yes	120V, 8Amomentary	0.04167		120	8	960	0.04	50	2
OP #9 Hygienist												
Operating Light	4 hr/day	1	Yes	120V, 2.8A, 95W halogen	32		120	2.8	95	3.04	50	152
Chair	20 min/day	1	Yes	120V, 10A	1.66667		120	10	1200	2	50	100
Ultrasonic Cleaner	30 min/day	1	Yes	120V, .5A	2.5		120	0.5	60	0.15	50	7.5
X-Ray	30 sec/day	1	Yes	120V, 8Amomentary	0.04167		120	8	960	0.04	50	2
OP #10 Hygienist												
Operating Light	4 hr/day	1	Yes	120V, 2.8A, 95W halogen	32		120	2.8	95	3.04	50	152
Chair	20 min/day	1	Yes	120V, 10A	1.66667		120	10	1200	2	50	100
Ultrasonic Cleaner	30 min/day	1	Yes	120V, .5A	2.5		120	0.5	60	0.15	50	7.5
X-Ray	30 sec/day	1	Yes	120V, 8Amomentary	0.04167		120	8	960	0.04	50	2
Pan												
Gendex Model #46-154870G3	2 min/wk	1	Yes	120V, 8.8A momentary, 1A cont.	0.03333		120	8.8	1056	0.0352	50	1.76
Sterilization												
Sterilizers	7 hours/day 4 days, 2 hours/day 1 day	2	Yes	120V, 12A	4.5	0.15	120	12	1440	6.48	50	324
Ultrasonic Cleaner Sterilization	4 hr /day 4 days, 1 hr/ 1 day	2	Yes	117V, 17A, 400W	17				400	6.8	50	340
Water Distiller	2 hr/day	1	Yes	120V, 750W	10				750	7.5	50	375
Suction/Air												
Compressor MDS Matrix OL1003	2 days / wk (10hr) (10% usage)	1	Yes	209-231V / 33A	1.6	0.1	231	33	7623	12.1968	50	609.84
Compressor Air Techniques AS70	2 days / wk (10hr), 1 day/wk (6 hr) (10% usage)	1	Yes	208-230V, 24A, 1 1/2hp	2.1	0.1	230	24	5520	11.592	50	579.6
Suction Airtechniques 54110	4 days/wk (10hr), 1 day/wk (6 hr) (60% usage)	1	Yes	200-240V, 15A, 3ph	2.52	0.12	240	15	3600	9.072	50	453.6
X-Ray												
Image Developer	20min/day	1	Yes	110V, 1A	1.66667		110	1	110	0.183333333	50	9.166667
Image Deleter	20min/day	1	Yes	108V,.75A	1.66667		108	0.75	81	0.135	50	6.75

Figure 3 - Example of Simple Process Energy Use Tabulation

Using the equipment schedule for IHG calculations takes a bit more time and a full understanding of the building and the building's mechanical system. First, if the building warrants it, create a zone concept for the building; if the building does not warrant a zonal calculation, then this first step is not necessary. Next, a basic mechanical system concept is required to determine if and how IHGs will be distributed throughout the building. As we all know by now, buildings are dynamic holistic systems and without an initial mechanical system concept, the effect of the IHG on the energy balance of the building will be almost impossible to determine accurately and with any degree of confidence. Once a mechanical concept is determined, you can apportion loads to zones and begin to determine the peak heating and cooling loads of these zones. This is schedule dependent, for example in a theater with 300 people and 150 par lights, the peak cooling load will occur during a sold our performance in the summer using ASHRAE summer outdoor design conditions as a guide. The peak heating load will occur when the theater is empty in the winter once again using ASHRAE winter outdoor design conditions as a guide. As PHPP is a static model, we cannot easily model the space hourly, as we can with dynamic models, but determination of peaks is what will guide our system selection and sizing and lead us to accurate predictions of energy use. One uses the maximum and minimum IHG to predict these loads.

MAX IHG

People - Sold out - During Performance - Auditorium

Main Auditorium Main Auditorium	Occupants #	Sensible Heat BTU / HR	Latent Heat BTU / HR	Total Sensible Heat BTU / HR	Total Latent Heat BTU / HR	TOTAL LOAD BTU / HR	Cooling TONS
Audience	275	215	135	59,125	37,125		
Cast	60	270	300	16,200	18,000		
Crew	20	250	250	5,000	5,000		
Band	10	250	250	2,500	2,500		
Front of house	5	215	185	1,075	925		
TOTAL	370			83,900	63,550	147,450	12.29

First Floor Load

People	12.29
Lighting	16.34
OA	6.38
TOTAL	35.00
TFA	11170
BTU/hr.	420,051.40
BTU/hr/sf	37.60

Theatrical - Lighting

Qty	Volts	Watts	Amps	Total Amperage	Amps per Phase	2/3 AMPS useage	2/3 use Wattage	2/3 use BTU	2/3 Tonnage
150	120	575	4.8	718.8	240	474.4	57500	196,075	16.34

Outside Air

Condition	Outside Air			Post Wheel			OA Flow	ROOM			Unsatisfed Load		TOTAL	Cooling
	Db [F]	Wb [F]	Grains	Db [F]	Wb [F]	Grains	CFM	Db [F]	Wb [F]	Grains	Sensible	Latent	BTU / HR	TONS
Summer	95	76	106	78	67.5	88.37	4000	75	62.5	65	12,960	63,566.40	76,526.40	6.38

Figure 4 - Example of Peak IHG Tabulation

The last and perhaps most difficult item to model is HVAC energy use in PHPP for dynamic building types. In the case of fairly static buildings, standard office buildings, school classrooms, the PHPP is quite satisfactory, but in the case of diverse and dynamic profiles, I find there is a dichotomy between a "good enough for certification" model and an "accurate enough for my prediction" model This is because in complex usage situations one must blend many different occupancy and use profiles (i.e. PHPP's) to come up with a final static PHPP for certification. In these dynamic building types, the certification model is a general blending of the occupancy pattern to determine annual total energy use and IHG. But for detailed prediction I use a dynamic model calculation that is synced with the PHPP. While this is more time consuming, it allows for both a cross check and a realistic prediction of building performance.

While the PHPP has some limitations, with a bit of extra effort and thought, it can be used to simulate many aspects of process load in building analysis.