February 24, 2015

Mr. Mark Sevier
Technical Representative
N**ational Grid**
939 Southbridge Street
Worcester, MA 01610

Subject: Blanchard Memorial School Detailed Scoping Study- Boxborough, MA

Dear Mark:

Applied Energy Engineering & Commissioning (AEEC) was retained by National Grid to perform a detailed scoping study for the Blanchard Memorial Elementary School in Boxborough, MA. Since electricity is not provided by NGRID this study concentrated on analyzing natural gas use and on potential natural gas reduction measures.

The intent of this Report is to assist in identifying natural gas end user(s) responsible for relatively high natural gas usage index and economically feasible energy savings projects to be included in a more detailed study and/or implementation by a National Grid approved expediter. The Report includes a list of potential measures with a "first cut" simple payback analysis. This analysis is sufficient to enable the Acton-Boxborough School System to determine which projects should be pursued under the appropriate NGRID program. The report also includes electric energy savings where appropriate.

This report is organized as follows:

I. Introduction
II. Billing Analysis and End Use
III. Energy Use Index
IV. Measures Evaluated
V. Conclusion/Recommendations
VI. Appendix – Equipment schedules, Pictures.

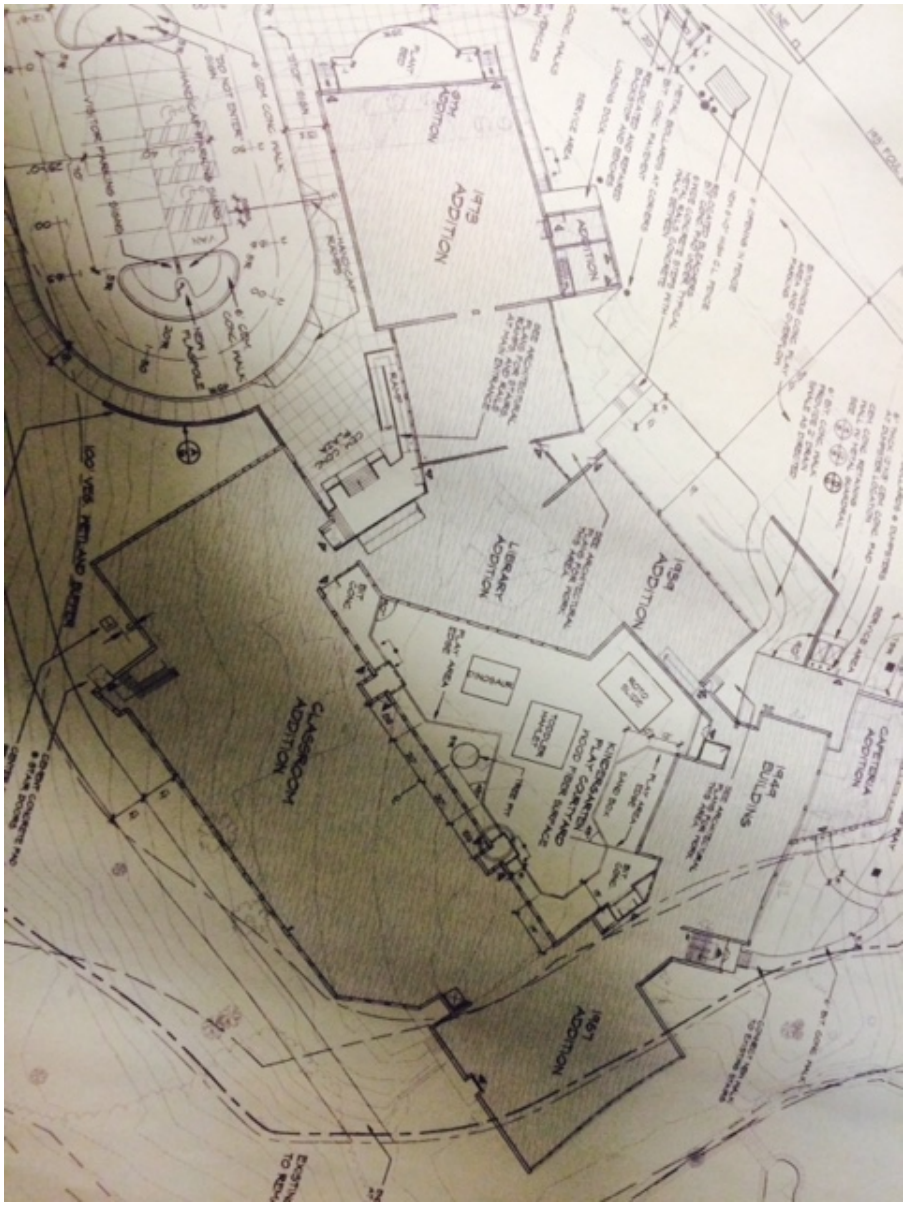
I. Introduction

Our investigation included a review of the building energy use and mechanical and control systems. Toward this end, we performed the following activities:

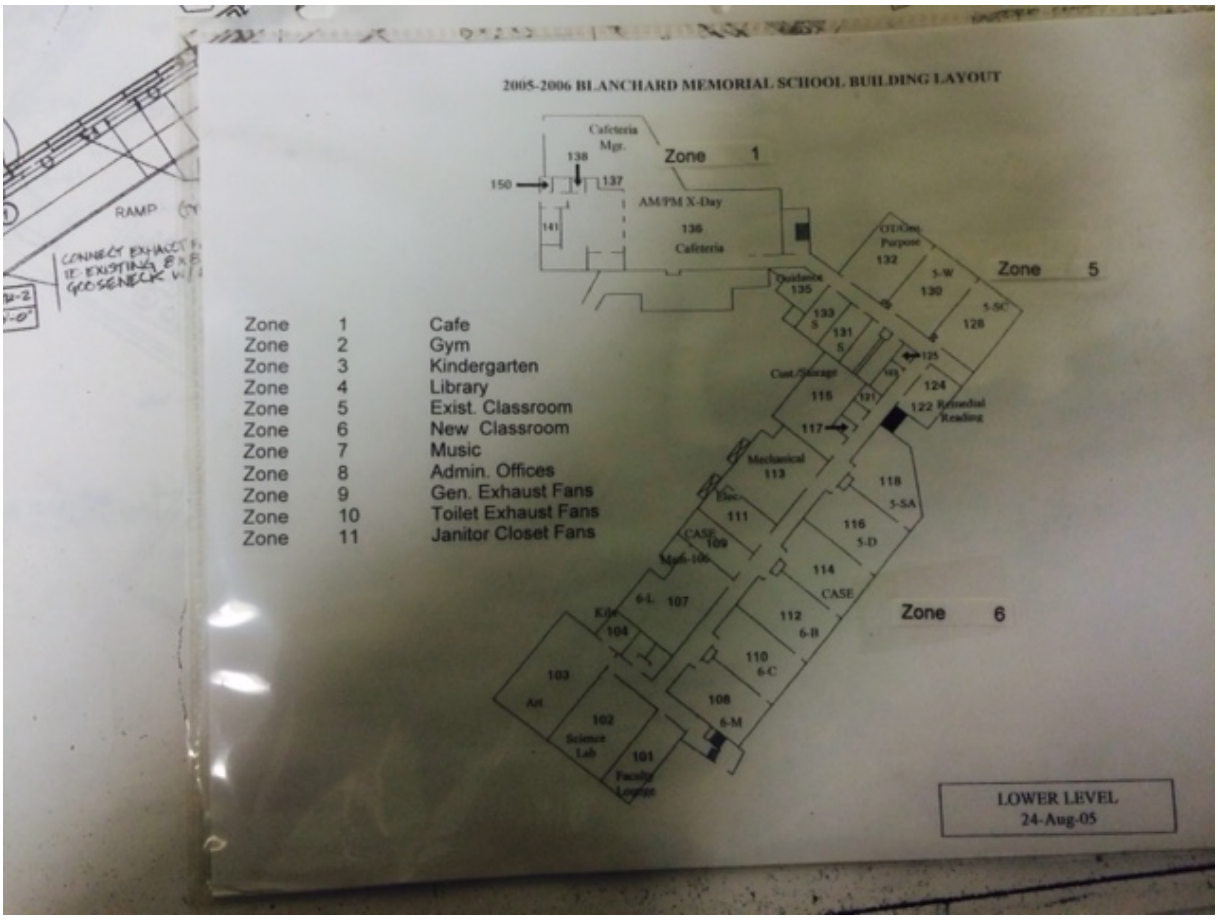
- Visited site with School System Energy Manager
- Reviewed mechanical drawings and equipment schedules provided by the school.
- Observed direct natural gas end users.
- Observed Johnson Controls pneumatic control system including day/night setback and boiler controls.

- Talked with kitchen staff regarding kitchen exhaust hood, RTU and kitchen oven use.
- Reviewed natural gas utility billing information provided by NGRID.
- Talked with school HVAC technician regarding control system operation.
- Identified potential electric and natural gas energy conservation measures for further study.

The Blanchard Elementary School is one contiguous building consisting of two levels (floors). The school occupies 71,395 gross square feet with additions to original building built in 1949:



The floor (level) layouts showing rooms and control zones (HVAC) are:



It appears the building occupancy during the school year (September through June) is 8 am to 5 pm Monday through Friday.

Building construction is:
Walls wood frame, with wood shingles and red brick facing siding
Roof: Wood deck with asphalt shingles.

Building Mechanical Systems:
During our walkthrough we were provided with information on the facility and how it is operated. The operations staff provided design drawings on the equipment that is installed. Below is a summary of our understanding of the information presented.

Hot Water System
Heating hot water is provided by two natural gas fired, sectional header, cast iron, non-condensing hot water boilers. Each boiler is rated at 4517 MBH (output) and the boilers are operated when the outdoor air temperature is below 55 F. Hot water is circulated at a constant volume by two pumps (operated lead/lag) to: Unit ventilators, Cabinet Unit Heaters, Rooftop Units (two of them), H&V Units (two of them), unit heaters and finned tube radiation (FTR). See equipment schedule in Appendix.

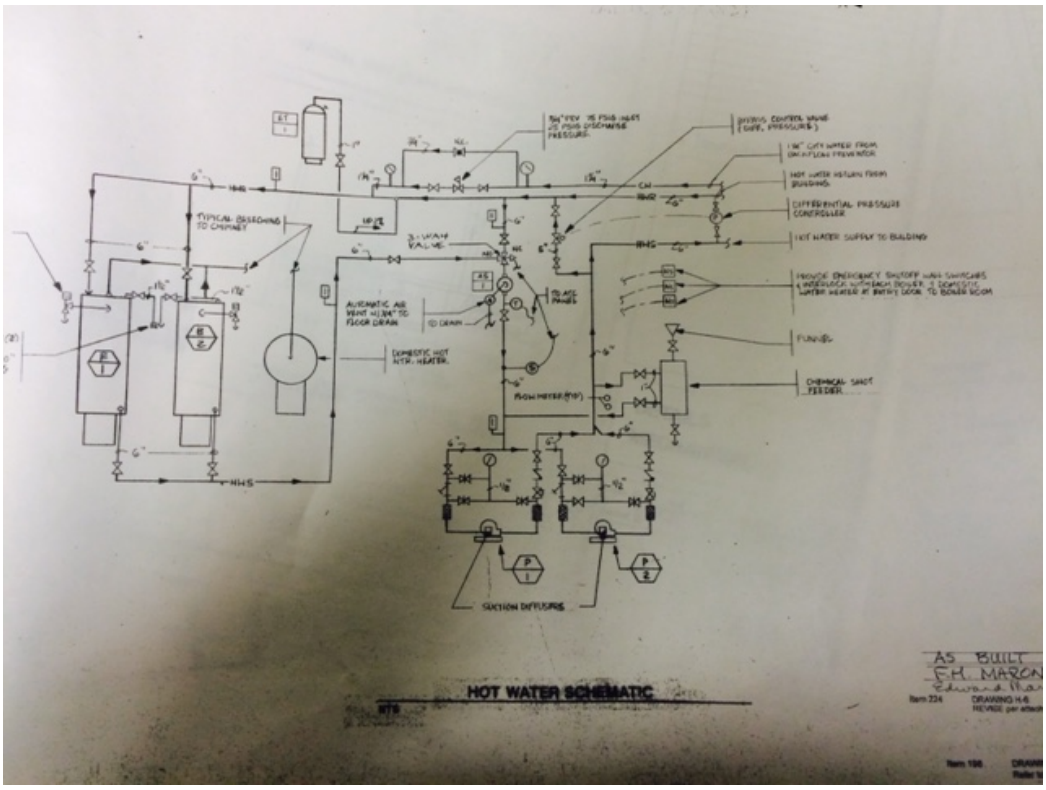
During our walkthrough we noted the results of recent combustion tests for both Boilers:

BOILER #1: 83% Efficiency (design combustion efficiency is 83%)
BOILER #2: 81 % Efficiency (design combustion efficiency is 83%)
See pictures of tests in Appendix:

The hot water supply temperature appears to be reset according to outdoor air temperature:

Hot Water Supply Temp	Outdoor Air temp
200 F	0 F
120 F	55 F

Hot Water supply temperature is maintained by a three way mixing valve. The hot water system maximum differential pressure is limited by a two way by-pass valve:



Air Side systems
Most of the School heating is provided by unit ventilators and finned tube radiation. Additional heating sources include: The Gym is heated by a heating and ventilation unit (H&V-2); The kitchen is heated by RTU-1 (interlocked with kitchen hood exhaust fan); the administrative offices are heated by an RTU; The lower level mechanical room is heated by a heating and ventilation unit (H&V-1); Cabinet Unit heaters (mostly in hallways and entry entryway), convectors and unit heaters.

- Unit Ventilators. There are about thirty (30) unit ventilators equipped with hot water coils. The units are controlled by local pneumatic day/night thermostats. The units all have outdoor air with minimum design cfm shown on schedule included in the appendix.

- Heating and Ventilating Units and finned tube radiation. There are two H&V units. H&V-1 uses hot water coil to heat outdoor air provided to the lower level mechanical room. The H&V-1 supply fan in interlocked with the two hot water boilers so that the boilers have an adequate source of combustion air. H&V-2 uses a hot water coil to heat mixed air provided to the Gym. Both units temperature control is by local pneumatic day/night thermostats. Finned tube hot water radiation is provided to supplement unit ventilators (using same local thermostat for controls) or as separate stand alone with dedicated local thermostat controls. Design schedules included in appendix.

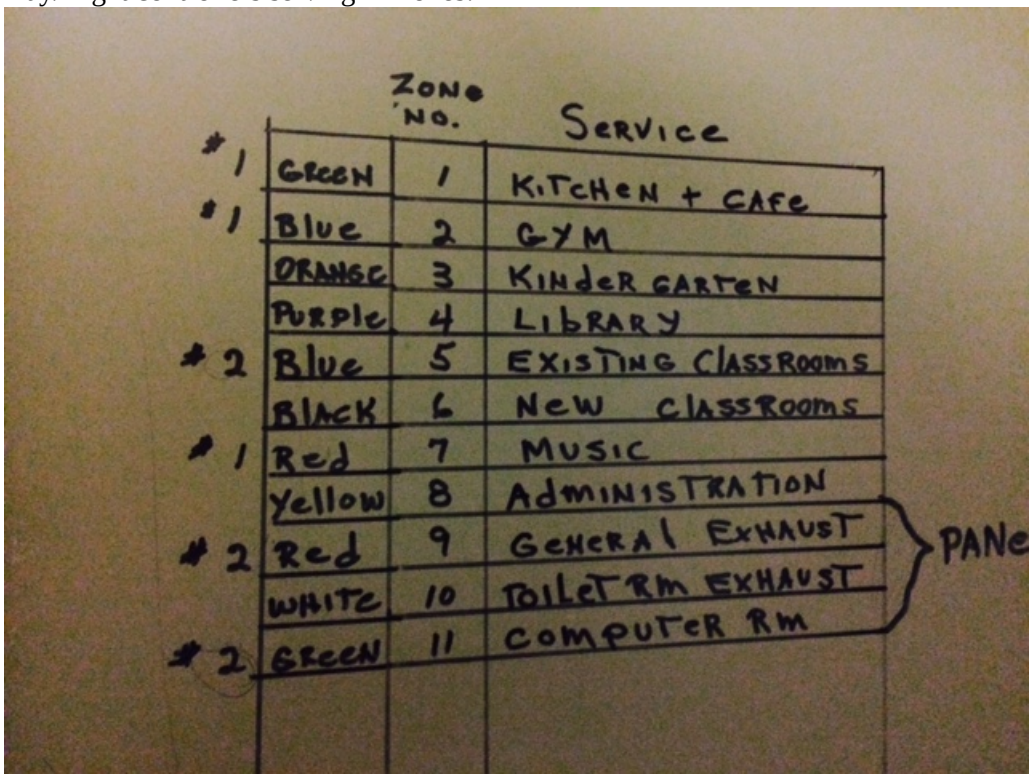
- Rooftop Units. One rooftop unit equipped with an air cooled split DX coil for cooling and hot water heating coil is used to condition the administrative offices. There is another rooftop unit equipped with a hot water heating coil used to provide heating and ventilation to the kitchen. This unit is interlocked with the exhaust hood and has two speed motor control (as does the exhaust hood). Kitchen staff indicate the exhaust hood is operated a maximum of two hours per day due to reduced oven use and issues with overheating from the RTU. Design schedules included in appendix.

- Cabinet Unit Heaters. There are about ten (10) cabinet unit heaters heating mostly hallways and entry ways. The units are controlled by local pneumatic day/night thermostats. Design schedules included in appendix.

- Propeller Unit Heaters and Convectors. There about six hot water unit heaters with local thermostats used mostly for storage and loading areas. There are about six hot water convectors located mostly in rest rooms. Design schedules included in appendix.

Building Automation and Controls
There are Johnson Controls Inc. pneumatic control panels in the 1st level mechanical room (Boiler room) including:

- Day/Night controllers serving 11 zones:



		Zone No.	Service
#1	Green	1	Kitchen + Cafe
#1	Blue	2	Gym
	Orange	3	Kinder garten
	Purple	4	Library
#2	Blue	5	Existing Classrooms
	Black	6	New Classrooms
#1	Red	7	Music
	Yellow	8	Administration
#2	Red	9	General Exhaust
	White	10	Toilet Rm Exhaust
#2	Green	11	Computer Rm

PANe

- Day controller design output is 16 psi; Night controller design output is 26 psi. NOTE WE OBESRVED BOTH AT 16 psi WHICH WILL KEEP SYSTEM IN DAY/OCCUPIED CONTINUOUSLY – see picture in appendix.
- Zones 1 through 8 use three way pneumatic control valves to send air at either day or night pressure to zone thermostats (day/night thermostats) and PE switches for supply and exhaust fans. Day/night schedule signal is provided to the valves by time clocks with 7 day schedule microprocessors located on one of the panels in the mechanical room. (See picture(s) in appendix).
- Zone 9 controls general exhaust fan operations (about 20 of them). Day/night schedule signal is provided to the zone by a 7 day schedule microprocessor located on one of the panels in the mechanical room.
- Zone 10 controls toilet room exhaust fan operations. Day/night schedule signal is provided to the zone by a 7 day schedule microprocessor located on one of the panels in the mechanical room.
- Zone 11 controls computer room equipment (electric power) operations. Day/night schedule signal is provided to the zone by a 7 day schedule microprocessor located on one of the panels in the mechanical room.
- Boiler Controls
    - Boiler 1 and 2 lead/lag control (with manual switch to designate lead)
    - Hot Water Supply Temperature reset set point and HWST (gage). Control 3-way mixing valve.
    - Outdoor air temperature (gage).
    - Hot Water pump selector (manual switch)
    - Hot water differential pressure (gage). Used to control HW system by-pass valve.

- H&V-1 Controls
    - Discharge air temperature control (HW control valve)
    - Discharge air temperature (gage).
    - Outdoor air temperature (gage).
    - Unit status

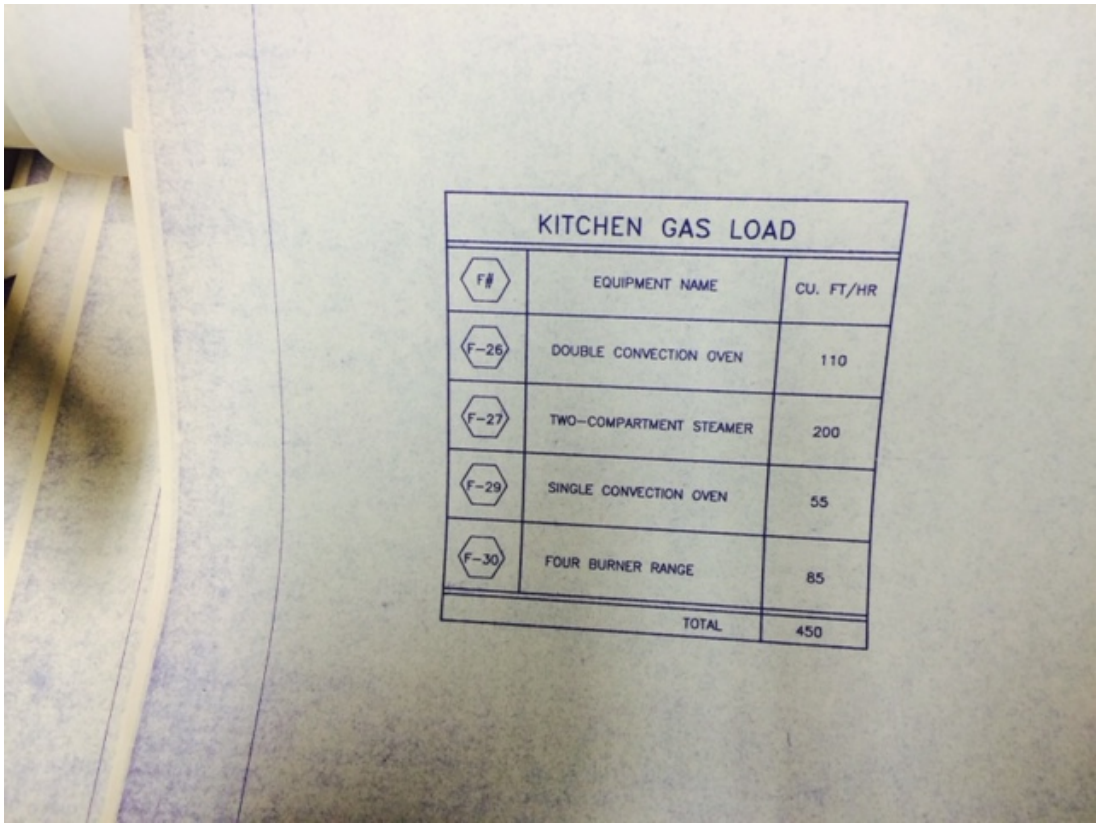
School operating personnel are uncertain on condition of day/night controls. It appears system has been operated on day only for at least this winter.

Domestic Hot Water Systems:

DHW heater is atmospheric, 150 MBH Natural Gas fired furnace with two 140 gallon storage tanks. Domestic hot water loop temperature is maintained by a circulating pump. . DHW loads are kitchen sinks, dishwasher, sinks (bathrooms) throughout school (no locker rooms in school).

Domestic hot water heater with two storage tanks:

Direct Kitchen Natural Gas Users:



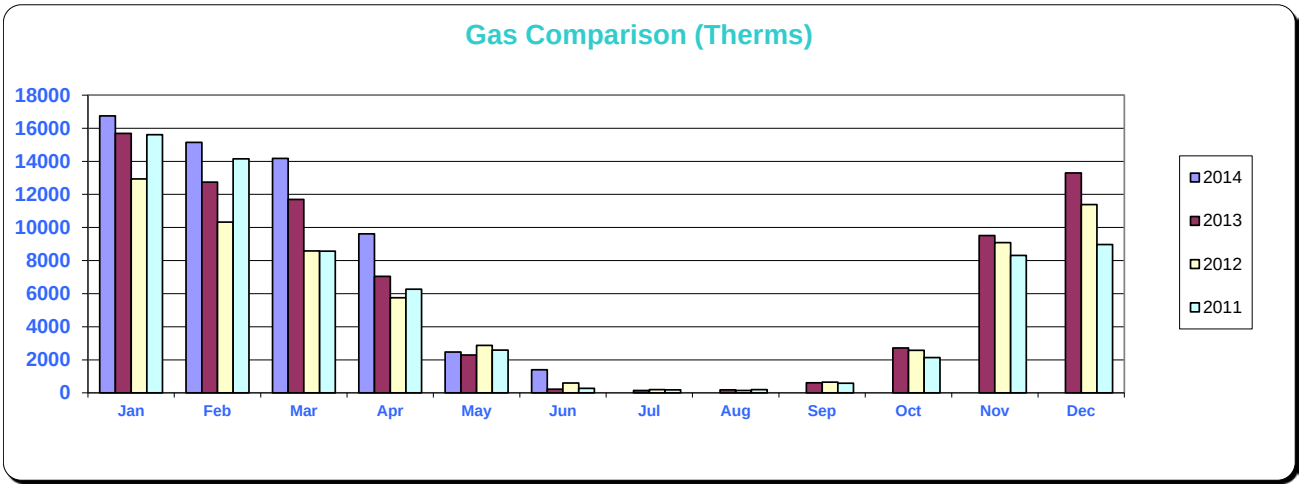
KITCHEN GAS LOAD

F#	EQUIPMENT NAME	CU. FT/HR
F-26	DOUBLE CONVECTION OVEN	110
F-27	TWO-COMPARTMENT STEAMER	200
F-29	SINGLE CONVECTION OVEN	55
F-30	FOUR BURNER RANGE	85
	TOTAL	450

According to kitchen staff due to reduced onsite cooking the ovens and steamer use has been reduced to about 2 hours per day (5 days per week) during the school year.

II. Billing Analysis and End Use

The natural gas uses profile is presented in further details in the following table and figure for the period from **January 2011** through **June-2014 Billing records.**



Gas Comparison														
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total	HDD Normalized
2013-2014	152	183	606	2,720	9,507	13,294	16,751	15,141	14,179	9,614	2,467	1,401	86,015	82,500
2012-2013	202	143	645	2,570	9,085	11,391	15,689	12,747	11,695	7,041	2,288	227	73,723	79,508
2011-2012	186	193	591	2,142	8,305	8,964	12,937	10,322	8,577	5,748	2,878	596	61,439	76,810

HDD Worcester, MA ORH (station)														
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total	Ratio to Ave
2013-2014	6	12	170	416	818	1,153	1,336	1,174	1,132	590	269	46	7,122	1.043
2012-2013	0	1	133	363	774	955	1,184	1,065	969	567	252	71	6,334	0.927
2011-2012	1	8	93	429	558	897	1,115	926	662	492	184	99	5,464	0.800
30yr Ave	9	20	158	478	764	1,119	1,284	1,094	952	601	278	74	6,831	

The natural gas usage follows typical school (education) building monthly patterns for space heating end users in that most usage is September through June with little to no usage July through August. This usage pattern confirms the hot water boilers are mostly off during the summer and there is no summer reheat end users.

Monthly heating degree day and 30-year monthly data show year 2013-2014 was colder (4%) than normal, 2012-2013 was warmer (7%) than normal and 2011-2012 was significantly warmer (20%) than normal.

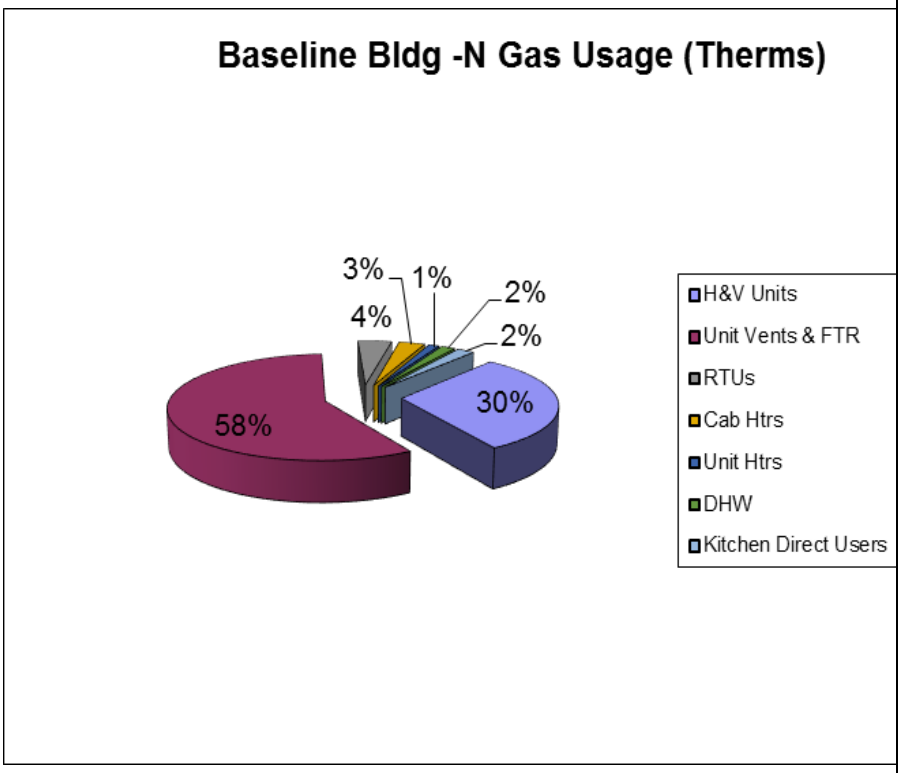
The natural gas consumption correlates to the heating degree data in that the usage for 2103-2014 was highest (coldest year), 2012-2013 usage was second highest year (7% warmer than normal) and 2011-2013 was lowest with warmest year (20% warmer than normal). Annual consumption was normalized to HDD (see HDD normalized column). The results show a normalized usage between 77,000 and 82,000 therm/year.

End-uses reconciliations

The above 12-month historical natural gas uses are further broken down in the following end-uses based on the results of excel spreadsheet estimates included in Appendix B. Note the calculated end use total usage is within 1% of the billed usage which is within acceptable margin of error.

Natural Gas End Use

End Load	**Therms/yr**
H&V Units	26,110
Unit Ventilators and FTR	49,697
RTUS	3,425
Cabinet Heaters	2,640
Unit Heaters	1,059
Domestic Hot Water	1,408
Direct Kitchen Users	1,768
Total	**86,108**



The end use calculation shows major users are space heating which assume there is no current night setback. If night setback were enabled our calculations show space heating (H&Vs, UVs, RTUs, Cabinet heaters, and unit heaters) usage could be reduced by more than 50% resulting in annual use reduced to about 42,000 therms/year (see Energy conservation measure section in this report for more details).

III. Energy Use Index

The following tables present the summary of recent 12-month historical uses of the natural gas energy use and EUI figures where applicable.

Total sf for EUI calculation		**71,395 gross SF**			
Electric	N/A	N/A	N/A	N/A	N/A
Natural Gas	86,015 Therm	1.21 Therm/SF/yr	.121 MBTU/SF/yr	$86,015	$1.20/SF/yr
Total	N/A	N/A	N/A	N/A	N/A
			Utility CO2 Emission	1,007,260	Lbs/yr
1 MBTU	= 1,000,000 BTU				
1 kWh	= 3,413 BTU				
1 CF Ngas	= 1,000 BTU				
Electric CO2 rate	0.92 lb/kWH				
N Gas CO2 rate	11.71lb/therm				

Natural Gas energy cost is based on $1.00 per therm from recent billing records and estimated supply charge.

Analysis
The nearest similar major building activity in the EIA data base for the building is “Education”.

EIA Energy Use Index for natural gas for education building activity is 47.0 CF/sf/yr. This is based on education facilities average of Mid Atlantic and East North Central Regions using the 2003 CBECS compilations (Table C27).

Blanchard Elementary School – Comparison to EIA Index for Education Facilities:
The billed natural gas index is 120.5 CF/Sf which is 157% more than the EIA Index for Mid Atlantic/East North Central education facilities. This indicates the school natural gas usage is significantly above the average education facility in the DOE/EIA database. Based on our walk through and preliminary end use calculations it is our opinion the control system not setting back thermostats to night set points and not shutting off exhaust fans, etc. is a significant factor in the facility’s relatively high natural gas usage.

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IV. Measures Evaluated (including Summary Table)

Based upon the "order of magnitude" calculations and estimates performed using Engineering best practices and experience, the following measures were identified and a preliminary evaluation performed. We recommend that school consider implementing the following Energy Conservation Measures. National Grid must pre-approve any applications for incentives prior to submitting studies/applications which will determine the amount of incentives.

Table 1: Summary of Energy Conservation Measures

		Annual Energy Savings						Total Cost Savings	Incremental Installed Costs	Simple Payback	Measure Incentives	
		Electric Savings		Gas Savings		Other					Electric	N Gas
ECM#	Measure Description	kWH	$	Therms	$	MMBTU	$	$	$	Years	$	$
ECM#1	Replace/Convert Pneumatic Control System to DDC	56,350	$ 7,325	44,577	$ 44,577	0	$ -	$ 51,903	$ 369,702	7.1	$ -	
ECM#2	Balance and Confirm Ventilation Rates	-	$ -	2,215	$ 2,215	0	$ -	$ 2,215	$ 16,440	7.4	$ -	
All Measures Combined with ECM-1A	Total Savings and Costs	56,350	$ 7,325	46,792	$ 46,792	0	$ -	$ 54,117	$ 386,142	7.1		
	Percentage Reductions	N/A		54%		0%						
	Incentives	Electric:	TBD	Gas:	TBD	Other:		Total Incentives:	TBD			
	Net Cost & Payback								$ 386,142	7.1		

Notes	Electr Rate NGRID	$ 0.1300	per kWH based on billing records from similar size facility
	Ngas rate thru 2011	$ 1.00	per therm based on billing records from NGRID ($0.51 per therm NGRID charge plus estimated supply rate)
	CO2 emissions reduction		
	ECM-1A is alternate e to	600 klbs/yr	ECM-1A&2
	Opinion of Cost Estimate based on Similar Past Projects--Need Proposal from Contractor/Engineer for Investment Grade Cost Benefit Analysis		
	Measure and total savings are NOT shown incremental -- no measures assume others have been implemented		
	Electr	0.92	lb/kWh
	Ngas	11.71	lb/therm
	#6 Oil	26.03	lb/gall
	#2,#4 Diesel Oil	22.38	lb/gall

A brief description of each measure is provided below.

ECM-1 Replace Pneumatics with DDC

As described in the Introduction, Mechanical System, building automation section in this report there is an existing pneumatic control system with control panels located in the lower level mechanical room (boiler room). During our site visit the day and night controllers were observed to be at the same pressure (16 psi) which would keep the controlled zones in occupied (day) temperature set points and operation continuously. It is our opinion this is a significant cause of the school's relatively high natural gas usage

We recommend replacing the existing pneumatic system with DDC (direct digital controls). The goal is to enable reliable night setback controls which would significantly reduce unoccupied space heating thus providing significant natural gas (and electric) savings. This alternative would control the same components using programmable electronic controllers, electronic thermostats and significantly reduce reliance on control compressed air. To reduce implementation costs we recommend obtaining an add alternate to installation proposal for leaving pneumatic actuators for hot water mixing and bypass valves as well as for all hot water control valves. Proposals should be obtained from controls contractor(s) and include turnkey installation price

including submittals for new control equipment and programming, as built control drawings and sequences and post installation testing/commissioning.

As part of the DDC implementation we recommend new energy saving program be included:
Demand Control Ventilation:
The Gym and cafeteria are relatively large spaces with dedicated ventilation sources. The Gym is provided ventilation air via H&V-2 and the cafeteria is provided ventilation air via unit ventilators. Both of these spaces are provided a minimum amount of outdoor air to meet requirements of designed occupancy.

If DDC option is implemented, we recommend installing equipment and programming for demand control ventilation. This program saves energy by resetting the minimum required outdoor air flow based on monitored CO2 levels. CO2 can be monitored at the unit return air and/or use room sensors. If CO2 levels are below set point then the outdoor air CFM can be reduced.

Further design engineering may be required to locate sensor(s) and determine compatibility with existing equipment.

ECM-2 Confirm and Balance Ventilation Rates.
Ventilation for the school is provided by: Unit Ventilators, H&V unit and RTUs. These units also have associated exhaust sources to prevent the building from over pressurizing. Design schedules (dated 1995) indicate minimum design outdoor air amounts:
Unit Ventilators (about 30) = 13,930 cfm (local exhaust fans)
H&V-1 (boiler room) = 3,200 cfm (boilers)
H&V-2 (Gym) = 9,400 cfm (return/relief fan)
RTU Admin = 500 cfm
RTU Kitchen = 2,800 cfm (kitchen hood exhaust fan)

This is a relatively constant ventilation load whenever the ventilation sources (equipment) is operating and is a significant user of natural gas for heating the outdoor air to maintain space temperature set point(s).

We recommend retaining a mechanical contractor/balancer to measure and balance ventilation and required exhaust rates to design conditions. We have estimated energy savings based on reducing the boiler room H&V discharge air temperature set point from 85 to 60 F since this unit serves a mechanical space with significant internal heat loads especially during heating months. Savings may increase if it is determined the existing minimum outdoor air quantities are above latest ASHRAE standard(s).

INVESTIGATED BUT NOT RECOMMENDED

ECM-3 Install Condensing Boilers
Heating hot water is provided by two natural gas fired, sectional header, cast iron, non-condensing hot water boilers. Each boiler is rated at 4517 MBH (output) and the boilers are operated when the outdoor air temperature is below 60 F. Hot water is circulated at a constant volume by two pumps to heating coils in Unit ventilators, H&Vs, RTUs, Cabinet Heaters and Finned tube radiation (FTR)- See equipment schedule in Appendix.

We investigated replacing the existing two hot water boilers with new natural gas fired condensing hot water boilers. The new boilers are significantly more efficient especially at part loads and lower hot water

temperatures (typically during shoulder months when the hot water temperature is reset according to outdoor air temperature). However, the boiler's higher efficiency rating is dependent on hot water return temperatures of 110 F or less. Since the hot water supply temperature set point is 140F or less only when the outdoor air temperature is less than about 45F there is not enough operating time to have a reasonable cost benefit based solely on energy cost savings.

ALTERNATE TO ECM-1

Implement Retro-Commissioning and Upgrade EMS Programming

If ECM-1 (retrofit controls with DDC) cannot be implemented, we recommend a controls contractor be retained to retro-commission the existing control system. The goal is to enable reliable night setback controls which would significantly reduce unoccupied space heating thus providing significant natural gas (and electric) savings. This would include:

- Point-to point check of system to determine if system can operate as designed for
    - Day/night thermostat control – verify calibration and operation at both settings
    - Exhaust fan control – verify operation and pressure settings of PE switches
    - Boiler sequencing control
    - Hot water supply temperature control (including outdoor air reset)
    - Hot water pump control
    - H&V-1 control
- Verification of pneumatic control system air dryer dryer operation and automatic blowdown.
- Document component(s) not operational and provide cost estimate to repair/replace
- After repairs/replacement, test control system including all eleven zones, boiler and hot water controls and H&V-1 controls.
- Provide updated controls specifications, sequences and 1 line drawings

V. Conclusion/Recommendations

We recommend sending this report to National Grid to determine potential incentive programs. There are a number of programs and National Grid can provide direction in applying for a program which maximizes incentive amounts.

The school is consuming natural gas at a rate that is significantly higher than regional levels for similar type and size buildings.

The school is capable of having natural gas consumption that is slightly higher than consumption levels in typical school in the northeast.

The conclusions and recommendations provided in this report are based upon “first-cut” energy savings and “rule-of-thumb” cost estimates.

We look forward to discussing items in this report with all parties. If you have any questions or comments please do not hesitate to call.

Respectfully Submitted by,

Applied Energy Engineering & Commissioning

Ron MacLellan, P. E.
Principal

Arthur W. Adler, P. E.
Principal

HOT WATER BOILER SCHEDULE

B

SYMBOL	CAPACITY GROSS MBH	HEATING SURFACE SQFT (MIN)	EWT ° F	LWT ° F	NUMBER OF PASSES	FUEL	FIRING RATE @ RATED BOILER CAPACITY	BURNER H.P.	COMBUSTION AIR FAN HP	MODEL NO.
B-1	3550	——	160	180	——	GAS	4474MBH GAS	3	——	BG-1488
B-2	3550	——	160	180	——	GAS	4474MBH GAS	3	——	BG-1488

1. SELECTIONS BASED ON WEIL MCLAIN.

HEATING AND VENTILATING UNIT (HOT WATER)

H&V

SYMBOL	CFM	TOTAL S.P. H20	MIN. WHEEL DIA.	MAX. TIP SPEED FPM	BHP	MOTOR HP (& RPM)	HEATING COIL @ 200 F. ENT. WATER MIN. SQ.FT.	GPM	MAX PRESS DROP FT.	EAT	LAT	TYPE FILTER BOX	REMARKS
HV-1	3200	1.75"	12 1/4"FC	3493	1.62	2 (1075)	5.5	16.0	1.9	-10F	80F	ANGULAR	①②③④⑤
HV-2	18800/9400	2.8"	24 1/2"FC	4554	15.63	20 (710)	33.6	42	3.9	34F	72F	HEAVY DUTY ANGULAR	⑥⑦⑧⑨⑩⑪⑫

1. BASED ON MCQUAY ① MODEL #LHD106 VERTICAL ② PROVIDE FULL SIZE FIELD FABRICATED 36" H PLENUM ③ FILTERS 13.3 SQ.FT.(6) 16"X20"2"TA ④ PROVIDE EXTERNAL FACE AND BYPASS DAMPERS SECTION ⑤ 311.1 MBH ⑥ MODEL #LSL-134D HORIZONTAL ⑦ PROVIDE FULL SIZE FIELD FABRICATED 36" DP PLENUM ⑧ FILTERS 66.6 SQ.FT.(24) 20"X20"X2"TA ⑨ PROVIDE 30" BLENDER SECTION W/R-M PRODUCTS BLENDER 30-BS-28 ⑩ PROVIDE 12" SPACER SECTION ⑪ 1031.0 MBH ⑫ 2 SPEED

HEATING COILS (HOT WATER)

BASED ON 180F EWT

HC

SYMBOL	CFM	COIL SIZE W	COIL SIZE H	AIR SIDE EAT	AIR SIDE LAT	AIR SIDE MAX SP	WATER SIDE GPM	WATER SIDE MAX PD	MBH	REMARKS
HC-1	3865	54"	18"	55.5F	80.0F	.15"	5.25	1.0"	104.6	1 ROW

1. SELECTIONS BASED ON MCQUAY.

AIR COOLED CONDENSING UNIT

ACCU

SYMBOL	SERVES	LOCATION	MODEL NO.	MBH	TONS	COMPRESSOR HP	COMPRESSOR FLA	COMPRESSOR LRA	CONDENSER HP	CONDENSER FLA	CONDENSER LRA	REMARKS
ACCU-1	HV-11	ROOF	AD060F	60	5	——	10.4	62.0	1/3	1.3	——	95 DEG F AMB

CUH-7	E-CEILING RECESS	400	21.7	1.0	180 F	1.1	85	41"L X 30"W X 11"D ② ④
CUH-8	A-VERTICAL CONCEAL	800	51.5	4.0	180 F	4.5	360	51"L X 26"H X 10"D ② ⑤
CUH-9	B-VERTICAL FLOOR	600	40.4	1.5	180 F	3.5	145	48"L X 25"H X 10"D ② ⑤
CUH-10	E-CEILING RECESS	200	14.4	1.0	180 F	1.2	60	33"L X 30"W X 11"D ② ④

SELECTIONS BASED ON TRANE.
① 2 ROW, 144FPF. ② 3 ROW 144FPF. ③ TOP AND BOTTOM GRILLES.
④ INLET AND OUTLET GRILLES. ⑤ TOP DISCH, FRONT INLET. ⑥ DUCTED INLET AND OUTLET, .4" SP.

UNIT VENTILATORS (HOT WATER) UV

SYMBOL	MODEL NO.	CFM		EAT	HOT WATER SIDE			HP	RPM	LOUVER MODEL NO.	MOTOR DATA			REMARKS
		O.A.	TOTAL		MBH	GPM	PD				V	PH	HTZ	
UV-1	AV3000	375	750	30 DEG	52.0	3.0	1.4	1/8	650	①	120	1	60	②
UV-2	AV4000	500	1000	30 DEG	70.0	4.0	2.6	1/8	650	①	120	1	60	②
UV-3	AV5000	415	1250	43 DEG	74.0	4.5	4.0	1/8	650	①	120	1	60	②
UV-4	AV6000	750	1500	30 DEG	101.0	5.0	5.2	1/8	650	①	120	1	60	②
UV-5	AH3000	250	750	43 DEG	46.0	3.0	1.4	1/8	650	①	120	1	60	③
UV-6	AH5000	415	1250	43 DEG	74.0	4.5	4.0	1/8	650	①	120	1	60	③
UV-7	AH6000	750	1500	30 DEG	101.0	5.0	5.2	1/2	1080	①	120	1	60	③ .25" ESP ⑤
UV-8	AH3000	250	750	43 DEG	46.0	3.0	1.4	1/2	1160	①	120	1	60	④ ⑤
UV-9	AH8000	670	2000	43 DEG	114.0	6.5	8.0	1/3	1070	①	120	1	60	③ ⑦
UV-10	AH8000	1000	2000	30 DEG	120.0	5.0	5.2	1/2	910	①	120	1	60	③ .25" ESP ⑤
UV-11	AH8000	400	2000	54 DEG	84.0	3.0	2.5	1/2	1070	①	120	1	60	④ ⑤ ⑥ .5" ESP
UV-12	AH4000	500	1000	30 DEG	77.0	6.0	5.0	1/8	650	①	120	1	60	② ③
UV-13	AH6000	750	1500	30 DEG	101.0	5.0	5.2	1/8	650	①	120	1	60	③

SELECTIONS BASED ON AAF WITH HIGH CAPACITY HOT WATER COILS.
① REFER TO ARCHITECTURAL PLANS FOR EXACT LOUVER SIZE.
② 21-7/8" DEEP CABINET.
③ BOTTOM DOUBLE DEFLECTION SA GRILLE (ARR G), BOTTOM RA GRILLE AND REAR DUCTED OA.
④ DUCTED SA (ARR F), REAR DUCTED OA AND RA, .45" ESP NOMINAL.
⑤ REFER TO PLANS FOR ACTUAL CFM. CHANGE MOTOR SPEED AS REQUIRED.
⑥ WITH REFRIGERANT COIL DRAIN PAN AND 5 TON REMOTE AIR COOLED CONDENSER.
⑦ SET AT LOW SPEED 1500 CFM.

FINNED TUBE RADIATION BASED ON 180F EWT FTR

SYMBOL	COVER TYPE	ROWS	TUBE SIZE	TUBE TYPE	FIN SIZE	FIN TYPE	FINS/ FOOT	BTUH PER LINEAR FOOT	REMARKS
FTR-1	20"H X 5 5/16" SLOPED TOP	2	1"	CU	[illegible]				①

ROOF EXHAUST FAN

SYMBOL	CFM	SP	MIN. FAN DIA.	MAX. TIP SPEED	MAX. BHP	MOTOR HP	TYPE DRIVE	REMARKS	
REF-1	5400/2700	2.0"	24"	7696	2.92	5.0	BELT	GREENHECK MODEL CUBE-240 HP	1
REF-2	800	.9"	10"	4720	.22	1/3	BELT	GREENHECK MODEL CUBE-100	1
REF-3	600	1.0"	9"	4715	.20	1/4	BELT	GREENHECK MODEL GB-90	1
REF-4	600	.9"	9"	4422	.17	1/4	BELT	GREENHECK MODEL GB-90	1
REF-5	390	.75"	8"	4305	.11	1/4	BELT	GREENHECK MODEL GB-80	1
REF-6	1350	.9"	14"	4728	.45	3/4	BELT	GREENHECK MODEL GB-140	1
REF-7	2300	.9"	18"	4600	.65	1.0	BELT	GREENHECK MODEL GB-180	1
REF-8	1400	.9"	14"	4840	.45	3/4	BELT	GREENHECK MODEL GB-140	1
REF-9	2650	.9"	18"	4840	.65	1.0	BELT	GREENHECK MODEL GB-180	1
REF-10	150	.5"	7"	3750	.05	1/4	BELT	GREENHECK MODEL GB-70	1
REF-11	150	.5"	7"	3750	.05	1/4	BELT	GREENHECK MODEL GB-70	1
REF-12	1100	1.0"	14"	4958	.42	3/4	BELT	GREENHECK MODEL GB-140	1
REF-13	1400	1.0"	14"	5000	.50	3/4	BELT	GREENHECK MODEL GB-140	1
REF-14	1620	1.0"	14"	5210	.51	3/4	BELT	GREENHECK MODEL GB-140	1
REF-15	350	.5"	8"	3600	.07	1/4	BELT	GREENHECK MODEL GB-80	1
REF-16	1275	.75"	14"	4479	.32	1/2	BELT	GREENHECK MODEL GB-140	1
REF-17	685	.75"	10"	4200	.15	1/4	BELT	GREENHECK MODEL GB-100	1
REF-18	900	.75"	10"	4500	.22	1/2	BELT	GREENHECK MODEL GB-100	1
REF-19	700	.75"	10"	4208	.15	1/4	BELT	GREENHECK MODEL GB-100	1
REF-20	150	.5"	7"	3750	.05	1/4	BELT	GREENHECK MODEL GB-70	1
REF-21	1100	.75"	14"	4307	.28	1/3	BELT	GREENHECK MODEL GB-140	1
REF-22	210	.5"	7"	4200	.09	1/4	BELT	GREENHECK MODEL GB-70	1
REF-23	600	.9"	9"	4422	.17	1/4	BELT	GREENHECK MODEL GB-90	1
REF-24	450	.5"	8"	3950	.10	1/4	BELT	GREENHECK MODEL GB-80	1

ROOFTOP UNIT

SYMBOL	SERVICE	LOCATION	TYPE	CFM		SUPPLY FAN					
				TOTAL	O.A.	CFM	T.S.P.	TIP SPEED	MIN. WHEEL DIA.	MAX BHP	MOTOR HP
RTU-1	KITCHEN	ROOF	DRAW THRU ROOFTOP	5600/2800	2800	5600/2800	2.75"	4575	15"X15"FC	5.2	7.5

1. BASED ON MCQUAY RDS-708 W/16"H CURB ① PROVIDE W/0-100 % ECONOMIZER SECTION W/GRAVITY RELIEF
R-M PRODUCTS TAH-18 BLENDERS SPACED 18" UP STREAM OF FILTERS ③ PROVIDE FACE AND BYPASS DAMPERS

PUMPS

SYMBOL	SERVICE	GPM	HEAD FT.	TYPE	IMPELLER DIAMETER	NPSHR	BHP	MOTOR HP
P-1	HW SYSTEM	365	90.0	END SUCTION	9.75"	28'	9.0	15
P-2	HW SYSTEM	365	90.0	END SUCTION	9.75"	28'	9.0	15

1. SELECTIONS BASED ON BELL AND GOSSETT.
2. PROVIDE WITH MODEL NO. GE-3 SUCTION DIFFUSER

CABINET UNIT HEATER (HOT WATER)

SYMBOL	ARRANGEMENT	CFM	MBH	WATER SIDE			MOTOR WATTS	REMAR
				GPM	EWT	MAX PD		
CUH-1	E-CEILING RECESS	600	33.0	1.5	180 F	3.2	60	51"L X 30"W
CUH-2	M-INVERTED WALL	800	47.6	3.0	180 F	3.0	160	56"L X 29"H
CUH-3	H-WALL RECESS	600	34.4	1.0	180 F	0.4	145	63"L X 30"H
CUH-4	B-VERTICAL FLOOR	600	29.8	1.0	180 F	1.4	130	48"L X 25"H
CUH-5	B-VERTICAL FLOOR	400	21.7	1.0	180 F	1.1	85	38"L X 25"H
CUH-6	B-VERTICAL FLOOR	800	57.9	3.0	180 F	3.7	175	56"L X 25"H
CUH-7	E-CEILING RECESS	400	21.7	1.0	180 F	1.1	85	41"L X 30"W
CUH-8	A-VERTICAL CONCEAL	800	51.5	4.0	180 F	4.5	360	51"L X 26"
CUH-9	B-VERTICAL FLOOR	600	40.4	1.5	180 F	3.5	145	48"L X 25"
CUH-10	E-CEILING RECESS	200	14.4	1.0	180 F	1.2	60	33"L X 30"

SELECTIONS BASED ON TRANE.
① 2 ROW 144FPF ② 1 ROW 144FPF ③

ROOFTOP AIR CONDITIONING UNIT (DIRECT EX

SYMBOL	SERVICE	LOCATION	TYPE	CFM		SUPPLY FAN				
				TOTAL	O.A.	CFM	T.S.P.	EXT. S.P.	MIN. WHEEL DIA.	MAX BHP
RTU-1	ADMIN	ROOF	PACKAGE	3865	500	3865	①	2.0	15"x15"	4.2

1.BASED ON CARRIER MODEL #50HJ012 WITH 12" CURB, 0-100 % ECONOMIZER W/ENTHALPY CONTROL, PARK
① MOTOR VALUES INCLUDE INTERNAL LOSSES (FILTERS, COILS, DAMPERS, ETC.). NOMINAL 10 TON UNIT. PR

ROOFTOP UNIT

SYMBOL	SERVICE	LOCATION	TYPE	CFM		SUPPLY FAN				
				TOTAL	O.A.	CFM	T.S.P.	TIP SPEED	MIN. WHEEL DIA.	MAX BHP
RTU-1	KITCHEN	ROOF	DRAW THRU ROOFTOP	5600/2800	2800	5600/2800	2.75"	4575	15"X15"FC	5.

1.BASED ON MCQUAY RDS-708 W/16"H CURB ① PROVIDE W/0-100 % ECONOMIZER SECTION W/GRAVITY
R-M PRODUCTS TAH-18 BLENDERS SPACED 18" UP STREAM OF FILTERS ③ PROVIDE FACE AND BYPASS

PUMPS

SYMBOL	SERVICE	GPM	HEAD FT.	TYPE	IMPELLER DIAMETER	NPSHR	BHP	MOT H
P-1	HW SYSTEM	365	90.0	END SUCTION	9.75"	28'	9.0	1

(DIRECT EXPANSION)

SUPPLY FAN					DIRECT EXPANSION COIL							
P.	EXT. S.P.	MIN. WHEEL DIA.	MAX BHP	MOTOR HP	MIN FACE AREA	EAT DB	EAT WB	LAT DB	LAT WB	SST	COIL VEL.	MAX AIR ΔP-" W.C.
	2.0	15"x15"	4.2	5.0	10.0	79.3	64.2	53.7	52.0	40	400	①

R W/ENTHALPY CONTROL, PARKER DAMPER ZONE CONTROL SYSTEM,
NOMINAL 10 TON UNIT. PROVIDE ALTERNATE MOTOR AND DRIVE.

SUPPLY FAN					HEATING COIL SECTION						
TIP SPEED	MIN. WHEEL DIA.	MAX BHP	MOTOR HP	MIN FACE AREA	EAT	LAT	MBH	GPM @ 180F EWT	MAX. WATER ΔP- FT.	MAX AIR ΔP-" W.
4575	15"X15"FC	5.2	7.5	.10" SQ.FT.	27.5 F	80 F	318.0	15.0	2.1	.21

ER SECTION W/GRAVITY RELIEF DAMPERS ② PROVIDE 33" BLENDER SECTION W/(2)
DE FACE AND BYPASS DAMPERS ④ PROVIDE 33" DISCHARGE PLENUM.

P

SHR	BHP	MOTOR HP	REMARKS
8'	9.0	15	MODEL NO. 3E
8'	9.0	15	MODEL NO. 3E

CONVECTORS (HOT WATE

SYMBOL	DESCRIPTION	W x H x L
C-1	WALL FULL RECESSED	4"X32"X36"

HEATING COIL SECTION							FILTERS	
CE	EAT	LAT	MBH	GPM @ 180F EWT	MAX. WATER ΔP - FT.	MAX AIR ΔP - " W.C.	TYPE	MIN FACE AREA REQ.
T.	27.5 F	80 F	318.0	15.0	2.1	.21	(6) 20"X25"X2" TA	20.8" SQ.FT.

PROVIDE 33" BLENDER SECTION W/(2)
33" DISCHARGE PLENUM.

CONVECTORS (HOT WATER)

SYMBOL	DESCRIPTION	W x H x L	MBH	EWT	LWT	END POCKETS
C-1	WALL FULL RECESSED	4"X32"X36"	3.3	180F	160F	(2) 44" LENGTH TOTAL
C-2	WALL FULL RECESSED	6"X32"X52"	7.6	180F	160F	(2) 60" LENGTH TOTAL
C-3	SLOPED TOP	8"X32"X44"	9.4	180F	160F	(1) 48" LENGTH TOTAL
C-4	SLOPED TOP	8"X32"X48"	10.3	180F	160F	(2) 56" LENGTH TOTAL
C-5	SLOPED TOP	8"X32"X36"	7.5	180F	160F	(2) 44" LENGTH TOTAL
C-6	WALL FULL RECESSED	6"X20"X28"	2.8	180F	160F	(2) 36" LENGTH TOTAL

1. SELECTIONS BASED ON STERLING.

ROOF EXHAUST FAN

SYMBOL	CFM	SP	MIN. FAN RPM	MAX. TIP SPEED	MAX. BHP	MOTOR HP	TYPE DRIVE	
							BELT	GREENHECK MODE

INDUCED DRAFT FANS

SYMBOL	NOMINAL CFM	NOM S.P. INCHES	MIN FAN DIA.	TYPE BLADES	TYPE DRIVES	MOTOR H.P.	ELEC.	MODEL
ID-1	250	1.0"	10" ROUND	PADDLE	BELT	0.75	460V/3PH	6K75

1. BASED ON WHITTY COMPANY, CENTRIFUGAL FANS. ID-1 DOMESTIC WATER HEATER RATING GAS 600 MBH INPUT, FLUE GAS 650 CFM +/- ,SHALL INCLUDE MULTIBLADED DISCHARGE DAMPERS MODULATING ACTUATOR BY BOILER INSTALLER.

PROPELLER UNIT HEATER (HOT WATER)

SYMBOL	ARRANGEMENT	CFM	MBH	WATER SIDE			MOTOR HP	RE
				GPM	EWT	MAX PD		
UH-1	HORIZONTAL	1215	28.1	1.5	180 F	.07'	1/8	MODEL #90S
UH-2	HORIZONTAL	815	19.7	1.5	180 F	.05'	1/20	MODEL #60S

1. SELECTIONS BASED ON TRANE.

COOLING COIL (DIRECT EXPANSION)

SYMBOL	CFM	COIL FPM	REFRIGERANT TYPE	SUCTION TEMP.	EAT		LAT		MBH	REM
					DB	WB	DB	WB		
DX-1	1980	—	22	40 DEG. F	80.6F	66.8F	59.2F	57.7F	59.2	95 DEG. F CONDENS

1. SELECTIONS BASED ON AAF.

6/18/14

COMBUSTION SERVICE CO.
OF NEW ENGLAND
25 Felt [illegible] Cambridge, MA 02140

[redacted]

testo 327-1
V1.13 01744306/USA

06/18/2014 13:31:51

Fuel Nat Gas
CO2 max 11.7 %

Flue gas

419.9	°F	T stack
6.90	%	CO2
8.6	%	Oxygen
9	ppm	CO
---	inH2O	Draft
82.4	°F	Ambient temp
81.2	%	EFF
62.0	%	ExAir
16	ppm	CO AirFree
83.3	°F	Instrum temp
---	°F	Diff. temp.
---	inH2O	Diff. Press
0	ppm	CO Ambient

OF NEW ENGLAND

Fair Oaks St ... A 02140

test: 327-1

V1.13 01744306/USA

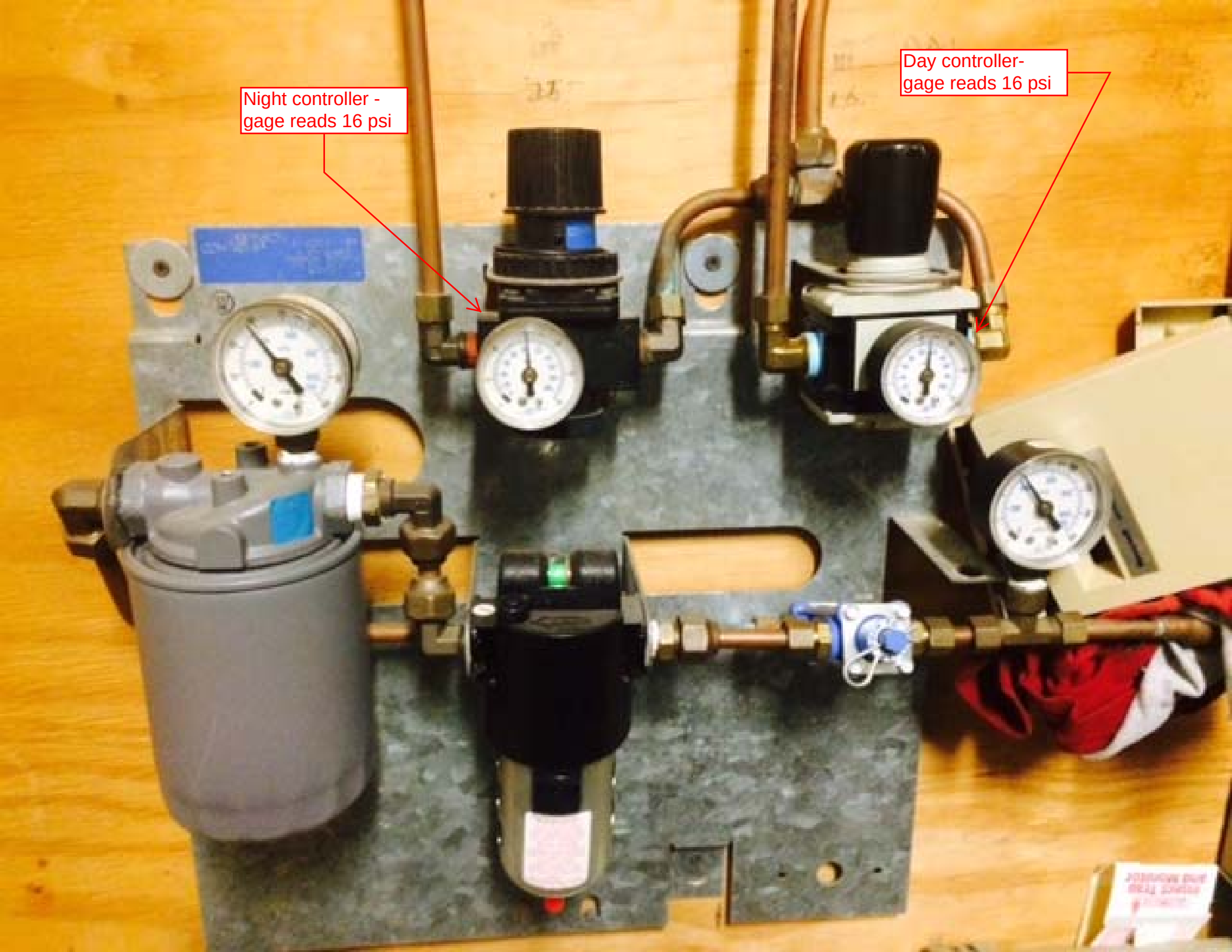
06/18/2014 13:37:42

Fuel Nat Gas

CO2 max 11.7 %

Flue gas

396.1	°F	T stack
8.18	%	CO2
6.3	%	Oxygen
4	ppm	CO
---	inH2O	Draft
82.8	°F	Ambient temp
83.1	%	EFF
38.3	%	ExAir
6	ppm	CO AirFree
83.5	°F	Instrum temp
---	°F	Diff. temp.
---	inH2O	Diff. Press
0	ppm	CO Ambient


Night controller -
gage reads 16 psi
Day controller-
gage reads 16 psi

Zone Microporocessors