- **Introduction**
- Mechanical Systems Overview
- Mechanical Depth
- Structural Breadth
- Acoustical Breadth
- Conclusions
- Recommendations
- Questions

Twin Rivers Elementary/Intermediate of
McKeesport Area School District

1600 Cornell St., McKeesport, Pa

Tessa Bauman
Mechanical Option

Technical Consultant: Laura Miller

- **Introduction**
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Building Statistics

Occupancy: Education

Size: 127,000 ft^2

Number of Stories: 2

Completion Date: February 2014

Project Cost: $29 million

Project Team

Owner: McKeesport Area School District

Architect: J C Pierce

Construction Manager: PJ Dick

General Contractor: Gurtner Construction

Civil Engineers: Phillips & Associates, Inc.

Structural & MEP Engineers: Loftus Engineers

Environmental Engineers: American Geosciences, Inc.

- **Introduction**
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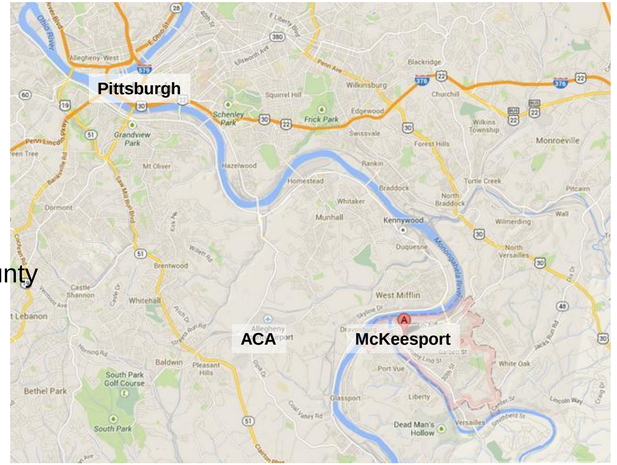
Location

- 20 miles SE of Pittsburgh, Pa
- 5 miles east of Allegheny County Airport



Building

- **Introduction**
- Mechanical Systems Overview
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Design Goals

•Tracking LEED Gold Accreditation
  •Mechanical designed with
    ASHRAE Advanced Energy Design Guide
    for K-12 School Buildings

•Education Aspects of Sustainable Design
  •LCD screens describing systems
  •Curtain wall system around Mechanical
    and Electrical Room

- Introduction
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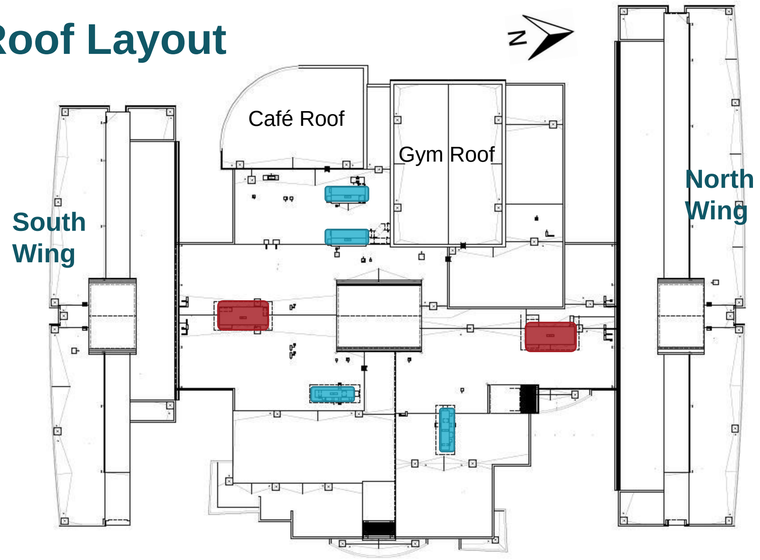
Ventilation

•2 DOAS
- •Heat Recovery Wheel
- •Desiccant Wheel

•4 AHUs
- •Single Zone VAV
- •Multi Zone VAV with reheat

•Partial Occupancy

Roof Layout



- Introduction
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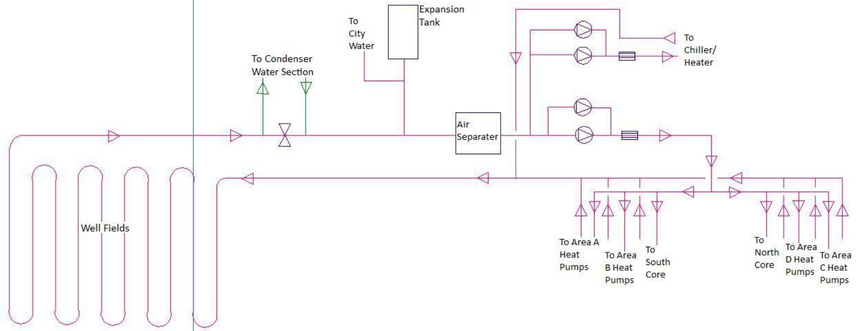
- Questions

Heating and Cooling

•Geothermal Heat Pumps
  - •Closed looped earth coupled vertical water loop
  - •60°F water
  - •Chiller supply
  - •Water to Air HPs located in classroom cabinets
  - •Auxiliary heating and cooling

•VAV Reheat to Library and Offices

Schematic



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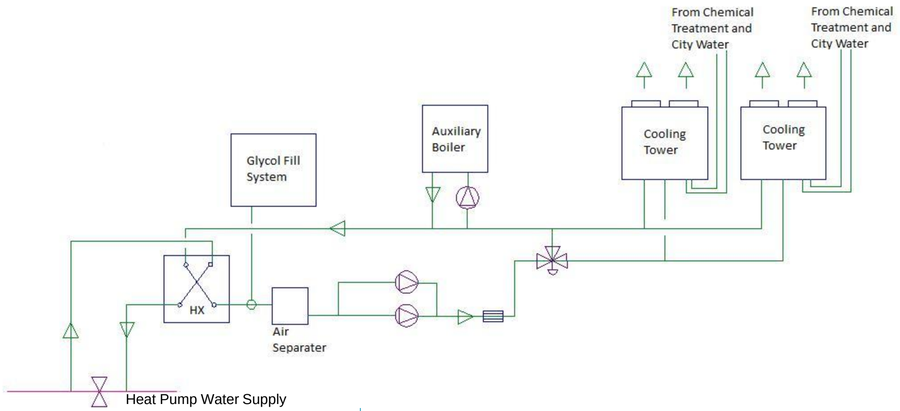
Condenser Water Loop

- 30% polyethylene glycol solution
- Heat Exchanger
- Cooling Towers
- Auxiliary Boiler

Domestic Hot Water

- Two 125 Gallon Water Heaters
- Supply at 140°F

Schematic



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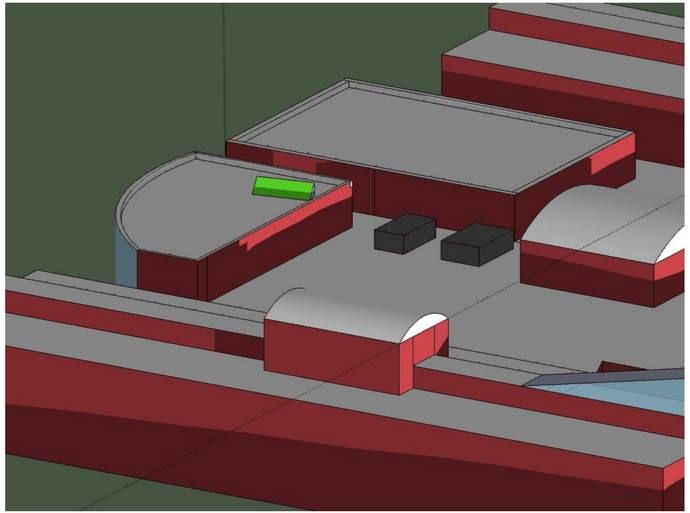
Solar Thermal Auxiliary

•Goals:
  - •Reduce dependency on natural gas
  - •Increase sustainability
  - •“If cost is no issue” possibility

•Boiler and Water Heater Reduced Loads

•Solar Thermal Array

Shading Analysis



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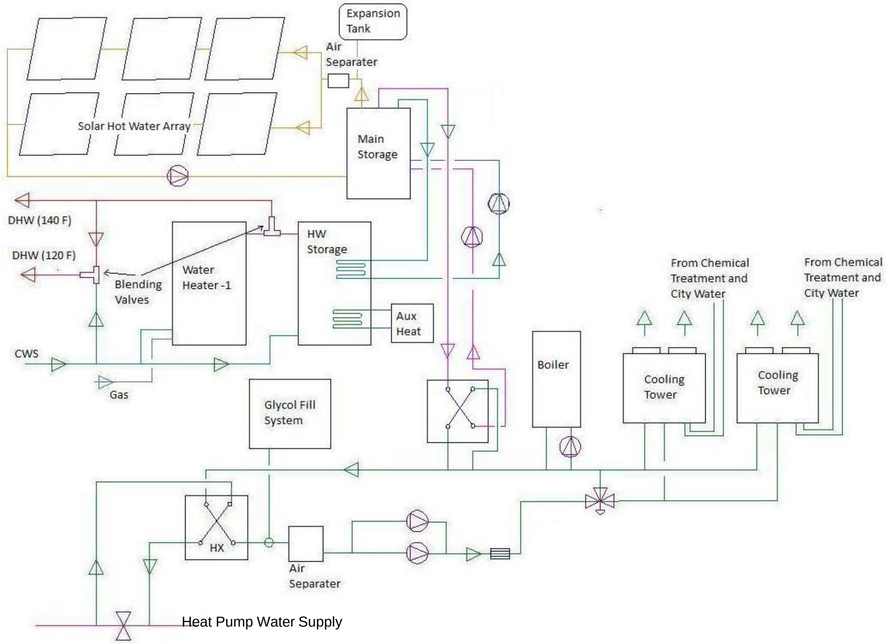
- Questions



Solar Thermal Auxiliary

Main Components

- FPC Array
- Main Storage Tank
- Solar Hot Water Tank
- GA Heat Exchanger

- Introduction
- Mechanical Systems Overview
- **Mechanical Depth**
- Structural Breadth
- Acoustical Breadth
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Hourly Solar Calculations

$$\delta = 23.45° sin\left(\frac{360}{365}(284+n)\right)$$

$$cos\theta = sin(\phi-\beta)sin\delta + cos(\phi-\beta)cos\delta cos\omega$$

$$G_T = DNIcos\theta + DHI\left(\frac{1+cos\beta}{2}\right) + \rho_g GHI\left(\frac{1-cos\beta}{2}\right)$$

Array Calculations

$$Q_u = A_c\left(F_r\tau\alpha G_T - F_r U_L(T_i - T_a)\right)$$

$$T_o = \frac{Q_u}{m_{dot}c_p} + T_i$$

- Introduction
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System Calculations

$$T_s' = T_s + \left(\frac{1}{c_p V_{tank}}\right)(Q_u - L_{tank} - L_{DHW} - L_{GA})$$

$$L_{tank} = UA(T_s - T_{a,mech})$$

$$L_{DHW} = \epsilon_{HX} m_{DHW} c_p (T_s - T_{r,DHW})$$

$$L_{GA} = \epsilon_{HX} m_{GA} c_p (T_s - T_{r,GA})$$

- Introduction
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System Calculations

6/21	m,dhw (gph)	2100	m, ga (gph)	2100

Start Time	End Time	Qu,array (MBH)	tank Loss (MBH)	DHW load (MBH)	GA load (MBH)	Ts (F)	Tr,dhw (F)	Tr,ga (F)	Tr (F)	Aux needed, DHW (MBH)	Aux needed, GA (MBH)	Solar Fraction
5:00 AM	6:00 AM	0	0.48195161	0	0	149.9374	119.9374	79.93741	114.93741	252.57232	427.5856925	0
6:00 AM	7:00 AM	0	0.48157453	0	0	149.8749	119.8749	79.87486	114.87486	252.57232	427.5856925	0
7:00 AM	8:00 AM	287.8563	0.48119774	335.4336	782.67841	41.98442	22.48442	-3.51558	9.4844189	-82.86128361	-355.092716	1.643900375
8:00 AM	9:00 AM	481.5536	-0.1687769	218.0318	508.74097	10.15893	-2.51607	-19.4161	-10.96607	34.54047765	-81.155273	1.068535244
9:00 AM	10:00 AM	601.894	-0.3605062	141.7207	330.68163	27.02325	18.7845	7.799501	13.292001	110.8516225	96.90406495	0.694547909
10:00 AM	11:00 AM	612	-0.2589089	92.11845	214.94306	66.6602	61.30501	54.16476	57.73489	160.4538666	212.6426346	0.451456141
11:00 AM	12:00 PM	581.6336	-0.0201203	59.87699	139.71299	116.28	112.7992	108.158	110.47859	192.6953253	287.8727049	0.293446491
12:00 PM	1:00 PM	487.2437	0.27880925	38.92005	90.813442	162.6748	160.4122	157.3955	158.90387	213.6522734	336.7722505	0.190740219
1:00 PM	2:00 PM	387.1472	0.5583097	25.29803	59.028737	201.9306	200.4599	198.499	199.47944	227.2742897	368.5569552	0.123981143
2:00 PM	3:00 PM	323.4228	0.79480181	16.44372	38.368679	236.7126	194.0441	192.7695	193.40678	236.1286003	389.2170133	0.080587743
3:00 PM	4:00 PM	272.1585	1.00434274	477.0823	491.33354	146.157	118.4225	117.594	118.00823	-224.5099953	-63.7478465	1.423810109
4:00 PM	5:00 PM	226.956	0.45880006	310.1035	319.3668	93.82163	75.79416	75.25565	75.524906	-57.53118493	108.2188922	0.925476571
5:00 PM	6:00 PM	154.6463	0.1435109	201.5673	207.58842	60.74904	49.03119	48.68116	48.856175	51.0050418	219.9972723	0.601559771
6:00 PM	7:00 PM	109.2878	-0.0557314	131.0187	134.93247	40.40991	32.79331	32.56579	32.679547	121.5535892	292.6532194	0.391013851
7:00 PM	8:00 PM	73.21783	-0.1782624	85.16218	0	38.88181	33.93102	-6.06898	33.931021	167.410145	427.5856925	0.125209398
									Average:	110.3871605	206.3730833	0.534284331

- Introduction
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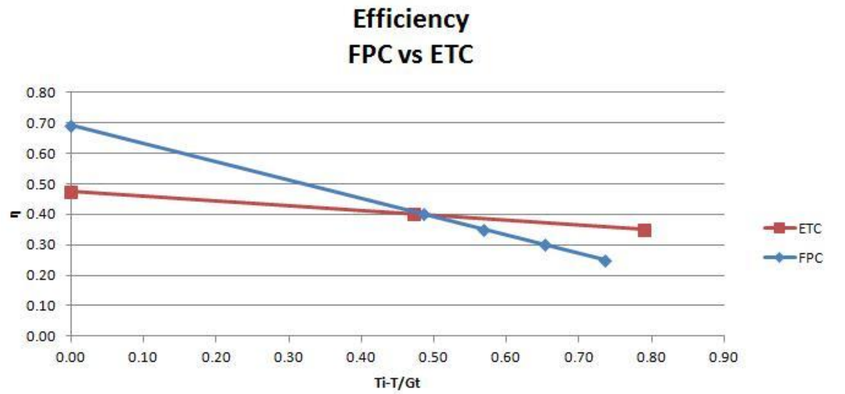
ETC VS FPC

ETC

Date	Total $Q_{u,avg}$ (MBH)	Axililary For DHW (MBH)	Axililary for GA (MBH)	Solar Fraction
12/21	35.27	218.83	427.59	5%
3/20	237.68	185.04	296.14	29%
6/21	225.06	203.56	328.31	22%
9/23	257.93	190.69	308.40	27%
11/30	45.52	204.45	402.34	11%
1/12	141.05	194.71	278.87	30%
Hourly Average:	157.09	199.55	340.28	21%

FPC

Date	Total $Q_{u,avg}$ (MBH)	Axililary For DHW (MBH)	Axililary for GA (MBH)	Solar Fraction
12/21	2.13	252.57	427.59	0%
3/20	418.05	197.34	221.40	38%
6/21	353.77	110.39	206.37	53%
9/23	453.75	171.00	240.63	39%
11/30	93.65	208.30	394.04	11%
1/12	419.23	182.59	252.63	36%
Hourly Average:	290.10	187.03	290.44	30%



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Cost Analysis

Cost of System: $371,450

Fuel Savings at Solar Fraction of 0.3: $3,386

Life Cycle Cost Analysis

- Introduction
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Cost Analysis

Year	Extra mortgage payment ($) : fixed	Fuel savings ($) : projected to increase by 1.03 each year	Extra insurance, maintenance, and parasitic cost ($) : projected to increase by 1.01 each year	Annual Solar savings ($)	PW of annual solar savings ($) : must use PW for each year	Cumulative Solar Savings ($)	Yearly Interest Payment ($) : need to multiply balance by 1.0575	Principle Payment	Principle Balance (total system cost, less 20% Down Payment)	Periodic Payment Present Worth Factor (15, 0, 0.0575)	Present Worth for Savings (n, 0, d) : must use 1/(1+d)^n
0		$3,686.60		-$74,290.00	-$74,290.00	$0.00		$297,160.00	$297,160.00	9.87288553	1.0000
1	-$30,098.60	$3,797.19	-$3,714.50	-$30,015.90	-$28,316.89	-$102,606.89	$0.00	-$30,098.60	$267,061.40		0.9434
2	-$30,098.60	$3,911.11	-$3,751.65	-$29,939.13	-$26,645.72	-$129,252.61	$15,356.03	-$14,742.57	$252,318.84		0.8900
3	-$30,098.60	$4,028.44	-$3,789.16	-$29,859.31	-$25,070.46	-$154,323.07	$14,508.33	-$15,590.26	$236,728.57		0.8396
4	-$30,098.60	$4,149.30	-$3,827.05	-$29,776.35	-$23,585.66	-$177,908.73	$13,611.89	-$16,486.70	$220,241.87		0.7921
5	-$30,098.60	$4,273.78	-$3,865.32	-$29,690.14	-$22,186.20	-$200,094.93	$12,663.91	-$17,434.69	$202,807.18		0.7473
6	-$30,098.60	$4,401.99	-$3,903.98	-$29,600.58	-$20,867.24	-$220,962.17	$11,661.41	-$18,437.18	$184,370.00		0.7050
7	-$30,098.60	$4,534.05	-$3,943.02	-$29,507.56	-$19,624.22	-$240,586.39	$10,601.27	-$19,497.32	$164,872.68		0.6651
8	-$30,098.60	$4,670.07	-$3,982.45	-$29,410.97	-$18,452.81	-$259,039.20	$9,480.18	-$20,618.42	$144,254.26		0.6274
9	-$30,098.60	$4,810.17	-$4,022.27	-$29,310.70	-$17,348.96	-$276,388.15	$8,294.62	-$21,803.98	$122,450.28		0.5919
10	-$30,098.60	$4,954.48	-$4,062.49	-$29,206.61	-$16,308.82	-$292,696.97	$7,040.89	-$23,057.71	$99,392.57		0.5584
11	-$30,098.60	$5,103.11	-$4,103.12	-$29,098.60	-$15,328.78	-$308,025.75	$5,715.07	-$24,383.52	$75,009.05		0.5268
12	-$30,098.60	$5,256.21	-$4,144.15	-$28,986.54	-$14,405.42	-$322,431.18	$4,313.02	-$25,785.58	$49,223.47		0.4970
13	-$30,098.60	$5,413.89	-$4,185.59	-$28,870.30	-$13,535.52	-$335,966.70	$2,830.35	-$27,268.25	$21,955.23		0.4688
14	-$30,098.60	$5,576.31	-$4,227.45	-$28,749.74	-$12,716.04	-$348,682.73	$1,262.43	-$28,836.17	-$6,880.94		0.4423
15	-$30,098.60	$5,743.60	-$4,269.72	-$28,624.72	-$11,944.10	-$360,626.83	-$395.65	-$30,494.25	-$37,375.19		0.4173
15				**Totals:**	$2,002.87	-$358,623.96	-$2,149.0737				

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- Questions

Array Effect on Structural Roof

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Array Effect on Structural Roof

$$w_{LL} = (1.2D + 1.6S + L_r)(joist\ spacing) + 1.2(joist\ weight)$$

$$w_{TL} = 1.2(D + S(or\ L_r))(joist\ spacing) + (joist\ weight)$$

where

- D = Dead Load
- S = Snow Load
- L_r= Roof Live Load

LRFD

STANDARD LOAD TABLE FOR LONGSPAN STEEL JOISTS, LH-SERIES
Based on a 50 ksi Maximum Yield Strength - Loads Shown In Pounds Per Linear Foot (plf)

Joist Designation	Approx. Wt in Lbs. Per Linear Ft. (Joists only)	Depth in inches	Max Load (plf)	SAFELOAD* in Lbs. Between		SPAN IN FEET													
			< 39	39-46	47-49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
32LH06	14	32	647	25230	25230	507 211	489 199	472 189	456 179	441 169	426 161	412 153	399 145	385 138	373 131	363 125	351 119	340 114	330 108	321 104
32LH07	16	32	728	28380	28380	568 235	549 223	529 211	511 200	493 189	477 179	462 170	447 162	432 154	418 146	406 140	393 133	381 127	370 121	360 116
32LH08	17	32	790	30810	30810	616 255	595 242	574 229	553 216	535 205	517 194	499 184	483 175	468 167	453 159	439 151	426 144	412 137	400 131	388 125
32LH09	21	32	992	38670	38670	774 319	747 302	720 285	694 270	670 256	648 243	627 230	606 219	586 208	568 198	550 189	534 180	517 172	502 164	487 157
32LH10	21	32	1096	42750	42750	856 352	825 332	796 315	768 297	742 282	717 267	693 254	667 240	645 228	624 217	603 206	583 196	564 186	546 178	529 169
32LH11	24	32	1201	46830	46830	937 385	903 363	870 343	840 325	811 308	783 292	757 277	732 263	709 251	687 239	664 227	643 216	624 206	604 196	585 187
32LH12	27	32	1409	54960	54960	1101 450	1068 428	1032 406	996 384	961 364	928 345	897 327	867 311	838 295	811 281	786 267	762 255	738 243	715 232	694 221
32LH13	30	32	1572	61320	61320	1225 500	1201 480	1177 461	1156 444	1113 420	1072 397	1035 376	999 354	964 336	931 319	900 304	871 288	843 275	816 262	790 249
32LH14	33	32	1618	63120	63120	1264 515	1239 495	1215 476	1192 458	1170 440	1149 417	1107 395	1069 374	1032 355	997 337	964 321	933 304	903 290	874 276	846 264
32LH15	35	32	1673	65250	65250	1305 532	1279 511	1255 492	1231 473	1207 454	1186 438	1164 422	1144 407	1125 393	1087 374	1051 355	1017 336	984 322	952 306	924 292
			< 43	43-46	47-56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
36LH07	16	36	590	25350	25350	438 177	424 168	411 160	399 153	387 146	376 140	366 134	355 128	345 122	336 117	327 112	318 107	310 103	301 99	294 95
36LH08	18	36	649	27900	27900	481 194	466 185	453 176	439 168	426 160	414 153	402 146	390 140	379 134	369 128	358 123	349 118	340 113	331 109	322 104
36LH09	21	36	832	35760	35760	616 247	597 235	579 224	561 214	544 204	528 195	513 186	499 179	484 171	471 163	459 157	445 150	433 144	423 138	412 133
36LH10	21	36	916	39390	39390	681 273	660 260	639 248	619 238	601 225	583 215	567 206	550 197	535 188	520 180	507 173	492 165	480 159	466 152	454 146
36LH11	23	36	1000	42990	42990	742 297	720 283	697 269	676 257	657 246	637 234	618 224	601 214	583 205	567 196	552 188	537 180	522 173	508 166	495 159
36LH12	25	36	1197	51450	51450	889 354	862 338	835 322	810 307	784 292	762 279	739 267	717 255	696 243	675 232	655 222	636 213	618 204	600 195	583 187

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- **Acoustical Breadth**
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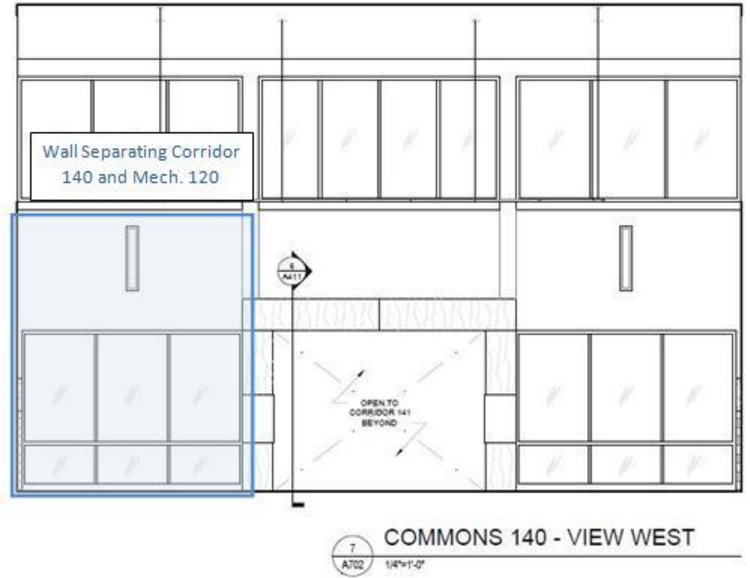
Redesign of Mechanical Room Walls



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- Questions

Redesign of Mechanical Room Walls

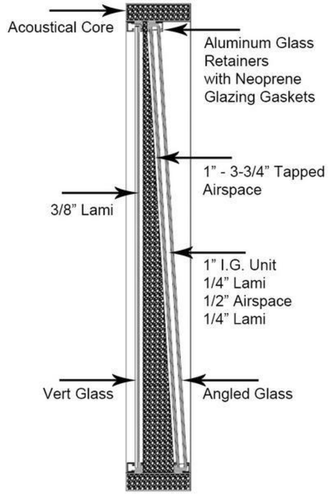
Table B.1 — Minimum STC ratings recommended between an ancillary space and an adjacent space

Receiving ancillary learning space	Adjacent space			
	Corridor or staircase [a], common-use, and public-use toilet and bathing room [b]	Music room	Office or conference room [a]	Mechanical equipment room [f], cafeteria, gymnasium, or indoor swimming pool
Corridor used as ancillary learning space	45	60[c]	45[d]	55[c]
Music room	45	60	60[e]	60
Office or conference room	45[d]	60[g]	45[d]	60

c) When the corridor will not be used as an ancillary learning space, the minimum STC rating may be reduced to not less than 45. Use of corridors as ancillary learning spaces should be avoided when they are located next to the noisy spaces indicated in the table by the high STC ratings.

Current STC of Glass Window: STC-30

Proposed Redesign



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- Acoustical Breadth
- **Conclusions**
- Recommendations
- Questions

Conclusions

•As Solar hot Water System is possible and economical

•Costly ramifications for structure

•Acoustical Treatment is necessary for the mechanical display windows

- Introduction
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- Structural Breadth
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- Conclusions
- **Recommendations**
- Questions

Recommendations

•Generate More Accurate Model

•Do not proceed with solar hot water system

- Introduction
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- **Questions**

Questions?

Special Thanks To:
David Nitchkey
Harry Bauman
David Winklebleck