

Thesis Proposal
Mechanical System Redesign Report



South Jefferson High School

Huyett Road
Charles Town, WV 25414

Prepared for Dr. Jelena Srebric
The Pennsylvania State University

By
Jonathon Gridley
Mechanical Option

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2.0 Executive Summary:

This report develops the proposed ideas for re-design and modification of South Jefferson High School. In order to provide orientation and makeup of the building, a short summary of the general building background is provided at the beginning of the report. Followed by, information on the original mechanical systems. The analysis of the existing mechanical systems shows specific areas in which the building can be improved with possible re-design or modification. After several alternatives are discussed, the proposed redesign is described.

The proposed re-design includes replacing existing direct expansion equipment with a more energy efficient chilled water system. A ground source heat pump system with energy recovery will be researched and compared to the existing VAV system. Humidity controls will be incorporated into the system to improve indoor air quality.

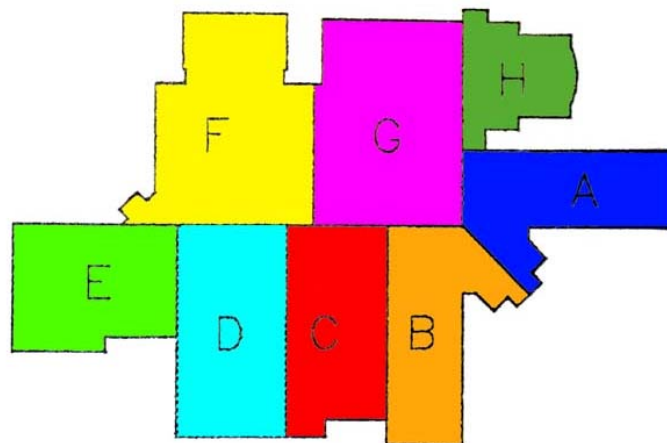
In addition to the main depth area of the thesis proposal, two breadth areas are also developed. The first deals with the replacement of existing lighting fixtures with more energy efficient models while maintaining the original light output. The second revolves around the added cost and scheduling concerns derived from installing chillers and a ground source heat pump well field and loop.

3.0 Building Background:

South Jefferson High School is a two story 232,705 s.f. secondary school utilized by 1200 students during the day, and a number of adult learners in the evening. The total capacity of the school is designed to accommodate up to 1500 students. The building is located in Charles Town, WV off of Route 1.

South Jefferson High School is broken into 8 separate zones named A thru H. The second floor is also broken into similar zones A, B, and G. The designation of each of these areas can be seen in Figure 1. The school has academic wings (1st Flr A & B, and 2nd Flr A), administration area (1st Flr A & B), and common facilities (1st Flr C thru H) for use by all students. Common facilities such as the Learning Resource Center (1st Flr G), dining (E), physical education (C & D), and creative arts (F) are accessible from the main corridors. The school's administrative offices and Student Services are located near the main entrance.

Figure 1 – South Jefferson High School Zone Designations



The Science (2nd Flr G) and Technology Center (2nd Flr B) is partially funded by a separate grant, this portion of the building includes the School's Science Department along with various technology oriented subject areas such as technology training labs, technology education, engineering, agricultural technology, and video conferencing. During regular school hours, the center supports the academic curriculum. In the evenings, the facilities will be available for continuing education classes open to the community at large.

The South Jefferson School District also plans to make the Learning Resource Center and computer facilities available to the community after normal school hours as well. Thus the community at large will have access to up-to-date facilities for instruction, research, and application that are not currently available in the School District.

4.0 Mechanical Systems Summary:

The HVAC system primarily consists of multi-zone variable air volume rooftop units (RTU) serving series-style fan powered boxes at classrooms. The classroom wings have rooftop units with ductwork chased down through rated shafts for outside air to a fan powered box at each classroom. The fan powered box serve ceiling mounted diffusers.

The Gymnasium, Auditorium and Cafeteria are served with single-zone air handling units located on the roof. These units incorporate demand-based ventilation controls in the form of CO₂ sensors.

All heating-only equipment such as cabinet unit heaters and horizontal unit heaters are installed in mechanical spaces, entry vestibules, and similar areas. The heating-only equipment, rooftop unit heating coils, and auxiliary heating coils are served by hot water generated by two electric boilers.

4.1 Air Side Mechanical Systems:

Cooling of South Jefferson high school is done by the school's 14 packaged roof top units (RTU) with condensing units, ranging in size from 4,500 cfm to 25,500 cfm. All refrigeration coils are direct-expansion instead of chilled water. This eliminates the need for chillers in the plant and chilled water piping throughout the building. Design airflow quantities for all roof top units can be seen below in Table 2.

Symbol	Variable or Constant Volume	Supply Air (CFM)	Design Outdoor Air (CFM)	OA Percent (%)	Cooling Airflow (CFM)	Heating Airflow (CFM)	Return Airflow (CFM)
RTU-8	CV	4,500	1,200	26.7	3,337	3,337	3,337
RTU-2	VV	25,500	10,600	41.6	20,877	22,605	22,605
RTU-3	VV	13,000	3,600	27.7	10,231	3,069	10,231
RTU-4	VV	24,000	10,500	43.8	18,776	18,840	18,840
RTU-5	CV	14,000	14,000	100.0	11,273	11,276	11,276
RTU-6	VV	12,000	2,700	22.5	6,993	7,156	7,156
RTU-7	VV	15,000	6,400	42.7	12,521	12,979	12,979
RTU-1	VV	22,000	9,600	43.6	1,951	19,741	19,741
RTU-9	CV	9,000	8,000	88.9	7,950	7,950	7,950
RTU-10	CV	13,000	7,500	57.7	9,963	9,963	9,963
RTU-11	CV	6,000	4,670	77.8	3,581	3,581	3,581
RTU-12	CV	12,000	12,000	100.0	7,448	7,448	7,448
RTU-13	CV	9,500	5,500	57.9	9,375	9,375	9,375
RTU-14	CV	9,500	5,500	57.9	9,662	9,662	9,662
Totals:		184,500	100,570		130,601	143,645	150,807

Table 2 - Design Airflow Quantities

A central cooling plant could be useful for South Jefferson High School. If two 300 ton chillers were installed to replace the existing condensing units, the reduction in kW/ton would help save energy, reducing annual energy consumption and cost.

4.2 Boilers and Hot Water Systems:

Heating-only equipment, hot water coils in the RTU's, plus auxiliary heating coils scattered throughout South Jefferson High School are heated hydronically by two identical hot water boilers. These boilers are designed for heating by electric resistance. Electric boiler data can be seen in Table 3.

Symbol	Total KW Input	Total Load Amps	MBH Output	Steps of Control	Elect Char	EWT °F	LWT °F
BLR-1	1,440	1,742	4,717	16	460V/3PH/60HZ	150	180
BLR-2	1,440	1,742	4,717	16	460V/3PH/60HZ	150	180

Table 3 – Electric Boiler Data

The heating system also incorporates a primary-secondary pumping system. Two primary and two secondary (building loop) system water pumps were installed. The pumps are provided with variable frequency controllers to offer an energy-saving variable flow system. Pump data can be seen in Table 4 below.

Symbol	Type	System	GPM	FT HD	Efficiency	Motor HP	Impellar Dia.	VFD	Operation
P-1	In Line	HWS/R	310	30	74.6	5	6.875"	No	Primary Duty
P-2	In Line	HWS/R	310	30	74.6	5	6.875"	No	Primary Duty
P-3	Flr Mtd	HWS/R	750	80	78.8	25	10.750"	Yes	Secondary Duty
P-4	Flr Mtd	HWS/R	750	80	78.8	25	10.750"	Yes	Secondary Standby

Table 4 – Pump Data

4.3 Mechanical Systems Controls:

All sequences of controls for the entire building are performed by direct digital controls (DDC). This DDC system monitors all the sensors, and it is able to adjust all the set points and time delays for the equipment. The DDC system also provides start/stop, speed control, monitoring, and alarms for the variable frequency drives (VFD). A few controls can be seen in the flow diagrams in Appendix

5.0 Indoor Humidity Conditions:

The humidity levels in the Charles Town area are relatively high. No additional means of removing humidity was taken incorporated into the systems design. Only the rooftop units cooling coils provide dehumidification of the air. A desiccant or enthalpy wheel can be incorporated to help control humidity in the supply air. Controlling humidity would improve thermal comfort and indoor air quality with in the building. It has been show in studies that improving these two areas can increase performance of students and lower absenteeism. Table 1 shows humidity profile data for a variety of spaces. There are a number of rooms in need of humidity control, most being the densely populated spaces.

SYSTEM HUMIDITY PROFILES

Room Description	---- Maximum----				----- Number of Hours at each Percentage Range -----											
	% Rh	Mo	Hr	Day	>70%	70-66	66-62	62-58	58-54	54-50	50-46	46-42	42-38	38-34	34-30	<30 %
CORRIDOR H112	71	8	8	2	176	245	671	449	739	1,237	1,162	1,034	829	628	626	964
VICE PRIN B107	64	1	7	1	0	0	0	8	306	1,128	1,991	2,191	1,050	935	529	622
COMPUTER LAB G103	92	1	11	1	0	0	0	337	505	1,590	1,810	1,052	1,172	635	1,659	
KEYBOARDING LAB G110	87	1	10	1	0	0	118	411	546	1,583	1,696	957	1,166	707	1,576	
LAB CADD G116	88	1	11	1	0	0	0	213	548	1,516	1,829	1,067	1,086	786	1,715	
BUSINESS CLASSROOM G110	100	1	14	1	0	103	462	489	757	1,842	1,602	1,049	1,009	564	374	509
PREP G118A	90	1	18	1	0	0	0	0	0	576	2,661	1,631	1,186	1,073	1,633	
FORENSICS LAB G118	67	1	9	1	0	0	0	0	586	2,144	1,671	913	1,261	602	1,583	
VISUAL COMM PRODN LAB G118	57	1	6	1	0	0	0	0	293	1,939	1,717	947	1,039	912	1,913	
CONTROL ROOM G120	58	1	6	1	0	0	0	0	416	2,010	1,616	947	998	943	1,830	
OFFICE TECH LAB G109	87	1	10	1	0	0	118	411	546	1,583	1,696	957	1,166	707	1,576	
SCHOOL STORE G105	100	12	24	2	1,327	4	36	9	50	11	614	3,871	1,449	861	281	247
INFO TECH REPAIR LAB G124	100	1	12	1	0	0	203	479	372	1,025	1,967	1,327	935	890	642	920
OFFICE G104A	71	1	12	1	0	0	0	0	0	547	2,543	1,529	942	1,041	2,158	
RECEPTION B103C	100	8	7	2	3,276	748	655	524	580	761	762	446	409	206	273	120
CORRIDOR D102	77	8	7	2	948	396	262	591	755	855	971	973	680	717	631	981
CORR H112	72	8	8	2	204	260	651	437	611	1,113	1,253	950	842	746	646	1,047
LOBBY B101	64	9	7	1	0	0	172	290	975	1,242	1,696	1,140	982	644	515	1,104
CORRIDOR A133	77	8	7	2	948	396	262	591	755	855	971	973	680	717	631	981
CORRIDOR B134	77	8	7	2	948	396	262	591	755	855	971	973	680	717	631	981
CORRIDOR B133 AHU3	61	8	13	8	0	0	806	751	1,238	1,397	1,164	936	656	725	1,087	
FACILITY PLANNING B114	71	7	10	2	10	101	243	1,290	1,673	1,320	1,344	612	888	645	313	321
LOUNGE B114A	81	12	9	2	59	260	700	770	1,443	2,311	1,357	731	554	217	235	123
PHYSICS LAB G207	58	5	14	1	0	0	0	36	250	1,163	2,052	1,738	1,462	1,107	952	
INSTRUCTOR PLANNING G101	73	1	6	1	114	288	378	537	564	1,450	1,231	918	853	591	519	1,317
CORR G125	59	1	8	2	0	0	74	1,747	965	118	814	4,303	680	59	0	
STAGE BACKSTAGE F125	58	6	14	1	0	0	0	0	126	379	522	890	1,809	1,638	3,396	
UNIVERSAL LAB G208	58	5	14	1	0	0	0	18	236	1,286	2,161	1,996	1,185	1,074	804	
UNIVERSAL LAB G209	58	5	14	1	0	0	0	36	280	1,288	2,387	1,741	1,099	1,106	823	
UNIVERSAL LAB G210	58	5	14	1	0	0	0	36	280	1,288	2,387	1,741	1,099	1,106	823	
UNIVERSAL LAB G211	58	5	14	1	0	0	0	36	271	1,349	2,382	1,726	1,109	1,052	835	
UNIVERSAL LAB G212	58	5	14	1	0	0	0	62	326	1,141	2,457	1,721	1,132	1,037	884	
PREP ROOM G208A	56	1	7	1	0	0	0	0	0	1,179	2,288	1,695	1,832	739	1,027	
PREP G210A	56	1	7	1	0	0	0	0	36	891	2,341	1,891	1,335	1,151	1,115	
PREP ROOM G212A	56	1	7	1	0	0	0	0	0	552	2,064	2,241	1,584	1,359	960	
UNIVERSAL LAB G213	58	5	14	1	0	0	0	62	326	1,141	2,457	1,721	1,132	1,037	884	
MARKETING CLASSROOM G104	100	1	14	1	261	414	633	613	1,089	1,888	1,164	941	640	475	373	269
CORR G126	55	1	6	1	0	0	0	0	51	204	1,583	2,302	1,353	1,205	2,062	
SPL ED OFFICE	88	8	7	2	1,916	544	555	666	891	672	404	810	853	488	365	596
CORR G128	54	1	1	1	0	0	0	0	0	0	1,458	2,219	1,183	1,037	2,863	

Table 1 – System Humidity Profile

6.0 Proposal Objective:

The results of this thesis will suggest alternative solutions to the design of the South Jefferson High School. All modifications are for academic purposes and do not imply flaws in the original design. All modifications are simply alternative solutions which will include one extensive modification to the mechanical system and resulting changes to the other building systems.

7.0 Considered Alternatives:

- Night Precooling

There are two variations on night precooling. One, termed night ventilation precooling, involves the circulation of outdoor air into the space during the naturally cooler nighttime hours. This can be considered a passive technique except for any fan power requirement needed to circulate the outdoor air through the space. The night ventilation precooling system benefits the building indoor air quality through the cleansing effect of introducing more ventilation air. With the other variation, mechanical precooling, the building mechanical cooling system is operated during the nighttime hours to precool the building space to a setpoint usually lower than that of normal daytime hours.

The location and mass of building are not ideal for this strategy. Thermal comfort is also a concern requiring building occupants to be more tolerant of the potential for slightly cooler temperatures during the morning hours.

- Displacement Ventilation

In displacement ventilation the range of supply air temperatures and discharge velocities is limited to avoid discomfort to occupants, displacement ventilation has a limited ability to handle high heating or cooling loads if the space served is occupied. The system is also costly and is not common in schools.

- Combustion Air Preheating

For fuel-fired heating equipment, one of the most potent ways to improve efficiency and productivity is to preheat the combustion air going to the burners. The source of this heat energy is the exhaust gas stream, which leaves the process at elevated temperatures. A heat exchanger, placed in the exhaust stack or ductwork, can extract a large portion of the thermal energy in the flue gases and transfer it to the incoming combustion air. Material and maintenance costs for this method are too expensive for a school budget.

8.0 Proposed Redesign:

The angle taken in the proposed redesign of South Jefferson High School is that of the green design initiative. A driver for green design is lowering the total cost of ownership in terms of resource management and energy efficiency. Green design is also recognized for the increased productivity from a building that is comfortable and enjoyable and provides healthy conditions. Comfortable occupants are less distracted, able to focus better on their tasks/activities, and appreciate the physiological benefits good green design provides.

-Chilled Water Plant

Calculated cooling capacities of the packaged DX roof top units were developed in the Trane TRACE 700 software and can be seen in Figure 2. This data shows that the total peak load cooling tonnage is 590.4 tons. This load is handled completely by the roof top units condensing units. Installing a central chilled water plant in which the condensing units could be replaced by two 300 ton chillers, would result in a significant annual energy savings,

Plant	System	Peak Plant Loads		Block Plant Loads		
		Main Coil ton	Peak Total ton	Time Of Peak mo/hr	Main Coil ton	Block Total ton
Cooling plant - 001		585.9	590.4	7/12	573.2	577.7
	AHU-8	6.4	10.9	7/12	6.4	10.9
	AHU-2	82.4	82.4	7/12	81.5	81.5
	AHU-3	30.2	30.2	7/12	30.2	30.2
	AHU-4	68.1	68.1	7/12	68.1	68.1
	AHU-5	40.7	40.7	7/12	40.7	40.7
	AHU-6	20.5	20.5	7/12	20.5	20.5
	AHU-7	49.3	49.3	7/12	47.5	47.5
	AHU-1	72.7	72.7	7/12	72.7	72.7
	AHU-9	37.1	37.1	7/12	36.6	36.6
	AHU-10	42.2	42.2	7/12	42.2	42.2
	AHU-11	10.0	10.0	7/12	4.5	4.5
	AHU-12	32.6	32.6	7/12	32.6	32.6
	AHU-13	46.1	46.1	7/12	44.4	44.4
	AHU-14	47.6	47.6	7/12	45.4	45.4
Building totals		585.9	590.4		573.2	577.7

Building peak load is 590.4 tons.

Building maximum block load of 577.7 tons occurs in July at hour 12 based on system simulation.

Table 5 – Design Cooling Load

-Ground Source Heat Pump

Once the results of adding the chilled water system are analyzed a ground source heat pump system will replace the existing fan powered boxes. Ground source heat pump systems take advantage of the earth's relatively constant

temperatures just below its surface (a range of 45° to 65°F). In the heating season, a fluid in the loop collects heat from the earth and transfers that heat to the building. The system then uses electrically driven compressors and heat exchangers to concentrate the heat and release it at a higher temperature into the building. The data will be compared to both the original mechanical system and the design with chilled water only.

-Air-to-Air Heat Recovery

Next, air-to-air heat recovery utilizing heat exchange enthalpy wheels will be integrated into the air-handling equipment or added through the use of energy recovery ventilators. The total HVAC system installed cost should lower because central heating and cooling equipment may be reduced in sized. Including a total energy wheel will reduce humidification costs in cold weather. Results for heat recovery will be calculated as an additional alternative, and as an incorporated component in the other two alternatives. Humidity control will be incorporated along with the enthalpy wheels in order to maintain humidity levels below 60%, ideally between 30% and 50%. The density of school population results in large amounts of outdoor air must move through the building to assure proper ventilation. If the air is not properly conditioned, small amounts of moisture in the outdoor air can lead to too much moisture indoors and moisture-related problems during the spring, summer, and fall.

-Software

Trane Trace 700 software package will be used to perform building load energy analysis and life cycle cost estimation.

9.0 Breadth Areas:

The two main breadth analysis areas proposed of South Jefferson High School were chosen because of the effect the analyses have on one another. The results of improving some of the lighting systems will directly affect the mechanical systems by decreasing cooling loads. Also, the redesign of the mechanical systems at South Jefferson High School will have effects on some of the building's cost and scheduling concerns.

-Lighting

A significant amount (25%) of the annual energy consumption is conditioning of lighting. If a lower watt per square foot values were maintained for lighting the energy savings from reducing cooling loads would considerably help annual energy costs. A summary of the total lighting fixture wattage calculation is provided in Appendix B. The lower watt per square foot lighting values will be incorporated into the Trane Trace inputs, therefore, becoming included in life cycle cost analyses.

-Construction Management

Adding chillers and ground source heat pumps will directly affect the cost and scheduling for the projects construction manager. Construction costs for installing chillers and ground source heat pumps will be generated using the RSMMeans Costworks software, while scheduling will be generated by the Primavera software package.

10.0 Project Method:

Various methods could be used to analyze the proposed redesign of South Jefferson High School. Most of the data for the redesign will be generated through the use of software. The major software packages that will be used are either accessible from Penn State or H.F. Lenz Company's available software collection.

11.0 References:

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APPENDIX A: Lighting Power Calculations

Section 1: Allowed Lighting Power Calculation


A	B Floor Area	C Allowed Watts / ft ²	D Allowed Watts
School/University	232705	1.2	279246
Total Allowed Watts =			279246

Section 2: Actual Lighting Power Calculation

A Fixture ID : Description / Lamp / Wattage Per Lamp / Ballast	B Lamps/ Fixture	C # of Fixtures	D Fixture Watt.	E (C X D)
Linear Fluorescent 1: RF-1: 3 - 32W T8 / Other / Electronic	3	500	96	48000
Linear Fluorescent 2: RF-2: 2 - 32W T8 / Other / Electronic	2	317	64	20288
Linear Fluorescent 3: RF-3: 3 - 32W T8 / Other / Electronic	3	160	96	15360
Linear Fluorescent 4: RF-4: 2 - 26W TRT / Other / Electronic	2	35	52	1820
Linear Fluorescent 5: RF-5: 3 - 32W T8 / Other / Electronic	3	118	96	11328
Linear Fluorescent 6: RF-6: 3 - 32W T8 / Other / Electronic	3	41	96	3936
Linear Fluorescent 7: RF-7: 2 - 26W TRT / Other / Electronic	2	90	52	4680
Linear Fluorescent 8: RF-8: 2 - 26W TRT / Other / Electronic	2	43	52	2236
Linear Fluorescent 9: RF-9: 2 - 26W TRT / Other / Electronic	2	53	52	2756
Linear Fluorescent 10: RF-10: 3 - 26W TRT / Other / Electronic	3	12	78	936
Linear Fluorescent 11: RF-11: 2 - 32W T8 / Other / Electronic	2	14	64	896
Linear Fluorescent 12: RF-12: 3 - 32W T8 / Other / Electronic	3	37	96	3552
Linear Fluorescent 13: RF-13: 4 - 32W T8 / Other / Electronic	4	7	128	896
Linear Fluorescent 14: RF-14: 6 - 32W T8 / Other / Electronic	6	53	192	10176
Linear Fluorescent 15: SF-1: 2 - 32W T8 / Other / Electronic	2	1	64	64
Linear Fluorescent 16: SF-2: 3 - 32W T8 / Other / Electronic	3	8	96	768
Linear Fluorescent 17: SF-3: 1 - 26W TRT / Other / Electronic	1	1	26	26
Linear Fluorescent 18: WSF-1: 1 - 26W TRT / Other / Electronic	1	3	26	78
Incandescent 1: WSI-1: 100W INCAND / Incandescent 100W	1	1	100	100
Linear Fluorescent 19: DF-1: 2 - 32W T8 / Other / Electronic	2	122	64	7808
Linear Fluorescent 20: DF-2: 3 - 32W T8 / Other / Electronic	3	17	96	1632
Linear Fluorescent 21: DF-3: 2 - 32W T8 / Other / Electronic	2	68	64	4352
Linear Fluorescent 22: DF-4: 3 - 32W T8 / Other / Electronic	3	12	96	1152
Linear Fluorescent 23: DF-5: 5 - 54W T5 / Other / Electronic	5	34	270	9180
Linear Fluorescent 24: DF-6: 1 - 32W TT / Other / Electronic	1	12	32	384
HID 1: DI-1: 500W QUARTZ / Other / Magnetic	1	32	500	16000
HID 2: DI-2: 250W QUARTZ / Other / Magnetic	1	22	250	5500
HID 3: RMH-1: 100W MH/100W QUARTZ / Metal Halide 100W / Magnetic	1	14	200	2800
HID 4: RMH-2: 100W MH / Metal Halide 100W / Electronic	1	15	100	1500
HID 5: RMH-3: 100W MH / Metal Halide 100W / Electronic	1	33	100	3300
HID 6: WMH-1: 175W MH/100W QUARTZ / Metal Halide 175W / Electronic	1	15	275	4125
HID 7: WMH-2: 175W MH / Metal Halide 175W / Electronic	1	26	175	4550
HID 8: SL-1: 400W MH / Metal Halide 400W / Magnetic	1	1	400	400
HID 9: SL-2: 100W MH / Metal Halide 100W / Electronic	1	1	100	100
Linear Fluorescent 1 copy 1: RF-1: 3 - 32W T8 / Other / Electronic	3	237	96	22752

Note: Calculated using the COMcheck Software Version 3.3.1 Lighting Application Worksheet.

January 2007

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday																																																																																									
	New Year's Day 1 Penn State Bowl Game Outback Bowl	2	3	4	5	6																																																																																									
7	8	9	10	11	12	13																																																																																									
14	ML King Day 15	Classes Begin 16 	17	18	19	20																																																																																									
21	22	23	24	25	26	27																																																																																									
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March 2007

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11	12	13	14	15	16	17
Spring Break Daylight Savings	Spring Break	Spring Break	Spring Break	Spring Break	Spring Break	St. Patrick's Day Spring Break
To be used if behind	To be used if behind	To be used if behind	To be used if behind	To be used if behind	To be used if behind	
18	19	20	21	22	23	24
Spring Break	Final Report Work Organization and Graphics	Final Report Work Organization and Graphics	Final Report Work Organization and Graphics	Final Report Work Writing	Final Report Work Writing	
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Final Report Work Writing	Final Report Work Writing	ASHRAE Meeting	Final Report Work Writing	Final Report Work Writing	Final Report Work Writing	
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