Mechanical Systems
Existing Conditions Evaluation

(Rendering Courtesy of Clark-Nexsen)

William & Mary
Virginia Institute of Marine Science
Marine Research Building Complex
Seawater Research Laboratory

Gloucester Point, VA

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1.0 Executive Summary

This report is a descriptive summary of the VIMS Seawater Research Laboratory's mechanical system and how it operates. The systems covered in this report are: heating, cooling, and ventilation. The heating source is two propane gas-fired modular boilers located in the mechanical room that provide 1760 MBtuH each. The cooling source is two 105 ton air cooled screw compressor water chillers located outside of the mechanical room. The spaces are ventilated with two air handling units and four make-up air units, all of which supply 100% outdoor air.

The mechanical system design was based on space use and function, considering the processes that occurred within them and also based on occupant safety. Cost wasn't a major factor in the design process. There are a few site factors that came into the design consideration but, nothing that greatly affected the design. The VIMS Seawater Research Laboratory is currently under construction so there isn't an actual operations cost to compare the estimated value calculated using the HAPv4.2 analysis program.

The operational sequences and controls that are discussed in this report cover: the exhaust system, the water heating system, the water cooling system, the space heat, cooling, and ventilating systems. The controls of these systems are configured to maintain space temperature, pressure, and humidity levels.

2.0 Design Objectives and Requirements

The design of the VIMS Seawater Research Laboratory was carefully thought out. One feature of the design is that the mechanical system can support the change of an administration space into a laboratory space. This was the main reason for the mechanical system using 100% outdoor air.

The location of the mechanical room is also well thought out. It is on the back side of the building allowing access to the equipment yard that is between the Seawater Research Laboratory and the Water Treatment Building. Also the mechanical room equipment is configured to allow for the addition of future equipment such as a third propane gas-fired modular hot water boiler. Outside the mechanical room there is room for an additional third air cooled screw compressor chiller. These configurations were made to allow for the future expansion of the VIMS Seawater Research Laboratory and its facilities.

3.0 Energy Sources and Rates

The VIMS Seawater Research Laboratory Utilizes propane gas-fired modular hot water boilers as the heating source for the mechanical systems, and electrical air cool screw compressor water chillers as the cooling source for the mechanical systems.

The electrical service to the facility is a 408/277Y three phase four wire from the main switchboard that is rated for 2000 amps. The facility utilizes dry type step-down transformers to provide to serve 208Y/120 volt loads.

The 30-day electric rates for the primary voltage of the VIMS Seawater Research Laboratory were found on the Virginia Electric and Power Company's website. The facility's electrical service is classified as Large General Service. The rates are as follows:

Distribution Service Charges

Basic Customer Charge:	$127.60 per billing month
Plus Distribution Charge:	
First 5000kW of Distribution Demand:	$1.000 per kW
Additional kW of Distribution Demand:	$0.755 per kW
Plus rkVA Demand Charge:	$0.15 per rkVA

Electricity Supply Service Charges

All On-Peak Electricity Supply Demand Charge:	
All On-Peak Electricity Supply Demand for Primary Service Voltage:	$12.003 per kW
All On-Peak Electricity Supply Demand for Transmission Service Voltage:	$11.715 per kW
Plus Off-Peak Electricity Supply Demand Charge:	
All Off-Peak kW Demand:	$0.632 per kW

Plus Electricity Supply Adjustment Demand Charge:	
First 5000kW of Demand:	$0.421 per kW
Additional kW of Demand:	$0.318 per kW
Plus Electricity Supply kWh Charge:	
All On-Peak kWh:	$0.404 per kWh
All Off-Peak kWh:	$0.272 per kWh

4.0 Cost Factors

The cost factors involved with the design and construction were kept to a minimum. The design of the VIMS Seawater Research Laboratory included energy analysis for justification for equipment used, which is reason for the use of the air to air coil energy recovery loop. The mechanical design decisions were for the most part made based on the process application. The mechanical system first cost is summarized in Table 1. The total first cost of the mechanical system is $1,681,744, which is 23.8% of the total overall building cost. A more detailed analysis is covered in *Technical Report #2 Building & Plant Energy Analysis Report*.

Table 1

System	Total Cost	Cost per ft^2
Plumbing	$358,893	$8.93/$ft^2$
HVAC	$1,143,347	$28.44/$ft^2$
Fire Protection	$179,504	$4.47/$ft^2$

5.0 Site Factors

The site of the VIMS Seawater Research Laboratory consisted of two grassed drain fields and contained: 2 brick buildings, a masonry dwelling, a double wide mobile trailer, and three garages. This site is also located 500 feet from the York River. The site is very accommodating to the construction process and unrestrictive to the building itself. There were only a few site factors that would control the design and construction process.

One of the factors was that the VIMS Seawater Research Laboratory utilize all existing utilities provided. The only utility that was not available was a natural gas service, which caused the building to utilize on site propane storage.

Another reason for the on site propane storage is because of the environmental sensitive nature of the VIMS mission and existing site characteristics. Given the topography of the site any oil spill or leak on the facility could drain directly into the York River. The fuel storage is located in the equipment yard between the Seawater Research Laboratory and the Water Treatment Building consisting of five 2000 gallon above ground propane tanks that sit on concrete saddles.

The storm water management of the half of the site needed to be reconfigured to utilize an existing moat. The other half of the site and the roof drainage utilizes another storm water management system. Both systems are connected to an outfall pipe that discharges directly into the York River.

6.0 Outdoor and Indoor Design Conditions

The outdoor design conditions used by Clark Nexsen are different than the values listed for that location used from the ASHRAE Standard 90.1. The design conditions are worse than the design values listed in the ASHRAE Standard 90.1, both are shown below. The AHSRAE outdoor design conditions are that of Norfolk, VA, which is the nearest location listed in the ASHRAE Standard 90.1. The reason for using worse design values is unknown, there is a possibility that the difference in the values is because of the use of different versions of ASHRAE Standard 90.1.

Outdoor Design Conditions:

Design Values

Summer: 92FDB
78FWB

Winter: 14FDB

ASHRAE Values

Summer: 91FDB
76FDB

Winter: 20FDB

The indoor design conditions were divided into six different space conditions based on the space use.

Indoor Design Conditions:

Offices:
Summer: 78FDB
Winter: 70FDB
Ventilation: 20cfm/person
Load Density:4watts/ft^2

Laboratory Spaces:
Summer: 75FDB
Winter: 70FDB
Ventilation: 20cfm/person
Load Density:8watts/ft^2

Open Bay Research Labs:
Summer: 90FDB
Winter: 65FDB
Ventilation: 1.8cfm/ft^2
Load Density: 4watts/ft^2

Mech./Elec. Rooms:
Summer: 90FDB
Winter: 55FDB
Ventilation: To limit temp. rise to 18^o
Load Density: 1watt/ft^2

Toilets:		**Communication Rooms:**	
Summer:	78FDB	Summer:	78FDB
Winter:	70FDB	Winter:	55FDB
Ventilation:	75cfm/water closet	Ventilation:	.5cfm/ft^2
Load Density:	1watt/ft^2	Load Density:	Per equipment in space

7.0 Design Ventilation Requirements

The minimum outdoor air provided was determined in accordance with the following codes:

ASHRAE Standard 62-99
NFPA 45
2000 VUSBC with October, 2003 amendments

The maximum outdoor air flow rates are based on the exhaust air requirements of the laboratory spaces, winter indoor space dew point temperature, and summer indoor space dry bulb temperature.

The VIMS Seawater research Laboratory is supplied with conditioned 100% outdoor air through two rooftop variable air volume air handling units and four rooftop variable air volume make-up air units and is distributed to the spaces throughout the building through air distribution ductwork. An air to air coil heat recovery loop is utilized to recover waste heat from the building exhaust air stream and provide it to either preheat or precool the outdoor air that is entering AHU-1.

The exhaust of the toilets, janitor's closets, and storage rooms is provided by ducted exhaust fans. The mechanical and electrical equipment rooms are ventilated by outdoor air intake louvers, and exhaust louvers by exhaust fans. These exhaust fans are controlled by thermostats to reduce the outdoor air heating load in the winter and to provide the maximum outdoor air during the summer to control the space temperature. The exhaust fans are also be controlled by the building DDC energy management and temperature control system.

The ventilation of the VIMS Seawater Research Laboratory surpasses the minimum outdoor air requirements of ASHRAE Standard 62.1 with the 2001 Supplement. A more detailed minimum outdoor air analysis is covered in *Technical Report #1 ASHRAE Standard 62.1 Compliance Report*.

8.0 Design Heating and Cooling Loads

The design loads and mechanical calculations were done in accordance with the following codes:

The 2000 VUSBC with October, 2003 amendments
Commonwealth of Virginia Construction and Professional Services Manual
ASHRAE Fundamentals Handbook 2001
NFPA 45
ANSI Z9.5-1992

The estimated design load of the VIMS Seawater Research Laboratory was calculated using Carrier Hourly Analysis Program (HAP)v4.2. The heating and cooling load calculations summarized in *Technical Report #2 Building and Plant Energy Analysis Report*.

Heating Loads:

The design heating loads calculated by HAPv.4.2 for all of the air handling and make-up air units, yielded the following:

Table 2

System	Heating Capacity MBH
AHU-1	289.9
AHU-2	88.6
MAU-1	3.3
MAU-2	5.1
MAU-3	2.6
MAU-4	3

Cooling Loads:

The design cooling loads calculated by HAPv.4.2 for all of the air handling and make-up air units yielded the following:

Table 3

System	Cooling Capacity MBH	Tons of Cooling
AHU-1	846.3	70.5
AHU-2	201.8	16.8

9.0 Mechanical System Equipment Summary

Air Handling and Make-up Air Units

The VIMS Seawater Research Laboratory utilizes two air handling units and four make-up air units. All of these units supply 100% outdoor air to the entire building and are located on the roof of the building. Every air handling unit and make-up are unit is provided with a variable frequency drive. The spaces supplied by these units are broken down in Table 4. The two air handling units utilize direct steam injection, as well as an 80% efficient bag filter section with 30%-40% efficient pleated media pre-filters.

Table 4

Air Handling Unit	Area Served
AHU-1	Admin. Coral Reef & Dry Labs
AHU-2	BSL-3 Lab
Make-up Air Unit	**Area Served**
MAU-1	BSL-1/2 Lab
MAU-2	Multi-purpose Lab
MAU-3	High Bay Area
MAU-4	Toxicology Lab

Air Handling Unit Schedule

MARK	SUPPLY FAN					PREHEAT COIL						COOLING COIL							
	MAX CFM	MIN CFM	ESP (IN WG)	MAX HP	OA (CFM)	AIR TEMP (DEG F) ENT.	AIR TEMP (DEG F) LVG.	MAX GPM	MAX WATER PD (FT WG)	MAX COIL FV (FPM)	AIR PD @ MAX. (IN WG)	ENTERING AIR (DEG F) DB	ENTERING AIR (DEG F) WB	LEAVING AIR (DEG F) DB	LEAVING AIR (DEG F) WB	MAX GPM	MAX WATER PD (FT WG)	MAX COIL FV (FPM)	MAX AIR PD (IN WG)
AHU-1	18,425	7,215	2.0	25	18,675	14.0	50	47.8	10.53	550	0.18	92	78	55	54.9	303	9.91	500	0.61
AHU-2	3,295	2280	1.5	5	3,295	14.0	50	8.5	1.14	550	0.16	92	78	55	54.9	56	11.28	500	0.64

Make-up Air Unit Schedule

MARK	LOCATION	SUPPLY FAN					HEAT COIL					
		MAX CFM	MIN CFM	ESP (IN WG)	MAX HP	OA (CFM)	AIR TEMP (DEG F) ENT.	AIR TEMP (DEG F) LVG.	MAX GPM	MAX WATER PD (FT WG)	MAX COIL FV (FPM)	AIR PD @ MAX. (IN WG)
MUA-1	ROOF	13,100	5,825	1.0	10	13,100	14	85	29.8	4.2	500	0.62
MUA-2	ROOF	21,960	9,760	1.0	15	21,960	14	85	49.9	3.1	500	0.36
MUA-3	ROOF	9,940	5,440	1.0	7.5	9,940	14	85	27.8	1.8	500	0.56
MUA-4	ROOF	6,985	3,105	1.0	7.5	6,985	14	85	15.9	1.0	500	0.66

Supply VAV & CAV Terminal Units

There are 16 variable air volume and 2 constant air volume supply terminal units. All of these units utilize duct mounted heating coils. The selection of these coils was based on 180°F coil entering water temperature with a 20o temperature drop across the coil. The box inlet size is based on multiple valve configurations. All Units are supplied by either AHU-1 or AHU-2 to laboratory and administrative spaces.

Supply VAV/CAV Terminal Unit Schedule

MARK NO.	LOCATION ROOM #	SERVICE ROOM #	MAX COOLING CFM	MIN VENT CFM	OFFSET CFM	VOL. REG. (CFM) BOX MAX. CFM	BOX MIN. CFM	INLET SIZE IN. RD.	HEATING COIL AIR TEMP (DEG F) ENT.	LVG.	FLOW @ MAX. GPM	DUCT SIZE IN
VAV-1-1	103	CONFERENCE RM 103	540	160	-100	540	170	1-8	55	80	1.0	10X12
VAV-1-2	101	CORAL REEF RM 101	805	625	-100	805	625	1-10	55	80	1.4	14X12
VAV-1-3	102	OBSERVATION RM 102/114/100	1345	200	-300	1,345	405	1-12	55	80	2.4	20X12
VAV-1-4	102	OFFICE RM 108~113	440	120	-150	450	185	1-8	55	80	1.0	10X10
VAV-1-5	114	SHOP RM 131	155	80	0	155	100	1-8	55	80	1.0	8X8
VAV-1-6	132	RAD II RM 132	375	435	100	525	525	1-8	55	80	1.0	10X12
VAV-1-7	133	RAD I RM 133	385	450	100	525	525	1-8	55	80	1.0	10X12
VAV-1-8	115	LAB RM 115	365	315	130	1,205	315	1-12	55	80	2.2	18X12
VAV-1-9	116	LAB RM 116	1420	1335	260	2,390	1,335	2-12	55	80	4.3	30X12
VAV-1-10	117	NECROPSY LAB RM 117	875	315	190	1,740	610	2-12	55	80	3.1	26X12
VAV-1-11	105	EXPOSURE LAB I RM 105	645	690	180	1,655	690	2-10	55	80	3.0	24X12
VAV-1-12	106	EXPOSURE LAB I RM 106	500	690	400	4520	930	4-12	55	80	8.1	56X12
VAV-1-13	106	EXPOSURE LAB I RM 106	500	690	240	2210	690	2-12	55	80	4.0	30X12
VAV-1-14	120	CORRIDOR RM 120	340	310	-360	360	110	1-8	55	80	1.0	12X8
VAV-2-1	123	BSL 3 PRE LAB RM 123	600	585	175	1,660	645	2-10	55	80	3.0	24X12
CAV-2-2	121	BSL 3 ENTRY RM 121	60	165	100	165	165	1-8	55	80	1.0	8X8
CAV-2-3	122	BSL 3 GOWN RM 122	60	165	100	165	165	1-8	55	80	1.0	8X8
VAV-2-4	124	BSL 3 WET LAB RM 124	820	1305	200	1,305	1,305	1-12	55	80	2.3	20X12

Fan Coil Units

There are three fan coil units located in the electrical support rooms of the lab spaces. These are ductless systems that provide 100% outdoor air to the spaces.

Split System Air Cooled Unit Schedule

INDOOR AIR COOLED UNIT							OUTDOOR CONDENSING UNIT				
		DIRECT EXPANSION COIL						SUMMER	ELECTRICAL LOAD		
				ENTERING AIR TEMP.		FAN					
MARK	LOCATION	SUPPLY CFM	CAPACITY MBH	DB (°F)	WB (°F)	MOTOR FLA	MARK	CAPACITY	FAN FLA	COMPRESSOR RLA	MINIMUM SEER
FCU-1	104	500	12.5	78.0	67.9	1.2	CU-1	MATCH INDOOR UNIT	0.65	8.9	10
FCU-2	104	350	12.5	78.0	67.9	1.2	CU-2	MATCH INDOOR UNIT	0.65	8.9	10
FCU-3	104	350	12.5	78.0	67.9	1.2	CU-3	MATCH INDOOR UNIT	0.65	8.9	10

Exhaust Fans

There are eight exhaust fans and two fume hood exhaust fans, all are located on the roof. Exhaust fans EF-1A, EF-1B, EF-2, EF-3, EF-4A, EF-4B are all constant air volume bypass fans. The rest of the exhaust fans are centrifugal rooftop fans. The fume hood exhaust system collects the exhaust from all downdraft hoods, snorkels, and general exhaust registers. The fume hood exhaust system is variable air volume system interlocked with the variable air volume supply system. The radioisotope hoods are constant air volume. The fume hood exhaust fans will be utilized so the one will be primary and the other is standby. The other exhaust fans are used to control the space pressure, to prevent any air transfer to another space.

Exhaust Fan Schedule

MARK	LOCATION	SERVICE	CFM		ESP	RPM	DBA	DRIVE	MOTOR
			MAX FROM SPACE	TOTAL	(IN WG)				HP
EF-1A	ROOF	BSL 3	3,865	8,050	5.00	1170	78.0	DIRECT	15
EF-1B	ROOF	BSL 3	3,865	8,050	5.00	1170	78.0	DIRECT	15
EF-2	ROOF	RAD I RADIO ISOTOPE HOOD	625	5,650	4.00	1770	67.0	DIRECT	10
EF-3	ROOF	RAD II RADIO ISOTOPE HOOD	625	5,650	4.00	1770	67.0	DIRECT	10
EF-4A	ROOF	FUME HOODS & GENERAL	17,765	19,651	5.00	1170	78.0	DIRECT	30
EF-4B	ROOF	FUME HOODS & GENERAL	17,765	19,651	5.00	1170	78.0	DIRECT	30
EF-5	ROOF	RM 108/109 TOILETS	515	-	0.40	1550	54.0	DIRECT	1/15
EF-6	ROOF	RM 130 TOILET	100	-	0.30	1550	42.0	DIRECT	1/30
EF-7	ELECTRICAL RM 137	ELECTRICAL RM 137	1,320	-	0.30	1725	65.0	BELT	1/4

Exhaust VAV and CAV Terminal Units

There are 14 constant air volume exhaust terminal units and 22 variable air volume exhaust terminal units. The box inlet sizes are based on multiple valve configurations. All terminal units are constructed of stainless steel or are coated with epoxy to protect from corrosion.

Exhaust VAV/CAV Terminal Unit Schedule

VAV BOX NO.	LOCATION ROOM #	SERVICE ROOM #	SERVICE	VOLUME REGULATOR		VALVE PD (IN WG)	BOX INLET SIZE (IN)	CONNECTING TYPE	CORROSION CLASS
				MAX (CFM)	MIN (CFM)				
CAV-E-1	123	BSL 3 PRE LAB RM 123	6' BSC EXHAUST	650	50	0.60	10	AIR GAP	B
VAV-E-2	123	BSL 3 PRE LAB RM 123	5' CFH EXHAUST	650	250	0.60	10	DIRECT	B
CAV-E-3	123	BSL 3 PRE LAB RM 123	CANOPY HOOD EX	500	500	0.60	8	DIRECT	B
VAV-E-4	123	BSL 3 PRE LAB RM 123	GENERAL EXHAUST	285	35	0.60	8	DIRECT	A
CAV-E-5	121	BSL 3 ENTRY RM 121	GENERAL EXHAUST	265	265	0.60	8	DIRECT	A
CAV-E-6	122	BSL 3 GOWN RM 122	GENERAL EXHAUST	265	265	0.60	8	DIRECT	A
CAV-E-7	124	BSL 3 WET LAB RM 124	VENTED CABINET	600	600	0.60	8	DIRECT	B
VAV-E-8	124	BSL 3 WET LAB RM 124	GENERAL EXHAUST	935	935	0.60	12	DIRECT	A
CAV-E-9	133	RAD I RM 133	4' RIH	625	625	0.60	10	DIRECT	B
CAV-E-10	132	RAD II RM 132	4' RIH	625	625	0.60	10	DIRECT	B
CAV-E-11	105	EXPOSURE I RM 105	GLOVE BOX	1000	90	0.60	12	DIRECT	B
VAV-E-12	105	EXPOSURE I RM 105	6' FUME HOOD	800	300	0.60	10	DIRECT	B
VAV-E-13	105	EXPOSURE I RM 105	GENERAL EXHAUST	480	35	0.60	8	DIRECT	A
CAV-E-14	106	EXPOSURE II RM 106	GLOVE BOX	1000	90	0.60	12	DIRECT	B
CAV-E-15	106	EXPOSURE II RM 106	GLOVE BOX	1000	90	0.60	12	DIRECT	B
VAV-E-16	106	EXPOSURE II RM 106	5' FUME HOOD	650	250	0.60	10	DIRECT	B
VAV-E-17	106	EXPOSURE II RM 106	8' POLYPROPYLENE HOOD	1135	450	0.60	12	DIRECT	B
VAV-E-18	106	EXPOSURE II RM 106	8' POLYPROPYLENE HOOD	1135	450	0.60	12	DIRECT	B
CAV-E-19	106	EXPOSURE II RM 106	STUB	2400	180	0.60	2-12	DIRECT	B
VAV-E-20	106	EXPOSURE II RM 106	GENERAL	750	50	0.60	10	DIRECT	A
CAV-E-21	115	LAB RM 115	6' BSC EXHAUST	650	50	0.60	10	AIR GAP	B
CAV-E-22	115	LAB RM 115	6' BSC EXHAUST	650	50	0.60	10	AIR GAP	B
VAV-E-23	115	LAB RM 115	GENERAL	395	35	0.60	8	DIRECT	A
VAV-E-24	116	LAB RM 116	5' FUME HOOD	650	250	0.60	10	DIRECT	B
VAV-E-25	116	LAB RM 116	5' FUME HOOD	650	250	0.60	10	DIRECT	B
VAV-E-26	116	LAB RM 116	GENERAL	680	50	0.60	10	DIRECT	A
VAV-E-27	116	LAB RM 116	5' FUME HOOD	650	250	0.60	10	DIRECT	B
VAV-E-28	116	LAB RM 116	5' FUME HOOD	650	250	0.60	10	DIRECT	B
VAV-E-29	117	LAB RM 117	5' FUME HOOD	650	250	0.60	10	DIRECT	B
CAV-E-30	117	LAB RM 117	6' NECROPSY TABLE	780	50	0.60	10	DIRECT	B
VAV-E-31	117	LAB RM 117	CANOPY HOOD	765	500	0.60	10	DIRECT	B
VAV-E-32	103	CONFERENCE RM 103	GENERAL	440	70	0.60	8	DIRECT	A
VAV-E-33	101	CORAL REEF RM 101	GENERAL	705	525	0.60	10	DIRECT	A
VAV-E-34	102	OFFICE RM 108~113	GENERAL	300	35	0.60	8	DIRECT	A
VAV-E-35	131	SHOP RM 131	GENERAL	155	100	0.60	8	DIRECT	A
VAV-E-36	102	OBSERVATION RM 102	GENERAL	1045	105	0.60	12	DIRECT	A

Screw Compressor Water Chillers

The source of cooling for the VIMS Seawater Research Laboratory is two 105 ton air cooled screw compressor chillers located on grade outside of the mechanical room. Each chiller has two independent refrigeration circuits with their own compressors. The chillers are sized to provide cooling to lower seawater at 100 gpm by 10°F, and to serve the chilled water coils of AHU-1 and AHU-2.

Air Cooled Chiller Schedule

		CONDENSER		EVAPORATOR					COMPRESSOR MOTOR		MIN.	STARTER	
MARK	MIN. CAPACITY (TONS)	FANS MOTOR(Each) k'W	ENT. AIR TEMP (DEG F)	WATER TEMP. (°F) ENT.	LVG.	GPM	MAX. P.D. (FT. WATER)	FOULING FACTOR (HR)(SQ. FT.)(DEG F)/BTU	MAX kW INPUT	UNIT MCA	EFFICIENCY EER /NPLV	TYPE	REFRIGERANT TYPE
C-1	105	1	95	52.5	42.0	241.0	19.8	0.0001	145.1	253.00	9.6/12.3	WYE DELTA	R-22
C-2	105	1	95	52.5	42.0	241.0	19.8	0.0001	145.1	253.00	9.6/12.3	WYE DELTA	R-22

Pumps

There are eight pumps located in the mechanical room and one located in the ceiling cavity above the multi-purpose lab. The primary chilled water circuit pumps are constant volume, and the secondary chilled water circuit pumps DCWP-1 and DCWP-2 are each equipped with a variable speed drive and sized to accommodate 100% of the total designed chilled water system flow. The distribution hot water system pumps DHWP-1 and DHWP-2 are each equipped with a variable speed drive. The hot water system pumps are constant volume. The coil energy recovery loop pump CLP-1 is constant volume.

Pump Schedule

MARK	LOCATION	GPM	FT HD	TYPE	SERVICE	MAX RPM	MOTOR HP
CWP-1	MECH ROOM	231.5	33	BASE MOUNTED END SUCTION	CHILLED WATER CH-1	1150	5
CWP-2	MECH ROOM	231.5	33	BASE MOUNTED END SUCTION	CHILLED WATER CH-2	1150	5
DCWP-1	MECH ROOM	463	55	BASE MOUNTED END SUCTION	DISTRIBUTION CHILLED WATER	1750	10
DCWP-2	MECH ROOM	463	55	BASE MOUNTED END SUCTION	DISTRIBUTION CHILLED WATER	1750	10
BHWP-1	MECH ROOM	150	17	BASE MOUNTED END SUCTION	HOT WATER B-1	1150	2
BHWP-2	MECH ROOM	150	17	BASE MOUNTED END SUCTION	HOT WATER B-2	1150	2
DHWP-1	MECH ROOM	300	31	BASE MOUNTED END SUCTION	DISTRIBUTION HOT WATER	1750	7.5
DHWP-2	MECH ROOM	300	31	BASE MOUNTED END SUCTION	DISTRIBUTION HOT WATER	1750	7.5
CLP-1	EXCHANGER	96	55	IN-LINE CLOSE-COUPLED	COIL ENERGY RECOVERY LOOP	1750	3

Unit Heaters

There is one electrical unit heater that is located in the mechanical room. The electric unit heater is a propeller type, that provides a minimum 6.4 MBH using a 1.9 kW, 208 volt single phase, 9 amp electric coil, and a 275 cfm fan providing a minimum throw of 16 feet.

Humidifiers

There are two LPG to steam humidifiers that provide direct steam injection to AHU-1 and AHU-2. Both humidifiers are serviced from the on site propane system. These steam grid humidifiers are mounted in both of the air handler access section.

Humidifier Schedule

MARK	LOCATION	SERVICE	CAPACITY		FACE AREA SQ FT(MIN)	RUN OUT SIZE					
			lb/Hr.	INPUT MBH		SUPPLY	CONDENSATE RETURN	DI WATER MAKE UP	DRAIN	GAS SUPPLY	VENT
H-1	ROOF	AHU-1	500.0	800	29	4"	3/4"	1/4"	1"	1 1/4"	8"
H-2	ROOF	AHU-2	88.3	200	5	2"	3/4"	1/4"	1"	1/2"	5"

Electrical Baseboard Heaters

There are three electrical baseboard heaters two of them are located in the main entry vestibule and the other is in the service corridor. Each one provides a minimum 5.1 MBH from a six foot long 1.5 kW, 120 volt single phase electric coil.

Electrical Baseboard Heater Schedule

MARK	LOCATION	MIN MBH	TYPE	ELECTRIC COIL KW	VOLTS/PHASE	ELEM. LGTH. (LF)	MOUNTING HEIGHT (IN)
BH-1	ROOM 100	5.1	BASEBOARD	1.5	120/1	6	16
BH-2	ROOM 100	5.1	BASEBOARD	1.5	120/1	6	16
BH-3	ROOM 120	5.1	BASEBOARD	1.5	120/1	6	16

Boilers

The source of heating the VIMS Seawater Research Laboratory is two propane gas-fired modular hot water boilers. Both boilers are located in the mechanical room, and are each sized at 1760 MBtuH net IBR heating capacity. The boilers are sized to provide heating capacity for all space and ventilation air heating requirements, also to raise seawater at 100gpm by 10^{o}F.

Boiler Schedule

MARK	LOCATION	PROPANE GAS (CFH)	MIN. EFFICIENCY	GROSS INPUT (MBTUH)	NET OUTPUT (MBTUH)	WATER TEMP (°F) ENT.	WATER TEMP (°F) LVG.	GPM	WATER P.D. (FT.)	BURNER TYPE	BURNER HP
B-1	MECH. RM 136	876.0	88.00	2000.0	1760	150.0	181.1	150.0	8.5	PROPANE	3/4
B-2	MECH. RM 136	876.0	88.00	2000.0	1760	150.0	181.1	150.0	8.5	PROPANE	3/4

Heat Exchangers

The source of heating for the preheating coil of AHU-1 is an air to air coil energy recovery loop that uses a 30% ethylene glycol refrigerant. The energy recovery loop uses energy from the exhaust air stream from exhaust fans EF-4A and EF-4B to either preheat or precool the intake air of AHU-1.

Air to Air Coil Energy Recovery Schedule

		Mark	HX-1
		Location	AHU-1
		Type	Coil Loop
Run-Around Coil OA Cooling		CFM	18425
	EAT	DB	92
		WB	78
	LAT	DB	85.1
		WB	76.2
		Max. GPM	96
		Max. Water PD	17.93
		Air PD @ Max.	0.63
Run-Around Coil Exhaust Air Cooling		CFM	17765
	EAT	DB	78
		WB	67.9
	LAT	DB	85.8
		WB	70.1
Run-Around Coil Outside Air Cooling		CFM	18425
	EAT	DB	14
		WB	10
	LAT	DB	41.1
		WB	27.9
Run-Around Coil Exhaust Air Cooling		CFM	17765
	EAT	DB	70
		WB	52.9
	LAT	DB	42.1
		WB	39.8
		Max. GPM	96
		Max. Water PD	21.1
		Air PD @ Max.	0.79

Air Separators and Expansion Tanks

There are three air separators and three expansion tanks that correspond to the air separators. All air separators are equipped with integral strainers and manufacturer installed clips. Air separator AS-3 is an inline air separator. Expansion tanks ET-1 and ET-2 are configured vertically, and expansion tank ET-3 is configured horizontally.

Air Control Schedule

SERVICE	AIR SEPARATOR				EXPANSION TANK				
	MARK	GPM	MAX PD. (PSI)	SIZE (IN)	MARK	TANK VOL. (GAL)	ACCEPT. VOL. (GAL)	TYPE	SIZE (IN x IN)
CHILLED WATER	AS-1	463	1	6.0	ET-1	8	5	BLADDER	14 DIA x 26
HOT WATER	AS-2	311	1	5.0	ET-2	112	61	BLADDER	24 DIA x 75
30 % GLYCOL WATER	AS-3	96.0	1	3.0	ET-3	7.8	2.5	BLADDER	12 DIA x 25

Filters

There are a total of nine filters, one for each air handler AHU-1 and AHU-2, one for each make-up air unit MAU-1, MAU-2, MAU-3, MAU-4, one for exhaust fan EF-1A and EF-1B, one for exhaust fan EF-2, and one for exhaust fan EF-3.

Filter Schedule

MARK	LOCATION	CFM	MAX FACE VEL. (FPM)	2" PLEATED PREFILTER			12" CARTRIDGE			HEPA		
				EFF. %	APD (IN.WG.) INITIAL	APD (IN.WG.) FINAL	EFF. %	APD (IN.WG.) INITIAL	APD (IN.WG.) FINAL	EFF. %	APD (IN.WG.) INITIAL	APD (IN.WG.) FINAL
F-1	ROOF	18,675	500	30	0.25	0.5	95	0.63	1.0	N/A	N/A	N/A
F-2	ROOF	3,295	500	30	0.25	0.5	95	0.63	1.0	N/A	N/A	N/A
F-3	ROOF	3,865	500	30	0.25	0.5	N/A	N/A	N/A	99.9	1.2	2.0
F-4	ROOF	625	500	30	0.25	0.5	N/A	N/A	N/A	99.9	1.2	2.0
F-5	ROOF	625	500	30	0.25	0.5	N/A	N/A	N/A	99.9	1.2	2.0
F-6	ROOF	13,100	500	30	0.25	0.5	N/A	N/A	N/A	N/A	N/A	N/A
F-7	ROOF	21,960	500	30	0.25	0.5	N/A	N/A	N/A	N/A	N/A	N/A
F-8	ROOF	9,940	500	30	0.25	0.5	N/A	N/A	N/A	N/A	N/A	N/A
F-9	ROOF	6,985	500	30	0.25	0.5	N/A	N/A	N/A	N/A	N/A	N/A

Relief Hoods

There are five relied hoods located on the roof that are interlocked with their respective make-up air units. These relief hoods are used to control pressure of the spaces. Relief hoods REF-3 and REF-4 serve the multi-purpose lab and are interlocked with MAU-2, relief hood REF-1 serves the BSL-1/2 lab and is interlocked with MAU-1, relief hood REF-2 serves the toxicology lab and is interlocked with MAU-4, and relief hood REF-5 serves the multi-purpose high bay area and is interlocked with MAU-3.

Air Intake/Exhaust Hood Schedule

MARK	LOCATION	MAX AIR FLOW (CFM)	THROAT SIZE (IN.)	INTAKE/EXHAUST FREE AREA (SF)	PD AT MAX CFM (IN. WG)
REH-1	AT ROOF	13,100	72X72	36	0.05
REH-2	AT ROOF	6,985	54X54	20.25	0.05
REH-3	AT ROOF	10,980	66X66	30.25	0.05
REH-4	AT ROOF	10,980	66X66	30.25	0.05
REH-5	AT ROOF	9,940	60X60	30.25	0.05

10.0 Annual Energy Use

The annual energy use was determined using Carrier HAPv4.2. The results show that the energy consumed by the mechanical system is very small compared to the processes that occur within the building spaces. The results from the HAPv4.2 energy use calculations are listed in Table 5, and the annual operation cost is listed in Table 6. A more detailed analysis of the VIMS Seawater research Laboratory's energy consumption is covered in *Technical Report #2 Building & Energy Analysis Report*.

Table 5

HVAC Components	
Electric (kWh)	580,093
Propane (Therms)	39,337
Non-HVAC Components	
Electric (kWh)	86,605,740
Propane (Therms)	1,401,600

Table 6

Component	Annual Cost	Cost/ft^2
Air System Fans	$4,256	$0.13
Cooling	$16,615	$0.52
Heating	$38,862	$1.22
Pumps	$2,284	$0.07
HVAC Total	$62,017	$1.95
Lights	$12,455	$0.39
Electric Equipment	$17,852	$0.56
Misc. Electric	$3,457,408	$108.71
Misc. Fuel	$1,377,913	$43.33
Non-HVAC Total	$4,865,628	$152.99
Grand Total	$4,927,645	$154.94

11.0 Mechanical System Schematics

12.0 Operation and Control Sequences of the Mechanical System

The mechanical system is controlled by a DDC energy management and temperature control system with pneumatic actuators for large dampers and valves, and electronic actuators for small dampers and valves.

The VIMS Seawater Research Laboratory heating system including the boilers, pumps, and controls are on the emergency generator circuit to prevent the building from freezing if the electrical power were to be interrupted

The buildings air conditioning and heating units, exhaust fans, and controls for the laboratory spaces are on the emergency generator circuit to protect the health and safety of the occupants if the electrical power were to be interrupted.

Cooling and Chilled Water System

The DDC system enables and disables the chilled water system.

When the system is indexed to disable, the chillers are to be de-energized and after a five minute delay all of the chilled water loop pumps will be stopped and all valves will be adjusted to their normal position.

When the system is indexed to enable, the lead distribution chilled water pumps are to be started and the isolation valve is to be opened. With proof of water flow the chillers will start up, since they are staged only one will start and run until the demand exceeds the chillers capacity. If the capacity of the chiller is exceeded then the second chiller will start and run. Both chillers once started will operate on their manufacturer's controls maintaining a leaving water temperature of 42^{o}F.

If the temperature of the water in the return pipe drops below 50^{o}F and remains there for at least five minutes then the DDC system will de-energize the second chiller and after a five minute delay the chilled water pump to that chiller will be stopped and the isolation valve will close the flow to that chiller.

The DDC system controls the distribution water pumps through variable frequency drives to maintain the differential pressure at 21psi. If the pressure differential falls below the set pressure a trouble signal is sent to the building BCMS system and the lag pump will be started.

Heating Water System Control

The DDC system enables and disables the heating water system.

When the system is indexed to disable, the boilers are to be de-energized and after a five minute delay all of the heating water loop pumps will be stopped.

When the system is indexed to enable, the lead distribution heating water pumps and lead boiler pumps are to be started. With proof of water flow the boilers will start up, since they are staged only one will start and run until the demand exceeds the boilers capacity. If the capacity of the boiler is exceed then the second boiler will start and run. Both boilers once started will operate on their manufacturer's controls maintaining a leaving water temperature of 180°F.

If the temperature of the water in the return pipe rises above 30°F and remains there for at least five minutes then the DDC system will de-energize the second boiler and after a five minute delay the lag boiler pump will be stopped.

The DDC controller shall control the heating water distribution pumps through variable frequency drives to maintain differential pressure at 21 psi. If the pressure differential falls below set pressure a trouble signal is sent to the building BCMS system and the lag pump will be started.

Air Handling Units

The DDC system controls the operation of the air handling units including the air to air coil energy recovery loop.

When the outdoor air temperature is below 45°F the DDC system opens the preheat coil isolation valve for one minute before the air handling units start up. Then the outdoor air and isolation dampers are opened, with proof of the dampers being opened the supply fan will run continuously. The DDC controls the supply fan speed through a variable frequency drive to maintain the duct static pressure. The DDC will reset the duct static pressure based on the space requiring the most pressure.

When the supply air temperature is above the designed supply set temperature of 55°F, the cooling coil valve will be modulated to maintain the supply air set temperature of 55°F. Also the heating coil isolation valve will be closed and the integral face bypass damper will be closed to the heating coil.

When the supply air temperature is below the design supply set temperature of 55°F, the cooling coil isolation valve will close. The integral and bypass damper to the heating coil will be opened and the heating coil isolation valve will be modulated to maintain the supply air set temperature of 55°F.

When the outdoor air coil temperature is below 55°F the 3-way control valve will be modulated to maintain the downstream outdoor air coil at 55°F. If the outdoor air coil temperature is above the exhaust air coil temperature the 3-way control valve will be modulated to maintain the downstream outdoor air coil at 55°F.

When the exhaust air stream relative humidity falls below 30% the humidifier will start up and run under the manufacturer's controls to maintain the exhaust air stream relative humidity at 50%.

Variable Air Volume Laboratory Terminal Unit

The DDC system controls the laboratory variable air volume terminal units in conjunction with their associated air handling unit.

The space temperature set point is configured by either a DDC global command or by a local room sensor.

Each VAV laboratory terminal unit is controlled by a dedicated space controller, designed for the application of that space. The space controller measures the temperature, supply airflow, and exhaust airflow of the space. The VAV laboratory terminal unit airflow damper is modulated to meet the required cooling and pressure (negative) for that space at all times. The VAV laboratory terminal unit reheat coil control valve is modulated to maintain the required space temperature.

Variable Air Volume Non-Laboratory Terminal Unit

The DDC system controls the non-laboratory variable air volume terminal units in conjunction with their associated air handling unit.

The space temperature set point in configured by either a DDC global command or by a local room sensor.

Each VAV non-laboratory terminal unit is controlled by a dedicated space controller, designed for the application of that space. The space controller measures the temperature, supply airflow, and exhaust airflow of the space. The VAV non-laboratory terminal unit airflow damper is modulated to meet the required cooling and pressure (positive) for that space at all times. The VAV non-laboratory terminal unit reheat coil control valve is modulated to maintain the required space temperature.

Make-up Air Units

The DDC system enables and disables the make-up air units.

When the system indexes the make-up air unit to enable, the unit's supply fan will start and run continuously. When the outdoor air temperature drops below 65°F, the variable speed drive will modulate the supply fan speed to maintain space temperature. The space set point temperature is based on the outdoor air temperature. If the space temperature drops below 65°F, the supply fan variable frequency drive shall modulate the supply fan speed to 45% (the minimum allowable) of the total design airflow rate to maintain the space temperature set point. If the space temperature continues to drop below the set point, the make-up air unit's heating coil control valve will modulate to maintain the space temperature set point.

When the space temperature rises above the set point temperature of 65oF, the heating coil control valve closes and the face and bypass damper closes to the coil, and the variable speed drive will modulate the supply fan to maintain the space temperature.

Relief Hoods

The DDC system enables and disables the relief hoods in conjunction with their associated make-up air units.

When the system indexes the relief hood to disable the relied air damper will be closed.

When the system indexes the relief hood to enable the air relief damper is controlled to maintain the required space pressure.

Exhaust System and Fume Hoods

The DDC system controls the variable air volume exhaust system in conjunction with the variable air volume supply terminals.

The fume hoods are equipped with sash position sensors, airflow sensors, and fume hood airflow sensors. Which operate with the variable flow exhaust valves and static pressure sensors to maintain the required space pressure. The DDC system controls the fan speed and damper positions, controlled by the sensors.

13.0 Critique of the Mechanical System

The mechanical system design was based on system function by space processes. Occupant safety was also a concern in the mechanical design process. The cost of the system was not as big of a design factor, because of the other priorities. For instance, the use of stainless steel or epoxy coated steel in the ductwork and mechanical equipment to prevent corrosion.

Because of the processes that occur within the building the mechanical system and its design is responsible for keeping the environment inside and outside of the building as clean as possible. The use of the filters in both the exhaust and supply systems helps keep both environments clean.

The overall layout of the mechanical systems was not difficult design factor to overcome, due to the fact that the building is designed based on the function of its spaces and the processes that occur in them. This caused there to be a very large ceiling cavity making the mechanical layout easy.

Overall the mechanical system provides proper function given the unusual requirements of the building, however, the materials and equipment used does cost more than usual.

14.0 References

ASHRAE Fundamentals 2001 I-P Edition

Dominion Power Online:
http://www.dom.com/customer/vabus_bundled.jsp