UNINTERRUPTIBLE CHILLED WATER SUPPORT STANDARD DESIGN AND WHITE PAPER

60% Submittal

July 20, 2007

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July 20, 2007

Boeing Service Company
Attn: Debbie Linton
4101 Pleasant Valley Road
Chantilly, VA 20151

Subject: Uninterruptible Chilled Water Support
Standard Design and White Paper
60% Submission

Dear Debbie:

Please find enclosed our 60 % submission on the referenced project.

The submission consists of six (6) report binders to MPO (delivered by hand) and an electronic copy to you.
Your review of the report will indicate:

1. There are seven (7) tabbed sections in the report body; they are:
    - 1. Executive Summary
    - 2. Introduction
    - 3. Scheme Descriptions
    - 4. Critical Path For Resolution
    - 5. Conclusions
    - 6. Recommendations
    - 7. Special Considerations
2. There are thirteen (13) tabbed sections in the Appendix; they are:
    - 8,1 Kick-off Meeting Minutes
    - 8.2 Site Visits/Equipment Data
    - 8.3 Criteria Conference Minutes
    - 8.4 60% Comments/Responses
    - 8.5 100% Comments/Responses
    - 8.6 Reliability Analysis
    - 8.7 Annual Maintenance Costs
    - 8.8 Life Cycle Maintenance Costs
    - 8.9 Space Calculations
    - 8.10 Install Cost Estimates
    - 8.11 Commissioning/Start-up Estimates
    - 8.12 Training Costs

- 8.13 Energy Use Analysis

The Executive Summary and the Recommendations provide an up-to-date scoring status and leading schemes for each of the four (4) horsepower groups. Seven of the eight evaluation factors selected as a result of the Criteria Conference have been essentially completed with Reliability being the one remaining factor to yet weigh-in.
The reliability analysis is a work in progress and its development will be the bulk of our work from here on out. Your review will note that several schemes are vying for acceptance and the final ranking of the schemes for each horse power group may change drastically when the results of the reliability work is in.

As discussed at the Kick-off meeting, we are providing your client (MPO) the six copies with a parallel electronic copy to you. This procedure is necessary since time is of the essence and it allows MPO time to review for our session next week.

BVSPC appreciates the cooperation and assistance that you, Dennis and the entire MPO team have demonstrated in this effort.

Sincerely,

Timothy C. Swart, P.E.
Project Engineer

Enclosure

Uninterruptible Chilled Water Support Standard Design and White Paper

60% Submittal

Black & Veatch Special Projects Corp.

20 July, 2007

Table of Contents

1 Executive Summary

Black & Veatch Special Projects Corp (BVSPC) was contracted by Boeing Services Corporation to produce a Standard Design and White Paper investigating several emergency back-up systems to ensure uninterruptible chilled water pumping capabilities for the variable frequency drive (VFD) controlled water pumps from 10-horsepower (HP) to 250-HP at 480-volt, 3-phase alternate current (AC) power in a typical government facility.

Nine schemes were analyzed for their ability to maintain adequate chilled water supply to high density heat load spaces. Through client interview and field research, the minimum ride-through requirement to accommodate minimum emergency generation start-up and synchronization was determined to be 90 seconds. Each of the following recommended Options satisfy this criterion.

Seven of eight of the evaluation factors have been included in this analysis at this point. (Reliability is not included). The leading options are indicated in the table below.

Group	Scheme	Score	Remarks
20HP			
Option 1	Scheme #2 Air Motor/ Pump	295.85	
Option 2	Scheme #6 VFD Ride thru/S.C.	295.81	Virtual tie between 1st and 2nd; reliability will determine
Option 3	Scheme #5 DC Motor/Pump	287.50	
50HP			
Option 1	Scheme #2 Air Motor/ Pump	294.57	
Option 2	Scheme #6 VFD Ride thru/S.C.	291.79	
Option 3	Scheme #1 Diesel Pump	285.50	
100HP			
Option 1	Scheme #1 Diesel Pump	290.67	
Option 2	Scheme #3 VFD Ride thru/Comp.	288.51	
Option 3	Scheme #6 VFD Ride thru/S.C.	288.38	Virtual tie between 2nd and 3rd ; reliability will determine
250HP			
Option 1	Scheme #1 Diesel Pump	292.11	
Option 2	Scheme #3 VFD Ride thru/Comp.	287.74	
Option 3	Scheme #5 DC Motor/Pump	285.71	

Implementation Design & Program Planning

BVSPC recommends creation of an Implementation Program to procure recommended scheme designs for use in MPO's chilled water plants. This Program would include but not limited to the following items:

- Procedures for securing funding for continuous investment for back-up chilled water pumping systems serving critical facilities.
- A Master Plan to incorporate the recommendations into existing and future facilities.
- A schedule for reassessment of the findings of this paper and their applicability every 2-3 years.

2 Introduction

The purpose of this document is to provide guidance to assist the Maryland Procurement Office (MPO) explore options/methods to provide sufficient ride-through capabilities to maintain adequate chilled water supply to critical high-density heat load spaces.

Key Goals

- Evaluation of nine Schemes for 90sec. ride-through capabilities.
- Provide Recommendations, Implementation Design & Program Planning (20, 50, 100, & 250 HP motor groups)

Assumptions

- The MPO facility maintains critical infrastructure that must operate 24-7 with no downtime. To mitigate this risk and increase system reliability, all schemes must operate in an N+1 configuration.
- Every scheme must complete start-up within 15 seconds to prevent damage to the high density process loads.
- In addition, a 90 second emergency generation start-up and synchronization time is used as the required recovery baseline for all nine schemes covered in this analysis.
- A Scheme Life of 30 years is required. During this time, proper maintenance is performed.
- Schemes not readily commercially available are not considered.
- All ride-through batteries are Wet-type.
- For schemes with batteries, the First Cost evaluation factor will include A/C and ventilation.
- For schemes with batteries, the *First Cost* and *Energy* evaluation factors will include cost for A/C and ventilation requirement upgrades.
- Cost of architectural changes for all systems are discounted as Space is an evaluation factor and addressed separately.

Back-up UPS and On-Line UPS

As uninterruptible power is vital to maintaining operations, it is important to understand the distinction between Back-Up UPS and On-Line UPS.

A Back-Up UPS functions in standby operation, allowing a short “gap” interruption in power before any temporary power storage is utilized prior to establishment of reliable emergency generation. Less than 15 seconds of “gap” is acceptable. More than 15 seconds of interrupted power endangers the critical loads.

An On-Line UPS provides continuous, uninterrupted power. This is obtained with 1-5 seconds of ride-through prior to storage and establishment of reliable emergency generation.

Ride-through and Storage

Each scheme utilizes various combinations of ride-through and/or storage technology.

Ride-through power is provided via parallel configuration with a flywheel or DC bus ride-thru capacitor bank. Energy *storage* takes the form of chemical (fuel oil or battery cells); mechanical (flywheel); compressed air storage; or electrical storage (capacitors and ultra-capacitors).

3 Scheme Descriptions

3.1 Back-up UPS (Non-Continuous)

3.1.1 Scheme 1: Diesel Pump with F.O. Storage Piped in Parallel (Schematic #1)

Concept Description
This scheme utilizes standard fire pump technology powered by a diesel engine. Fuel Oil is supplied to the diesel engine by a day tank. In this configuration, the diesel pump is piped in parallel to the primary chilled water pump. This technology is commonly found in typical facility construction.

Emergency Operation
Upon loss of power, primary pump controls activate the diesel engine (approx. 10sec gap). The diesel engine powers a pump until emergency generator power is established and synchronized.

3.1.2 Scheme 2: Pneumatic Driven Pump with Compressed Air Storage – Standby Operation (Schematic #2)

Concept Description
This scheme is comprised of a pump powered by an air motor. The compressed air is stored in manifolded tanks at 3,000 PSI and supplied by pneumatic piping containing a solenoid and pressure reducing valve at 100 PSI to the motor.

Emergency Operation
Upon loss of power, primary pump controls open a solenoid valve that activates a pneumatic motor driving an end-suction pump (approx. 5second gap), supplying power to the primary pump until emergency generator power is established and synchronized.

The controls of the pneumatic pump run off of batteries, separating it from the power grid. In addition, the compressed air tank manifold must be sized to store enough air to run the pump for at least 90 seconds.

3.2 On-Line UPS (Continuous)

3.2.1 Scheme 3: VFD DC Bus Ride-Thru with Compressed Air and Flywheel Storage (Schematic #3)

Emergency Operation

Upon utility power failure, capacitors supply the VFD DC bus for 2 seconds of ride-through capability. Between 2-5 seconds, a Flywheel maintains the DC bias until the compressed air tank can spin the turbine /alternator. The Alternator in-turn spins the flywheel to supply DC power to the VFD until an AC line condition is detected by the current sensor which will deactivate the DC supply indicating the presence of reliable emergency generation.

Advantages

- When power is unreliable, banks of batteries are not needed. The capacitor bank, which is the size of a small disconnect switch, takes care ride-through for this.

Disadvantages

- No power conditioning

Analysis

This scheme is available for all motor sizes.

3.2.2 Scheme 4: Diesel UPS/CPS (Schematic #4)

Normal Operation:

The generator (G1) acts as a synchronous condenser that maintains the speed of the outer rotor of the induction coupling (M2 Flywheel). It supplies reactive power to the load and works together with the reactor as an active filter.

Emergency Operation:

The generator (G1) no longer acts as a motor and instead is driven by the induction coupling (M2 Flywheel – for 15 seconds) then by the diesel engine, which supplies power to the critical load until verification of reliable utility power. (HiTec Power Protection, 2007)

Advantages

1) System is in parallel
2) Used for Large Dedicated Systems

Disadvantages

1) No Filter when in Emergency Operation
2) Inner bearings within the kinetic energy source cannot be lubricated under routine schedule

3) Diesel engines have a very high component count and therefore a very low MTBF and very high MTTR for the system
4) Anti-pollution by-laws in certain cities may not approve the use of a diesel engine for such applications without a catalytic converter
5) Often the slew rate and/or the frequency window (Delta F) are widened to reduce frequent starting of the diesel engine but sacrificing the power quality.
6) There is a major limitation with regard to impact load (100% step load) performance exhibited by such UPS' as it can take as long as 120 msecs to reach steady state condition whereas a static UPS can easily achieve this condition within 20 msecs
7) Synchronization between multiple parallel UPS' of this design can take up to 10-15secs assuming that there are no impact load conditions at the time. This timescale is extremely long when compared with a static UPS which barely takes 1 or 2 msecs.
8) Diesel Rotary systems cannot be easily retrofitted into a large building say on 10th floor as structural design needs to be taken into consideration. A typical 600 KVA diesel UPS can weigh as much as 13 tons of concentrated loading
9) Noise (diesel engines are noisy (112-120 dBA). Exhaust gas emission, bulk fuel storage tank, an exceptional amount of cooling and many other similar problems must be overcome.
10) Since this is a rotating type UPS the vibrations being transferred to the building structure may cause a resonance situation with the natural frequency of vibration of the building
11) Since the system efficiency is very low (around 84%), running costs can be exceptionally high when compared to similar static UPS
12) When maintaining the Diesel Rotary UPS system simply replacing the bearings in the kinetic energy source (even a simple component swap) can take in excess of 36 hours. Furthermore, carrying out this procedure would require a crane suitable for lifting the heavy (3 tons for 600KVA) kinetic energy module. As well as maintenance costs for these units being exceptionally high, the initial UPS project cost can be almost 50-60% higher than that of a similar static UPS (Shri Karve, MGE UPS Systems, 2007).

Analysis

This scheme uses technology developed almost 35 years ago and uses basic components. An In-line conditioner choke is used between the main input and load which generates unwanted phase shift. This system falls under line interactive topology since it cannot correct mains frequency fluctuations. If the diesel does not fire within 3-5 seconds, the critical load will have to drop if there is no redundant UPS.

3.2.3 Scheme 5: DC Motor Driven Pump with Drive (Schematic #5)

Normal Operation: The utility power travels through the rectifier (AC/DC) (charging batteries isolated with a static switch) while supplying the drive for a DC Motor that supplies the critical load in an on-line series configuration.

Emergency Operation: The static switch isolated batteries supply the DC motor drive until emergency power is initiated and on-line.

Advantages

1) Simple configuration

Disadvantages

1) Not many installations
2) Controls integration difficulties
3) Battery maintenance

Analysis

This scheme is not used in many commercial applications as it is difficult to locate many high HP VSD motors. In addition, complications may occur when switching from AC to DC controls to operate the VSD.

3.2.4 Scheme 6: VFD w/ DC Buss Ride-Through (Schematic #6)

Normal Operation:

Utility main is converted AC/DC to charge DC ride-thru/ultra-capacitors and supply AC to the VFD’s critical load.

Emergency Operation:

400VDC is provided directly to the VFD’s critical load using a DC Bus Ride-thru (approx. 2 seconds). Next, via a storage bank of ultra-capacitors for (2-90 seconds)

Advantages

1) In Parallel with system
2) Simplistic Configuration

Disadvantages

1) On an existing VFD there may be maintenance (Space) issues accessing DC bus.

Analysis

This works well for motors 10-50 HP

3.2.5 Scheme 7: Pneumatic Driven Pump with Compressed Air – Active Operation (Schematic #7)

Concept Description

This scheme uses a pump powered by an air motor as the primary chilled water pump. The compressed air for the air motor is stored in a tank and supplied through pneumatic piping that contains a solenoid and pressure reducing valve. When the utility power is supplied, the tank is continuously refilled with air by an air compressor.

Emergency Operation

Upon loss of power, primary pump controls continue to use compressed air remaining in tank to actuate an air motor (active operation) which supplies power to the primary pump until emergency generator power is established and synchronized.

The controls of the pneumatic pump run off of batteries, separating it from the power grid. In addition, the compressed air tank must be sized to store enough air to run the pump for at least 90 seconds.

Advantages

- Completely separate from main power
- Since the main chilled water pump is powered by the air tank, there would be no interruption of operation in case of a power failure

Disadvantages

- Requires air compressor and air storage tank;
- Limited sizes;
- Pneumatic pumps are not as energy efficient as centrifugal pumps in continuous operation.

Analysis

The size of the pneumatic pumps is limited (covering only specific motor sizes). This scheme may be the most reliable and cost effective system for the sizes it can accommodate.

3.2.6 Scheme 8: Double Conversion Static UPS with Compressed Air and Flywheel Storage (Schematic #8)

Normal Operation

Utility power is conditioned via a standard double conversion static UPS. The utility power travels through the (AC/DC) converter (charging the batteries), and then travels through a (DC/AC) inverter to supply the critical load with conditioned power.

Emergency Operation:

Upon utility power failure, the on-line Flywheel maintains the DC bias (approx. 2 seconds) until the compressed air tank can spin the turbine/Alternator to maintain the DC bias supplying the critical load (via DC/AC inverter) until verification of reliable utility power.

Advantages

1) No Batteries
2) If you have the Air Source/Compressor Available
3) No environmental conditions required

Disadvantages

4) Not in Parallel (vs. Bonitron which can directly feed the VFD)
5) Only 5 Installed Nationwide (Using the Compressed Air Tank)

Analysis

This is a prototype scheme. Not many installations exist at this time. All components are readily commercially available.

3.2.7 Scheme 9: Double Conversion Static UPS (Schematic #9)

Normal Operation:

The utility power travels through the (AC/DC) converter charges batteries, and then travels through a (DC/AC) inverter to supply the critical load with conditioned power.

Emergency Operation:

The batteries carry the load until the emergency generator power is established and synchronized. This may take up to 90 seconds as there may be several generators to come on-line (as they are parallel on a bus).

Advantages

1) Proven Technology

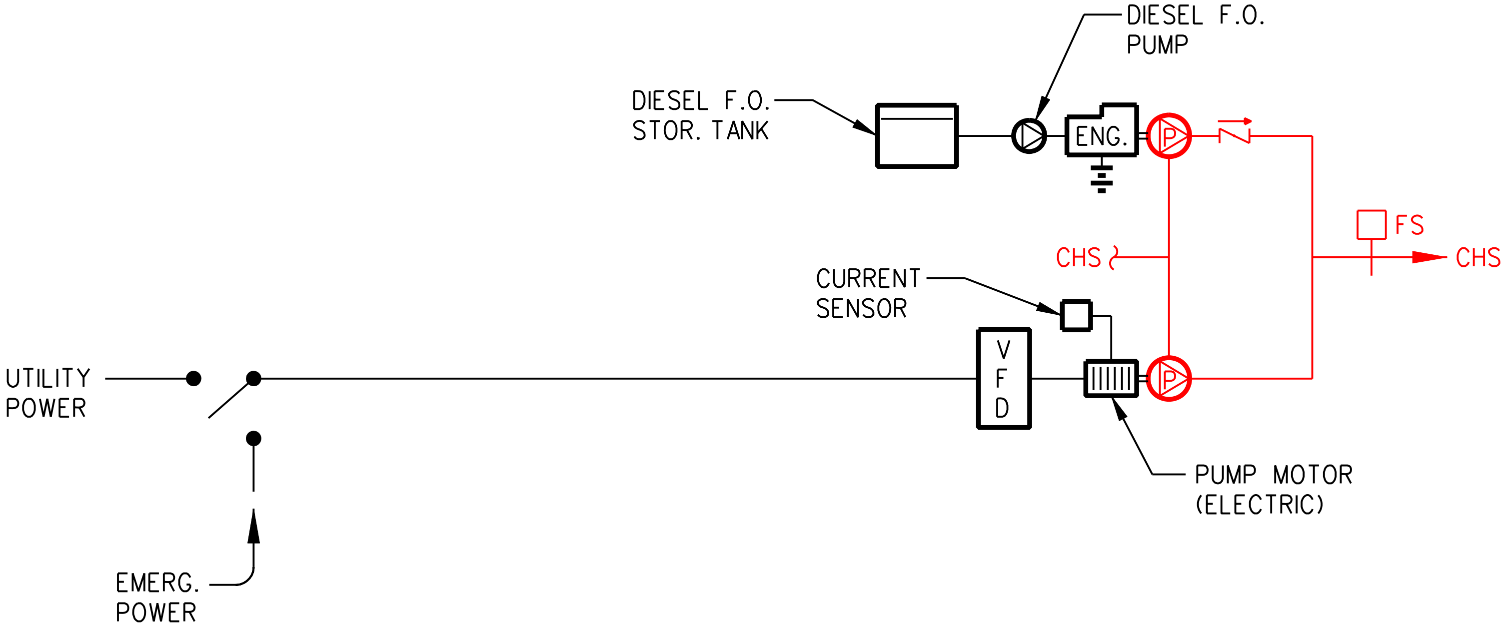
Disadvantages

1) Not in Parallel
2) Special Environmental Considerations (Controlled A/C – Low Dust)

Analysis

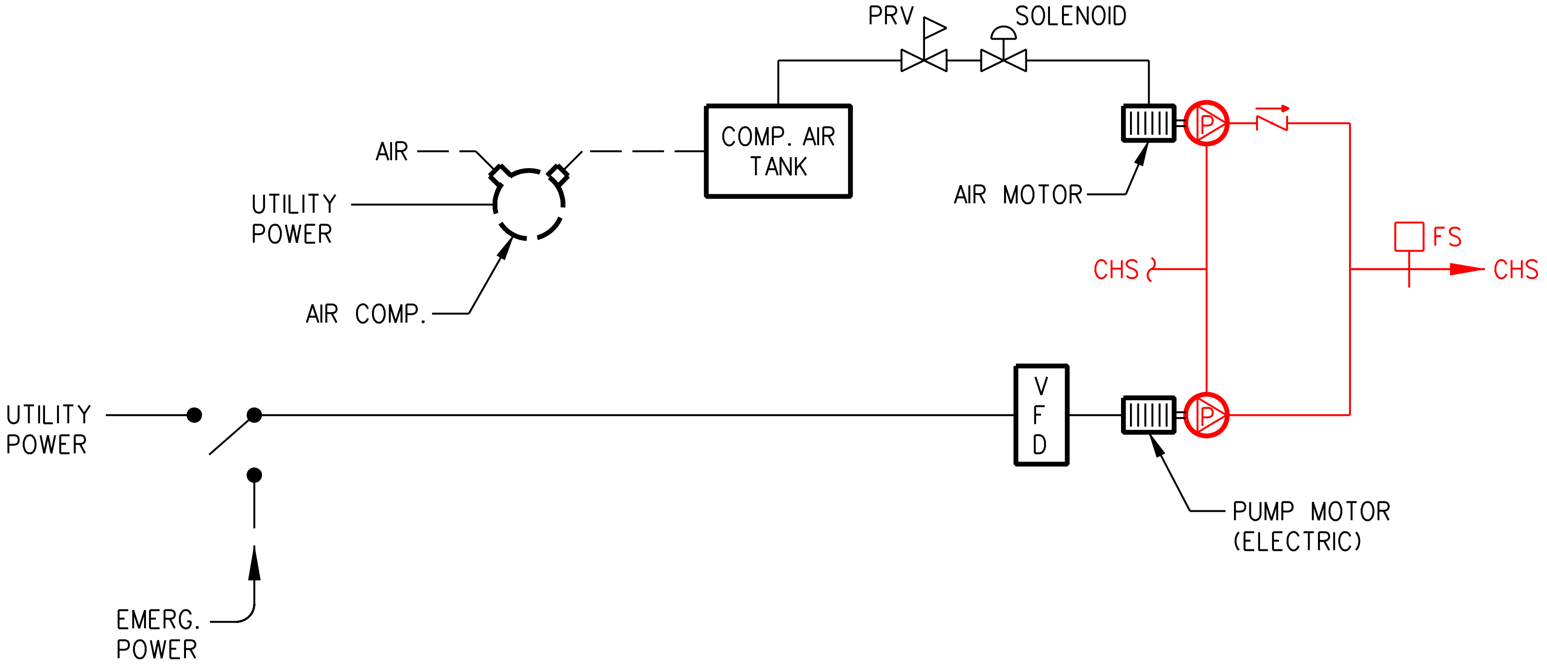
Thousands of these systems are currently installed. Volumes of reliability information is known.

— CHILLED WATER SYSTEM
— ELECTRICAL SYSTEM



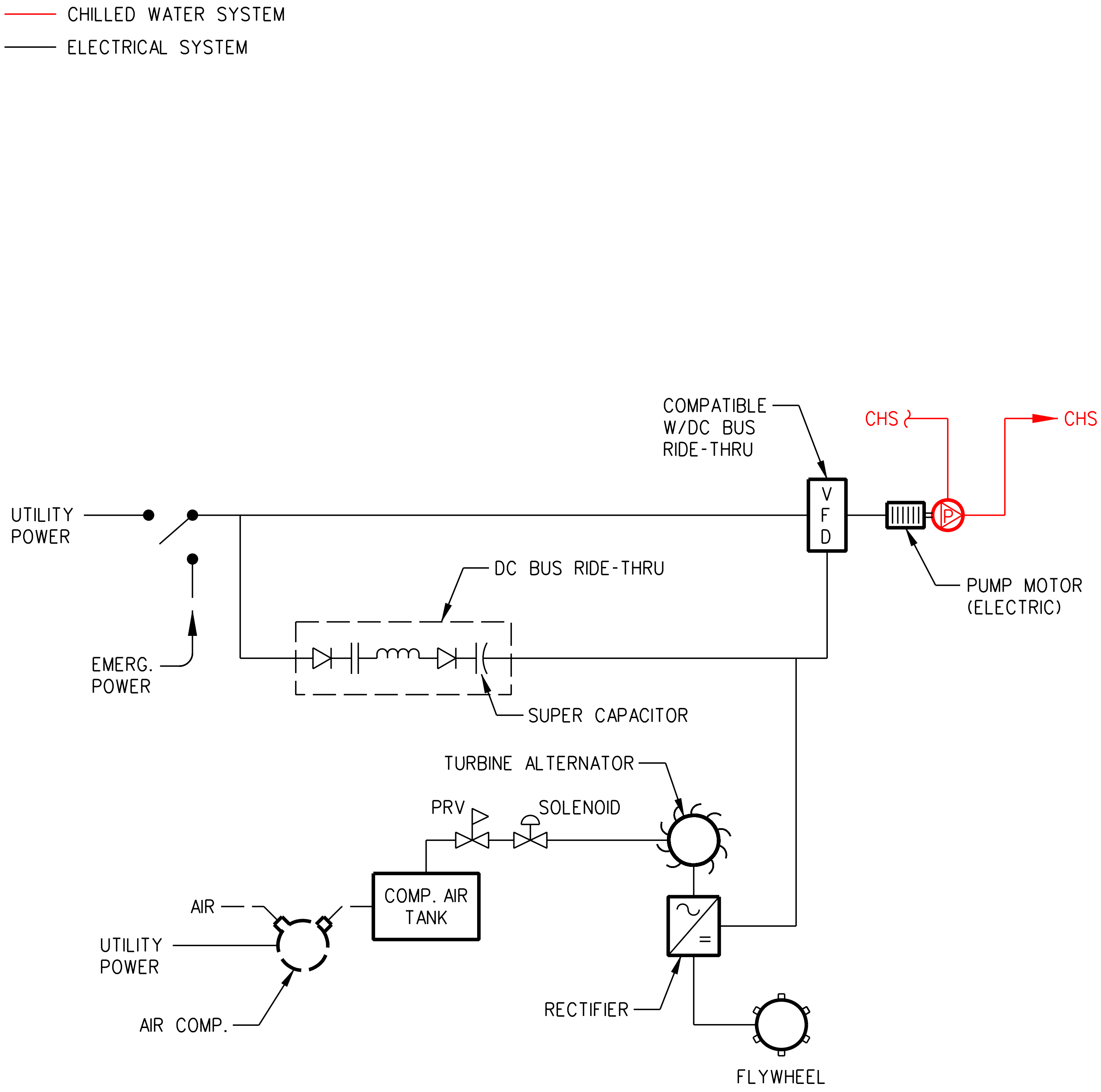
DIESEL PUMP W/F.O. STORAGE PIPED IN PARALLEL

SCHEMATIC NO. 1



PNEUMATIC DRIVEN PUMP W/COMPRESSED AIR STORAGE
STANDBY OPERATION

SCHEMATIC NO. 2

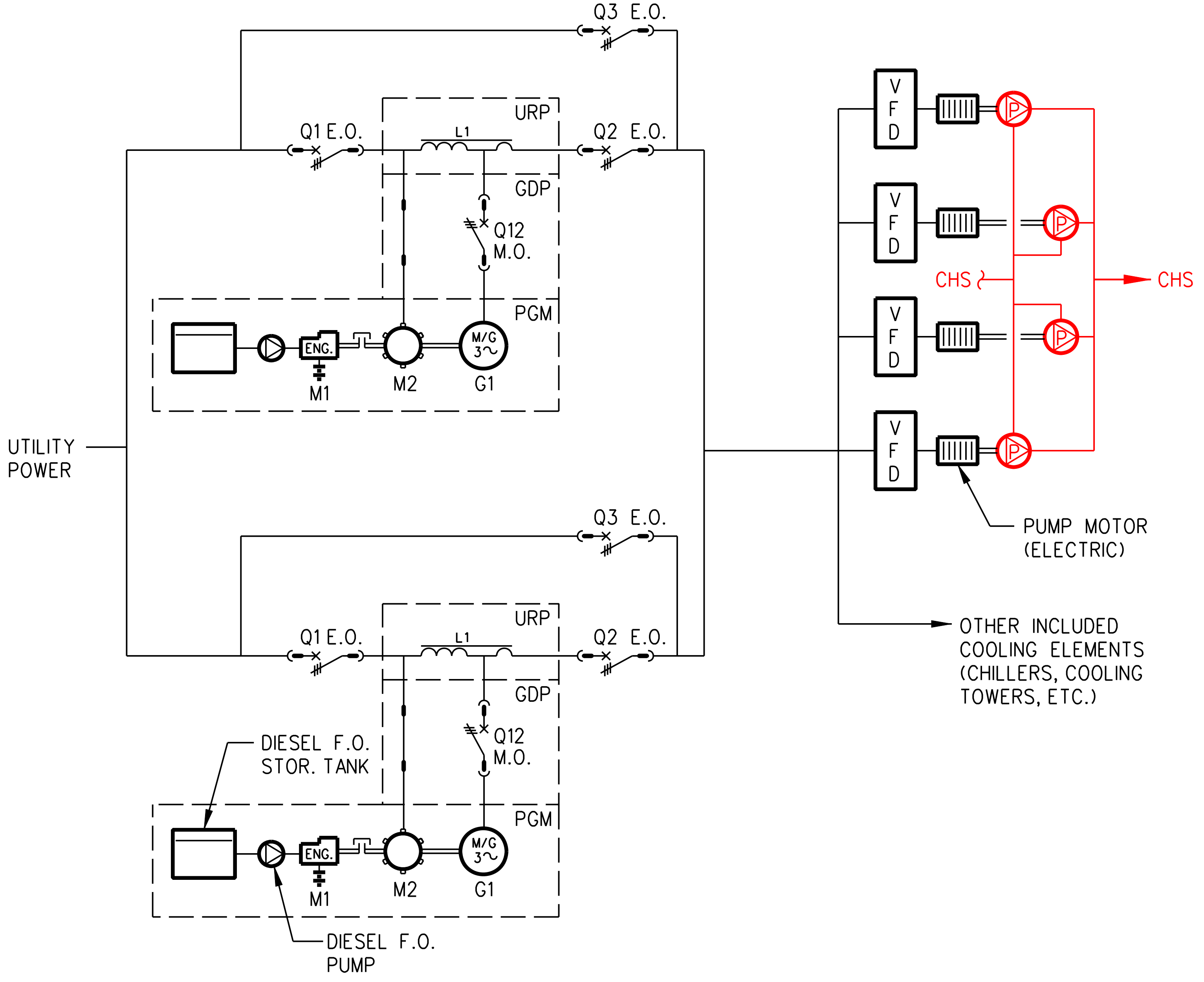


VFD DC BUS RIDE-THRU W/COMPRESSED AIR & FLYWHEEL STORAGE

SCHEMATIC NO. 3

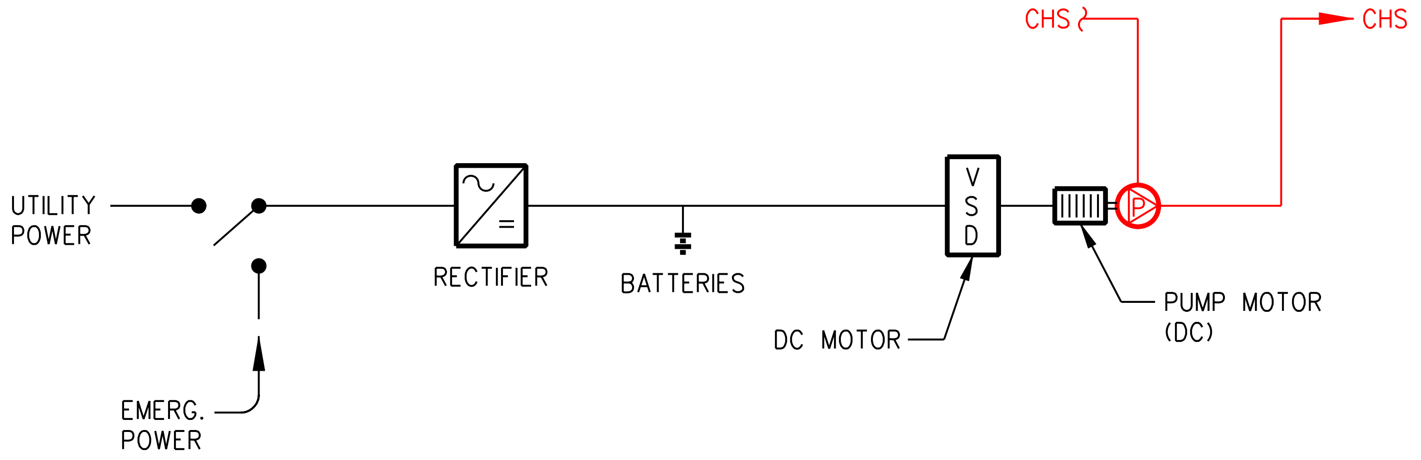
— CHILLED WATER SYSTEM

— ELECTRICAL SYSTEM



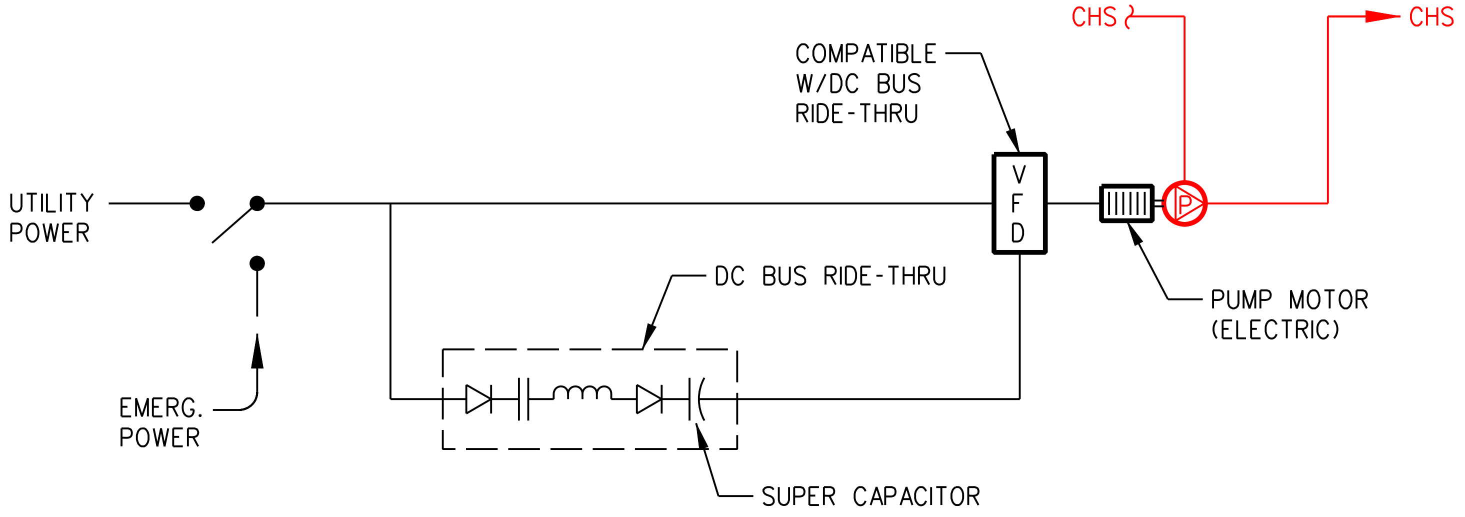
DIESEL UPS/CPS

— CHILLED WATER SYSTEM
— ELECTRICAL SYSTEM



DC MOTOR DRIVEN PUMP W/BATTERY STORAGE

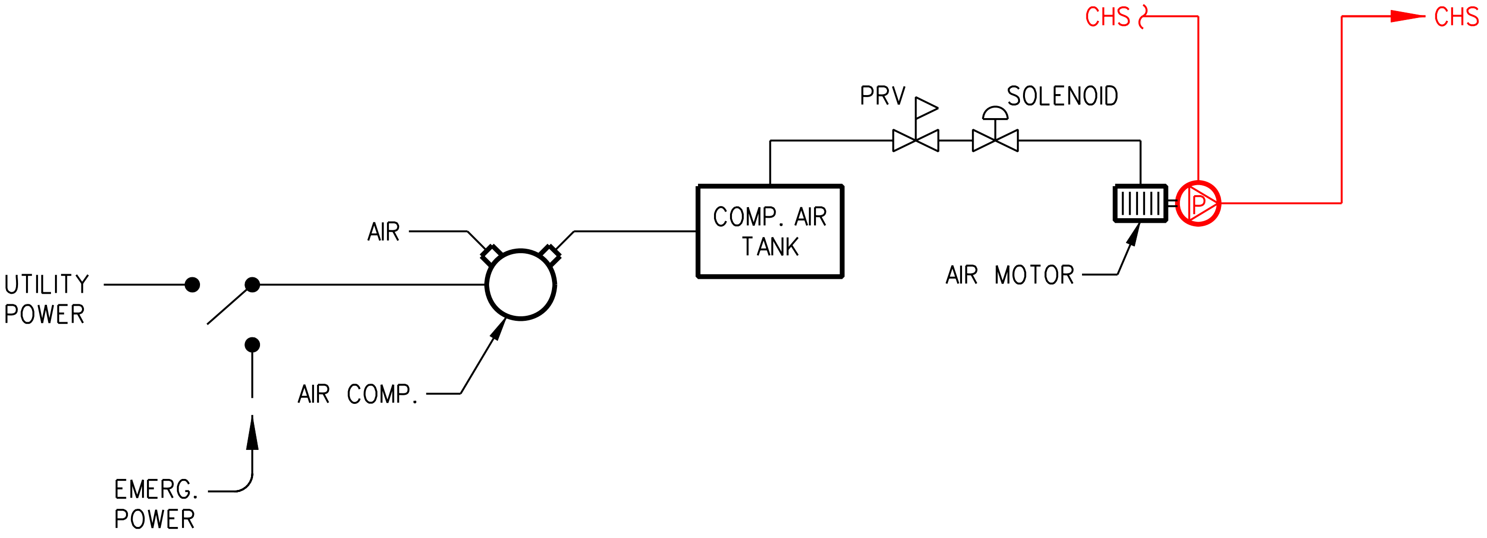
SCHEMATIC NO. 5



VFD W/DC BUS RIDE THRU W/CAPACITOR STORAGE

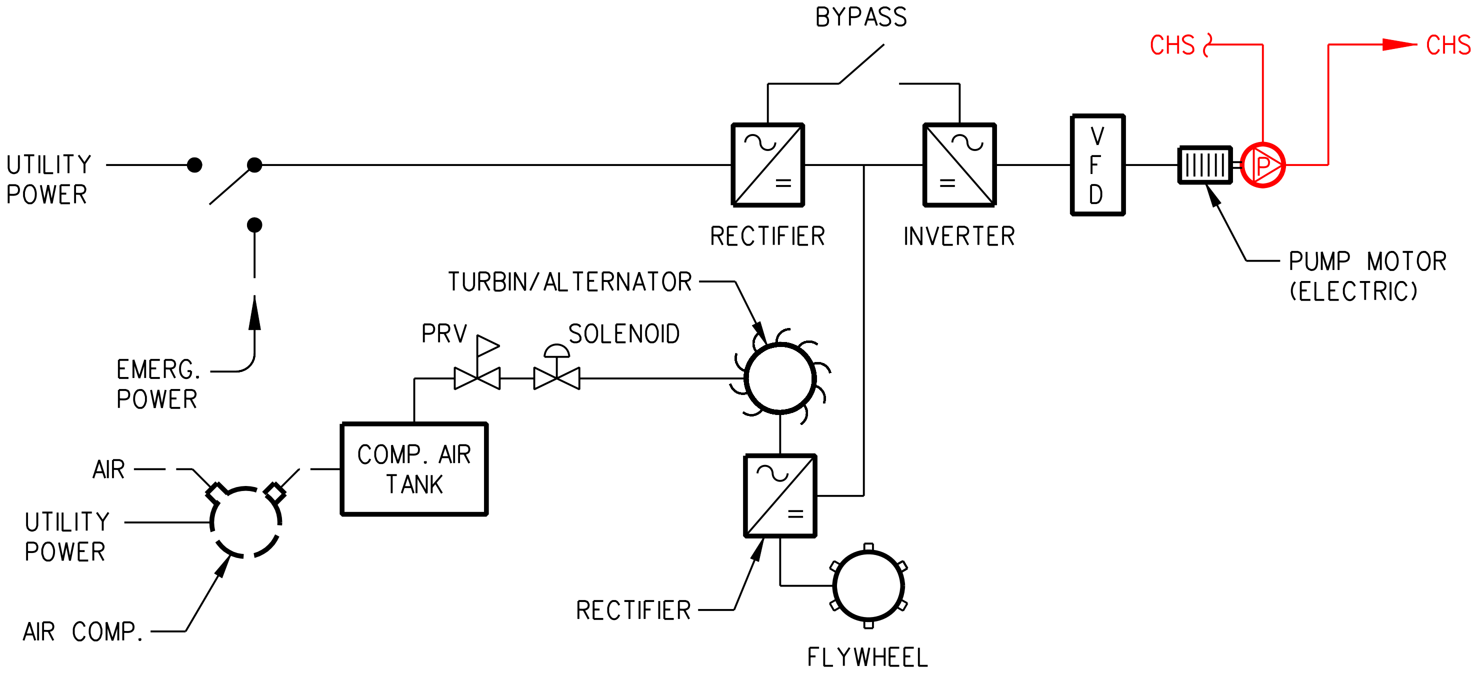
SCHEMATIC NO. 6

— CHILLED WATER SYSTEM
— ELECTRICAL SYSTEM



PNEUMATIC DRIVEN PUMP W/COMPRESSED AIR STORAGE
ACTIVE OPERATION

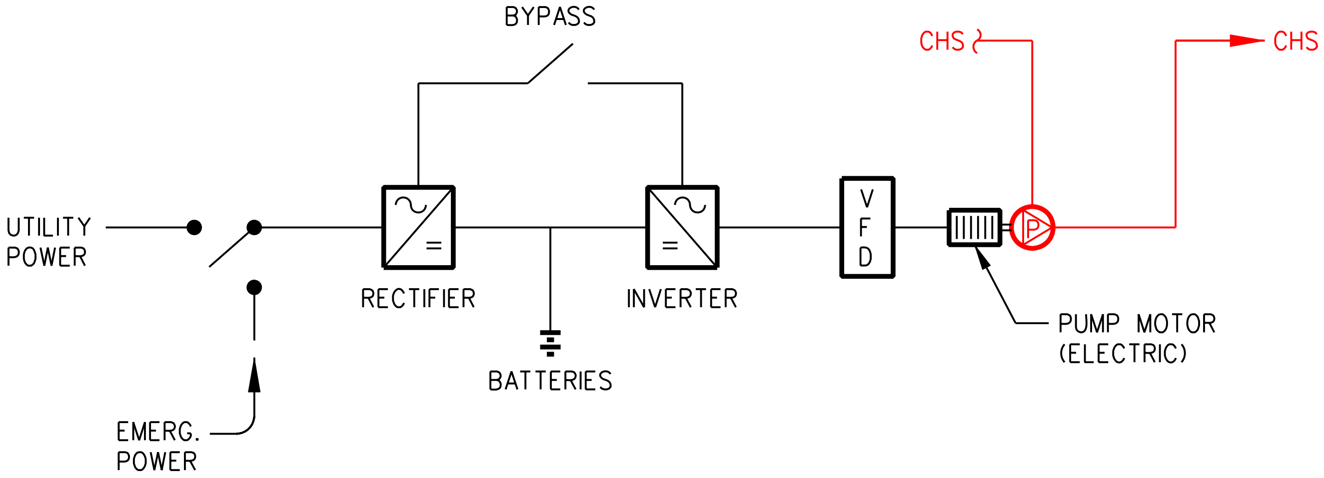
SCHEMATIC NO. 7



DOUBLE CONVERSION STATIC BYPASS W/COMPRESSED AIR & FLYWHEEL STORAGE

SCHEMATIC NO. 8

— CHILLED WATER SYSTEM
— ELECTRICAL SYSTEM



DOUBLE CONVERSION STATIC UPS W/BATTERY STORAGE

4 CRITICAL PATH FOR RESOLUTION

4.1 Discussion

UPS systems are categorized by their ability to provide continuous uninterruptible power Back-Up UPS, Line Interactive, and Online. Of the nine schemes, #1 and #2 operate as “standby” Back-UP UPS and #3-9 are “ride-through” On-line.

This section details the procedure for selecting the appropriate UPS solution of four distinct HP load groups (20HP, 50hP, 100HP, & 250HP).

Black and Veatch Special Project Corp. (BVSPC), Boeing Service Company (BSC), and Maryland Procurement Office (MPO) collaborated in a Criteria Conference held on Monday, July 9 to identify and rate evaluation factors utilized as baseline criteria for each of the nine schemes. The representative criteria in ranking order are:

1. Reliability
2. Annual Maintenance Cost
3. LLC Maintenance Cost
4. Space
5. Installation Cost
6. Commissioning/Start-Up
7. Training
8. Energy

4.1.1 Methodology

The following Matrix Analysis Process was utilized as the framework for this analysis. When several factors must be considered in the selection of options, a Matrix Analysis Process is often used and is universally accepted as industry-standard tool in decision making. The procedure is:

Step 1: Convene a Criteria Conference
A multi-discipline team of ten personnel from BCS, MPO and BVSPC participated in the Criteria conference on July 9, 2007. Each conference attendee had a vested interest in the resulting solution and was relatively familiar with the operations of the organization.

Step 2: Determine Evaluation Factors (EF)
By round table discussion, the conference attendees selected evaluation factors considered important when evaluating each scheme. Care was taken to not “waterdown” the evaluation process with factors that are nebulous or unimportant to the eventual solution.

Step 3: Determine Relative Importance of Each EF

A secret ballot was taken (by 9 Attendees) to determine the rank of importance of these factors.

Step 4: Determine Evaluation Weight of Each EF (EW)

A second secret ballot was taken (by 10 Attendees) to assign a relative weight of importance to each ranked evaluation factor. Each attendee assigned any number (rounded to the nearest 100th) from 0-10 to each evaluation factor. From all the ballots, the numbers were added for each evaluation factor (with the highest and lowest weights thrown out). The total was then divided by the number of attendees voting minus two (since the highest and lowest weights were thrown out).

Step 5: Determine a Numerical Value for Each Option for Each EF

Obtained as a result of calculations, cost estimates, measurements, empirical data, etc.

Step 6: Determine a Normalized Numerical Value ($V_{EF\text{-}OPT}$) for Each Option for Each EF

When higher the value, the better:

$$V_{EF\text{-}OPTION} = 6 - \left(\frac{\textit{highest} \text{ value in factor range - value of option for the factor}}{\text{highest value in factor range - lowest value in factor range}} \right)$$

When lower the value, the better

$$V_{EF\text{-}OPTION} = 5 + \left(\frac{\textit{highest} \text{ value in factor range - value of option for the factor}}{\text{highest value in factor range - lowest value in factor range}} \right)$$

Step 7: For Each Option Multiply Each of Its V_{EF}'S Times the Associated

Step 8: EW and Tabulate Results in a Matrix Table and Total Results.

Step 9: Recommend Option with Highest Score

4.1.2 Results from Criteria Conference

Criteria Conference Evaluation Factor Final List		
Ranking	**Evaluation Factor**	**Relative Weight of Importance (0-10)**
1	**Reliability**	**10**
2	**Annual Maintenance Cost**	**9.36**
3	**LLC Maintenance Cost**	**8.81**
4	**Space**	**7.80**
5	**Installation Cost**	**7.56**
6	**Commissioning / Start-Up**	**6.86**
7	**Training**	**5.99**
8	**Energy**	**3.71**

(See Appendix 8.1 for Criteria Conference Meeting Minutes)

4.1.3 Evaluation Factors

Evaluation Factors were determined via a brainstorming session with all attending conference members. A round table discussion followed to select the most important evaluation factors from the list. See the table below for original evaluation factor list and selection, grouping, & elimination reasoning. Eight evaluation factors were selected.

Criteria Conference Brainstorming Session		
Item #	**Original Evaluation Factor List**	**Selection, Grouping, & Elimination Reasoning**
1	**Color**	**Eliminated – not critical**
2	**Reliability – Normal Operation**	**Grouped under Reliability**
3	**Reliability – Emergency Operation**	**Grouped under Reliability**
4	**Maintainability**	**Grouped under Annual Maintenance Cost**
5	**Annual Maintenance Cost**	**Selected**
6	**LLC Maintenance Cost**	**Selected**
7	**Energy**	**Selected**
8	**First Cost**	**Selected**
9	**Resource Availability**	**Grouped as part of Annual Maintenance & Reliability**
10	**Simplicity**	**Grouped as part of Annual Maintenance & Reliability**
11	**Carbon Footprint**	**Grouped as part of Energy**
12	**Space**	**Selected**
13	**Impacts of installation**	**Grouped as part of Installation/First Cost**
14	**Commissioning**	**Grouped with Start-Up - Selected**
15	**Training**	**Selected**
16	**Start-up**	**Grouped with Commissioning - Selected**
17	**Expandability**	**Eliminated – not critical**
18	**Political**	**Eliminated – not critical**
19	**Compatibility**	**Eliminated – All systems technically compatible**
20	**Proven Technology**	**Grouped as part of Annual Maintenance & Reliability**
21	**Time (Procurement of Parts)**	**Grouped as part of LCC Maintenance & Reliability**
22	**Continuous Maintenance Cost**	**Grouped as part of Annual Maintenance Cost**

4.1.4 HP Grouping

The size pumps considered in this white paper serve chilled water systems from 100 to 2,000 tons. Pumps are typically categorized as either end-suction or double suction. To streamline the results of this analysis, it was resolved that the end suction pumps used up to 50 hp and larger are typically the purview of double suction pumps.

It was determined that 10, 15 and 20 horsepower end suction pumps are very similar and the evaluation factors associated for the largest should apply for all smaller pumps for the purposes of this analysis. Similar reasoning applied for the 25, 30, 40 and 50 as well as the 60/75/100 and 125/150//200/250 double suction grouping.
The horsepower groups were identified by the largest motor for that group.

4.1.5 Elimination of HP Group/Scheme Alignment by Narrative

Contending Schemes by HP Group									
Group	**Scheme #1**	**Scheme #2**	**Scheme #3**	**Scheme #4**	**Scheme #5**	**Scheme #6**	**Scheme #7**	**Scheme #8**	**Scheme #9**
20 HP	X	X	X	X	X	X	X	X	X
50 HP	X	X	X	X	X	X	X	X	X
100 HP	X	-	X	X	X	X	-	X	X
250 HP	X	-	X	X	X	X	-	X	X

<u>20 HP Group</u>
All schemes are appropriate for evaluation.

<u>50 HP Group</u>
All schemes are appropriate for evaluation.

<u>100 HP Group</u>
The two schemes (#2 & #7) that require air motors utilize equipment that is not readily commercially available (systems greater than 50HP). All other schemes satisfy this requirement for all groups. This was the primary threshold for inclusion in the analysis. Though scheme #6 has its own practical application faults - which include large install and space allotments, and high costs for super capacitors (for larger horsepower systems); it was included in the analysis on the basis that it satisfies the equipment availability pre-condition.

<u>250 HP Group</u>
Same as 100 hp group.

5 CONCLUSIONS

There follows a brief description of considerations utilized in developing the eight evaluation factors' numerical values.

5.1 Narrative

5.1.1 Reliability – See Appendix 8.6

High importance is placed upon computer modeling of reliability information utilizing *Reliasoft* computer program modeling. Schematics of each scheme have been assembled detailing each equipment module input to be used in the reliability simulation. Items included in the analysis (in-scope) are indicated in bold on the *Reliability Block Diagrams* included in Appendix 8.6.

5.1.2 Annual Maintenance – See Appendix 8.7

BVSPC utilized a collective contribution of historical data and codified industry experience to calculate the annual maintenance of each scheme. All calculations are in today's dollars.

5.1.3 Life Cycle Maintenance – See Appendix 8.8

Life Cycle Maintenance Cost was calculated by multiplying annual maintenance by the 30 year life of the system (plus added any expected equipment replacements, sometimes multiple, over the life of the system) provided the final LCC Maintenance data. All calculations are in Today's dollars.

5.1.4 Space – See Appendix 8.9

A space calculation was completed by assessing the square feet of all equipment for each scheme for each horsepower group. A 3 foot clearance was provided for maintenance access where required for proper maintenance. In addition, additional space allowances were considered for any associated ventilation and air conditioning equipment required.

5.1.5 Installation Cost – See Appendix 8.10

BVSPC utilized manufacturer's data, RS Means Cost Estimating and industry standards based upon field experience.

5.1.6 Commissioning and Start-UP – See Appendix 8.11

There is an evaluated level of man-hour effort used to start-up the various pieces of equipment. Based upon commissioning experience, special consideration was allowed to include man-hours for testing, de-bugging, balancing and simulating an outage.

5.1.7 Training – See Appendix 8.12

Training costs were dependant upon the number of disciplines required for attendance (Electrical, Mechanical, IT, etc.). An estimation of man-days was made based upon the level of expected effort and complexity or familiarity of typical operating personnel with the equipment involved in each scheme.

5.1.8 Energy – See Appendix 8.13

Annual energy was estimated utilizing 10^6 Btu increments. Energy for associate ventilation, make-up air and air conditioning were included where required. Special consideration was made for standby systems, by including the energy associated with exercising the equipment or simulating a power outage.

See the following page for the current scoring status of all schemes, presented in matrix form.

5.2 Table No.1 – Matrix Analysis for 20 HP Group

EF Score vs. Scheme

Matrix Analysis - 20 HP Group

Scheme	Reliability			Annual Maintenance			Life Cycle Maintenance			Space			Installation Cost			Commissioning / Start-Up			Training			Energy			Current Score
	WT	NV	Score	WT	NV	Score	WT	NV	Score	WT	NV	Score	WT	NV	Score	WT	NV	Score	WT	NV	Score	WT	NV	Score	
1	10.00		0.00	9.36	5.36	50.20	8.81	5.62	49.49	7.80	5.87	45.78	7.56	5.50	41.58	6.86	5.81	39.87	5.99	5.93	35.52	3.71	6.00	22.25	**284.70**
2	10.00		0.00	9.36	5.77	54.03	8.81	6.00	52.86	7.80	6.00	46.80	7.56	5.68	42.94	6.86	5.98	41.02	5.99	6.00	35.94	3.71	6.00	22.26	**295.85**
3	10.00		0.00	9.36	5.55	51.91	8.81	5.54	48.79	7.80	5.72	44.60	7.56	5.42	40.98	6.86	5.83	40.02	5.99	5.64	33.78	3.71	5.99	22.22	**282.29**
4	10.00		0.00	9.36	5.27	49.35	8.81	5.39	47.49	7.80	5.00	39.00	7.56	6.00	45.36	6.86	5.00	34.30	5.99	5.00	29.95	3.71	5.89	21.86	**267.32**
5	10.00		0.00	9.36	5.56	52.08	8.81	5.69	50.14	7.80	5.59	43.58	7.56	6.00	45.36	6.86	5.75	39.45	5.99	5.86	35.10	3.71	5.87	21.80	**287.50**
6	10.00		0.00	9.36	6.00	56.16	8.81	5.93	52.24	7.80	5.94	46.33	7.56	5.52	41.73	6.86	6.00	41.16	5.99	6.00	35.94	3.71	6.00	22.26	**295.81**
7	10.00		0.00	9.36	5.85	54.80	8.81	5.83	51.39	7.80	5.70	44.43	7.56	5.07	38.33	6.86	5.92	40.59	5.99	5.93	35.52	3.71	5.00	18.55	**283.60**
8	10.00		0.00	9.36	5.00	46.80	8.81	5.00	44.05	7.80	5.83	45.44	7.56	5.00	37.80	6.86	5.54	38.02	5.99	5.42	32.47	3.71	5.89	21.87	**266.44**
9	10.00		0.00	9.36	5.36	50.20	8.81	5.40	47.59	7.80	5.33	41.54	7.56	6.00	45.36	6.86	5.75	39.45	5.99	5.64	33.78	3.71	5.89	21.85	**279.78**

5.3 Table No.2 – Matrix Analysis for 50 HP Group

EF Score vs. Scheme

Matrix Analysis - 50 HP Group

Scheme	Reliability			Annual Maintenance			Life Cycle Maintenance			Space			Installation Cost			Commissioning / Start-Up			Training			Energy			Current Score
	WT	NV	Score	WT	NV	Score	WT	NV	Score	WT	NV	Score	WT	NV	Score	WT	NV	Score	WT	NV	Score	WT	NV	Score	
1	10.00		0.00	9.36	5.36	50.20	8.81	5.64	49.67	7.80	5.89	45.95	7.56	5.56	42.03	6.86	5.81	39.87	5.99	5.93	35.52	3.71	6.00	22.25	**285.50**
2	10.00		0.00	9.36	5.77	54.03	8.81	6.00	52.86	7.80	6.00	46.80	7.56	5.51	41.66	6.86	5.98	41.02	5.99	6.00	35.94	3.71	6.00	22.26	**294.57**
3	10.00		0.00	9.36	5.55	51.91	8.81	5.52	48.66	7.80	5.75	44.85	7.56	5.74	43.39	6.86	5.83	40.02	5.99	5.64	33.78	3.71	5.99	22.22	**284.83**
4	10.00		0.00	9.36	5.27	49.35	8.81	5.42	47.71	7.80	5.00	39.00	7.56	6.00	45.36	6.86	5.00	34.30	5.99	5.00	29.95	3.71	5.93	21.99	**267.66**
5	10.00		0.00	9.36	5.56	52.08	8.81	5.62	49.53	7.80	5.63	43.88	7.56	5.75	43.47	6.86	5.75	39.45	5.99	5.86	35.10	3.71	5.88	21.81	**285.31**
6	10.00		0.00	9.36	6.00	56.16	8.81	5.73	50.50	7.80	5.94	46.31	7.56	5.22	39.46	6.86	6.00	41.16	5.99	6.00	35.94	3.71	6.00	22.26	**291.79**
7	10.00		0.00	9.36	5.85	54.80	8.81	5.64	49.70	7.80	5.63	43.88	7.56	5.00	37.80	6.86	5.92	40.59	5.99	5.93	35.52	3.71	5.00	18.55	**280.83**
8	10.00		0.00	9.36	5.00	46.80	8.81	5.00	44.05	7.80	5.86	45.70	7.56	5.32	40.22	6.86	5.54	38.02	5.99	5.42	32.47	3.71	5.90	21.89	**269.15**
9	10.00		0.00	9.36	5.36	50.20	8.81	5.33	46.98	7.80	5.47	42.66	7.56	6.00	45.36	6.86	5.75	39.45	5.99	5.64	33.78	3.71	5.90	21.88	**280.31**

5.4 Table No.3 – Matrix Analysis for 100 HP Group

EF Score vs. Scheme

Matrix Analysis - 100 HP Group

Scheme	Reliability			Annual Maintenance			Life Cycle Maintenance			Space			Installation Cost			Commissioning / Start-Up			Training			Energy			Current Score
	WT	NV	Score	WT	NV	Score	WT	NV	Score	WT	NV	Score	WT	NV	Score	WT	NV	Score	WT	NV	Score	WT	NV	Score	
1	10.00		0.00	9.36	5.36	50.20	8.81	6.00	52.86	7.80	5.98	46.64	7.56	5.76	43.55	6.86	5.81	39.87	5.99	5.93	35.52	3.71	5.94	22.02	**290.67**
2	Not Available																								**-**
3	10.00		0.00	9.36	5.55	51.91	8.81	5.78	50.95	7.80	5.76	44.91	7.56	5.95	44.98	6.86	5.83	40.02	5.99	5.64	33.78	3.71	5.92	21.96	**288.51**
4	10.00		0.00	9.36	5.27	49.35	8.81	5.68	50.03	7.80	5.00	39.00	7.56	6.00	45.36	6.86	5.00	34.30	5.99	5.00	29.95	3.71	5.29	19.62	**267.61**
5	10.00		0.00	9.36	5.56	52.08	8.81	5.87	51.68	7.80	5.64	43.96	7.56	5.86	44.30	6.86	5.75	39.45	5.99	5.86	35.10	3.71	5.00	18.55	**285.12**
6	10.00		0.00	9.36	6.00	56.16	8.81	5.48	48.26	7.80	6.00	46.80	7.56	5.00	37.80	6.86	6.00	41.16	5.99	6.00	35.94	3.71	6.00	22.26	**288.38**
7	Not Available																								**-**
8	10.00		0.00	9.36	5.00	46.80	8.81	5.00	44.05	7.80	5.91	46.09	7.56	5.68	42.94	6.86	5.54	38.02	5.99	5.42	32.47	3.71	5.19	19.24	**269.61**
9	10.00		0.00	9.36	5.36	50.20	8.81	5.42	47.76	7.80	5.45	42.55	7.56	6.00	45.36	6.86	5.75	39.45	5.99	5.64	33.78	3.71	5.18	19.20	**278.30**

5.5 Table No.4 – Matrix Analysis for 250 HP Group

EF Score vs. Scheme

Matrix Analysis - 250 HP Group

Scheme	Reliability			Annual Maintenance			Life Cycle Maintenance			Space			Installation Cost			Commissioning / Start-Up			Training			Energy			Current Score
	WT	NV	Score	WT	NV	Score	WT	NV	Score	WT	NV	Score	WT	NV	Score	WT	NV	Score	WT	NV	Score	WT	NV	Score	
1	10.00		0.00	9.36	5.36	50.20	8.81	6.00	52.86	7.80	6.00	46.80	7.56	5.88	44.45	6.86	5.87	40.25	5.99	5.93	35.52	3.71	5.93	22.02	**292.11**
2	Not Available																								**-**
3	10.00		0.00	9.36	5.55	51.91	8.81	5.86	51.63	7.80	5.67	44.20	7.56	5.81	43.92	6.86	5.88	40.35	5.99	5.64	33.78	3.71	5.92	21.95	**287.74**
4	10.00		0.00	9.36	5.27	49.35	8.81	5.87	51.69	7.80	5.00	39.00	7.56	6.00	45.36	6.86	5.00	34.30	5.99	5.00	29.95	3.71	5.39	20.00	**269.65**
5	10.00		0.00	9.36	5.56	52.08	8.81	5.88	51.81	7.80	5.61	43.77	7.56	5.88	44.45	6.86	5.82	39.95	5.99	5.86	35.10	3.71	5.00	18.55	**285.71**
6	10.00		0.00	9.36	6.00	56.16	8.81	5.00	44.05	7.80	5.93	46.28	7.56	5.00	37.80	6.86	6.00	41.16	5.99	6.00	35.94	3.71	6.00	22.26	**283.65**
7	Not Available																								**-**
8	10.00		0.00	9.36	5.00	46.80	8.81	5.52	48.65	7.80	5.89	45.93	7.56	5.68	42.94	6.86	5.68	38.94	5.99	5.42	32.47	3.71	5.21	19.32	**275.05**
9	10.00		0.00	9.36	5.36	50.20	8.81	5.64	49.68	7.80	5.41	42.21	7.56	6.00	45.36	6.86	5.82	39.95	5.99	5.64	33.78	3.71	5.20	19.30	**280.48**

6 Recommendations

6.1 20 HP Group – (all nine schemes considered)

6.1.1 20HP Group: Option 1

The current leading candidate for this pump horsepower group is **Scheme # 2**(Air Motor/Pump) with a score of **295.85** within a range of (**300.54 max possible high score / 250.45 for minimum possible low score)** for the 7 factors analyzed to date. The reliability of each system has been modeled but not yet evaluated; will be the subject of much scrutiny, discussion and analysis and will comprise the bulk of the work assignment between the 60% and pre-final submission.

Top 5 Evaluation Factors

Reliability - **TBD**

Maintenance Costs

- Annual – **$3,500**
- Life Cycle **- $105,000** for the 30 - year life of the system. This cost includes 30 years of annual maintenance and no equipment replacement

Space Required – **95sf** to house the pump and manifolded compressed air tanks plus a space allowance for proper maintenance. See Appendix 8.9.

Installation Cost - **$216,000 –** See Appendix Tab 8.10 for cost estimate.

Typical Layouts

Typical layout designs are created through a collective requirement and information gathering process; involving the investigation of typical equipment footprints, maintenance and installation guides. Equipment details and space requirement sketches are combined with typical floor plans to create a standard virtual CADD model for the selected scheme. These drawings are created once final recommendations have been made.

6.1.2 20HP Group: Option 2

An extremely close second candidate for this pump horsepower group is **Scheme # 6** (VFD Ride-thru/Super Capacitors) with a score of **295.81** within a range of (**300.54 max possible high score / 250.45 for minimum possible low score)** for the 7 factors analyzed to date. The reliability of each system has been modeled but not yet evaluated;

will be the subject of much scrutiny, discussion and analysis and will comprise the bulk of the work assignment between the 60% and pre-final submission.

Top 5 Evaluation Factors

Reliability – **TBD**

Maintenance Costs

- Annual – **$1,000**
- Life Cycle **- $130,000** for the 30 - year life of the system. This cost includes 30 years of annual maintenance + one replacement of super capacitors.

Space Required - **84sf** to house the super capacitors, Ride-thru, and control cabinet plus a space allowance for proper maintenance. See Appendix 8.9.

Installation Cost - **$232,000 –** See Appendix Tab 8.10 for cost estimate.

Typical Layouts

Typical layout designs are created through a collective requirement and information gathering process; involving the investigation of typical equipment footprints, maintenance and installation guides. Equipment details and space requirement sketches are combined with typical floor plans to create a standard virtual CADD model for the selected scheme. These drawings are created once final recommendations have been made.

6.1.3 20HP Group: Option 3

The third candidate for this pump horsepower group is **Scheme # 5** (DC Motor/Pump) with a score of **287.50** within a range of (**300.54 max possible high score / 250.45 for minimum possible low score)** for the 7 factors analyzed to date. The reliability of each system has been modeled but not yet evaluated; will be the subject of much scrutiny, discussion and analysis and will comprise the bulk of the work assignment between the 60% and pre-final submission.

Top 5 Evaluation Factors

Reliability – **TBD**

Maintenance Costs

- Annual – **$5,800**
- Life Cycle **- $214,000** for the 30 - year life of the system. This cost includes 30 years of annual maintenance + one equipment replacement and 2 entire battery replacements.

Space Required - **100sf** to house the pump, batteries, rectifier, and A/C equipment plus a space allowance for proper maintenance. See Appendix 8.9.

Installation Cost - **$183,000 –** See Appendix Tab 8.10 for cost estimate.

Typical Layouts

Typical layout designs are created through a collective requirement and information gathering process; involving the investigation of typical equipment footprints, maintenance and installation guides. Equipment details and space requirement sketches are combined with typical floor plans to create a standard virtual CADD model for the selected scheme. These drawings are created once final recommendations have been made.

6.2 50 HP Group – (all nine schemes considered)

6.2.1 50HP Group: Option 1

The current leading candidate for this pump horsepower group is **Scheme # 5** (DC Motor/Pump) with a score of **294.57** within a range of (**300.54 max possible high score / 250.45 for minimum possible low score)** for the 7 factors analyzed to date. The reliability of each system has been modeled but not yet evaluated; will be the subject of much scrutiny, discussion and analysis and will comprise the bulk of the work assignment between the 60% and pre-final submission.

Top 5 Evaluation Factors

Reliability - **TBD**

Maintenance Costs

- Annual – **$3,500**
- Life Cycle **- $105,000** for the 30 - year life of the system. This cost includes 30 years of annual maintenance and no equipment replacement

Space Required - **103sf** to house the pump and manifolded compressed air tanks plus a space allowance for proper maintenance. See Appendix 8.9.

Installation Cost - **$295,000 –** See Appendix Tab 8.10 for cost estimate.

Typical Layouts

Typical layout designs are created through a collective requirement and information gathering process; involving the investigation of typical equipment footprints, maintenance and installation guides. Equipment details and space requirement sketches are combined with typical floor plans to create a standard virtual CADD model for the selected scheme. These drawings are created once final recommendations have been made.

6.2.2 50HP Group: Option 2

The second candidate for this pump horsepower group is **Scheme # 6** (VFD Ride-thru/Super Capacitors) with a score of **291.79** within a range of (**300.54 max possible high score / 250.45 for minimum possible low score)** for the 7 factors analyzed to date. The reliability of each system has been modeled but not yet evaluated; will be the subject of much scrutiny, discussion and analysis and will comprise the bulk of the work assignment between the 60% and pre-final submission.

Top 5 Evaluation Factors

Reliability – **TBD**

Maintenance Costs

- Annual – **$1,000**
- Life Cycle **- $205,000** for the 30 - year life of the system. This cost includes 30 years of annual maintenance + one replacement of super capacitors.

Space Required - **100sf** to house the super capacitors, Ride-thru, and control cabinet plus a space allowance for proper maintenance. See Appendix 8.9.

Installation Cost **- $341,000 –** See Appendix Tab 8.10 for cost estimate.

Typical Layouts

Typical layout designs are created through a collective requirement and information gathering process; involving the investigation of typical equipment footprints, maintenance and installation guides. Equipment details and space requirement sketches are combined with typical floor plans to create a standard virtual CADD model for the selected scheme. These drawings are created once final recommendations have been made.

6.2.3 50HP Group: Option 3

The third candidate for this pump horsepower group is **Scheme # 1** (Diesel Pump) with a score of **285.50** within a range of (**300.54 max possible high score / 250.45 for minimum possible low score)** for the 7 factors analyzed to date. The reliability of each system has been modeled but not yet evaluated; will be the subject of much scrutiny, discussion and analysis and will comprise the bulk of the work assignment between the 60% and pre-final submission.

Top 5 Evaluation Factors

Reliability – **TBD**

Maintenance Costs

- Annual – **$8,000**
- Life Cycle **- $240,000** for the 30 - year life of the system. This cost includes 30 years of annual maintenance and no equipment replacement.

Space Required - **115sf** to house the pump, day tank, make-up/exhaust system plus a space allowance for proper maintenance. See Appendix 8.9.

Installation Cost **- $287,000 –** See Appendix Tab 8.10 for cost estimate.

Typical Layouts

Typical layout designs are created through a collective requirement and information gathering process; involving the investigation of typical equipment footprints, maintenance and installation guides. Equipment details and space requirement sketches are combined with typical floor plans to create a standard virtual CADD model for the selected scheme. These drawings are created once final recommendations have been made.

6.3 100 HP Group - (seven of the nine schemes considered; pneumatic driven pumps not readily available)

6.3.1 100HP Group: Option 1

The current leading candidate for this pump horsepower group is **Scheme # 1**(Diesel Pump) with a score of **290.67** within a range of (**300.54 max possible high score / 250.45 for minimum possible low score)** for the 7 factors analyzed to date. The reliability of each system has been modeled but not yet evaluated; will be the subject of much scrutiny, discussion and analysis and will comprise the bulk of the work assignment between the 60% and pre-final submission.

Top 5 Evaluation Factors

Reliability – **TBD**

Maintenance Costs

- Annual **– $8,000**
- Life Cycle **- $240,000** for the 30 year life of the system. This cost includes 30 years of annual maintenance and no equipment replacement

Space Required - **125sf** to house the pump, day tank, make-up/exhaust system plus a space allowance for proper maintenance. See Appendix 8.9.

Installation Cost – **$361,000 –** See Appendix Tab 8.10 for cost estimate.

Typical Layouts

Typical layout designs are created through a collective requirement and information gathering process; involving the investigation of typical equipment footprints, maintenance and installation guides. Equipment details and space requirement sketches are combined with typical floor plans to create a standard virtual CADD model for the selected scheme. These drawings are created once final recommendations have been made.

6.3.2 100HP Group: Option 2

The second candidate for this pump horsepower group is **Scheme # 3**(VFD Ride-thru/Comp.Air/Flywheel) with a score of **288.51** within a range of (**300.54 max possible high score / 250.45 for minimum possible low score)** for the 7 factors analyzed to date. The reliability of each system has been modeled but not yet evaluated; will be the subject of much scrutiny, discussion and analysis and will comprise the bulk of the work assignment between the 60% and pre-final submission.

Top 5 Evaluation Factors

Reliability – **TBD**

Maintenance Costs

- Annual – **$6,000**
- Life Cycle **- $298,000** for the 30 year life of the system. This cost includes 30 years of annual maintenance + 12 bearing replacements + rectifier replacement.

Space Required - **150sf** to house the ride-thru, controls, flywheel, rectifier, compressed air storage plus a space allowance for proper maintenance. See Appendix 8.9.

Installation Cost **- $288,000 –** See Appendix Tab 8.10 for cost estimate.

Typical Layouts

Typical layout designs are created through a collective requirement and information gathering process; involving the investigation of typical equipment footprints, maintenance and installation guides. Equipment details and space requirement sketches are combined with typical floor plans to create a standard virtual CADD model for the selected scheme. These drawings are created once final recommendations have been made.

6.3.3 100HP Group: Option 3

A very close third candidate for this pump horsepower group is **Scheme # 6** (VFD Ride-thru/Super Capacitor) with a score of **288.38** within a range of (**300.54 max possible high score / 250.45 for minimum possible low score)** for the 7 factors analyzed to date. The reliability of each system has been modeled but not yet evaluated; will be the subject of much scrutiny, discussion and analysis and will comprise the bulk of the work assignment between the 60% and pre-final submission.

Top 5 Evaluation Factors

Reliability – **TBD**

Maintenance Costs

- Annual – **$1,000**
- Life Cycle **- $380,000** for the 30 year life of the system. This cost includes 30 years of annual maintenance + one replacement of super capacitors.

Space Required - **120sf** to house the capacitor bank, ride-thru, control cabinet plus a space allowance for proper maintenance. See Appendix 8.9.

Installation Cost **- $653,000 –** See Appendix Tab 8.10 for cost estimate.

Typical Layouts

Typical layout designs are created through a collective requirement and information gathering process; involving the investigation of typical equipment footprints, maintenance and installation guides. Equipment details and space requirement sketches are combined with typical floor plans to create a standard virtual CADD model for the selected scheme. These drawings are created once final recommendations have been made.

6.4 250 HP Group - (seven of the nine schemes considered; pneumatic driven pumps not readily available)

6.4.1 250 HP Group: Option 1

The current leading candidate for this pump horsepower group is **Scheme # 1**(Diesel Pump) with a score of **292.11** within a range of (**300.54 max possible high score / 250.45 for minimum possible low score)** for the 7 factors analyzed to date. The reliability of each system has been modeled but not yet evaluated; will be the subject of much scrutiny, discussion and analysis and will comprise the bulk of the work assignment between the 60% and pre-final submission.

Top 5 Evaluation Factors

Reliability – **TBD**

Maintenance Costs

- Annual – **$8,000**
- Life Cycle **- $240,000** for the 30 year life of the system. This cost includes 30 years of annual maintenance and no equipment replacement.

Space Required - **150sf** to house the pump, day tank, makr-up/exhaust systems plus a space allowance for proper maintenance. See Appendix

Installation Cost – **$494,000** – See Appendix Tab 8.10 for cost estimate.

Typical Layouts

Typical layout designs are created through a collective requirement and information gathering process; involving the investigation of typical equipment footprints, maintenance and installation guides. Equipment details and space requirement sketches are combined with typical floor plans to create a standard virtual CADD model for the selected scheme. These drawings are created once final recommendations have been made.

6.4.2 250HP Group: Option 2

The second candidate for this pump horsepower group is **Scheme # 3**(VFD Ride-thru/Comp. Air/Flywheel) with a score of **287.74** within a range of (**300.54 max possible high score / 250.45 for minimum possible low score)** for the 7 factors analyzed to date. The reliability of each system has been modeled but not yet evaluated; will be the subject of much scrutiny, discussion and analysis and will comprise the bulk of the work assignment between the 60% and pre-final submission.

Top 5 Evaluation Factors

Reliability – **TBD**

Maintenance Costs

- Annual – **$6,000**

- Life Cycle **- $333,000** for the 30 year life of the system. This cost includes 30 years of annual maintenance + 12 bearing replacements + one rectifier replacement

Space Required - **200sf** to house the ride-thru, controls, flywheel, rectifier, compressed air storage plus a space allowance for proper maintenance. See Appendix 8.9.

Installation Cost - **$577,000 –** See Appendix Tab 8.10 for cost estimate.

Typical Layouts

Typical layout designs are created through a collective requirement and information gathering process; involving the investigation of typical equipment footprints, maintenance and installation guides. Equipment details and space requirement sketches are combined with typical floor plans to create a standard virtual CADD model for the selected scheme. These drawings are created once final recommendations have been made.

6.4.3 250HP Group: Option 3

The third candidate for this pump horsepower group is **Scheme # 5** (DC Motor/Pump) with a score of **285.71** within a range of (**300.54 max possible high score / 250.45 for minimum possible low score)** for the 7 factors analyzed to date. The reliability of each system has been modeled but not yet evaluated; will be the subject of much scrutiny, discussion and analysis and will comprise the bulk of the work assignment between the 60% and pre-final submission.

Top 5 Evaluation Factors

Reliability – **TBD**

Maintenance Costs

- Annual – **$5,800**
- Life Cycle **- $319,000** for the 30 year life of the system. This cost includes 30 years of annual maintenance + one equipment replacement + 2 entire battery replacements.

Space Required - **150sf** to house the pump, batteries, rectifier plus a space allowance for proper maintenance. See Appendix 8.9.

Installation Cost - **$496,000 –** See Appendix Tab 8.10 for cost estimate.

Typical Layouts

Typical layout designs are created through a collective requirement and information gathering process; involving the investigation of typical equipment footprints, maintenance and installation guides. Equipment details and space requirement sketches are combined with typical floor plans to create a standard virtual CADD model for the selected scheme. These drawings are created once final recommendations have been made.

7 SPECIAL CONSIDERATIONS

Results from this analysis may indicate that Scheme #4 (Diesel UPS/CPS), when compared with the other schemes does not perform favorably. This system (Hi-Tec Solution) offers a UPS system that is designed to support ride-through support for entire plants. The scale of this solution is much larger than the other schemes and should be given special attention and consideration.

BVSPC recommends a follow-on study of this technology as it presents a unique solution for providing uninterruptible power to large scale critical command and control, communications, computer, intelligence, surveillance, and reconnaissance facilities.

8 APPENDIX

8.1 K.O. Mtg. Minutes

8.2 Site Visits/Equip. Data

8.3 Criteria Conf. Minutes

8.4 60% Comments/Responses (not included)

8.5 100% Comments/Responses (not included)

8.6 Reliability Analysis

- **Schematics**
- **Computer program results (not included)**
- **Normalization calculations (not included)**

8.7 Annual Maint. Costs

- **Estimate sheet per scheme**
- **Normalization calculations**

8.8 L.C. Maint. Costs

- **Estimate sheet(s) per scheme**
- **Normalization Calculations**

8.9 Space Calculations

- **Layout for each scheme/HP Group**
- **Normalization Calculations**

8.10 Install. Cost Estimate

- **Estimate sheets for each scheme/HP Group**
- **Normalization Calculations**

8.11 Comm./Start-up Estimates

- **Estimate sheet(s) for each scheme**
- **Normalization calculations**

8.12 Training Costs

- **Estimate sheet(s) for each scheme**
- **Normalization calculations**

8.13 Energy Use Analyses

- **Analysis for each scheme/HP Group**
- **Normalization calculations**