

**Statement of Work for Testing-Adjusting-Balancing (TAB) the Heating, Ventilation and Air  
Conditioning Systems for U.S. Embassy Dar es Salaam Compound  
December 2015**

**I. INTRODUCTION**

1. The Department of State's Bureau of Overseas Buildings Operations (OBO) requires on-site professional engineering services to accomplish **Testing-Adjusting-Balancing (TAB) of the Heating, Ventilation and Air Conditioning (HVAC) Systems** at the following U.S. Embassy or consulate compound:

**U.S. Embassy Dar es Salaam**

2. The TAB effort shall include the following buildings and facilities on the post compound:
  - a. Chancery
  - b. Marine Security Guard Residence
  - c. Warehouse and Warehouse Offices
  - d. USAID Building
  - e. All compound chillers and their supporting circulation equipment

**II. SCOPE**

1. The contractor shall perform testing, adjusting and balancing in accordance with ANSI/ASHRAE Standard 111-1988 – “Practices for Measurement, Testing, Adjusting, and Balancing of Building Ventilation, Air-Conditioning, and Refrigeration Systems.” See Appendix A for a compilation of definitions used in this statement of work (SOW)
2. Compound facility drawings and equipment schedules shall be furnished to the contractor via ProjNet. Some drawings and equipment schedules may be classified and the contractor shall be provided access to these separately. The previous TAB report shall also be provided via ProjNet.
3. The Contractor shall conduct TAB procedures as specified in Appendix B to this SOW to ensure HVAC design objectives for the facility are met. These shall include the following:
  - a. Balancing airflow and water flow at source equipment and/or within distribution systems, including sub-mains, branches, and terminals, to indicated quantities according to specified tolerances.
  - b. Adjusting total HVAC systems to provide indicated quantities.

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- c. Measuring electrical performance of HVAC equipment.
  - d. Verifying that automatic control devices are functioning properly.
  - e. Reporting results of the activities and procedures specified in Appendix B.
  - f. The contractor shall plug all holes that have been made in the ducts for taking test readings, in order to prevent air leakage. Disruption of duct, pipe, and/or equipment insulation shall also be appropriately repaired by the contractor.
4. PERFORMANCE COMMENCEMENT. Performance shall begin not later than 60 days after notice to proceed.

### III. DELIVERABLES

The contractor shall provide the following deliverables to the Government as specified:

1. Work and Testing Plan. The contractor shall provide a work and testing plan to the government for review and approval prior to the departure of the on-site testing team to the work site.
2. System Labelling. See discussion of system labelling requirements on page 3 of Appendix B to this SOW.
3. Testing, Adjusting, and Balancing Reports:
  - a. The contractor shall summarize the findings and results of the TAB in a narrative section at the front of the report. This shall be in the format compatible to **Microsoft Word 2007** or earlier. This section shall address the following issues:
    - i. Summary of the overall TAB effort, to include the TAB crew, the methods used, and the dates/duration of the effort.
    - ii. Overall results of the TAB effort.
    - iii. Equipment items that are not in compliance and could not be brought into adjustment.
    - iv. Recommendations for further modifications and for any repairs or replacements required to bring the systems into compliance with the design.
  - b. The contractor shall use standard forms from AABC's "National Standards for Testing, Adjusting, and Balancing" or NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems" each time a testing, adjusting, and balancing report is created.

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- c. **SPECIAL NOTE:** *All deliverables shall be classified, marked and handled in accordance with the Security Classification Guide for the Design and Construction of Overseas Facilities, dated 21 May 2003. Be advised that drawings provided by OBO or Post may or may not be classified IAW the most current classification guide. Any red-lining or annotations on existing drawings/documentation provided by Post or OBO shall be reviewed for re-classification in accordance with the Security Classification Guide (SCG) for the Design and Construction of Overseas Facilities, dated May 2003. Any documentation determined to be classified shall be returned to the COR via secure means by post, and in turn, will be provided to the contractor's cleared domestic office approved container. Any generation of new drawings by the contractor based on these archival/as-built records shall be appropriately classified, marked and handled IAW the SCG.*

**IV. QUALIFICATIONS AND SECURITY REQUIREMENTS.**

1. Qualifications and Equipment Requirements for the Contractor's Field Staff

a. Technical.

- i. The contractor shall engage a testing, adjusting, and balancing agent certified by either AABC or NEBB. Qualification Data and shall submit evidence, to the COR not later than 30 calendar days prior to the site work, that testing, adjusting, and balancing agent meets the qualifications specified in "Quality Assurance" Article.
- ii. The contractor shall be equipped with all necessary special tools, hardware, computer, and communications equipment to perform technical inspections on the specific equipment undergoing TAB.
- iii. Instrumentation Type, Quantity, and Accuracy: As described in AABC national standards if AABC report form is used or as described in NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems," Section II, "Required Instrumentation for NEBB Certification" if NEBB report form is used.
- iv. Instrumentation Calibration: The contractor shall use instruments that have been calibrated within the 6 months by a certified calibration facility, or shall have been calibrated within a shorter period of time if required by the instrument manufacturer.

- b. Security. The contractor shall comply with the requirements, below, to obtain clearance to travel to post from the Bureau of Diplomatic Security. Team members shall possess the following clearances:

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- i. One team member shall possess a **TOP SECRET** clearance and all other team members shall, as a minimum, possess a **SECRET** clearance.
  - ii. The DD Form 254 issued with the base IDIQ contract shall apply, or a separate DD Form 254 shall be obtained for those instances of individual contracts.
2. Requirements For Travel To Site And Work.
- a. Visit Authorization Request. The contractor shall submit a Visit Authorization Request (VAR) for the traveling engineers and technician to Bureau of Diplomatic Security point of contact at the following address: *DSINDOBOVARs@state.gov*
  - b. Country Clearance. The contractor shall submit to the COR at least 14 days in advance of travel, the technicians flight itinerary and security information for a Department of State Country Clearance, which will be submitted thru the COR, thru the Bureau of Diplomatic Security to the post for approval, before travel will be allowed. The following information must be provided to the COR:
    - full name, date and place of birth,
    - passport number, passport type, and expiration date,
    - name of employer, position/discipline,
    - clearance level,
    - If air travel, the flight numbers, departure cities, dates and times, arrival cities dates and times.
  - c. Passport Visa and Health Inoculations. The contractor shall be responsible for the traveler's passport, visa, inoculations, and travel arrangements.
  - d. The contractor and their sub-contractors shall comply with all requirements of the Federal Travel Regulations and Department of State regulations regarding travel.

V. COORDINATION

1. Service Interruptions. The engineers and technicians shall plan, coordinate, and schedule all site work with the post Facility Manager. Any and all service interruptions, such as shut off of air handling equipment, shall be subject to approval by the post Facility Manager.
2. The contractor shall review all Division 15 drawings and specifications of systems to be tested, adjusted and balanced in order to become familiar with installation prior to the day when testing, adjusting and balancing is performed.

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3. Site Restoration. The contractor shall ensure that all facilities receiving this work shall be left in a condition acceptable to the Facility Manager at post, upon completion of the work.
4. Disposal Of Materials Removed. The Facility Manager shall be responsible for the disposal of all trash created while performing this work. The contractor shall transport all materials to be disposed of from the point of removal to the designated disposal storage site, and shall ensure that all items removed through this work are disposed of properly.
5. Equipment. The contractor shall furnish all tools and equipment required to execute this work. The sole exception to this shall be ladders for accessing overhead spaces, which shall be provided by the facility engineer at the post.
6. Safety. Safety is the highest priority on this project. The contractor shall bring any safety concerns immediately to the attention of the Facility Manager.

**VI. TRAVEL AND PER DIEM.**

1. The contractor shall comply with Department of State rules and guidelines prior to incurring any costs. The contractor shall submit with their proposal(s) detailed costs for travel utilizing coach class rates. Travelers performing travel over 14 hours are allowed one paid rest stop including not greater than eight hours labor and one day of per diem per one direction (outbound, inbound). The rest day is to be scheduled as close as possible, within reason, to the mid-point of travel, or may be taken the day after arrival on site or on return to CONUS.
2. The contractor shall under no circumstances incur any travel or other costs, or begin the travel to the work site or work at the site until they receive the following: notice to proceed (NTP) from the Contracting Officer (CO), as well as site visit permission from Diplomatic Security, and "country clearance" from post. Once all needed material is on site visit dates will be coordinated between Embassy personnel, contract COR and the contractor.
3. Business Class Travel: Approval of business class travel shall be approved on a case-by-case basis in writing by the CO prior to travel, contingent on the following:
  - a. Contractor personnel are required to report for work the same or next business day after completing travel (both outbound and inbound);
  - b. The contractor shall submit with their proposal(s) detailed costs for travel utilizing Business Class rates for travel exceeding 14 hours, including connection time (wheels up at point of departure to wheels down at destination). The contractor shall also supply the cost of an economy ticket for the same itinerary for comparison purposes.

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4. Costs incurred in violation of established travel rules and guidelines of the Department of State shall not be paid. Required passport and visa are a responsibility of the contractor.

VII. POINT OF CONTACT Contracting Officer's Assistant Representative is -  
Facility Manager – John Rexford; rexfordjf@state.gov

**ENCLOSURES**

Appendix A – Definitions

Appendix B – TAB Procedures

Appendix C – TAB Report

Appendix D – summary of HVAC system that is to be TAB (contractor must verify the list with OBO ProjNet)

## Appendix A – Definitions

The following definitions are used throughout this SOW and the TAB procedures.

1. AABC: Associated Air Balance Council.
2. AMCA: Air Movement and Control Association.
3. NEBB: National Environmental Balancing Bureau.
4. ASHRAE. American Society of Heating, Refrigerating and Air Conditioning Engineers.
5. ANSI. American National Standards Institute
6. SMACNA: Sheet Metal and Air Conditioning Contractors' National Association.
7. CTI: Cooling Tower Institute.
8. Adjust: The final setting of balancing devices such as dampers and valves, adjusting fan speeds, in addition to automatic control devices such as thermostats and pressure controllers to achieve maximum specified system performance and efficiency during normal operation.
9. Building Automation System (BAS). The digital distributed control system that operates the HVAC equipment. There are generally two separate systems in new embassy compounds.
10. Balance: To proportion flows within the distribution system, including sub-mains, branches, and terminals, according to design quantities.
11. Draft: A current of air, when referring to localized effect caused by one or more factors of high air velocity, low ambient temperature, or direction of airflow, whereby more heat is withdrawn from a person's skin than is normally dissipated.
12. Dynamic (velocity) Pressure: In a moving fluid, the pressure that would induce an equivalent velocity if applied to move the same fluid through an orifice, so that all pressure energy is converted into kinetic energy. Velocity pressure is always a positive value. The difference between the total pressure and static pressure (relative to the same datum).
13. HVAC: Heating, Ventilation and Air Conditioning.
14. Procedure: An approach to and execution of a sequence of work operations to yield repeatable results.
15. Report Forms: Test data sheets for recording test data in logical order.
16. Sheave: A grooved wheel or pulley for belt-driven equipment.
17. Static Head: The pressure due to the weight of the fluid above the point of measurement. In a closed system, static head is equal on both sides of the pump.

## Appendix A – Definitions

18. Static Pressure: The measure of potential energy of a unit of air in a particular cross section of duct. Air pressure on a duct or plenum wall is considered static.
19. Suction Head: The height of fluid surface above the centerline of the pump on the suction side.
20. System Effect: A phenomenon that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.
21. System Effect Factors: Allowances used to calculate a reduction of the performance ratings of a fan when installed under conditions different from those presented when the fan was performance tested.
22. Testing, Adjusting and Balancing (TAB): The three major steps used to achieve proper operation of HVAC systems.
23. Terminal: A point where the controlled medium, such as fluid or energy, enters or leaves the distribution system.
24. Test: A procedure to determine quantitative performance of a system or equipment; the use of specialized and calibrated instruments to measure temperatures, pressures, rotational speeds, electrical characteristics, velocities and air and water quantities for an evaluation of equipment and system performance.
25. Testing, Adjusting, and Balancing Agent: The entity responsible for performing and reporting the testing, adjusting, and balancing procedures.
26. Total Pressure: The pressure the air exerts in the direction of flow (dynamic/velocity pressure) plus the pressure the air exerts perpendicular to the plenum or container through which the air moves (static pressure). In other words, total pressure is the sum of dynamic/velocity pressure plus static pressure.

## Appendix B – Testing, Adjusting, And Balancing Procedures

- I. EXAMINATION. The contractor shall conduct the following examinations in preparation for the TAB effort:
  - a. Examine as-built drawings and documents to become familiar with facility HVAC system features that may impact proper testing, adjusting, and balancing of systems and equipment.
  - b. Examine available project record documents to include earlier test-adjustment-balance reports
  - c. Examine equipment performance data, including fan and pump curves, in order to restore equipment operation to its intended state.
  - d. Examine systems for functional deficiencies that cannot be corrected by adjusting and balancing.
  - e. Examine air-handling equipment to ensure clean filters are functional, bearings are greased, belts are aligned and tight, drains are properly installed and equipment with functioning controls is ready for operation.
  - f. Examine terminal units, such as variable-air-volume boxes and mixing boxes, to verify their controls are connected and functioning. Identify any operational issues discovered during TAB.
  - g. Examine plenum ceilings, walls and enclosures utilized for return air, to verify that they are airtight. Verify that pipe penetrations and other holes are sealed.
  - h. Examine all hydronic strainers for clean screens and proper perforations. This task will be performed with support from post maintenance staff who will open strainer enclosures and then re-seal them.
  - i. Examine 3-way valves for proper installation for their intended function of diverting or mixing fluid flows.
  - j. Examine heat-transfer coils for correct piping connections and for clean and straight fins.
  - k. Examine open-piping-system pumps to ensure absence of entrained air in the suction piping.
  - l. Examine equipment for installation and for properly operating safety interlocks and controls.
  - m. Examine automatic temperature system components to verify the following:
    1. Dampers, valves, and other controlled devices operate by the intended controller.
    2. Dampers and valves are in the position indicated by the controller.

## Appendix B – Testing, Adjusting, And Balancing Procedures

3. Integrity of valves and dampers for free and full operation and for tightness of fully closed and fully open positions. This includes dampers in multizone units, mixing boxes, and variable-air-volume terminals.
  4. Automatic modulating and shutoff valves, including 2-way valves and 3-way mixing and diverting valves, are properly connected.
  5. Confirm the locations of thermostats, humidistats, occupancy sensors, CO2 sensors and pressure sensors, etc on floor plans or within air handling units and ductwork.
  6. Confirm that sensors are located to sense only the intended conditions, note any operational issues observed.
  7. Note controller set points for review against design values. Observe and record system reactions to changes in conditions. Record default set points if different from design values.
  8. Interlocked systems are operating.
- n. Report deficiencies discovered before and during performance of testing, adjusting, and balancing procedures.

### II. PREPARATION

- a. Prepare a testing, adjusting, and balancing plan that includes strategies and step-by-step procedures.
- b. Complete system readiness checks and prepare system readiness reports. Verify the following:
  1. Permanent electrical power wiring is complete.
  2. Hydronic systems are filled, clean, and free of air.
  3. Automatic temperature-control systems are operational.
  4. Equipment and duct access doors are securely closed.
  5. Balance, smoke, and fire dampers are open.
  6. Isolating and balancing valves are open and control valves are operational.
  7. Ceilings are installed in critical areas where air-pattern adjustments are required and access to balancing devices is provided.
  8. Windows and doors can be closed so design conditions for system operations can be met.

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### III. GENERAL TESTING AND BALANCING PROCEDURES

- a. Perform testing and balancing procedures on each system according to the procedures contained in AABC national standards or NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems" and this Section.
- b. Cut insulation, ducts, pipes, and equipment cabinets for installation of test probes to the minimum extent necessary to allow adequate performance of procedures. After testing and balancing, close probe holes and patch insulation with new materials identical to those removed. Restore vapor barrier and finish according to the insulation Specifications for this Project.
- c. Mark equipment settings with paint or other suitable, permanent identification material, including damper-control positions, valve indicators, fan-speed-control levers, and similar controls and devices, to show final settings.

### IV. INSTALL LABELS ON THE SYSTEM

- a. The contractor shall put a small sticker on the frame of the Supply Air Diffuser, in a readily accessible space located above the ceiling, indicating:
  - i. source of air
  - ii. designed quantity of air
  - iii. actual quantity of air.

For example: "AHU-1 Design: 200 CFM Actual: 180 CFM".

- b. Contractor shall mark air damper positions, -fully open/fully close, especially where the duct is wrapped around with insulation.

### V. FUNDAMENTAL AIR SYSTEMS' BALANCING PROCEDURES

- a. Prepare test reports for both fans and outlets. Obtain manufacturer's outlet factors and recommended testing procedures. Crosscheck the summation of required outlet volumes with required fan volumes. Manufacturers' data are available in the operations and maintenance library at the facility manager's office at the post. Contractors shall include time to research data in these libraries in their efforts.
- b. For variable-air-volume systems, develop a plan to simulate diversity.
- c. Determine the best locations in main and branch ducts for accurate duct airflow measurements.
- d. Check the airflow patterns from the outside-air louvers and dampers and the return- and exhaust-air dampers, through the supply-fan discharge and mixing dampers.

## Appendix B – Testing, Adjusting, And Balancing Procedures

- e. Locate start-stop and disconnect switches, electrical interlocks, and motor starters.
- f. Verify that motor starters are equipped with properly sized thermal protection.
- g. Check dampers for proper position to achieve desired airflow path.
- h. Check for airflow blockages.
- i. Check condensate drains for proper connections and functioning.
- j. Check for proper sealing of air-handling unit components.

### VI. CONSTANT-VOLUME AIR SYSTEMS' BALANCING PROCEDURES

- a. The procedures in this Article apply to constant-volume supply-, return-, and exhaust-air systems. Additional procedures are required for variable-air-volume supply-air systems. These additional procedures are specified in other articles in this Section.
- b. Adjust fans to deliver total design airflows within the maximum allowable rpm listed by the fan manufacturer.
  - 1. Measure fan static pressures to determine actual static pressure as follows:
    - a. Measure outlet static pressure as far downstream from the fan as practicable and upstream from restrictions in ducts such as elbows and transitions.
    - b. Measure static pressure directly at the fan outlet or through the flexible connection. NOTE: No holes are to be made in the flexible connections whatsoever.
    - c. Measure inlet static pressure of single-inlet fans in the inlet duct as near the fan as possible, upstream from flexible connection and downstream from duct restrictions.
    - d. Measure inlet static pressure of double-inlet fans through the wall of the plenum that houses the fan.
  - 2. Measure static pressure across each air-handling unit component.
  - 3. Measure static pressures entering and leaving other devices such as sound traps under final balanced conditions.
  - 4. Compare design data with installed conditions to determine variations in design static pressures versus actual static pressures. Compare actual system effect factors with calculated system effect factors to identify where variations occur. Recommend corrective action to align design and actual conditions.

## Appendix B – Testing, Adjusting, And Balancing Procedures

5. Adjust fan speed higher or lower than design with the approval of OBO. Make required adjustments to pulley sizes, and electrical connections to accommodate fan-speed changes.
  6. **NOTE:** Comment in the TAB report on any instances where the motor size appears inappropriate for the particular application.
  7. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure no overload will occur. Measure amperage in full cooling, full heating, and economizer modes to determine the maximum required brake horsepower.
- c. Adjust volume dampers for main duct, submain ducts, and major branch ducts to design airflows within specified tolerances.
1. Measure static pressure at a point downstream from the balancing damper and adjust volume dampers until the proper static pressure is achieved.
    - a. Where sufficient space in submains and branch ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets and calculate the total airflow for that zone.
  2. Remeasure each submain and branch duct after all have been adjusted. Continue to adjust submains and branch ducts to design airflows within specified tolerances.
- d. Measure terminal outlets and inlets without making adjustments.
1. Measure terminal outlets using a direct-reading hood or the outlet manufacturer's written instructions and calculating factors.
- e. Adjust terminal outlets and inlets for each space to design airflows within specified tolerances of design values. Make adjustments using volume dampers rather than extractors and the dampers at the air terminals.
1. Adjust each outlet in the same room or space to within specified tolerances of design quantities without generating noise levels above the limitations prescribed by the Contract Documents.
  2. Adjust patterns of adjustable outlets for proper distribution without drafts.

### VII. VARIABLE-AIR-VOLUME SYSTEMS' ADDITIONAL PROCEDURES

- a. **Compensating for Diversity:** When the total airflow of all terminal units is more than the fan design airflow volume, place a selected number of terminal units at a maximum set-point airflow condition until the total airflow of the terminal units equals the design airflow of the fan. Select the reduced airflow terminal units so they are distributed evenly among the branch ducts.

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- b. Pressure-Independent, Variable-Air-Volume Systems: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:
  1. Set outside-air dampers at minimum, and return- and exhaust-air dampers at a position that simulates full-cooling load.
  2. Select the terminal unit that is most critical to the supply-fan airflow and static pressure. Measure static pressure. Adjust system static pressure so the entering static pressure for the critical terminal unit is not less than the sum of the terminal unit manufacturer's recommended minimum inlet static pressure plus the static pressure needed to overcome terminal-unit discharge duct losses.
  3. Measure total system airflow. Adjust to within 10 percent of design airflow.
  4. Set terminal units at maximum airflow and adjust controller or regulator to deliver the designed maximum airflow. Use the terminal unit manufacturer's written instructions to make this adjustment. When total airflow is correct, balance the air outlets downstream from terminal units as described for constant-volume air systems.
  5. Set terminal units at minimum airflow and adjust controller or regulator to deliver the designed minimum airflow. Check air outlets for a proportional reduction in airflow as described for constant-volume air systems.

NOTE: If air outlets are out of balance at minimum airflow, report the condition but leave the outlets balanced for maximum airflow.

6. Re-measure the return airflow to the fan while operating at maximum return airflow and minimum outside airflow. Adjust the fan and balance the return-air ducts and inlets as described for constant-volume air systems.
7. Measure static pressure at the most critical terminal unit and adjust the static-pressure controller at the main supply-air sensing station to ensure adequate static pressure is maintained at the most critical unit.
8. Record the final fan performance data.

### VIII. FUNDAMENTAL PROCEDURES FOR HYDRONIC SYSTEMS

- a. Prepare test reports with pertinent design data and number in sequence starting at pump to end of system. Check the sum of branch-circuit flows against approved pump flow rate. Correct variations that exceed plus or minus 5 percent.
- b. Prepare hydronic systems for testing and balancing according to the following, in addition to the general preparation procedures specified above:
  1. Open all manual valves for maximum flow.

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2. Check expansion tank liquid level or bladder tank charge pressure; and adjust charge pressure as needed.
3. Check makeup-water-station pressure gage for adequate pressure for highest vent.
4. Check flow-control valves for specified sequence of operation and set at design flow.
5. Set differential-pressure control valves at the specified differential pressure. Do not set at fully closed position when pump is positive-displacement type, unless several terminal valves are kept open.
6. Set system controls so automatic valves are wide open to heat exchangers.
7. Check pump-motor load. If motor is overloaded, throttle main flow-balancing device so motor nameplate rating is not exceeded.
8. Check air vents for a forceful liquid flow exiting from vents when manually operated.

### IX. HYDRONIC SYSTEMS' BALANCING PROCEDURES

- a. Determine water flow at pumps. Use the following procedures, except for positive-displacement pumps:

Verify impeller size by operating the pump with the discharge valve closed. Verify with the pump manufacturer that this will not damage pump. Read pressure differential across the pump. Convert pressure to head and correct for differences in gage heights. Note the point on the manufacturer's pump curve at zero flow and confirm that the pump has the intended impeller size.

1. Check system resistance. With all valves open, read pressure differential across the pump and mark the pump manufacturer's head-capacity curve. Adjust pump discharge valve until design water flow is achieved.
  2. Verify pump-motor brake horsepower. Calculate the intended brake horsepower for the system based on the pump manufacturer's performance data. Compare calculated brake horsepower with nameplate data on the pump motor. Report conditions where actual amperage exceeds motor nameplate amperage.
  3. Report flow rates that are not within plus or minus 5 percent of design.
- b. Set calibrated balancing valves, if installed, at calculated presettings.
  - c. Measure flow at all stations and adjust, where necessary, to obtain first balance.
    1. System components that have Cv rating or an accurately cataloged flow-pressure-drop relationship may be used as a flow-indicating device.

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- d. Measure flow at main balancing station and set main balancing device to achieve flow that is 5 percent greater than design flow.
- e. Adjust balancing stations to within specified tolerances of design flow rate as follows:
  - 1. Determine the balancing station with the highest percentage over design flow.
  - 2. Adjust each station in turn, beginning with the station with the highest percentage over design flow and proceeding to the station with the lowest percentage over design flow.
  - 3. Record settings and mark balancing devices.
- f. Measure pump flow rate and make final measurements of pump amperage, voltage, rpm, pump heads, and systems' pressures and temperatures, including outdoor-air temperature.
- g. Measure the differential-pressure control valve settings existing at the conclusions of balancing.

### X. VARIABLE-FLOW HYDRONIC SYSTEMS' ADDITIONAL PROCEDURES

- h. Balance systems with automatic 2- and 3-way control valves by setting systems at maximum flow through heat-exchange terminals and proceed as specified above for hydronic systems.

### XI. PRIMARY-SECONDARY-FLOW HYDRONIC SYSTEMS' ADDITIONAL PROCEDURES

- i. Balance the primary system crossover flow first, then balance the secondary system.

### XII. HEAT EXCHANGERS

- a. Measure water flow through all circuits.
- b. Adjust water flow to within specified tolerances.
- c. Measure inlet and outlet water temperatures.
- d. Record safety valve settings.
- e. Verify operation of air release mechanisms.
- f. Verify operation of steam traps.

### XIII. MOTORS

## Appendix B – Testing, Adjusting, And Balancing Procedures

- a. Motors, 1/2 HP and Larger: Test at final balanced conditions and record the following data:
  1. Manufacturer, model, and serial numbers.
  2. Motor horsepower rating.
  3. Motor rpm.
  4. Efficiency rating if high-efficiency motor.
  5. Nameplate and measured voltage, each phase.
  6. Nameplate and measured amperage, each phase.
  7. Starter thermal-protection-element rating.
- b. Motors Driven by Variable-Frequency Controllers (VFC):
  1. Test for proper operation at speeds varying from minimum to maximum.
  2. Test the manual bypass for the controller to prove proper operation.
  3. Record observations, including controller manufacturer, model and serial numbers, and nameplate data.
  4. Verify and document that proper parameters are set up within the VFC.

### XIV. CHILLERS

Balance water flow through each evaporator and condenser to within specified tolerances of design flow with all pumps operating. With only one chiller operating in a multiple chiller installation, do not exceed the flow for the maximum tube velocity recommended by the chiller manufacturer. Measure and record the following data with each chiller operating at design conditions:

5. Evaporator water entering and leaving temperatures, pressure drop, and water flow.
6. Condenser water entering and leaving temperatures, pressure drop, and water flow.
7. Evaporator and condenser refrigerant temperatures and pressures, using instruments furnished by the chiller manufacturer.
8. Power factor if factory-installed instrumentation is furnished for measuring kW.
9. The kW input if factory-installed instrumentation is furnished for measuring kW.
10. Capacity: Calculate in tons of cooling.

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11. Air-Cooled Chillers: Verify condenser-fan rotation and record fan data, including number of fans and entering- and leaving-air temperatures.

### XV. COOLING TOWERS (where applicable).

Shut off makeup water for the duration of the test, and then make sure the makeup and blow-down systems are fully operational after tests and before leaving the equipment. Perform the following tests and record the results:

12. Measure condenser water flow to each cell of the cooling tower.
13. Measure entering- and leaving-water temperatures.
14. Measure wet- and dry-bulb temperatures of entering air.
15. Measure wet- and dry-bulb temperatures of leaving air.
16. Measure condenser water flow rate recirculating through the cooling tower.
17. Measure cooling tower pump discharge pressure.
18. Adjust water level and feed rate of makeup-water system.

### XVI. CONDENSING UNITS

Verify proper rotation of fans and measure entering- and leaving-air temperatures. Record compressor data.

### XVII. BOILERS (Where applicable)

Measure entering- and leaving-water temperatures and water flow.

### XVIII. HEAT-TRANSFER COILS

Water Coils: Measure the following data for each coil:

1. Entering- and leaving-water temperatures.
2. Water flow rate.
3. Water pressure drop.
4. Dry-bulb temperatures of entering and leaving air.
5. Wet-bulb temperatures of entering and leaving air for cooling coils.
6. Airflow.

## Appendix B – Testing, Adjusting, And Balancing Procedures

7. Air pressure drop.
8. Calculate and document resulting air and water side heat balance.

### XIX. TEMPERATURE TESTING

During testing, adjusting, and balancing, report need for adjustment in temperature regulation within the automatic temperature-control system.

### XX. TEMPERATURE-CONTROL VERIFICATION

- a. Verify that controllers are calibrated and commissioned.
- b. Check transmitter and controller locations and note conditions that would adversely affect control functions.
- c. Record controller settings and note variances between set points and actual measurements.
- d. Verify operation of limiting controllers (i.e., high- and low-temperature controllers).
- e. Verify free travel and proper operation of control devices such as damper and valve operators.
- f. Note operation of electric actuators using spring return for proper fail-safe operations.

### XXI. AIR LEAKAGE TEST TOLERANCE VERIFICATION

Set HVAC system airflow and water flow rates within the following tolerances:

1. Supply, Return, and Exhaust Fans: Plus 5 to plus 10 percent.
2. Air Outlets and Inlets: 0 to minus 10 percent.
3. Heating-Water Flow Rate: 0 to minus 10 percent.
4. Cooling-Water Flow Rate: 0 to minus 5 percent.

## Appendix C – Testing, Adjusting, And Balancing (TAB) Report

### TAB REPORT

- a. Final test reports shall be provided to the Contracting Officer for forwarding to the Systems Engineer/Condition Monitoring Office/Predictive Testing Group for inclusion in the Maintenance Database.
- b. General: Typewritten, or computer printout in letter-quality font, on standard bond paper, in 3-ring binder, tabulated and divided into sections by tested and balanced systems.
- c. Include a certification sheet in front of binder signed and sealed by the certified testing and balancing engineer.
- d. Include a list of the instruments used for procedures, along with proof of calibration.
- e. General Report Data: In addition to the form titles and entries, include the following data in the final report, as applicable:
  1. Title page.
  2. Name and address of testing, adjusting, and balancing Agent.
  3. Project name.
  4. Project location.
  5. Report date.
  6. Signature of testing, adjusting, and balancing Agent who certifies the report.
  7. Summary of contents, including the following:
    - a. Design versus final performance.
    - b. Notable characteristics of systems.
    - c. Description of system operation sequence if it varies from the Contract Documents.
  8. Narrative section that addresses the following topics:
    - a. Summary of the overall TAB effort, to include the TAB crew, the methods used, and the dates/duration of the effort.
    - b. Overall results of the TAB effort.
    - c. Equipment items found to be in compliance with the design.

## Appendix C– Testing, Adjusting, And Balancing (TAB) Report

- d. Equipment items that are not in compliance and could not be brought into adjustment.
  - e. Recommendations for further modifications and for any repairs or replacements required to bring the systems into compliance with the design.
9. Nomenclature sheets for each item of equipment.
  10. Data for terminal units, including manufacturer, type size, and fittings.
  11. Notes to explain why certain final data in the body of reports vary from design values.
  12. Test conditions for fans and pump performance forms, including the following:
    - a. Settings for outside-, return-, and exhaust-air dampers.
    - b. Conditions of filters.
    - c. Cooling coil, wet- and dry-bulb conditions.
    - d. Face and bypass damper settings at coils.
    - e. Fan drive settings, including settings and percentage of maximum pitch diameter.
    - f. Inlet vane settings for variable-air-volume systems.
    - g. Settings for supply-air, static-pressure controller.
    - h. Other system operating conditions that affect performance, to include verification of glycol type used in chilled water system and its percentage within the system. Provide a correction factor chart for use as part of the performance data.
- f. The contractor shall annotate system drawings and diagrams any quantities and measurements missing from the drawings, to include the following:
    1. Quantities of outside, supply, return, and exhaust airflows.
    2. Water and steam flow rates.
    3. Duct, outlet, and inlet sizes.
    4. Pipe and valve sizes and locations.
    5. Terminal units.
    6. Balancing stations.

## Appendix C– Testing, Adjusting, And Balancing (TAB) Report

7. Pressure zones, differential pressure sensing devices and control set points, and quantitative measured differential pressure between zones, and outdoors, as applicable.
- g. Air-Handling Unit Test Reports: For air-handling units with coils, include the following:
  1. Unit Data: Include the following:
    - a. Unit identification.
    - b. Location.
    - c. Make and type.
    - d. Model number and unit size.
    - e. Manufacturer's serial number.
    - f. Unit arrangement and class.
    - g. Discharge arrangement.
    - h. Sheave make, size in mm, and bore.
    - i. Sheave dimensions, center-to-center and amount of adjustments in mm.
    - j. Number of belts, make, and size.
    - k. Number of filters, type, and size.
  2. Motor Data: Include the following:
    - a. Make and frame type and size.
    - b. Horsepower and rpm.
    - c. Volts, phase, and hertz.
    - d. Full-load amperage and service factor.
    - e. Sheave make, size in mm, and bore.
    - f. Sheave dimensions, center-to-center and amount of adjustments in mm.
  3. Test Data: Include design and actual values for the following:
    - a. Total airflow rate in L/s.

## Appendix C– Testing, Adjusting, And Balancing (TAB) Report

- b. Total system static pressure in Pa.
  - c. Fan rpm.
  - d. Discharge static pressure in Pa.
  - e. Filter static-pressure differential in Pa.
  - f. Preheat coil static-pressure differential in Pa.
  - g. Cooling coil static-pressure differential in Pa.
  - h. Heating coil static-pressure differential in Pa.
  - i. Outside airflow in L/s.
  - j. Return airflow in L/s.
  - k. Outside-air damper position.
  - l. Return-air damper position.
  - m. Vortex damper position and/or variable frequency drive setting.
- h. Apparatus-Coil Test Reports: For apparatus coils, include the following:
- 1. Coil Data: Include the following:
    - a. System identification.
    - b. Location.
    - c. Coil type.
    - d. Number of rows.
    - e. Fin spacing in mm o.c..
    - f. Make and model number.
    - g. Face area in sq. m.
  - 2. Test Data: Include design and actual values for the following:
    - a. Airflow rate in L/s.
    - b. Average face velocity in m/s.
    - c. Air pressure drop in Pa.

## Appendix C– Testing, Adjusting, And Balancing (TAB) Report

- d. Outside-air, wet- and dry-bulb temperatures in deg C.
  - e. Return-air, wet- and dry-bulb temperatures in deg C.
  - f. Entering-air, wet- and dry-bulb temperatures in deg C.
  - g. Leaving-air, wet- and dry-bulb temperatures in deg C.
  - h. Water flow rate in L/s.
  - i. Water pressure differential in kPa.
  - j. Entering-water temperature in deg C.
  - k. Leaving-water temperature in deg C.
  - l. Refrigerant expansion valve and refrigerant types.
  - m. Refrigerant suction pressure in kPa.
  - n. Refrigerant suction temperature in deg C.
- i. Fan Test Reports: For supply, return, and exhaust fans, include the following:
- 1. Fan Data: Include the following:
    - a. System identification.
    - b. Location.
    - c. Make and type.
    - d. Model number and size.
    - e. Manufacturer's serial number.
    - f. Arrangement and class.
    - g. Sheave make, size in mm, and bore.
    - h. Sheave dimensions, center-to-center and amount of adjustments in mm.
  - 2. Motor Data: Include the following:
    - a. Make and frame type and size.
    - b. Horsepower and rpm.
    - c. Volts, phase, and hertz.

## Appendix C– Testing, Adjusting, And Balancing (TAB) Report

- d. Full-load amperage and service factor.
  - e. Sheave make, size in mm, and bore.
  - f. Sheave dimensions, center-to-center and amount of adjustments in mm.
  - g. Number of belts, make, and size.
3. Test Data: Include design and actual values for the following:
- a. Total airflow rate in L/s.
  - b. Total system static pressure in Pa.
  - c. Fan rpm.
  - d. Discharge static pressure in Pa.
  - e. Suction static pressure in Pa.
- j. Round and Rectangular Duct Traverse Reports: Include a diagram with a grid representing the duct cross-section and record the report data indicated immediately below.

Report Data: Include the following:

- a. System and air-handling unit number.
  - b. Location and zone.
  - c. Traverse air temperature in deg C.
  - d. Duct static pressure in Pa.
  - e. Duct size in mm.
  - f. Duct area in sq. m.
  - g. Design airflow rate in L/s.
  - h. Design velocity in m/s.
  - i. Actual airflow rate in L/s.
  - j. Actual average velocity in m/s.
- k. Air-Terminal-Device Reports: For terminal units, include the following:
- 1. Unit Data: Include the following:

## Appendix C– Testing, Adjusting, And Balancing (TAB) Report

- a. System and air-handling unit identification.
  - b. Location and zone.
  - c. Test apparatus used.
  - d. Area served.
  - e. Air-terminal-device make.
  - f. Air-terminal-device number from system diagram.
  - g. Air-terminal-device type and model number.
  - h. Air-terminal-device size.
  - i. Air-terminal-device effective area in sq. m.
2. Test Data: Include design and actual values for the following:
    - a. Airflow rate in L/s.
    - b. Air velocity in m/s.
    - c. Preliminary airflow rate as needed in L/s.
    - d. Preliminary velocity as needed in m/s.
    - e. Final airflow rate in L/s.
    - f. Final velocity in m/s.
    - g. Space temperature in deg C.
1. System-Coil Reports: For reheat coils and water coils of terminal units, include the following:
    1. Unit Data: Include the following:
      - a. System and air-handling unit identification.
      - b. Location and zone.
      - c. Room or riser served.
      - d. Coil make and size.
      - e. Flowmeter type.

## Appendix C– Testing, Adjusting, And Balancing (TAB) Report

2. Test Data: Include design and actual values for the following:
  - a. Airflow rate in L/s.
  - b. Entering-water temperature in deg C.
  - c. Leaving-water temperature in deg C.
  - d. Water pressure drop in kPa.
  - e. Entering-air temperature in deg C.
  - f. Leaving-air temperature in deg C.
- m. Packaged Chiller Reports: For each chiller, include the following:
  1. Unit Data: Include the following:
    - a. Unit identification.
    - b. Make and model number.
    - c. Manufacturer's serial number.
    - d. Refrigerant type and capacity in L.
    - e. Starter type and size.
    - f. Starter thermal protection size.
  2. Condenser Test Data: Include design and actual values for the following:
    - a. Refrigerant pressure in kPa.
    - b. Refrigerant temperature in deg C.
    - c. Entering-water temperature in deg C.
    - d. Leaving-water temperature in deg C.
    - e. Entering-water pressure in kPa.
    - f. Water pressure differential in kPa.
  3. Evaporator Test Reports: Include design and actual values for the following:
    - a. Refrigerant pressure in kPa.
    - b. Refrigerant temperature in deg C.

## Appendix C– Testing, Adjusting, And Balancing (TAB) Report

- c. Entering-water temperature in deg C.
  - d. Leaving-water temperature in deg C.
  - e. Entering-water pressure in kPa.
  - f. Water pressure differential in kPa.
4. Compressor Test Data: Include design and actual values for the following:
- a. Make and model number.
  - b. Manufacturer's serial number.
  - c. Suction pressure in kPa.
  - d. Suction temperature in deg C.
  - e. Discharge pressure in kPa.
  - f. Discharge temperature in deg C.
  - g. Oil pressure in kPa.
  - h. Oil temperature in deg C.
  - i. Voltage at each connection.
  - j. Amperage for each phase.
  - k. The kW input.
  - l. Crankcase heater kW.
  - m. Chilled water control set point in deg C.
  - n. Condenser water control set point in deg C.
  - o. Refrigerant low-pressure-cutoff set point in kPa.
  - p. Refrigerant high-pressure-cutoff set point in kPa.
5. Refrigerant Test Data: Include design and actual values for the following:
- a. Oil level.
  - b. Refrigerant level.
  - c. Relief valve setting in kPa.

## Appendix C– Testing, Adjusting, And Balancing (TAB) Report

- d. Unloader set points in kPa.
  - e. Percentage of cylinders unloaded.
  - f. Bearing temperatures in deg C.
  - g. Vane position.
  - h. Low-temperature-cutoff set point in deg C.
- n. Compressor and Condenser Reports: For refrigerant side of unitary systems, stand-alone refrigerant compressors, air-cooled condensing units, or water-cooled condensing units, include the following:
- 1. Unit Data: Include the following:
    - a. Unit identification.
    - b. Location.
    - c. Unit make and model number.
    - d. Manufacturer's compressor serial numbers.
    - e. Compressor make.
    - f. Compressor model and serial numbers.
    - g. Refrigerant weight in kg.
    - h. Low ambient temperature cutoff in deg C.
  - 2. Test Data: Include design and actual values for the following:
    - a. Inlet-duct static pressure in Pa.
    - b. Outlet-duct static pressure in Pa.
    - c. Entering-air, dry-bulb temperature in deg C.
    - d. Leaving-air, dry-bulb temperature in deg C.
    - e. Condenser entering-water temperature in deg C.
    - f. Condenser leaving-water temperature in deg C.
    - g. Condenser water temperature differential in deg C.
    - h. Condenser entering-water pressure in kPa.

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- i. Condenser leaving-water pressure in kPa.
  - j. Condenser water pressure differential in kPa.
  - k. Control settings.
  - l. Unloader set points.
  - m. Low-pressure-cutout set point in kPa.
  - n. High-pressure-cutout set point in kPa.
  - o. Suction pressure in kPa.
  - p. Suction temperature in deg C.
  - q. Condenser refrigerant pressure in kPa.
  - r. Condenser refrigerant temperature in deg C.
  - s. Oil pressure in kPa.
  - t. Oil temperature in deg C.
  - u. Voltage at each connection.
  - v. Amperage for each phase.
  - w. The kW input.
  - x. Crankcase heater kW.
  - y. Number of fans.
  - z. Condenser fan rpm.
  - aa. Condenser fan airflow rate in L/s.
  - bb. Condenser fan motor make, frame size, rpm, and horsepower.
  - cc. Condenser fan motor voltage at each connection.
  - dd. Condenser fan motor amperage for each phase.
- o. Cooling Tower or Condenser Test Reports: For cooling towers or condensers, when present, include the following:
- 1. Unit Data: Include the following:

## **Appendix C– Testing, Adjusting, And Balancing (TAB) Report**

- a. Unit identification.
  - b. Make and type.
  - c. Model and serial numbers.
  - d. Nominal cooling capacity in kW.
  - e. Refrigerant type and weight in kg.
  - f. Water-treatment chemical feeder and chemical.
  - g. Number and type of fans.
  - h. Fan motor make, frame size, rpm, and horsepower.
  - i. Fan motor voltage at each connection.
  - j. Sheave make, size in mm, and bore.
  - k. Sheave dimensions, center-to-center and amount of adjustments in mm.
  - l. Number of belts, make, and size.
2. Pump Test Data: Include design and actual values for the following:
- a. Make and model number.
  - b. Manufacturer's serial number.
  - c. Motor make and frame size.
  - d. Motor horsepower and rpm.
  - e. Voltage at each connection.
  - f. Amperage for each phase.
  - g. Water flow rate in L/s.
3. Water Test Data: Include design and actual values for the following:
- a. Entering-water temperature in deg C.
  - b. Leaving-water temperature in deg C.
  - c. Water temperature differential in deg C.
  - d. Entering-water pressure in kPa.

## Appendix C– Testing, Adjusting, And Balancing (TAB) Report

- e. Leaving-water pressure in kPa.
  - f. Water pressure differential in kPa.
  - g. Water flow rate in L/s.
  - h. Bleed water flow rate in L/s.
4. Air Data: Include design and actual values for the following:
- a. Duct airflow rate in L/s.
  - b. Inlet-duct static pressure in Pa.
  - c. Outlet-duct static pressure in Pa.
  - d. Average entering-air, wet-bulb temperature in deg C.
  - e. Average leaving-air, wet-bulb temperature in deg C.
  - f. Ambient wet-bulb temperature in deg C.
- p. Heat-Exchanger Test Reports: For hot-water heat exchangers, include the following:
- 1. Unit Data: Include the following:
    - a. Unit identification.
    - b. Location.
    - c. Service.
    - d. Make and type.
    - e. Model and serial numbers.
    - f. Ratings.
  - 2. Primary Water Test Data: Include design and actual values for the following:
    - a. Entering-water temperature in deg C.
    - b. Leaving-water temperature in deg C.
    - c. Entering-water pressure in kPa.
    - d. Water pressure differential in kPa.
    - e. Water flow rate in L/s.

## Appendix C– Testing, Adjusting, And Balancing (TAB) Report

3. Secondary Water Test Data: Include design and actual values for the following:
  - a. Entering-water temperature in deg C.
  - b. Leaving-water temperature in deg C.
  - c. Entering-water pressure in kPa.
  - d. Water pressure differential in kPa.
  - e. Water flow rate in L/s.
  
- q. Pump Test Reports: For pumps, include the following data. Calculate impeller size by plotting the shutoff head on pump curves.
  1. Unit Data: Include the following:
    - a. Unit identification.
    - b. Location.
    - c. Service.
    - d. Make and size.
    - e. Model and serial numbers.
    - f. Water flow rate in L/s.
    - g. Water pressure differential in kPa.
    - h. Required net positive suction head in kPa.
    - i. Pump rpm.
    - j. Impeller diameter in mm.
    - k. Motor make and frame size.
    - l. Motor horsepower and rpm.
    - m. Voltage at each connection.
    - n. Amperage for each phase.
    - o. Full-load amperage and service factor.
    - p. Seal type.

## Appendix C– Testing, Adjusting, And Balancing (TAB) Report

2. Test Data: Include design and actual values for the following:
  - a. Static head in kPa.
  - b. Pump shutoff pressure in kPa.
  - c. Actual impeller size in mm.
  - d. Full-open flow rate in L/s.
  - e. Full-open pressure in kPa.
  - f. Final discharge pressure in kPa.
  - g. Final suction pressure in kPa.
  - h. Final total pressure in kPa.
  - i. Final water flow rate in L/s.
  - j. Voltage at each connection.
  - k. Amperage for each phase.
- r. Instrument Calibration Reports: For instrument calibration, include the following:
  1. Report Data: Include the following:
    - a. Instrument type and make.
    - b. Serial number.
    - c. Application.
    - d. Dates of use.
    - e. Dates of calibration.

## Appendix D – summary of HVAC system that is to be TAB

### BAS Systems:

#### BAS#1

- a. Manufacturer of the BAS: KMC Control System (KMC) –Chancellery & USAID
- b. BAS System Product Line Name: WinControl XL+
- c. BAS Software Version: 2.1.0.19
- d. BAS Communication Network Type: Proprietary
- e. Quantity and Type of Controllers Installed: Lan Controller one each at Chancellery and USAID.

#### BAS#2

- a. Manufacturer of the BAS: Johnson Controls –Marine house & Warehouse
- b. BAS System Product Line Name: METASYS
- c. BAS Software Version: M3 workstation.
- d. BAS Communication Network Type: Proprietary
- e. Quantity and Type of Controllers Installed: 2no. N30 Supervisory Controllers; 2no. DX 8154 & DX 8454 Sub Controllers

### HVAC System:

- a. Air Handling Units – Quantity 5(Chancellery); 6(USAID); 1 (Marine Hs.); 1 (Warehouse)
- b. Terminal Units - VAVs – Quantity 97(Chancellery); 83(USAID); 30 (warehouse & marine hs.)
- c. Chilled Water System: –  
Chancellery Quantities:
  - 3 Air Cooled Chillers (2 YORK YCAS and 1 YCAL),
  - 3 Primary Chilled Water Pumps.
  - 11 exhaust fans

#### USAID Building Quantities:

- 3 Air Cooled Chillers (YORK YCAL),
- 3 Primary Chilled Water Pumps.
- 1 exhaust fans

## Appendix D – summary of HVAC system that is to be TAB

### Warehouse Quantities:

- 1 Package Air Cooled Chiller (TRANE),
- 15 exhaust fans

### Marine House Quantities:

- 1 Package Air Cooled Chiller (TRANE),
- 4 exhaust fans

- d. Fan Coil Units – Quantity 10 (Chancellery); 5 (USAID)
- e. Computer Room Air Conditioning Units (Cooling Only) – Quantity 1 (Chancellery)

