POWERING HEALTH – ZAMBIA UPDATE – SEPTEMBER 2010

IMPROVING HEALTH FACILITY INFRASTRUCTURE

TASK ORDER EPP-I-01-03-00008-00, ORDER NO. 7

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1. OVERVIEW

CDC and AHPL interest in the energy assessment of key laboratories in Zambia was driven by the effort to reach laboratory accreditation in 5 facilities. One of the requirements for accreditation is the assurance of backup power to maintain laboratory operation and to ensure that no samples or tests are lost.

We visited each of the five laboratories in the accreditation process, looking at the inventory of laboratory instruments and equipment, identification of “contact” and “no-contact” loads, inspection of the laboratory and its surroundings, including standby generator, and interviews with laboratory management staff.

Our findings are summarized as follows:

- Power outages do not constitute an immediate problem, since hospitals appear to be on special circuits that are immune to load shedding. However there is general uncertainty in the country regarding power supply, with recent 30-40% rate increases and future projected increases, making laboratory staff very concerned about proper backup power systems, and wanting to ensure the most conservative system available.
- Electrical connections appear to be in reasonable condition, but no separate identification of circuits is available at the panels.
- Many computers and sensitive instruments have individual UPS systems installed; however, all are simply backup power systems (not clean power, or no-contact power), and essentially all are beyond their performance age, and none have been maintained.
- Emergency generators are available for essentially all of the laboratories, except for the large teaching hospital (UTH) in Lusaka, although the generators are hospital-wide and not dedicated to the laboratories.

We recommend the installation of high quality “double conversion” UPS units on all “no-contact” loads, and voltage regulators on “contact” loads, in both cases counting on the emergency generator to be turned on within a few minutes of a grid power failure. Instruction manuals and training programs must be developed to ensure the sustainability and reliability of this effort, especially since the double-conversion UPS units are relatively new to Zambia. In the case of UTH, generator repair and additional generator procurement is needed.

While there was some interest in the Ministry of Health for providing energy through solar PV in remote clinics, the current priority is clearly the upgrading of backup power for labs in the accreditation process. With many larger, and higher priority programs, USAID/Lusaka does not have funding and oversight capability to participate in a rural health energy program at this time.

2. SUMMARY DESCRIPTION OF THE TRIP

2.1 TRIP OBJECTIVES

Mark Oven of Tetra Tech undertook this trip under the Improving Health Facility Infrastructure (IHFI) project, with two primary objectives:

1) Follow up with USAID, CDC and the Ministry of Health on the next steps in health facility energy support, based on a previous mission to Zambia that resulted in the July 2009 USAID report "Options for Improving Energy Services at Health Facilities in Zambia."

2) Address current needs and priorities of the Zambian Ministry of Health and the CDC regarding energy-related issues in Zambian health facilities. Specifically, evaluate requirements for backup power availability as part of the Ministry of Health efforts to obtain certification of the laboratories at five key hospitals in the country.

In the previous year, the CDC had allocated a budget to the Association of Applied Health Laboratories (APHL) on the order of US$ 0.5 million for health facility energy improvements. Both CDC and APHL were interested in the technical observations of this trip in order to prioritize expenditures under this budget.

This was a short trip, with arrival on August 28 and departure midday on September 2, 2010, allowing 3.5 working days in the country, taking advantage of a prior stop in Mozambique. It was meant to provide some guidance to CDC and Ministry of Health on energy infrastructure issues, and lay out some next steps for energy improvements in health facilities.

2.2 TRIP ACTIVITIES

During the trip, Tetra Tech met with representatives of the CDC and the Ministry of Health, and made visits to five hospitals to obtain a general understanding of the energy situation at each facility. The technical visits and observations are described in more detail in Section 3. A list of people met is provided in Appendix A.

In a brief telephone meeting, Randy Kolstad of USAID/Lusaka explained that USAID did not plan to contribute to activities in the health energy sector at this time, primarily due to lack of ability to provide sufficient management oversight. The USAID Mission capacity is already stretched with several large infrastructure and development projects under way in other sectors. That said, USAID recognized the needs of the health sector in Zambia, and would like to be apprised of activities and progress in this area.

Final debriefing meetings were held at the CDC offices and at the offices of the Ministry of Health on September 2.

3. EVALUATION OF HOSPITAL LABORATORIES

The objectives of the evaluation visits to the five hospital laboratories were to assess their current energy situation and review their backup power capability, that is, their ability to continue uninterrupted operation in the event of a power failure. This confirmation of this capability is a prerequisite to certification of these laboratories, which is a priority of the Zambian Ministry of Health, supported by CDC and APHL.

Tetra Tech set out to determine the required backup power system requirements and equipment (inverters, batteries, regulators, uninterruptible power systems, emergency generators, and/or auxiliary equipment) for each laboratory. The objective was to provide initial estimates of installed costs, and to lay out the issues that the Ministry of Health should consider in the effort to provide adequate and appropriate backup power to these laboratories.

3.1 FACILITIES VISITED

The scope of the project was limited to laboratory installations at the following sites.

University Teaching Hospital – located in Lusaka, this is the largest hospital in the country, with more than 1600 beds; and comprising 11 different laboratories; also the main teaching institution for the country's doctors and nurses

Maina Soko Military Hospital – small 60-bed facility in Lusaka serving members of the Zambian armed forces.

Kitwe Central Hospital: – medium-sized hospital with more than 600 beds located in the copperbelt city of Kitwe; another of the three teaching hospitals in Zambia.

Ndola Central Hospital – medium-sized hospital with approximately 800 beds located in the center of Ndola in the copperbelt region.

Arthur Davison Children's Hospital – a medium-sized hospital for children located in Ndola; this is the largest pediatric hospital in the country.

3.2 TYPES OF ELECTRICAL LOADS

The concern of health laboratories is to ensure that "critical loads" can be stably maintained in the face of unreliable or poor quality electric power. Critical loads are those loads that are crucial to the operation of a facility and must continue to be available when grid or generator power (primary power) goes out. These loads need to be connected to some type of backup power system to ensure extended operation without primary power. For health facilities, these typically include: lighting, laboratory instruments, emergency room, operating room, night lighting, vaccine, sample and reagent refrigerators and freezers, and computer and information systems equipment. Air conditioners, heaters and other heavier loads, such as autoclaves, are not usually considered to be critical.

Critical loads are further subdivided into two types: contact loads and no-contact loads:

"Contact loads" are those critical loads for which the quality of electrical energy and the transfer time from the primary source of energy to the back-up source are not critical factors. Quality of electricity implies minimum voltage fluctuation with pure sine wave variation. Transfer times for these loads can take more than a second without affecting the performance of the loads. These loads can be connected to a back-up battery/inverter system that is automatically connected when the primary power goes out.

"No-contact loads" are those critical loads for which electrical quality is paramount, and which require uninterrupted transfer between the primary and back-up sources of energy. These loads must be permanently connected to a battery/inverter system which provides continuous high quality power (constant voltage and perfect sine wave), even when the primary power is cut.

Table 1 provides a summary comparison of critical loads in health facility laboratories.

Table 1. Characterization of Critical Loads

CHARACTERISTICS	CONTACT LOADS	NO-CONTACT LOADS
High power quality	Preferable	Required
Transfer time to emergency or backup power	Immediate (within minutes) (can withstand a manual transfer switch)	Need instantaneous switching, best with a UPS that can cover the time for manual transfer
Autonomy, hours (time during which backup power is available)	Variable, dependent on local conditions	Variable, dependent on local conditions
System reliability	99 %	>99 %
Monitoring	Recommended but not necessary	Required
Example loads	Lighting; miscellaneous laboratory equipment; some refrigeration	Key laboratory analysis instruments; computers

3.3 TECHNICAL APPROACH

Tetra Tech applied the following approach consistently to all of the facilities visited.

- Interview with the laboratory director, or person in charge to: explain objectives and activities; obtain permission for data retrieval; and request explanations of any problems or issues with electricity, including surges, power failures, or other effects on the instruments and laboratory operation.

- Inventory of major equipment in the laboratory. Each load is identified, along with its full-load nameplate amperage or wattage. In addition, the loads are identified as "contact" or "no-contact" according to their sensitivity.

- Instantaneous current measurement at the electrical panel of the laboratory, where possible, and where local technician was available

- Inspection of the surrounding hospital area, including location and state of the emergency generator.

The Ministry of Health representative, Fales Mwamba, accompanied all of the visits and facilitated access to each of the laboratories and their management.

3.4 OVERALL FINDINGS

The following points summarize the observations and results of the visits to the laboratories.

- In all cases, electrical power is stable and available consistently on a 24-hour basis. In all cases, there were no complaints of power cuts, failures or instabilities. It appears that the hospitals in Lusaka are on a priority feeder that is not subject to power cuts even while certain areas of the city suffer load shedding.

- On a qualitative basis, laboratory operators identified power failures to happen on the order of once per month, but no one could remember even any short failures since a nationwide blackout in June 2010.

- Electrical power also appears to be of reasonable quality. While actual measurements were not taken, there was no evidence of voltage variation or frequency problems, and none of the laboratories had any complaints about equipment damage or failure due to the quality of the electricity supply.

- Nevertheless, the laboratory staff appeared to be consistently worried about ensuring backup power. This likely arises from a history of power cuts in Zambia (a situation that has improved over the last 10 years due to reduced output of the copper mines), and the knowledge that there are areas of the country (including parts of Lusaka) that do not have access to constant electrical power. Thus it appears the need for good backup power is important not only for laboratory accreditation but for the peace of mind of the laboratory analysts.

- In almost all cases, laboratory staff expressed desire for a dedicated backup or emergency generator just for the laboratory, citing lack of confidence in the hospital's central emergency generator.

- Many computers and sensitive laboratory instruments have individual UPS systems installed; these were likely installed with each instrument when new, likely at least several years ago. All of the UPSs observed are basic models, which offer 15-20 minutes of backup power (when new), and which have not proven to last more than 2 years without battery replacement. On a number of these units, the indicator lights were not functioning properly; others were showing a full battery charge when the experience in the laboratory was that the UPS did not last more than a few minutes. No one seems to do anything about maintaining these units, although some of the staff recognize that the batteries need regular replacement. We suggest that these UPS systems offer a false sense of security, and are likely beyond their useful life.

3.5 DISCUSSION OF APPLICABLE BACKUP POWER TECHNOLOGIES

Following are descriptions of common technologies available to improve the quality and reliability of electrical energy, each developed to satisfy particular needs. Appendix B provides a comparative table of the different technologies for reference.

1) **Battery/inverter** systems are often used due to their capacity to withstand difficult conditions. They are modular and can be designed to sizes of 10 kW and more, usually limited by the number and capacities of batteries, and the space for their installation. These are heavy duty, usually robust pieces of equipment with a very high reliability in the field, used mostly where grid electricity is not available or the service is very limited; rural environments characterized by dust, high levels of humidity and little maintenance. This technology has evolved and improved with its use in solar PV systems. Given the stability of the grid, and availability of electricity to the hospitals, these systems do not appear to represent a cost-effective solution for Zambia.

   Battery/inverter systems can be used for both "contact" loads (loads are normally on grid or generator power and automatically transfer to battery operation if power is cut or power quality is compromised), as well as for "no-contact" loads (those connected permanently to the inverter providing perfect sine wave current fed by the batteries, which are charged by grid or generator power – hence the term "no-contact"). No-contact loads always see high quality battery power and are never exposed to grid or generator power).

2) **Uninterruptible Power Supplies (UPS)** are very common in industries, institutions and even homes, basically for computers, servers and other IT equipment. The typical UPS is designed to provide 15-20 minutes of backup power when primary power is cut or compromised in quality. This is typically sufficient time to properly power down IT systems. However, it may not be sufficient to maintain the integrity of tests run on some laboratory instruments.

   The UPS industry is growing and the manufacturers have developed higher quality and higher capacity models, along with increased periods of backup time. The typical UPS models used for home and office computers operate similar to battery/inverter applications for "contact" loads: when power is cut or compromised, the UPS switches to battery operation (although battery power is usually limited to 20-30 minutes. Higher quality, "double conversion" UPSs are designed to connect to "no-contact" loads, with all input power going through the internal battery and inverted to perfect sine wave output, i.e., high quality power, again, similar to the battery/inverter description for "no-contact" loads above. This effect also maintains voltage stability with no spikes.

A possible downside to the UPS installations is the size and quality of the batteries. For typical "contact" UPS systems, these batteries may last up to 2 years, if they are regularly checked and maintained. However, the new double conversion UPS systems come equipped with no-maintenance batteries that are available in lives of 5 years, and even 10 years.

An additional limitation of the UPS systems is their relatively short backup time period, or autonomy. These systems are typically designed with a 20-30 backup time, although many offer options to install additional batteries to double this period of time. Still, these systems will not usually be able to provide much more than one hour of autonomy. Only a large battery bank with a battery/inverter system is able to cost-effectively provide long periods of autonomy. On the other hand, if a facility has a working emergency generator, an autonomy of more than a few minutes is not necessary, since as soon as the generator comes on, it will begin to charge the batteries of the UPS. Meanwhile the loads will continue to see high quality current from the inverter output. In the case of the laboratories observed in Zambia, long periods of autonomy do not seem to be needed, given the stability of the grid; furthermore, in most cases emergency generators are available to supply power in the rare case when grid power is off.

3) **Voltage regulators** are very useful where the quality of the electricity is poor, especially where surges or large variations in voltage or frequency are experienced. Good voltage regulators correct both voltage variations and frequency variations. However, these regulators are only good when power is available – they offer no backup capability. Thus they are limited to "contact" loads when a high quality of energy is needed with no backup requirement. For "no-contact" loads, the voltage regulation is better taken care of in the battery/inverter system, or in the double conversion UPS.

4) **Engine generators**, often referred to as backup generators or emergency generators are extremely useful for backup power due to the fact that they are available in much higher capacities than batteries, UPS or solar PV systems. However, they are also limited to providing backup to "contact" loads, which can accept the slight delay or dip in power when the generator is started either automatically or, in many cases, manually. While automatic transfer time is typically less than 100 milliseconds, sensitive IT equipment and laboratory instruments may not survive this (these are "no-contact" loads). In the case of a manual transfer switch, the transfer time is likely to be up to several minutes. Even a manually switched generator can work adequately with most "contact" loads, and can effectively support a double conversion UPS or battery/inverter system, since in both cases, the battery will continue to provide power during the period when neither grid nor generator is operating.

5) **Solar PV systems** are also often considered among the backup power technologies. In applications where battery/inverter systems are installed, solar PV can be used to charge the batteries. If batteries are not already installed, implementation of solar PV will have a correspondingly higher cost. Alternatively, solar PV could be dedicated to certain loads in the hospital, without batteries, but this will require switches to transfer between solar and grid or generator power for the loads connected to solar. The switching can be avoided if solar PV is connected directly to the grid; however, this is not permitted by many utilities (including ZESCO in Zambia). Finally, where grid power

has a relatively low cost, like in Zambia, solar PV systems will take a long time to recover the investment (possibly more than 10 years).

4. LABORATORY-SPECIFIC FINDINGS AND RECOMMENDATIONS

4.1 UNIVERSITY TEACHING HOSPITAL (UTH)

This sprawling hospital houses at least a dozen different laboratory sites, scattered throughout the hospital buildings. We visited the laboratories briefly, and developed a preliminary list as presented in Table 2. We were accompanied by a maintenance staff person, but who had no knowledge of how the laboratory electrical supply was distributed. Illustrative estimates of electrical loads have been included in Table 2 to provide a starting point for discussions and estimates; however, no measurements were taken and no specific circuits were identified.

Table 2. UTH Laboratories Qualitative Summary

Laboratory	kVA (est.)	Comments
Hematology	3-5	ABX Pentra 80; Sysmex XT2000; fridges; misc.
Histopathology	1-2	Microscopes only
Clinical Chemistry	2-3	Olympus AU400; fridges
Histopathology	3-4	Miscellaneous
Chemistry	1-2	Reverse Osmosis machine
Outpatient	1-2	Miscellaneous
STI	3-5	Miscellaneous; fridges and freezers
Parasitology	3-5	Hoods, fridges and freezers
Bacteriology	3-5	Not including washer and autoclaves (up to 30 kVA)
High-cost	2-3	ABX Pentra 60; misc.
Pediatrics	2-4	Not visited
TB		Not visited; dedicated 40 kVA emergency generator
Virology		Not visited; dedicated 35 kVA emergency generator
Total Estimate	30-50	Needs to be confirmed with measurements

Note: kVA estimates do not include air conditioners

The problem is that these laboratories are scattered among a number of wings and offices on several floors, often interspersed with other medical facilities, thus making it impossible to provide a single emergency backup generator without significant rewiring. The hospital electrical maintenance staff did not appear to be knowledgeable about the wiring and circuits. Furthermore, a number of the laboratory areas were under construction or refurbishment, contributing to the difficulty of specifying with exactitude the loads and backup requirements.

Table 3 summarizes the information on emergency generators at UTH as related by the electrical maintenance staff. Again, this is preliminary information provided to underline the need for a coherent approach to laboratory backup power.

Table 3. UTH Emergency Generators Qualitative Summary

Generator	kVA	Comments
TB Laboratory	40	Dedicated generator, installed in last 5 years
Virology Laboratory	35	Dedicated generator, installed in last 5 years
Hospital Generator	262	Not clear on wiring and interconnection; cannot handle all the hospital loads
D Block	125	Appears to be operational
A Block 1	150	Not operational due to starter problem; not clear if there is another 150 kVA generator for this Block
B Block	125	Not operational
Virology lab offices	40	Operational but not used
Blood Bank	50	Not operational

What is clear is that the laboratories (except for TB and Virology) do not have adequate backup power installations. The UPS systems installed on some of the computers and sensitive machines have not been maintained, and no one is knowledgeable about them or responsible for them. At the same time, there is no guarantee that any of the laboratories are on the backup the emergency generator systems, or that those systems are able to provide a reliable backup. It should be mentioned that even TB and Virology may not have adequate UPS installations

Recommendations

1) Undertake a program to define the wiring of the laboratory electrical circuits, ascertain if they are wired to one of the emergency generators at the hospital. Work closely with hospital electrical maintenance staff, but maintain independent documentation.

2) Develop a formal listing of each laboratory facility of interest. Use Table 2 as a starting point, but ensure the ability to provide a definitive description of each facility.

3) For each laboratory, identify circuits, label them, and carry out electrical measurements. Measure current and voltage at several times during the work day during several days. Work closely with the hospital technicians, but maintain own records.

4) For laboratory circuits that are not connected to a working emergency generator, identify whether they can still be connected (based on wiring location and capacity of generator), or size a new generator to be procured and installed.

5) Identify “no-contact” loads in each laboratory. Size and procure a new “double conversion” UPS system for each sensitive instrument and/or computer. Several instruments/computers may be combined for a single UPS.

6) Set up a maintenance program for laboratory backup power systems, whether for the UPS and/or for the dedicated emergency generator(s).

4.2 MAINA SOKO MILITARY HOSPITAL

This clean, apparently well-run hospital has a spacious laboratory area that includes biochemistry, hematology, immunology and serology. Electrical measurements were not available but a quick, preliminary estimate of the load is 10-15 kVA, excluding the air conditioners. All of this load is connected to the hospital-wide generator, an F.G. Wilson diesel machine rated at 135 kVA (108 kW at 0.8 power factor, and rated current at 194.9 A).

The generator appears to be well-maintained. It is operated for 30 minutes weekly. The automatic transfer switch is tested on a monthly basis. No power failures were reported recently (except for the June 2010 nationwide blackout), and the generator shows as having operated for 200 hours.

The laboratory staff insist on the need for a dedicated emergency generator for the laboratory. However, the installed cost of a 15 kVA system is will likely be close to US$ 25,000, along with annual maintenance costs.

Inside the laboratories, UPS units are connected to all of the main instruments and computers. The systems are clean, but do not appear to be technically maintained. Given that they are several years old, it is likely that the battery backup may not provide more than a few minutes of backup power. In addition, the sensitive instruments are not protected from variations in voltage or frequency from the grid power, although no incidents of problems were reported by the laboratory staff when interviewed.

Recommendations

1) Carry out measurements on the electrical junction box serving the laboratory. Ideally a logger would be installed on the panel for 48-72 hours, but a combination of instantaneous measurements can be made to suffice. Instantaneous measurements should be made at several (3-4) intervals during the day for several (2-3) days, noting the loads in the different laboratories at the times of measurement. These measurements will provide a good estimate of the laboratory electrical demand, which can be used to ensure the hospital generator has sufficient capacity to cover laboratory backup, or to size a dedicated laboratory generator if necessary.

2) Review the electricity bills of the facility to confirm average and maximum electrical demands in the hospital over the past 12 months. This will determine whether there is sufficient capacity on the current generator to provide backup power. If the bill review shows that hospital demand is greater than the 135 kVA capability of the generator, a decision can be made on whether some capacity can be reduced elsewhere in the hospital to ensure full backup for the laboratory. Our thinking is that, if necessary, other hospital loads on the emergency generator can be reduced. Both cost-wise and operation-wise, it would be preferable to utilize the existing generator, rather than purchasing, installing and maintaining a small additional generator dedicated to the laboratory.

3) Regardless of the decision made above, the old UPS systems should be removed, as they are not providing the needed protection. For "contact" loads, no replacement of UPS is required, since backup is provided by an emergency generator, whether hospital-wide or dedicated to the laboratory. For "no-contact" loads, "double conversion" UPS systems should be installed. These loads include all sensitive laboratory instruments, their corresponding computers and any other computers installed and used in the laboratory. A definitive list of these loads should be developed and reviewed with laboratory management and staff. UPS systems can be purchased for individual loads, or for combinations or groups of loads.

4) Develop a UPS maintenance program based on manufacturer's recommendations for the "double conversion" UPS systems.

4.3 KITWE CENTRAL HOSPITAL

The laboratories are all together in large, contiguous rooms on one floor of the hospital, and include hematology, clinical biochemistry, pathology and microbiology. In hematology, a number of sensitive instruments are operated without any UPS (ABX Pentra 60; ABX Micros 60; BD FACS Count; BD FACS Calibur). Nevertheless, the laboratory has not experienced any problems with these machines, which would typically be considered "no-contact" critical loads.

Power outages are rare (one maybe every two months, according to one lab technician), and the electricity is of good quality. The June 2010 all-day outage was remembered, but no other power failures could be recalled. Still, there was a unanimous opinion among the technicians that an independent emergency generator dedicated to the laboratory is what is needed. One of the concerns was the doubt that the hospital generator had enough fuel available to operate for more than 3 hours (something that may have occurred during the all-day outage mentioned above).

An instantaneous measurement by an accompanying electrical technician in what was identified as the panel serving the laboratory loads yielded 42-45 A at 227 V single phase, resulting in an instantaneous measurement of approximately 10 kVA. This is simply a data point; it was not correlated to the level of use within the laboratory.

The hospital has a 2003 model Caterpillar 300F diesel generator rated at 300 kVA, and showing a total run time to date of 187 hours. The generator started right up when switched on. It appeared to be in very good condition, and according to the technician, it is tested and run for 20-30 minutes every week. The technician admitted that the automatic transfer switch was not operating properly, and the load had to be switched manually to the generator in emergency situations. This is not adequate to maintain operation of many of the sensitive instruments and computers.

A check of the hospital electricity meter showed a maximum demand reading of 452 kVA, but there was no way to determine the date of that reading. If true, this is significantly above the 300 kVA capacity of the emergency generator, which the technician admitted was heavily loaded when it operated in backup mode. Ideally, the last year's electricity bills should be reviewed to confirm the monthly maximum demand; however, no bills were available during the visit.

Recommendations

1) Carry out measurements on the electrical junction box (or boxes) serving the laboratory. Ideally a logger would be installed on the panel for 48-72 hours, but a combination of instantaneous measurements can be made to suffice. Instantaneous measurements should be made at several intervals (3-4) during the day for several days (2-3), noting the loads in the different laboratories at the times of measurement. These measurements will provide a good estimate of the laboratory electrical demand, which can be used to ensure the hospital generator has sufficient capacity to cover laboratory backup, or to size a dedicated laboratory generator if necessary.

2) Review electric bills to confirm the monthly maximum demand of the facility over the past year. This will determine whether there is sufficient capacity on the current generator to continue to provide backup power to the laboratories. If the bill review shows that hospital demand is greater than the 300 kVA capability of the generator, a decision can be made on whether some capacity can be reduced elsewhere in the hospital to ensure full backup for the laboratory. As suggested for Maina Soko, it is preferable that other hospital loads on the emergency generator be reduced. Both cost-wise and operation-wise, it would be better to utilize the existing generator, rather than purchasing, installing and maintaining a small additional generator dedicated to the laboratory.

3) For “no-contact” loads, “double conversion” UPS systems should be installed. These loads include all sensitive laboratory instruments, their corresponding computers and any other computers installed and used in the laboratory. A definitive list of these loads should be developed and reviewed with laboratory management and staff. UPS systems can be purchased for individual loads, or for combinations or groups of loads.

4) Develop a UPS maintenance program based on manufacturer’s recommendations for the “double conversion” UPS systems.

5) Obtain a quotation to replace or repair the automatic transfer switch. If this cost is prohibitive, the operation could remain manual: the “double conversion” UPS systems would protect the “no-contact” loads even if the transfer took several minutes.

4.4 NDOLA CENTRAL HOSPITAL

This laboratory, in a spacious ground-floor area, is apparently one of the farthest along in the laboratory accreditation process led by the Ministry of Health. Laboratories include histopathology, hematology, microbiology.

In one of the laboratory areas, special (brown-colored) outlets are installed and were once connected to the generator (for backup power). In fact, they are likely still connected to the generator line through the transfer switch, but the switch itself is no longer working. Another transfer switch, on the other side of the hospital is apparently still working, allowing the generator to provide backup power to the "old wing" of the hospital.

No measurements were made. Electricity bills were requested from the Principal Hospital Administrator, but were not obtained due to the short time of the visit.

The generator is a PUMA with a 437 kVA nameplate, run by a Dorman engine, both of UK manufacture. This machine is 25 years old, or older, and was likely installed in 1974 when the hospital was built. It is run for 15 minutes every two weeks.

The laboratory staff, as in other facilities, insisted in obtaining a dedicated generator for the laboratory. They have some equipment on UPS systems, but claim to need more UPS to support additional instruments and equipment.

Recommendations

1) Carry out measurements on the electrical panels serving the different laboratory rooms. Ideally a logger would be installed on each panel for 48-72 hours, but a combination of instantaneous measurements can be made to suffice. Instantaneous measurements should be made at several intervals (3-4) during the day for several days (2-3), noting the loads in the different laboratories at the times of measurement. These measurements will provide a good estimate of the laboratory electrical demand, which can be used to ensure the hospital generator has sufficient capacity to cover laboratory backup, or to size a dedicated laboratory generator if necessary.

2) Review electric bills to confirm the monthly maximum demand of the facility over the past year. This will determine whether there is sufficient capacity on the current generator to continue to provide backup power to the laboratories. If the bill review shows that hospital demand is greater than the 437 kVA capability of the generator, a decision can be made on whether some capacity can be reduced elsewhere in the hospital to ensure full backup for the laboratory. As suggested for Maina Soko, it is preferable that other hospital loads on the emergency generator be reduced. Both cost-wise and operation-wise, it would be better to utilize the existing generator, rather than purchasing, installing and maintaining a small additional generator dedicated to the laboratory.

3) Develop a list of "no-contact" loads, and review them with the laboratory management. For these, "double conversion" UPS systems should be installed. These loads include all sensitive laboratory instruments, their corresponding computers and any other computers installed and used in the laboratory. UPS systems can be purchased for individual loads, or for combinations or groups of loads.

4) Develop a UPS maintenance program based on manufacturer's recommendations for the "double conversion" UPS systems.

5) Obtain a quotation to diagnose the problem and replace or repair the automatic transfer switch. This switch should be repaired not only for the laboratory, but for other areas in the newer wing of the hospital.

4.5 ARTHUR DAVISON CHILDREN'S HOSPITAL

Contrary to the other laboratories visited and described above, this facility is experiencing severe issues with power quality and availability. According to the laboratory director, the power cuts are almost on a daily basis, and certain sensitive instruments have been turned off to protect them. One chemical analyzer was burned out by a power surge.

No UPS systems are installed on any of the instruments or equipment.

The grid power comes into the hospital at two different transformers and meters: 85 kVA for the hospital loads; and 240 kVA for the electric boilers for the laundry and sterilization. According to the electrical staff, the laboratory loads are estimated as high as 25 to 30 kVA out of a total 75-85 kVA demand for the whole hospital.

The backup generator is a two-year old Cummins system rated at 110 kVA peak and 100 kVA prime. The problem is that the automatic transfer switch is not working, so the generator cannot be used. A quotation from Cummins estimates its repair at ZMK 17 million (US$ 3,500).

At the same time, the Ministry of Health is in the process of providing a new 400 kVA generator with its own transfer switch. The foundation has already been poured, and the fenced and roofed enclosure was almost complete at the time of the visit. This brings up two options: 1) repair the ATS and use the Cummins for the whole hospital; and 2) use the new 400 kVA unit for the whole hospital, and dedicate the Cummins unit to the laboratory, once the ATS is repaired.

Recommendations

1) Update the current status of the hospital, given the imminence of the installation of the 400 kVA generator, and the possible repair of the ATS for the Cummins 110 kVA generator. If it has not yet been done, proceed to repair the ATS.

2) Carry out measurements of the voltage variations in the laboratory electrical panels to understand the seriousness of the power quality problem. Ideally, these values should be logged in order to provide a continuous register of voltage and its variations. It is important to gain an understanding of what is really happening with the power quality, and whether it is a grid problem, or one possibly caused internal to the hospital.

3) Develop a list of "no-contact" loads, and review them with the laboratory management. For these, "double conversion" UPS systems should be installed. These loads include all sensitive laboratory instruments, their corresponding computers and any other computers installed and used in the laboratory. UPS systems can be purchased for individual loads, or for combinations or groups of loads.

4) Develop a UPS maintenance program based on manufacturer's recommendations for the "double conversion" UPS systems.

4.6 SUMMARY OF THE LABORATORIES AND THE RECOMMENDATIONS

Similar problems were identified at all of the laboratories:

- Old and non-functional UPS systems, or missing UPS on critical loads
- No knowledge of the quantity of electrical loads connected in the laboratories
- Distant hospital generator, with questions of whether there is sufficient capacity to provide laboratory backup, doubts about the reliability of the generator and issues with the automatic transfer switches.

On the positive side, none of the laboratories has any electric power problems (except for Arthur Davison Children's Hospital).

A short comparative summary of the hospital laboratory systems visited and the range of investment required is presented in Table 4.

Table 4. Summary of Potential Laboratory Investment Requirements

Hospital	Approximate Electrical Load	Cost of Dedicated Laboratory Emergency Generator	Cost of "Double Conversion" UPS Systems
University Teaching Hospital	30-50 kVA	$40,000 – $50,000	$8,000 - $13,000
Maina Soko Military Hospital	10-15 kVA	$15,000 – $20,000	$3,000 - $4,500
Kitwe Central Hospital	10-15 kVA	$15,000 – $20,000	$3,000 - $4,500
Ndola Central Hospital	15-20 kVA	$20,000 – $25,000	$4,500 - $6,500
Arthur Davison Children's Hospital	25-30 kVA	Not required	$7,000 - $8,000
Notes: electrical loads represent preliminary estimates only; generator costs include installation, but not annual maintenance; UPS systems assumed to be required for 25% of the typical load in the laboratory; further analysis is recommended before proceeding with any investment.			

Our overall recommendations can be summarized as follows:

1) Begin an organized focus on each laboratory starting with the development of good data, including measurements of loads and analysis of the electricity bills.

2) Identify no-contact loads and size and specify the appropriate "double conversion" UPS systems. These are more expensive than the common UPS, and the ones that we have found installed in many of the laboratories. This increase in cost, however, is well worth it to

3) Ensure proper training and maintenance around the use of the "double conversion" UPS systems. Since they apply to all of the laboratories visited, there should be a common approach in their procurement, installation and maintenance.

4) Review capacities of existing generators as specified in the detailed recommendations for each laboratory. We recommend proceeding with installation of laboratory-specific generators only if capacities of hospital-wide generators are determined to be insufficient to ensure coverage of laboratory loads.

Finally, given the number of activities that arise out of the recommendations above, we recommend that consideration be given to an electrical technician assigned to laboratory energy systems. A draft position description is provided in Appendix C. We suggest there are enough activities to justify a full-time technician, especially to maintain ongoing monitoring of laboratory loads, ensure proper use of new UPS systems, and be responsible for ongoing maintenance, training and documentation required for these systems. If the decision is made to go forward with the installation of laboratory-dedicated emergency generators, such a technician may be assigned the additional responsibilities of ensuring maintenance and readiness of this equipment, if he or she has the capability to take these on.

4.7 ADDITIONAL CONSIDERATIONS

A number of related issues were brought up in the course of the visit, and are briefly documented in the following sections.

4.7.1 Laboratory Information Systems

Laboratory information systems are being contemplated as a next step of improving laboratory services in key hospitals in Zambia. When and if this occurs, it will represent an important upgrade of laboratory capabilities, but will also bring requirements of additional loads, especially computer equipment. This will be an opportunity to review laboratory loads, and will likely increase the requirements for backup power and the installation of additional UPS systems. It will be important to do this in a manner consistent with the recommended activities and installations suggested in this report, and may help make the case for a dedicated electrical technician serving the hospital laboratories.

4.7.2 Local Technology Providers

Two areas of technology and capability are key in the improvement of the laboratory backup systems in Zambian health laboratories: engine generators and UPS systems. The identification of and contact with local companies that provide these and other energy backup-related services and equipment is another fundamental step that needs to be taken to strengthen the backup power services for laboratories in Zambia.

Engine generators: There are a number of representatives of multinational engine-generator companies located in Lusaka. Time did not permit identifying all of them, but we visited the largest one, Barloworld, a Caterpillar representative. This entity offers complete services in the procurement, installation, maintenance and repair of engine-generators of all sizes. They are also linked with a Caterpillar training facility in South Africa. Finally they are able to identify local electrical consultants who specialize in the design and analysis of electrical installations focused on backup power.

UPS systems: Due to time constraints we were not able to identify local suppliers of this equipment, although there are representatives of certain UPS manufacturers located in Zambia. UPS systems are also available from numerous international companies that are experienced in shipping their products all over the world, and some may have the ability to provide local support in Zambia. This will require some research, but is an important task to develop. It should be noted that the focus will be on “double-conversion” UPS systems, as discussed elsewhere in this report.

4.7.3 Solar PV Systems

Solar photovoltaic (PV) systems have not been considered as realistic additions to the laboratories evaluated during this visit. Their high initial costs and requirements for batteries do not make them competitive with the UPS and generator combinations recommended in this report. The cost of installing solar PV systems is more than double the initial estimates provided for generators, and may still require the installation of UPS systems for no-contact equipment.

It is in remote and other off-grid areas where solar PV systems are applicable and recommended, as discussed in the July 2009 USAID report “Options for Improving Energy Services at Health Facilities in Zambia.” Updates to that report were not considered as part of this visit, due to the focus on backup power for key laboratories on their way to accreditation. Nevertheless, solar PV remains a viable and recommended option for remote clinics, and should be considered as part of the Ministry of Health’s national priorities. This sentiment was clearly supported by the Director, Clinical Care and Diagnostic Services of the MoH, who noted the viability of solar for off-grid installations, and suggested coordination with the National Institute for Rural Electrification. Such work might concentrate on optimizing solar PV installations, and might be an interesting complement to the backup power efforts in support of the laboratories in the process of accreditation.

Appendix A. List of Persons Met

Institution	Staff
CDC	Clement Ndongmo, Country Director
Ministry of Health	Fales Mwamba, Deputy Director, Clinical Care and Diagnostic Services Dr. Siakantu, Director, Clinical Care and Diagnostic Services
University Teaching Hospital (UTH)	Victor Mudenda, Head Histopathology Laboratory Timothy Kantenga, Laboratory Manager Mr. McKandawire, Electrical Technician
Maina Soko Military Hospital	Maj. Changu, Laboratory Director Maj. J. Mwanza, Officer Commanding the Engineering Department
Barloworld (Caterpillar distributor)	Kasolo Bwalya
Kitwe Central Hospital	Joe, Head Electrician
Ndola Central Hospital	Messrs Daca and Rupiah, maintenance staff Mr. Chilufya, Principal Hospital Administrator Paul Kamboyi, Electrician Efrem, Assistant Laboratory Manager
Arthur Davison Children's Hospital	Tumeyo Nyenga, 2^{nd} In Charge, Maintenance Grace Mwikuma, Laboratory Director
DOD PEPFAR Office	Dawson Ngoma

Appendix B. Comparison of Power Quality and Backup Power Technologies

PARAMETER	INVERTER AND BATTERIES	UPS	VOLTAGE REGULATOR	DIESEL GENERATOR
Investment ranges	$1.4 to $2.4 US$/Watt installed (Batteries included)	$0.18 to $1.1 USD / VA	$0.07 to $0.5 USD/ VA	$140 to $300/kW depending on size
O&M	$300 USD/year and battery replacement every 5 to 8 years	$500 USD/year and batter replacement every 5 or 10 years		$1.2 to $3.8 USD/kWh depending on size
Skilled labor for installation	Yes	Not always	Yes	Yes
Skilled labor for operation and Maintenance	No	No	No	Yes
Capacities available	1.3 to 2.16 kW modular (capacity as rectifier)	0.5 to 160 kVA	1 to 2000 kVA	1.5 KVA to 4000 KVA
Back up time (Range)	Depending on design. From minutes to hours and days	Depending on design. From minutes to hours and days	Zero	Indefinite
Robustness	Heavy duty	Moderate	Moderate	Heavy duty
Withstand the humidity with no condensations	Yes	Yes	Yes	Yes
Clean room requirements	No	No	Possibly	No
Monitoring	*Limited – not*	*Optional*	*Optional*	*Optional*

PARAMETER	INVERTER AND BATTERIES	UPS	VOLTAGE REGULATOR	DIESEL GENERATOR
including	*remote monitoring not logging long periods of time*			
Expected Life time	20 years (with battery maintenance and replacement)	10 years (for double conversion)	15 years	20 Years
Warranty period	10 years	1 year	2 years	1 year
Voltages available	120, 220	120, 220	120, 220	all
Frequency (HZ)	50 and 60 Hz	50 and 60 Hz	50, 60 Hz	50, 60
Output voltage variation	+/- 2% for "no-contact" loads	+/- 2% for double conversion units	+/- 3% to 4%	+/- 3% to 4%
Harmonics variations	2% to 4%	2% to 3%	< 0.4%	2% to 4%
Efficiency of rectifier side (battery charger)	60%	60%	N.A.	N.A.
Inverter efficiency	92%	95-97%	98% a 99%	N.A.

Appendix C: Draft Position Description for Laboratory Energy Specialist / Electricity Technician

Candidate will serve as a technical advisor to the Ministry of Health in matters related to energy services in hospitals and clinics. Specifically, Candidate will provide support in clean and backup power systems for health facilities to ensure adequate and proper protection of sensitive electrical equipment and systems to provide continuous power in the case of grid power cuts or failures. The focus will be on laboratories, but may extend to other critical operations of the health facility. Candidate will work with typical electrical backup power systems, including: emergency generators; uninterruptible power systems (UPS); and potentially solar photovoltaic (PV) energy systems in rural health clinics.

Candidate will work in an organized way to compile information files on each health facility, the loads and monitor the energy situation over time. He/she may carry out field measurements as necessary to determine electrical loads in key health facilities to ensure adequate capacity of backup power systems. He/she may be required to specify new backup generators and UPS systems, and work with contractors to install and maintain them.

Candidate will develop, coordinate, implement and/or contract training programs for health facility technicians on generator maintenance and UPS maintenance. This will include emergency generator testing and maintenance and replacement/refurbishment of UPS systems. He/she will develop formats or protocols to track and follow the maintenance procedures.

Candidate will work closely with the staff of the Ministry of Health. He/she will focus on all health facilities identified as priority facilities by the Ministry. Candidate will establish technical contact, make regular visits and maintain communications with maintenance and laboratory staff at these health facilities. Candidate will report to and take direction from the APHL home office and the appropriate Ministry of Health officer. He/she will organize and document ongoing health facility-related energy issues, including power failures and performance of emergency backup power systems. Candidate will maintain a separate file for each health facilities to include critical loads, their electrical values, and the corresponding backup systems. He/she may be asked to provide cost and budget information for different types of maintenance and training programs as well as capital investments at the facilities. He/she will provide monthly reports of activities and recommendations to the Ministry and APHL arising from the work.

Qualifications

The ideal Candidate will have a technology degree or engineering degree in the electrical or electro-mechanical field, and a minimum of 7-10 years of practical experience in operation, maintenance and preventive maintenance of electrical systems. Candidate should be knowledgeable about electrical loads and their measurement. Candidate should be familiar with emergency generators, UPS systems and batteries, including their operation and maintenance. Candidate must demonstrate good interpersonal skills and the ability to write and prepare reports. Candidate should be able to work independently, and develop and implement his/her own program of activities with minimum guidance from Ministry staff.