Montaña de Luz
Generator System Repair and Integration

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1. Introduction

The team travelled to the orphanage, Montaña de Luz (MdL), in Honduras from Friday, March 13, 2014 through Sunday, March 22, 2014 to complete a humanitarian engineering service project as part of an engineering service-learning course at The Ohio State University. Montaña de Luz is an orphanage for children affected by HIV/AIDS.

Montaña de Luz (MdL) had two diesel generators that were donated several years ago and had been not been used. This was due to lack of the proper equipment necessary to incorporate the generators into the compound’s electrical system. Due to lack of maintenance, the generator batteries had deteriorated and a few of the fuel system components were missing.

The team consisted of three undergraduate students and three trip advisors. Two of the trip advisors were fluent in Spanish, and two of the three team members had intermediate Spanish skills and could provide brief translations and listening skills. Below is the list of the members, roles, and majors:

- **Undergraduate Students**
  - Nathan Derry - Technical Manager
  - Ishmeet Grewal - Communications Director
  - Aaron Staib - Research Leader

- **Trip Advisors**
  - Dr. Edgar Casale, Senior Lecturer, COE EEIC Programs
  - John Schrock, Senior Lecturer
  - Isabel Fernandez-Puentes, Graduate Teaching Assistant
2. Project Details

Montana de Luz experiences power outages which can lead to food and medicines stored in the refrigerators and freezer to perish. A solution to this problem is to have backup power available for the refrigerators and freezer. This project focuses on repairing an existing diesel generator and delivering an integrated generator system capable of providing backup power capability for these critical loads.

2.1. Problem Definition

MdL needs at least one working backup generator. During power outages, it is critical that the refrigerators and freezer continue to be operational so that the food and HIV medication do not spoil. Having a backup generator will keep these appliances operational.

2.2. Scope

The objective of this project was to create a functioning generator system capable of powering the critical load of 2 refrigerators and 1 freezer. This objective required two separate projects, repairing the generator and connecting it to the kitchen circuit. The generator was repaired by purchasing and installing a new battery, changing the oil, and replacing and reinstalling the missing fuel system components, which were three fuel lines, a fuel filter, as well as a valve and Y component which connected in series with the fuel lines.

Once the generator was functional, a transfer switch was installed to allow the generator system to provide power to the kitchen circuit breaker box. The necessary appliances are currently powered through breakers in that circuit breaker box. The generator system is able to supply enough power for these appliances during power outages. Other appliances can be powered using this generator, as long as the total power usage does not exceed the rated capacity of the generator system, which is the average power provided by the generator.
2.3. Deliverables

Upon completion of our project, MdL was provided with an integrated generator system including:

- Backup power capability for:
  - Two refrigerators
  - One freezer
  - One microwave
  - Kitchen lights and fans
  - Three electrical sockets for small appliances
- One manual transfer switch rated for 100 amps
  - This transfer switch allows switching between main and generator power. The switch is installed next to the kitchen circuit breaker box. A lock is provided with the transfer switch to protect the children from dangerous high voltages.
- One functional generator
  - All Power America Silent Diesel Generator Model #APG3202D capable of producing 6500W of peak power and 5000 W of average power.
- Troubleshooting and Operation documents, available in English and Spanish
  - These instructions will assist in operating the generator and the transfer switch to provide backup power for the kitchen and troubleshooting minor problems with the generator and the integrated system.
- Generator Manual
  - The manual provides operation and maintenance instructions for the generator. Schematics for the generator sub-assemblies are also available in the manual.
- Staff Training
  - Long-term volunteer Dr. Chris Radcliffe and Osman, one of the MdL guards, walked through the steps to turn on the generator during a real power outage during our stay there. They were able to turn on the generator and operate the entire system by following the directions provided with minimal guidance.
- Property Layout Sketches and Video
  - The property sketches, while not to scale, are a good representation of the layout of the compound. These sketches will be instrumental for future teams to gauge the layout of the compound
3. Design Ideas

3.1. Research

The diesel generators at Montana de Luz are All Power America Model #APG3202D. In order to help with troubleshooting, the team located a manual for the generator and read through it thoroughly. After gaining familiarity of the generator functions, the team requested more information from their contact Chris Ratcliff who is a long term service volunteer at MdL. Chris provided pictures of the generators and the team determined the faults with the equipment.

Of the two generators, one was missing a battery and the other generator's battery had been depleted of charge. An inspection of the generators showed that other components were also missing. One generator was missing fuel lines and had a bad fuel injector pump. Both the generators were also missing the ignition keys necessary to start the generator. The team decided to procure replacements for the missing parts and a new battery to repair one generator.

Once a generator was functional, it had to be integrated with the MdL electrical grid to provide backup power to the two refrigerators and one freezer. After more correspondence from Chris, the team determined that all the appliances were powered from one sub-panel circuit breaker box located outside the kitchen. In order to protect the generator from power surges when the grid power came back online after a power outage, the team searched for an appropriate transfer switch.

A transfer switch enables switching from grid power to generator power without damaging the system. The team located a manual transfer switch capable of withstanding a current of 100
Amperes, or powering a load of 12 kW. This transfer switch was to be installed between the main electric grid and the kitchen sub-panel circuit breaker box.

The team then researched the appropriate wire necessary to power the system. The wire needed to carry a current of 30 Amperes over 25-50 feet with minimal drop in voltage. It was established that 10 AWG copper conductor wire would accomplish this goal. In order to purchase the cable, the team searched local as well as online retailers. However, it was determined that purchasing the wire in Honduras would be extremely cost effective and prevent the team from having to transport heavy cable to Honduras.

### 3.2. Electrical System Schematic

Figure 1 illustrates an overview of the proposed changes to integrate the generator system into MdL’s existing electrical system. Figure 2 provides further details of this planned process. The manual transfer switch will be installed between the main grid and the kitchen circuit breaker box. The utility lines provide power from the grid, which will flow into the transfer switch through the main service disconnects. The manual transfer switch will also receive power from the generator, which will be wired into two 120 volts phases at 30 amps using a 240 volts output on the generator at 30 amps. These two separated phases will be able to supply an effective 60 amps at 120 volts to the transfer switch.

The manual transfer switch can be locked out, to control a double throw switch inside. This double throw switch can be set to off position, grid power on position, or generator on position. In the case of either on setting, power from the selected source flows through the transfer switch and circuit breakers to power the appropriate appliances. When in the off position, no electrical contact is made between either source and the circuit breaker path box, preventing the circuit breaker box from being powered.
Figure 1: Proposed System Changes

Figure 2: Detailed proposed system schematic
3.3. Calculations

The critical load requirements are detailed below. The MdL staff requested backup power capability for two refrigerators and a freezer in order to protect food and medicines from spoiling during long power outages.

Table 1: Power requirements for appliances in scope.

<table>
<thead>
<tr>
<th>Appliance</th>
<th>Voltage (Volts)</th>
<th>Current (Amperes)</th>
<th>Power (Watts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigerator 1</td>
<td>115</td>
<td>5.7</td>
<td>656</td>
</tr>
<tr>
<td>Refrigerator 2</td>
<td>115</td>
<td>7.7</td>
<td>886</td>
</tr>
<tr>
<td>Freezer</td>
<td>120</td>
<td>10</td>
<td>1200</td>
</tr>
<tr>
<td><strong>Total Power Required by Appliances</strong></td>
<td></td>
<td></td>
<td><strong>2742</strong></td>
</tr>
<tr>
<td><strong>Average power Supplied by Generator</strong></td>
<td></td>
<td></td>
<td><strong>5000</strong></td>
</tr>
</tbody>
</table>

The Generator is able to provide power for up to 8 hours on a full tank of fuel. The fuel tank capacity of the generator is 16 liters.

- Approximate cost of diesel fuel = $1/liter
- Cost to run generator for 8 hours = 16 liters x $1/liter = $16

The generator can provide 40 kWh on a full fuel tank.

3.4. Sustainability and Maintainability

In order to ensure that the generator system will remain functional in the future, documentation will be created that contains detailed operating and troubleshooting instructions for the generators. These documents will be available in both English and Spanish. The local residents will also be encouraged to take ownership of the generator system and keep them in optimal performance conditions to ensure durability. Training on the proper operation of the generators will take place for members of long-term MdL staff. The generator is capable of providing power for up to 8 hours for the fuel cost of $16. MdL residents will benefit from the sustained access to electricity to use their appliances even during power outages and prevent loss and spoilage of food products and HIV medications.
4. Pre-Trip Progress

4.1. Schedule - Prior to Departure

Research began on January 26 and continued to February 18. During this time, the team communicated with Chris Ratcliff, a long term volunteer at MdL, to gather information about the current state of the generators and a general layout of the compound. During this time, team roles were also assigned and a team agreement document was created. Based on the research, the team formulated a plan for repairing and integrating the generator system with the MdL electric grid. From February 18 to March 6, the team created a budget and located tools and materials necessary for this project.

After determining an overall budget of $600 for the project, the team ordered parts from online retailers and purchased some necessary tools from local hardware stores. On March 9, the team received news that the replacement fuel system which was ordered from an online retailer was back ordered and would not arrive in time. The team then visited local hardware stores to piece together a fuel system from general parts. From March 9 – 11, the team packed everything in storage bins, which would be checked in on the flight to Honduras, and prepared for departure.
4.2. Schedule - Expected In-Country

Below is a tentative schedule for the repair and integration of the generator system.

Table 2: In-country project plan.

<table>
<thead>
<tr>
<th>Date</th>
<th>To Be Completed</th>
</tr>
</thead>
</table>
| 3/16  | • Disassemble generator and clean components (Ishmeet and Aaron-3 hrs)  
       | • Begin reinstalling parts that are found to function properly (Nate-3 hrs)  
       | • If needed, troubleshoot non-functioning components (All-3 hrs) |
| 3/17  | • If needed, troubleshoot non-functioning components (Ishmeet and Aaron-3 hrs)  
       | • Finish reinstalling functioning components (Nate-3 hrs)  
       | • Replace old fuel lines and battery with new equipment (Ishmeet and Aaron-3 hrs)  
       | • Replace all interior components in working order, reinstall housing (Nate-3 hr) |
| 3/18  | • Take readings from appliances/breakers for verifying appropriate load (Aaron-1 hr)  
       | • Install transfer switch and housing between generator and breaker (All-5 hrs)  
       | • Test generator and transfer switch functioning (All-1 hr) |
| 3/19  | • Verification and testing under load (All-3 hrs)  
       | • Training MdL staff on operation and troubleshooting (All-2 hrs)  
       | • Reviewing documentation with MdL staff (All-1 hr) |
| 3/20  | • Remaining time in case additional training or troubleshooting are required (All-6hrs) |
### 4.3. Planned Budget Overview

Table 3 shows the planned budget of materials that the team had procured in the United States and materials that Chris Ratcliff had purchased in Honduras for the project. This budget was 56 cents over the team’s budget of $600.

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel System</td>
<td>1</td>
<td>$76.35</td>
</tr>
<tr>
<td>Oil Filter</td>
<td>1</td>
<td>$9.27</td>
</tr>
<tr>
<td>Fuel Filter</td>
<td>1</td>
<td>$7.87</td>
</tr>
<tr>
<td>Keyed Ignition</td>
<td>1</td>
<td>$14.10</td>
</tr>
<tr>
<td>10AWG Cable (buy in Honduras)</td>
<td>300 feet</td>
<td>$75.00</td>
</tr>
<tr>
<td>Battery (buy in Honduras)</td>
<td>1</td>
<td>$85.00</td>
</tr>
<tr>
<td>NEMA Plug</td>
<td>1</td>
<td>$17.99</td>
</tr>
<tr>
<td>SAE10W-30 Oil</td>
<td>2 Quarts</td>
<td>$30.00</td>
</tr>
<tr>
<td>Manual Transfer Switch</td>
<td>1</td>
<td>$118.00</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>Assorted Tools</td>
<td>$62.00</td>
</tr>
<tr>
<td>Masonry drill bits</td>
<td>2</td>
<td>$10.00</td>
</tr>
<tr>
<td>Flashlight</td>
<td>1</td>
<td>$10.00</td>
</tr>
<tr>
<td>Degreaser (buy in Honduras)</td>
<td>1</td>
<td>$10.00</td>
</tr>
<tr>
<td>Brackets and Screws</td>
<td>Set of 5</td>
<td>$20.00</td>
</tr>
<tr>
<td>Shipping and Expenses (Estimated)</td>
<td>N/A</td>
<td>$54.98</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>$600.56</strong></td>
</tr>
</tbody>
</table>
5. In-Country Implementation

5.1. Workday 1

When we arrived in Honduras, the first step was to prepare the worksite in the Bodega where tools and the generators are stored. We had to remove the coverings off both generators and do a full inspection to determine which one would have the best chance of becoming operational. One generator was in a considerably worse condition because it had been stored outside for a long time. The other generator was in acceptable condition except for corroded fuel lines which were unattached, old engine oil, and a broken fuel gauge.

![Figure 3: One of the generators was in better condition. We decided to repair this one.](image)

We decided it would be a much better investment of time to work on the second generator and started by dusting off the inside and cleaning it. Next, we reverse engineered the fuel system by using the tears in the tubing and the tubing size to determine fit. We were able to map out the fuel system successfully. Then we replaced the corroded tubing with the polyethylene tubing we had brought as a replacement for the fuel tubes.

![Figure 4: A close-up of the corroded fuel system connections.](image)
The next step was to start the generator but there was no diesel available at MdL, so we had to wait until the next day. For the remainder of the day, we located a suitable shed to house the generator during operation, took measurements for the transfer switch wiring, and planned the integration for the generator system.

5.2. Workday 2

On the second day, the goal was to start the generator and do any necessary troubleshooting. The oil needed to be changed and we needed to fill it with diesel before starting. At this point we had a setback of about an hour because after filling up the generator we noticed a fuel leak so we had to check all of the connections in our tubing. After tightening all of our connections, it was time to start it up. The generator started on the first try and we ran it for about ten minutes while powering an oscillating fan to verify that it was outputting current. After running for the ten minutes, we turned it off and noticed white smoke coming out from near the engine. We investigated further and found that the polyethylene tubing was melting due to the high temperatures of some of the engine components. This was another setback that caused us to have to stop work and go into a nearby town and purchase more appropriate tubing. We got back to MdL late that day and reinstalled the fuel system using the new tubing before ending for the day.

5.3. Workday 3

On day 3, the first task was to test the generator with the new fuel system. We let it run for about 45 minutes to check that the components were still operational after extended use. After turning it off, we did another inspection and noticed that the voltage across the 12V battery was at only 10.1V. We tested with a continuity meter and determined that there was still a closed circuit with the bridge rectifier. This determined that it would be critical to disconnect the battery whenever the generator is not running so that the battery would not be drained.

We used the second half of the day to install the wire system. After drilling and chiseling a hole through the kitchen wall, we threaded a length of wire from the generator shed, up along the eaves of the building, and through the wall into the kitchen. After cutting one
length, we measured it and cut four equal lengths since we would be using the 2 phase output from the generator. We threaded these wires through a piece of polyethylene tubing we were using to protect it from the weather.

![Figure 5: Installing wiring from the generator shed to the kitchen.](image)

5.4. Workday 4

The fourth day was dedicated to making all electrical connections and installing the transfer switch. After securing all the wiring and installing the NEMA plug on one end of the wire, we opened the circuit breaker box. We tested all the circuits in the kitchen to make an accurate diagram of what circuits were attached to which breakers. The main line was also coming in through a breaker rather than simply to the conductors in the back of the box. The main came through the concrete wall and the maintenance staff told us that there was no main service disconnect, so we had to change our implementation slightly. Instead of connecting the transfer switch between the main line and the circuit breaker, our plan was to connect it between the circuit breaker and the individual circuits, as shown in the Final Schematic. This configuration provides multiple advantages. The first advantage is that when the main
power comes back online the other appliances will come back on automatically. The second is that the transfer switch needs to be rated only for the circuits that it is connected to. This saves us from having to limit the power being drawn through the circuit breaker box. It also does not limit the expansion of the circuit breaker box.

![Figure 6: NEMA plug connected to the wires feeding to the kitchen.](image)

![Figure 7: Generator in the shed with the NEMA plug plugged into the 240V socket.](image)

After getting the transfer switch installed on the wall, we wired the circuits for the 2 refrigerators, freezer, lights, fans, and 3 electrical sockets. We threw the transfer switch to pull current from the generator and tested the circuits. First we found that the generator cannot handle the starting current drawn by all of the circuits at one time. The most convenient workaround is to unplug the older refrigerator (since it draws the most current) that is on wheels before turning the transfer switch to generator power. We discovered
another problem while testing that had to do with the configuration of the circuit breaker box. Two circuits that we had connected to different phases were wired to the same side of the circuit breaker, which meant we created a short between two circuits being out of phase by 180 degrees. Essentially, both circuits were trying to pull maximum current from the other phase and this was causing a short in our system. After troubleshooting and discovering the source, the fix was simple. We moved the breaker at fault to the other side of the panel and everything worked as intended. After cleaning the kitchen and throwing the switch back to grid power, work was done for the day.

Figure 8: The kitchen circuit breaker box with identified circuits.
Figure 9: Final position of the transfer switch next to the circuit breaker box. The transfer switch is locked for safety.

5.5. Workday 5

The team used day 5 to teach the staff at MdL how to operate the generator system. We had long term volunteer Chris Ratcliff and the security guard on duty follow our written instructions without any further input from the team and they were able to operate the system as designed. After documenting our work with pictures and cleaning up all of our workspaces, the team presented our project to all of MdL and declared the project finished.
5.6. Implemented Electrical Schematic

Upon arrival at MdL, we discovered that the system was not as simple as we had assumed it to be. To the extent of the knowledge of everyone present, the kitchen circuit breaker received power straight from the Honduran main line and there was no existing switch that could turn off power to the circuit breaker box temporarily. Therefore, in order to proceed with our proposed plan, we would have had to do live wire maintenance, which is a dangerous process.

Installing the manual transfer switch before the circuit breaker box also raised another complication. The generator is only capable of producing 5000W of average power with a maximum current of 60 amps. However, there are other circuits connected to the circuit breaker box besides the ones in the scope of this project. In order to operate the system, every other circuit would have to be turned off, which introduces more steps and room for error in operation. Therefore, the team decided to install the transfer switch after the circuit breaker box and isolated the circuits included in the project scope.

Figure 10 details the final electrical layout created to run the generator system. The transfer switch is installed after the circuit breaker box. The switch receives power from the circuit breakers that originally powered the circuits in scope. The switch also receives power from the generator. Thus, when a power outage occurs, the transfer switch connects the necessary circuits directly to the generator when the switch is thrown and bypasses the circuit breaker box. However, the circuit is not compromised as the generator also contains a 30 amp circuit breaker, maintaining the safety in the system.

By circumventing the circuit breaker box for the targeted circuits, the team ensured that when a power outage occurs, the generator can power the necessary loads. However, when power is restored, the generator will continue to provide power to the kitchen until the transfer switch is manually switched over to grid power. This means that the circuits in the circuit breaker box that are out of scope for this project are left untouched and function normally. Thus, the transfer switch protects the generator from surges and the generator protects the kitchen appliances from surges.
Figure 10: Detailed final system schematic.
6. Post-Trip Results

6.1. Objectives Achieved

Our team had three main objectives: repair a generator capable of providing backup power for two refrigerators and one freezer, integrate the generator into the MdL electric grid with a manual transfer switch, and provide staff training to operate and maintain the system over time. All these objectives were completed and the scope of the project expanded to include the entire kitchen except the electric stove. The team repaired one generator by replacing the fuel system and installing a new battery. A manual transfer switch was installed and connected to the kitchen circuits so that the generator could be used to power the kitchen during power outages. The team also provided rigorous documentation for operating and troubleshooting the system. Chris Ratcliff, the long term volunteer at MdL, and Osman, a guard with an electrical background, were able to follow the documentation and operate the system with minimal guidance. Documentation was also provided in Spanish to keep the system operational in the absence of English speaking volunteers. A generator manual that details service and maintenance guidelines was also provided to MdL.

6.2. Sustainability

All parts necessary to implement this project are available in Honduras. The fuel tubes necessary for repairing the generator fuel system were purchased in-country at a hardware store. The battery, engine oil, and diesel fuel are also readily available. The copper wire necessary to connect the generator to the transfer switch was also purchased in-country. The only component that the team brought from the United States was the manual transfer switch. This decision was fueled by the lack of information of what kind of materials might be available in Honduras, and the transfer switch was a crucial component for the project to be successful. However, a manual transfer switch could easily be constructed by using different size circuit breakers which are readily available in Honduras. The generators are fueled by diesel, which, even though is not the most sustainable fuel, is readily available in Honduras. Since the generators are to be used in emergencies, they will be operational as long as diesel fuel is available.
The documentation provided by the team for operating the system was easily followed by MdL staff to turn on the generator during a power outage. Since then, email communication from Chris has informed us that the generator was in use for multiple days during power outages and worked without any issues. Hence, the team was successful in providing sufficient documentation for operating the system and the system should be maintainable in the future.

6.3. Cost Analysis

The two tables below show the cost of operating the kitchen using Honduran grid power and the generator system, respectively. MdL grid power cost was calculated using the current price of electricity at the time of the trip converted to US Dollars. The Generator power cost was calculated using the price of diesel fuel at the time of the trip. The calculation also assumed full load of 5000W for the entire 8 hours of run time from a whole tank. Using these parameters, the calculated cost of grid power is $.184/kWh while using the generator system costs $.349/kWh. The increase in price is justified by the capacity to preserve the food and HIV medications on-site during power outages.

<table>
<thead>
<tr>
<th>MdL Grid Power Cost Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy Cost (L)</strong></td>
</tr>
<tr>
<td>16269.33</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Generator Power Cost Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fuel Capacity (Gal)</strong></td>
</tr>
<tr>
<td>4.22675</td>
</tr>
</tbody>
</table>
6.4. Final Project Budget

Table 6 shows the final project budget. The team was around $200 under budget due to returning most parts that were not necessary in the final implementation. The system was also made cost-effective by purchasing a majority of the components in Honduras.

<table>
<thead>
<tr>
<th>Item</th>
<th>Vendor</th>
<th>Category</th>
<th>Qty</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil Filter</td>
<td>Sears</td>
<td>Material</td>
<td>1</td>
<td>9.27</td>
</tr>
<tr>
<td>Male NEMA Plug</td>
<td>Amazon</td>
<td>Material</td>
<td>1</td>
<td>17.99</td>
</tr>
<tr>
<td>10AWG Wire</td>
<td>Larach &amp; CIA</td>
<td>Material</td>
<td>100 m</td>
<td>54.78</td>
</tr>
<tr>
<td>SAE10W-30 Oil</td>
<td>UNO</td>
<td>Material</td>
<td>2 Qts</td>
<td>12.37</td>
</tr>
<tr>
<td>3/16 Hose</td>
<td>San Carlos</td>
<td>Material</td>
<td>3 ft</td>
<td>2.11</td>
</tr>
<tr>
<td>5/16 Hose</td>
<td>San Carlos</td>
<td>Material</td>
<td>3 ft</td>
<td>7.03</td>
</tr>
<tr>
<td>Battery</td>
<td>LTH</td>
<td>Material</td>
<td>1</td>
<td>86.65</td>
</tr>
<tr>
<td>Transfer Switch</td>
<td>Menard's</td>
<td>Material</td>
<td>1</td>
<td>118.00</td>
</tr>
<tr>
<td>Drill Bit</td>
<td>Lowe's</td>
<td>Tool</td>
<td>1</td>
<td>6.97</td>
</tr>
<tr>
<td>Breathing Masks</td>
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<td>4.97</td>
</tr>
<tr>
<td>Clamps</td>
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<td>Material</td>
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<td>2.96</td>
</tr>
<tr>
<td>Needle Nose Pliers</td>
<td>Lowe's</td>
<td>Tool</td>
<td>1</td>
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6.5. Lessons Learned

The team learned important lessons related to engineering and project management in general throughout the trip. The first lesson learned was that you should always follow the pre-planned schedule as closely as possible. We learned this on day 2, when we were filling the generator with diesel for the first time. According to the original plan, we were supposed to put only a small amount in the tank and check for leaks in the fuel system. In the moment of excitement, however, we filled it with almost 3 gallons of fuel before noticing it was leaking onto the ground. Had we stuck to the original plan, we would have caught the leak much sooner and spent far less time cleaning up and recovering the diesel from the tank.

A second important lesson learned was that it pays to plan for the worst case scenario. At the outset of the project, the exact location of the generator and transfer switch were still unknown. This led to uncertainty in the amount of electrical wire required to connect the system. We chose to plan for the worst case scenario and bought enough wire for the farthest reasonable distance we could calculate. This number was almost twice as large as our original estimate, but it turned out to be necessary. We bought 100 meters of wire and had about 10 meters left over afterward. Our original estimate of 40 meters of wire would have been insufficient to complete the project so it was essential to account for the larger span.

The last and perhaps most important lesson to outline is the importance of documentation and communication. The relative lack of documentation and information at the beginning of our project led to uncertainty and inefficiency in developing our scope of work. Communication with the staff at MdL was the remedy for this situation as it allowed the team to fill in any gaps in knowledge about the generators and electrical system. Applying this lesson, our team has put together this documentation, as well as diagrams of the generator fuel system and MdL’s property which are attached as appendices.

6.6. Recommendations for Future Project Teams

In addition to following the general lessons outlined in the previous section, we recommend further steps be taken to improve the ventilation of exhaust from our generator. The current system relies on natural ventilation but a chimney made of piping capable of withstanding high temperatures should be installed to discharge the exhaust further from the MdL complex. This
chimney could be made from a lightweight metal piping about 15 feet long running vertically from the site of the generator and would help greatly to increase the safety of the environment around the generator site. Another factor that would improve the atmosphere around the generator storage site is the addition of doors on the shed. Including solid doors rather than the current screen doors would contain the fumes and help force them up the chimney.

The team also recommends further progress be made to implement a second functional generator. There is one more identical generator at MdL which, according to testing and observation, is plagued by the same problems as the one we fixed on our trip. It would be simple and relatively cheap to repair this second generator by following our daily progress logs, fuel system diagrams, and photographs. This second generator could be used with a transfer switch system similar to ours or as a portable system for emergency applications at the pump house.
Appendix A
Operation Manuals
Directions for operating the generator system

1. Starting the Generator
   1. Check the fuel and oil levels
   2. Unplug the 240v plug from the generator’s control panel

![Figure 11: Kitchen Plug. Plugs into the generator.](image1)

3. Make sure the AC Switch is **OFF**
4. Connect the Battery terminals. Red wire to + and Black wire to –
5. Open the door with the latch.

6. Open the fuel valve. It should be pointing straight down, rotated clockwise.

7. Open the 3-way valve. This is located above the top right corner of the generator’s housing. The valve is open when the lever is pointing along the fuel line’s path.
8. Wait for ten seconds.
9. Close the 3-way valve, by rotating it so that it is perpendicular to the fuel line.

10. Set the engine’s speed lever to **RUN** by pulling the larger red lever to the right.
11. Insert a screwdriver into the control panel’s ignition. Turn the screwdriver to the right, past ON, and hold it at the START position until the generator has clearly started.
12. Let the generator run for 3 minutes.
13. Plug in the kitchen wire.
14. Turn the AC switch to ON
15. Make sure the output voltage switch is set to “120v/240v”, pointing to the right.
16. Verify the voltmeter is reading somewhere between 200 and 300 volts.
17. Read all associated documents in this packet to finish setup.

2. Operating the Transfer Switch
   1. Power goes out
   2. Start the generator, if you have not already. Follow “#1 Starting the Generator” instructions.
   3. Come back to the kitchen. Unplug the older, Frigid-Aire refrigerator
   4. Unlock the transfer switch’s right-hand lock. The combination is 05 27 01. Remove this lock temporarily.
   5. Pull the transfer switch down to the “Generator/Generador” position.
   6. Lock the switch into this position as a safety measure to prevent injury or loss of power.
   7. Plug in the older, Frigid-Aire refrigerator.
   8. Enjoy the power
3. Stopping the Generator

1. When the power comes back on other lights and appliances will turn back on.
2. Unlock the transfer switch’s right hand lock. The combination is 05 27 01. Push the switch to the “Main/Principal” position.
3. Turn the AC Switch off on the generator’s control panel.
4. Remove the 240v plug from the control panel.
5. Let the generator run for another 3 minutes.
6. Open the housing door.
7. Depress the smaller red lever on the right hand side to turn engine speed to stop.
8. Turn the ignition to the left, to OFF on the control panel using a screwdriver.
9. Close the fuel valve by turning it counter clockwise. It is important the valve is completely closed.

10. Disconnect the battery.

*Figure 18: Fuel Valve Closed*
4. Troubleshooting the Generator

**Generator won’t start**
1. Check battery connection and reattach if necessary
2. Check the gas level and fill if needed
3. Check oil level using the orange dipstick at the base of the engine and refill if needed
4. Check the battery charge using the multimeter from the Bodega on the 20V setting and recharge, refill with distilled water, or replace if needed

**Kitchen Appliances won’t turn on**
1. Check AC Switch on Control Panel and switch to **ON** if needed
   a. If this fails again, unplug another appliance in the kitchen and switch AC Switch on Control Panel to **ON** again
2. Check connection between plug and control panel and adjust if needed
3. Check Voltage Selector switch and turn to “120V/240V” if needed
Instrucciones para el funcionamiento del sistema de generador

#1 Cómo Activar el Generador

18. Verificar el nivel de diesel y aceite
19. Desconecte el enchufe del generador

Figure 19: Enchufe de cocina. Se enchufa en el generador.

Figure 20: Panel de control del generador

20. Apague el interruptor de AC (AC SWITCH -> OFF)
21. Abra la puerta del generador.
22. Conecte los cables de la batería a la batería. **Rojo a + y Negro a –**


25. Espere durante diez segundos.

27. Ajuste la velocidad del motor a **RUN** girando la palanca roja hacia la derecha.
28. Gire el destornillador hasta el final a la derecha y manténgalo en esa posición hasta que empieza el generador.
29. Deje que el generador funcione durante tres minutos
30. Conecte el enchufe en el generador
31. Encienda el interruptor de AC (AC SWITCH -> ON)
32. Gire el interruptor de la tensión de salida a “120v/240v”.
33. Make sure the output voltage switch is set to “120v/240v”. Se debe apuntar a la derecha.
34. verificar el voltímetro muestra un valor entre 200 y 300 voltios
35. Por favor, lea todas las páginas en este paquete para finalizar la configuración.

#2 Cómo Operar el Interruptor de Transferencia
9. La electricidad se apaga
10. Activar el generador. Por favor lee “#1 Cómo Activar el Generador”.
11. Ve a la cocina.
12. Desenchufe el refrigerador viejo (Frigid-Aire). Esto es muy importante!
14. Cambie el interruptor de transferencia a la “Generator/Generador”.
15. Ponga el bloqueo hacia atrás y bloquear el interruptor.
16. Enchufe el refrigerador viejo (Frigid-Aire).
17. Ahora tiene electricidad!

#3 Para Apagar el Generador

11. Cuando la electricidad se enciende, otras luces y los aparatos se encenderán
12. Ve a la cocina.
13. Abra la cerradura de interruptor de transferencia. La combinación es 05-27-01.
    Retire temporalmente la cerradura.
14. Cambie el interruptor de transferencia a la “Main/Principal”.
15. Ponga el bloqueo hacia atrás y bloquear el interruptor.
16. Aa al Generador
17. Apague el interruptor de AC (AC SWITCH -> OFF)
18. Desconecte el enchufe del generador.
19. Deje que el generador funciona tres minutos más.

20. Abra la puerta del generador.
21. Empuje la palanca roja más pequeña a la derecha para establecer la velocidad del motor a la posición STOP.
22. Gire el interruptor de encendido hasta el final a la izquierda con un destornillador.
23. Cierre la válvula de combustible girándola hacia la izquierda. Es muy importante que esté completamente cerrada.
24. Desconecte la batería.
#4 Soluciones de Problemas Generales

**Generador no se inicia**

5. Compruebe las conexiones de la batería
6. Compruebe el nivel de diesel y llene si es necesario
7. Compruebe el nivel de aceite con la varilla naranja en la parte inferior del motor y llene con 10W30 aceite si es necesario
8. Compruebe la carga de la batería con the multimeter from the Bodega. Recarge, rellene o cambiar la batería si es necesario

**Electrodomésticos de cocina no se encienden**

4. Compruebe el interruptor de AC del generador. Se debe apuntar a ON (AC SWITCH -> ON)
   a. Si esto no funciona de nuevo, desenchufe otro aparato en la cocina e intente encender el interruptor en ON de nuevo
5. Compruebe la conexión entre el enchufe y el generador si es necesario
6. Compruebe el interruptor selector de voltaje del generador y gire a “120V/240V” si es necesario
References


http://www.searspartsdirect.com/All-power-america-Generator-Parts/Model-
APG3202/3325/0702250.html

CA: All Power America, 2005. Print

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