POWER WALKER

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19 February 2015

Dr. Andrew Rawicz
School Of Engineering Science
Simon Fraser University
Burnaby, Canada
V5A 1S6

**Re: ENSC 440/305W Functional Specification** for an Energy Harvesting and Storing System

Dear Dr. Rawicz,

Please find enclosed a copy of our functional specification for an Energy Harvesting and Storing System. The goal of POWER WALKER is to produce a renewable source of energy by means of walking in order to help maintain a sustainable way of living. This document contains the functional requirements necessary for our product as well as a test plan on how it will be implemented.

The functional specification provides detailed requirements for all the components necessary to build the SolexPro system such as the Energy Harvesting Unit, Energy Storage Unit, Energy Dissipation Unit and the User Interface Unit. POWER WALKER will use this document as a reference during the designing, development and testing of the SolexPro system. POWER WALKER will also make sure that all of the components will meet the minimum requirements in order to maintain safety, reliability and longevity of the product.

Our team of senior engineers who are dedicated to this project include: Pouya Aein, Shelvin Chandra, Vani Choubey, Tommy Lu, Shervin Mirsaedi and Arshit Singh. We are ecstatic to work on this project and hope you share the same enthusiasm. We look forward to your support over the term and if you have any questions or concerns, please contact us via email at vchoubey@sfu.ca.

Sincerely,

Arshit Singh
Chief Operating Officer
Power Walker

POWER WALKER

# A Functional Specification for Energy Harvesting and Storing System

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# Executive Summary

*"Invention is the most important product of man's creative brain. The ultimate purpose is the complete mastery of mind over the material world, the harnessing of human nature to human needs." – Nikola Tesla*

In this modern era of technology source of portable energy is crucial at any stake of life. Running out of cellphone battery could put you in misery; you would not be able to check your messages, access social networking websites, and worst of all making an emergency phone call when needed. At POWER WALKER our objective is to provide the essential portable source of energy when needed the most.

Power Walker's SolexPRO will be the next "step" in renewable energy. This device is intended to generate electricity simply by walking. SolexPRO uses a customized version of solenoids built in-house. As the user walks, the magnet inside the solenoids translates this walking momentum into electricity by converting kinetic energy to potential energy.

The development of SolexPRO is divided into two phases; the prototype and the final product. This document outlines all the requirements needed from the product as functional specifications.

These requirements are carefully created to establish the specification details that will be required at various production stages and it outlines the scope of our products. These requirements are prioritized according to its utility, user friendliness, functional and safety requirements. Our highest priority requirements will be implemented on the prototype stage. After completing the prototyping phase the medium to low prioritized requirements will be implemented during the construction of the production model and final marketable product respectively.

These requirements will define and broad on various aspects of our device, including the Energy Harvesting Unit (EHU), Energy Storage Unit (ESU), Energy Dissipation Unit (EDU) and User Interface Unit (UIU). Thus it is highly recommended for anyone working with this product, such as a technician or an engineer to refer to this document.

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# 1 Introduction

Power Walker believes there is a great potential in harvesting green energy for personal use. The company's goal is to harvest reusable energy from an average person's everyday errands. Our products SolexPRO E and SolexPRO F aim to harvest energy from simple walking motion. These two products convert mechanical energy from the motion of the feet to electrical energy which is stored as electrical potential in batteries. SolexPRO E will be designed based upon an electrical system while SolexPRO F will be designed based upon a fluid system. Our objective is to choose the product with the most durability, efficiency, safety, and user satisfaction.

## 1.1 Scope

The scope of this document is to outline the functional requirements of POWER WALKER's SolexPRO E and SolexPRO F energy harvesting shoes. The specifications in this document fully describe the functionalities of our proof-of-concept prototypes and will serve as a basis for future iterations of the products. This document will also provide a development test plan that will be used to ensure the shoes meet product requirement and safety standards. Moreover, these requirements carry out the system overview and product design.

## 1.2 Intended Audience

The functional specification is written as a guideline for the design and implementation of the SolexPRO E and F prototypes. It is intended for use by all members of Power Walker. The team should refer to this document in every phase of development to ensure that the prototypes meet the predefined function requirements.

## 1.3 Classification

Throughout this document, the following convention shall be used to denote functional requirements:

[Rn-p]          functional requirement

Where "R" is an abbreviation for requirement and "n" is a number uniquely assigned to each requirement. The letter "p" denotes the priority of the functional requirement, which is classified as follows:

| | | |
|---|---|---|
| 1 | High | This requirement will be met for the prototype |
| 2 | Medium | This requirement will be met for the prototype if time permits |
| 3 | Low | This requirement will be met for the final production stage |

# 2 System Requirements

## 2.1 System Overview

A high-level system block diagram representing the SolexPRO is given below in Figure 1.

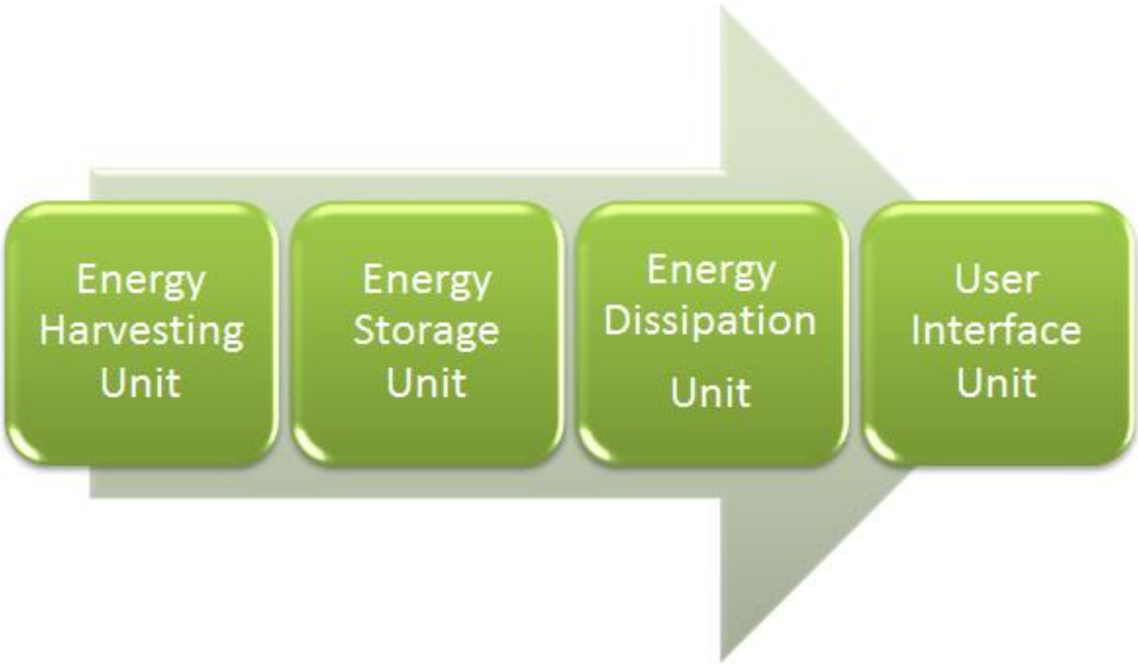


**Figure 1. High-level SolexPRO System Block Diagram**

The SolexPRO consists of four main components which will be designed, implemented and tested separately then further integrated. Due to the time and budget constraints, the proof-of-concept will be built through two development stages.

### 2.1.1 Development Stage I

In this stage the aim is to deliver the core functionality of the products, which is to harvest energy using translational walking movements. To meet this objective, two prototypes named SolexPRO F and SolexPRO E are to be implemented and designed to harvest energy using Fluid Mechanics and Electromagnetism respectively.

At POWER WALKER our goal is optimum safety and comfort for the users, therefore, in order to reduce any potential harm to the users all components are enclosed and secured in the soles of the shoes. In addition, the shoes are coated with high level hydrophobic coating [1] to repel water and make the shoes waterproof.

### 2.1.1.1 SolexPRO E

SolexPRO E uses multiple solenoids with turns ranging between 200-500, 2-4 magnets/solenoids, a battery and a rectifier to convert the kinetic energy from walking into stored reusable electrical energy. The solenoids are placed vertically and horizontally at the end and middle section of the shoe respectively. This is done to ensure maximum energy conversion during a gait. A cross sectional view of vertical solenoid placements are shown in Figure 2.

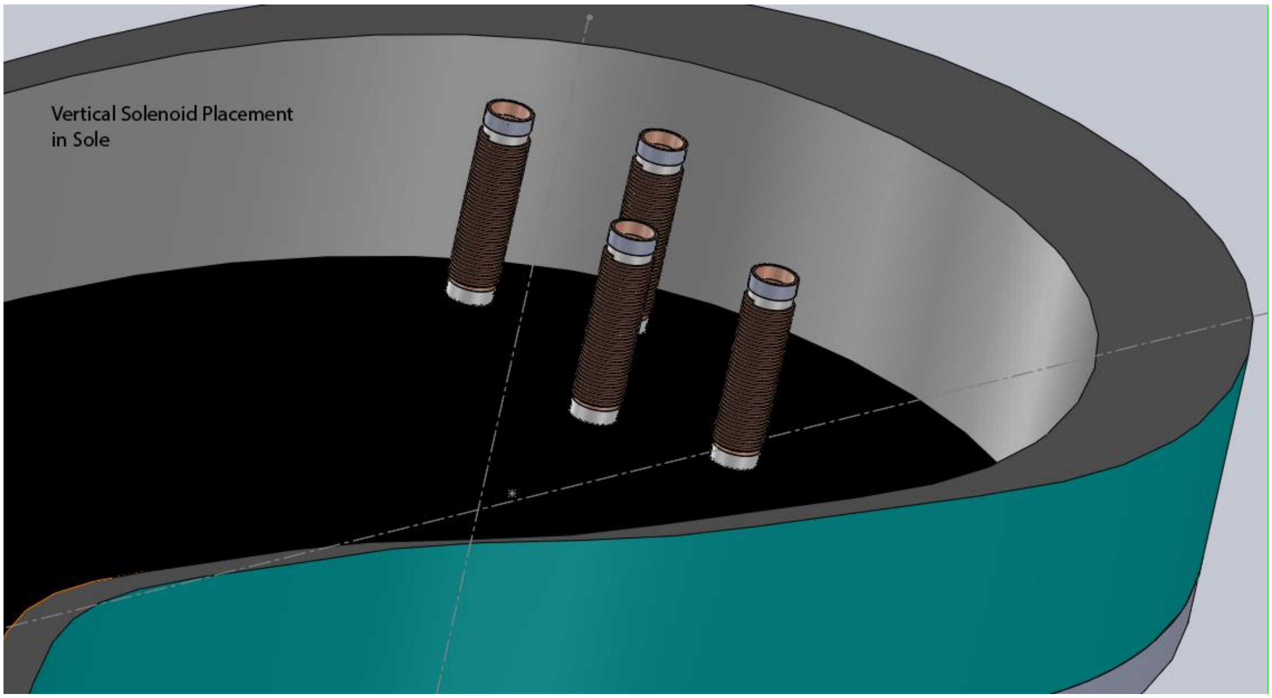


**Figure 2. Cross sectional view of vertical solenoids placements inside the sole**

Referring to figure 2, the solenoids alongside the magnets are positioned in the sole vertically. The magnets travel up and down inside the solenoid in a linear pattern; this displacement generates AC current that is further conserved in a lithium ion battery connected to the solenoids after being transformed into DC current using a rectifier.

### 2.1.1.2 SolexPRO F

SolexPRO F uses a Micro Turbine, a battery, a rectifier and a pump with tubing attached to convert the translational movement to electricity. A cross sectional view Micro-tube and pump relationship is shown in Figure 3.

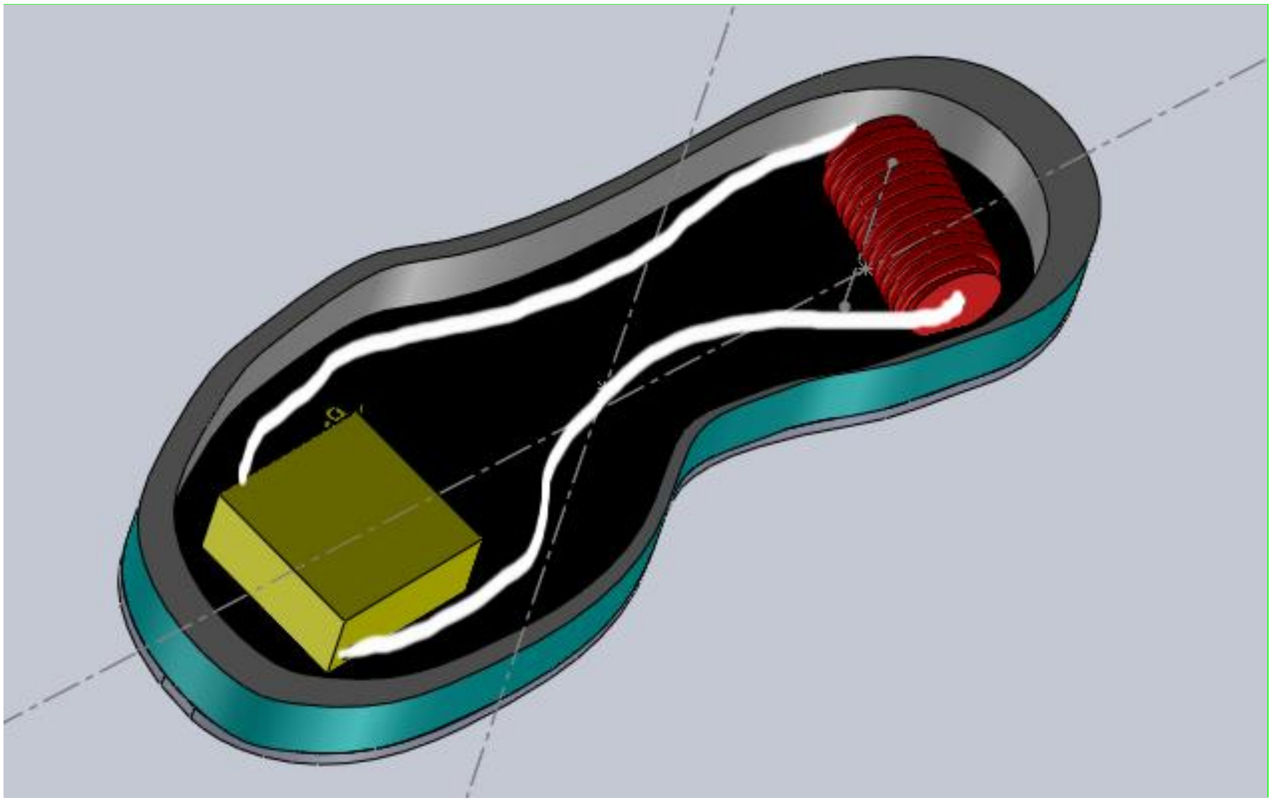

**Figure 3. Cross sectional view of pump and micro turbine attachment in the sole**

As shown in Figure 3, end of two tubes are attached to pumps and the micro turbine. The water travels through the tubes while a pressure is applied on the pump as the user walks. By each flow of water in the system, a small current is generated inside the Micro turbine that is further conserved in a lithium ion battery connected to the Micro Turbine. (not shown in Figure 3).

### 2.1.2 Development Stage II

After completion of Development Stage I, the efficiency, durability, safety and reliability of two prototypes are tested and the one superior in the mentioned categories would be chosen as our final main product.
At this stage of the development, a USB PCB mount port is connected to the battery source for the user output interaction. In addition, to ensure safety of the user and electrical components, rubber casing materials are used around the USP port implementation in the shoe to prevent any possible water leakage in the shoe.

The final product allows the users to charge electronic devices compatible with USB 2.0 via the USB output integrated in the shoe after removing the water resistant USB housing cover.

## 2.2 General Requirements

[R1-1] All components should not intrude insole materials to cause injury to the user
[R2-1] SolexPRO E and F should have USB 2.0 port for external device connection
[R3-1] Each solenoid should produce 0 V to 3.2 V
[R4-1] SolexPRO should provide sufficient charge to a phone to make emergency calls after at least two hours of walking
[R5-2] SolexPRO should be compatible in various weather conditions
[R6-1] SolexPRO must have nominal to no training time to use
[R7-2] SolexPRO must be aesthetically appealing or neutral
[R8-1] The built cost of SolexPRO should be less than $500 CAD in single production
[R9-2] The built cost of SolexPRO should be less than $200 in mass production
[R10-3] SolexPRO must have a modular design and servicing must be possible by swapping parts
[R11-1] SolexPRO should be non-accessible and hidden from the user

## 2.3 Physical Requirements

[R12-2] Weight of each pair of the shoe should not exceed 280g/0.625 lbs [2]
[R13-1] Shoe Material should be durable, flexible and elastic
[R14-1] SolexPRO should be waterproof
[R15-1] Water should not leak from tubes
[R16-1] Solenoid should not damage the housing
[R17-2] SolexPRO power harnessing system should not make any noise
[R18-2] SolexPRO electronics circuitry must not have loose wires
[R19-1] The device must be balanced when equipped
[R20-1] SolexPRO must not be cumbersome to the user when equipped
[R21-2] SolexPRO must be reasonably comfortable when equipped
[R22-1] SolexPRO must be able to withstand 250 lbs [3] in total weight in the initial development stage
[R23-2] SolexPRO must be able to withstand 500 lbs in total weight in the final development stage
[R24-1] The assembly of SolexPRO harnessing system must not fall apart due to the vibration and impact generated at human walking speed
[R25-2] The assembly of SolexPRO shall withstand impacts from collisions occurring at twice the human walking speed
[R26-2] The assembly of SolexPRO shall withstand a free fall from 2.0m

## 2.4 Electrical Requirements

[R27-1] Circuit should be able to produce 3.7- 5V and 1A [3]
[R28-2] SolexPRO should have minimum power wastage due to internal electrical components
[R29-1] There should be no chemical leakage from battery
[R30-1] The battery should not explode
[R31-1] Electrical components should be waterproof and secured in a housing
[R32-1] Safety fuse implementation in case of short circuit

## 2.5 Environmental Requirements

[R33-1] Operating temperature: 0° to 45° C (32° to 113° F) [5]
[R34-1] Storage temperature: –25° to 45° C (–13° to 113° F) [5]
[R35-1] Relative humidity: 0% to 90% non-condensing [5]
[R36-3] Operating altitude: tested up to 1000 m (3,300 feet) [5]
[R37-3] Maximum storage altitude: 4500 m (15,000 feet) [5]

## 2.6 Standards and Safety Requirements

[R38-1] The device must be electrically insulated from the user
[R39-1] Contents of the battery must be sealed
[R40-1] The electronic components must not create any electrical discharge or sparks
[R41-1] SolexPRO shall conform to CSA/UL 60950-1 standards [4]
[R42-1] Lithium battery should be resistant to temperature changes

## 2.7 Reliability and Durability

[R43-1] SolexPRO should be durable
[R44-3] SolexPRO energy harvesting components should be accessible for service and maintenance
[R45-2] SolexPRO should not have an excessive heat dissipation that might harm the user
[R46-2] The Tubing used in SolexPRO should be durable and leak-proof
[R47-2] EMF produced by solenoids should be within ICNIRP standards limits of 0-5 GHz [6]

# 3 Energy Harvesting Unit (EHU) Requirements

## 3.1 General Requirements

| | |
|---|---|
| [R48-2] | The housing encapsulating all the electronic components should be able to withstand up to 500 lbs of user weight |
| [R49-1] | EHU encasements should be waterproof and durable |
| [R50-2] | EHU encasement should not conduct electricity |

## 3.2 Environmental Requirements

| | |
|---|---|
| [R51-2] | Operating temperature: 0° to 45° C (32° to 113° F) [5] |
| [R52-3] | Operating altitude: tested up to 1000 m (3,300 feet) [5] |

## 3.3 SolexPRO E

### 3.3.1 Physical Requirements

| | |
|---|---|
| [R53-1] | There should be enough solenoids to generate a current of approximately 1A and 5 Volts |
| [R54-1] | Magnets should be able to move freely in the solenoid with least amount of rubbing against the encasement |
| [R55-1] | Distance between solenoids should be enough so the magnetic fields of one solenoid does not interfere with that of other |
| [R56-1] | Number of turns per solenoid should be around 200 - 500 turns |
| [R57-1] | Length of solenoid should be of max length 3- 4cms |

### 3.3.2 Electrical Requirements

| | |
|---|---|
| [R58-1] | Low resistant wires should be used while connecting the electronic components. |
| [R59-1] | Wires should be able handle maximum of 1.5 A [7] |

## 3.4 SolexPRO F

### 3.4.1 Physical Requirements

| | |
|---|---|
| [R61-2] | The tubing should be leak-proof |
| [R62-1] | Tubing should be tightly secured in both ends of Micro Turbine and the pump |
| [R63-2] | Tubing should be flexible and durable |
| [R64-1] | Length of the tubing should be from 16-24inches depending upon the size of the shoe [8] |

### 3.4.2 Electrical Requirements

[R65-1] All the wires connecting the hydro water generator to the battery should be encased and the encasement should be waterproof
[R66-1] Low resistant wires should be used in Micro Turbine
[R67-1] Wires should be able handle maximum of 1.5 A [7]

### 3.4.3 Mechanical Requirements

[R68-1] Water should flow freely in tubes from pump to Micro turbine back and forth

# 4 Energy Storage Unit (ESU) Requirements

The ESU is connected to the EHU and will act as a reservoir to all the energy captured or harvested by the EHU. Furthermore, it provides energy to be used by an external device via the EDU.

## 4.1 General Requirements

[R69-1] The ESU shall be able to store the energy generated by the EHU

## 4.2 Physical Requirements

[R70-2] The ESU and associated wires, connections and ports should be weather resistant and waterproof
[R71-2] The ESU and associated wires, connections and ports shall be durable for daily normal usage and shall not show signs of wear
[R72-1] The ESU should be electronically and environmentally insulated
[R73-1] The ESU should not have excessive heat dissipation
[R74-1] The ESU should be able to withstand 250 lbs of user weight
[R75-2] The ESU should be able to withstand 500 lbs of user weight
[R76-2] The ESU should operate silently when in use
[R77-2] The ESU must not have loose wires

## 4.3 Electrical Requirements

[R78-1] The ESU unit should be able to store up to 5 V and 1.5 mA current to charge a portable device of 1650mAh rating
[R79-1] The ESU should have an automatic safety fuse disconnect in case of current shortage

# 5 Energy Dissipation Unit (EDU) Requirements

The EDU is responsible for allowing an external device to safely utilise the energy stored by the ESU via a UIU.

## 5.1 General Requirements

| | |
|---|---|
| [R80-1] | The EDU should be connectable via a USB port to an external device for charging |

## 5.2 Physical Requirements

| | |
|---|---|
| [R81-2] | The EDU and associated wires, connections and ports shall be weather resistant and waterproof |
| [R82-2] | The EDU and associated wires, connections and ports shall be durable for daily normal usage and shall not show signs of wear |
| [R83-1] | The EDU should be well insulated |
| [R84-1] | The EDU should not have excessive heat dissipation |
| [R85-1] | The EDU should be able to withstand 250 lbs of user weight |
| [R86-2] | The EDU should be able to withstand 500 lbs of user weight |
| [R87-2] | The EDU should operate silently when in use |
| [R88-2] | The EDU must not have loose wires |

## 5.3 Electrical Requirements

| | |
|---|---|
| [R89-1] | The EDU should be able to output up to 5V and 1.5 mA current to charge a portable device of 1650 mAh rating |
| [R90-1] | The ESU should have an automatic safety fuse disconnect in case of current shortage |

# 6 User Interface Unit (UIU) Requirements

The user interface unit shall consist of an USB port, where electrical peripherals may be plugged in. The output from the UIU will be dependent on the outputs from the processing unit.

## 6.1 General Requirements

| | |
|---|---|
| [R91-2] | The primary input will be a USB peripheral that may include, but not limited to, USB charging cables, USB LED light, USB Sensors |
| [R92-3] | UIU will also comprise of a RED LED that will light up when the charge left on the battery falls below a certain percentage |

## 6.2 Usability Requirements

[R93-2] In order for the user to initiate a user-induced power drain, they have to insert the USB peripheral in the USB port

## 6.3 Physical Requirements

[R94-1] This UIU should be easily accessible to the user
[R95-3] UIU should have a slide-up/down waterproof cover to hide the USB port

## 6.4 User Documentation Requirements

[R96-3] User documentation will include both a hard and soft copy user manual written in English, French, Spanish and mandarin.
[R97-2] User documentation will include a website with a general support and troubleshooting information as well as a technical datasheet.
[R98-2] The audience for our user manual is going to be someone with a minimal knowledge of electronic components
[R99-2] A detailed technical troubleshooting guide will be created for technicians and vendors
[R100-1] Customer Support information will be available to consumers through our website

# 7 System Test Plan

Power Walker has developed a series of test procedures to confirm satisfactory performance of the overall and individual parts of the system. The first stage covers performance testing of each individual part of our products and sub products such as solenoids, magnets and etc.
In our prototypes electrical and mechanical components are tested separately prior to product assembly. Mechanical tests are conducted to ensure that a significant current can be produced through walking using the micro-turbine and electromagnetic induction. Electrical test plans are also conducted to ensure individual power consumption of electrical components are meet to maximum efficiency of the overall system.

The second stage of testing involves performance testing of all the components working together to ensure the product behaves and performs as expected and meets standard and safety requirements.

## 7.1 The Solenoids and Magnets

- SOLEX PRO energy harvesting system must harvest substantial amount of current by walking motion
- SOLEX PRO energy harvesting system must not be affected by vibration
- SOLEX PRO energy harvesting system must not have magnetic field cancellation by other solenoid and magnets
- SOLEX PRO energy harvesting system must be concealed from environment to prevent corrosion and possible other interactions
- SOLEX PRO energy harvesting system must not create too much heat
- SOLEX PRO energy harvesting system must not make any noise or cause any kinds of discomfort
- SOLEX PRO energy harvesting system must be protected by the noise created by other electronic components

## 7.2 Micro-Turbine

- SOLEX PRO Micro turbines must harvest substantial amount of current harvested from fluids pumped inside the micro turbine due to walking
- SOLEX PRO Micro turbines must be sealed to insure that fluids don’t leak to other components.
- SOLEX PRO Micro turbines must be placed at a location which does not cause any discomfort on sole of the shoe
- SOLEX PRO Micro turbines must not be affected by vibration
- SOLEX PRO Micro turbines must be concealed from environment to prevent corrosion and possible other interactions

## 7.3 Lithium Ion batteries:

- SOLEX PRO batteries must not create too much heat
- SOLEX PRO batteries must be concealed from environment to prevent corrosion and possible other interactions
- SOLEX PRO batteries must not be affected by vibration

## 7.4 Rectifier

- SOLEX PRO Rectifier must be concealed from environment to prevent corrosion and possible other interactions
- SOLEX PRO Rectifier must be protected by the noise from other electronic components
- SOLEX PRO Rectifier must not be affected by vibration

# 8 Conclusion

POWER WALKER is committed in creating an effective solution to provide renewable and portable energy. Our team is excited to develop the “SolexPRO”, a revolutionary pair of shoes that generates sustainable source of energy by walking and/or running. The functional specifications for the SolexPRO have been presented in this document. The requirements are not absolute and may be modified throughout the completion of the project. Power Walker will use these functional specifications to supply its staff with the necessary information to implement the product.

# 9 References

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