SAM 5000

Shower Automation Machine

Developed by Just Right Showers

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Table of Contents

Executive Summary

This document will provide a detailed description of the SAM 5000 shower management system. First, the motivation behind developing the SAM 5000 as a method of maintaining the shower's temperature at a desired level will be explained. The system's most important functions will be highlighted, and the benefits it will provide for the user will be shown. The system's user interface will be described in detail, along with the intended interactions that the user can have with the system. A high-level overview of the system's function classes and their relationships will be provided. Finally, the structure of our team at Just Right Showers will be provided including a breakdown of the project into sub-sections according to the team members who will be responsible for them.

The Functional Specification section will provide a high-level overview of the goals of the system. It will detail the problems that it will solve for the user, and provide a general description of how the proposed system is supposed to work. This section will also touch on the hardware requirements for the system

The Data Flow section contains detailed breakdown of the system's interaction with external units (sensors, data, gauges, etc.). This section provides the user with the back-end workings of our system, which will be set up and configured during the installation of the system. This section mainly focuses on identifying sources of data required by the system and describing how the system produces output. The output produced by the system depends on the system state, user input and the data it is receiving. It includes the actual, physical state of the shower (temperature and pressure) as well as the visual output on the touch screen display.

The User Manual contains several use cases and instructions on completing such scenarios. Images of the system are provided for users to quickly recognize, adapt to and able to operate the system efficiently. This section examines each screen of the user interface in turn, providing detailed information about what actions are possible in each state. It also describes which actions are not possible and provides error handling information.

The Management Plan contains a detailed breakdown of the SAM 5000 system's proposed features.

1 Functional Specification

1.1 The System: SAM 5000

The SAM 5000 or Shower Automation Machine 5000 is a comprehensive smart shower solution. It is comprised of a touch screen interface inside the shower, a mechanical shower system to turn the shower on/off and modify the temperature via user input to the touch screen, and sensors installed in the hot water heater.

Its main function will be to show the user how much hot water is left. It allows the user to set a shower routine, which turns the shower on / off at specific time intervals during a shower session and sets the temperature. The user can save these routines and temperature preferences. It calculates how much longer the user must wait for a full tank of water, and displays this information.

The SAM 5000 is targeted primarily at multi-person households, though single people with small hot water tanks could also benefit from the information it provides.

The system is targeted at users who need to keep track of how much hot water remains in their hot water tank. This is primarily an issue in households where multiple people are using hot water around the same time, which creates a risk for hot water running out mid-shower. No one likes the water suddenly running cold on them, and the aim is to avoid such an unpleasant situation. To that end, the system provides a warning to the user if the hot water is running low, allowing the user to avoid the unpleasant shock of being frozen.

In tandem with this, the shower system will allow users to set "shower routines", where the water will turn on/off automatically at the chosen times. This service is provided for users who need to conserve hot water, once again, to avoid running out mid-shower. In addition, the hot water conservation will allow the user to save water for the next people who need to shower. The system should not only prevent a cold shower, but allow thoughtful users to save some hot water for their family members or roommates.

Another benefit of shower routines is that users will no longer need to fiddle with the temperature endlessly to get it right; instead, the shower routine sets the temperature to a pre-chosen value using an electromechanical control system.

The SAM 5000 system's objectives are as follows:
- Inform the user of how much hot water is remaining
- Prevent the user from accidentally having a cold shower
- Implement user-defined "shower routines" and preferences like temperature
- Help the user save water for other household members / the environment
- Make the whole showering experience more streamlined and efficient

The system will help users make shower-related decisions by delivering important shower information to them in real-time. It will help the user have a pleasant shower experience by remembering temperature and duration preferences, making the showering experience more streamlined with

fewer interruptions. This also helps users save water, benefiting other members of the household as well as the environment. Finally, the system helps users avoid that most terrible fate of a sudden - and unwanted - cold shower.

Most important features:
- Interactive, information-based touch screen interface.
  Touch screen features: displays remaining "hot water time", percent hot water remaining, temperature, current routine, and current stage.
- Shower routines to automatically adjust water temperature and flow at user defined time intervals.

1.2 System hardware

Since the system will need to control the shower flow and temperature, a control system will need to be in place. For this reason, the system will require installing a new shower. This part of the project will be subcontracted. The shower installed will need to conform to the following:
- actuators to turn the hot and cold water on and off
- a control system to set the shower temperature based on an input temperature.

The touch screen interface will be installed inside the shower, set into the wall. It will be covered in waterproof glass to prevent damage to the internal electronics. A small embedded system will be the basis for the interface, since the system does not require any web connectivity or very demanding computations.
The touch screen will be a resistive touch screen, meaning that it will be less responsive but will still perform when wet. The glass will be treated in order to prevent fogging.
The system will also need to interface with sensors, both in the shower head and in the hot water tank. The hot water tank will have a sensor attached to its outgoing valve to measure water flow. Upon installation, a technician will program it with information about the water tank's capacity and the speed with which it heats the water. Using these parameters, it will monitor the outgoing flow and temperature of the water. This data will be sent to the touch screen's MPU, which will make the calculations necessary to estimate how much hot water remains in the tank (in terms of time). Based on these calculations, the system will display the amount of hot water remaining on the touch screen. The shower head itself should have a simple temperature sensor that can convey temperature information electronically, which will allow the system to display the actual temperature of the water. These sensors, and the wiring required for them to interface with the touch screen microcontroller/embedded system, will be installed when the shower is renovated.
In order to install the SAM 5000, the shower's knob-based system for turning the hot and cold water on and off will need to be removed and replaced with a combined mechanical and electrical system. This system will receive input from the main system and change the flow of water from the hot and cold pipes according to the state (on/off) and temperature instructions it receives. The system will include an emergency shutoff button as a contingency to protect against malfunctions.

In addition, the touch screen interface will need to be installed in the wall of the shower and properly sealed. The shower head will also need to be replaced with an upgraded, sensor-fitted model.

Due to the extensive nature of these renovations, a complete shower replacement will often be desirable. The system will be compatible with most hot water tanks, so replacement should not be necessary.

The precise design of the shower control subsystem, as well as its installation, will be handled by a subcontractor, being outside of the expertise of our team at Just Right Showers Inc.

2 User Manual

2.1 Home screen

The Home screen is the first view the user can see when the system is working. This screen contains the following icons:
1. Login / Current User
2. Water Level Gauge
3. Temperature adjustment Slider
4. Preset Routines (Luxury, Classic, Environment-friendly)
5. Shower Turn On
6. Current Time

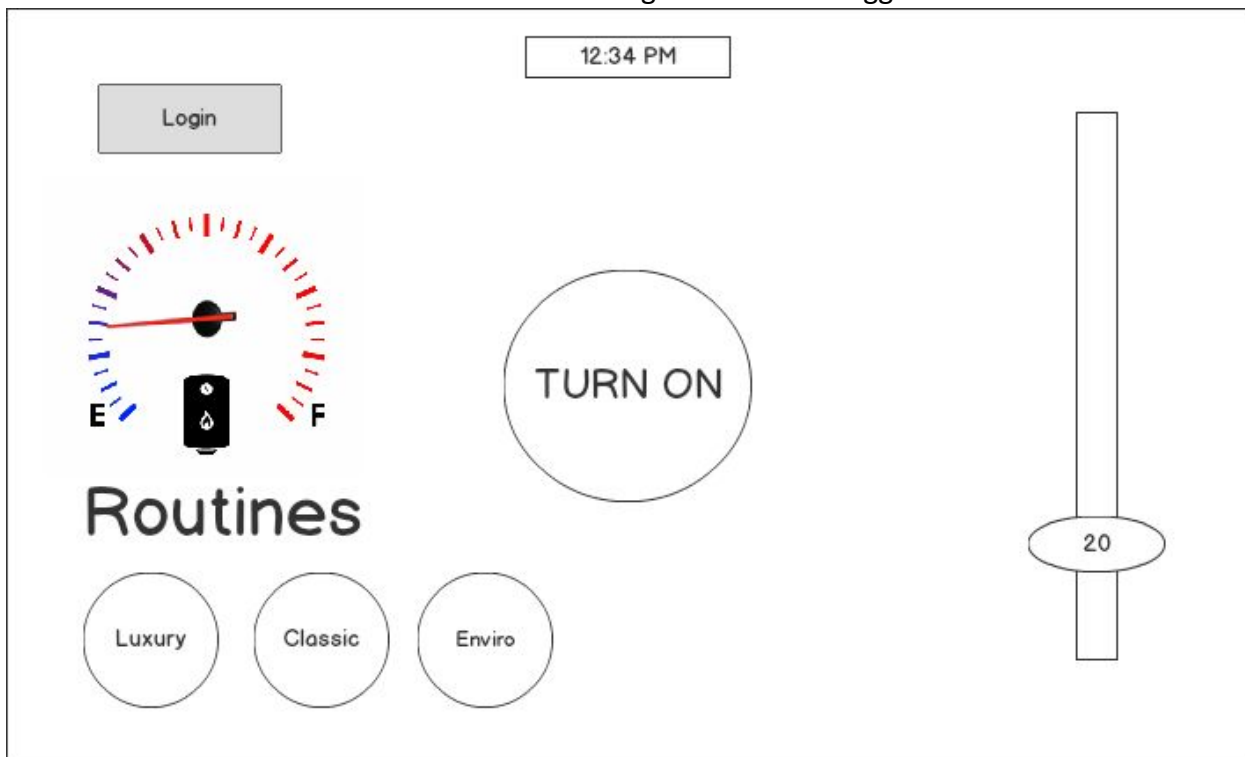Below show is the Home screen of SAM 5000 for guest user and logged in user:
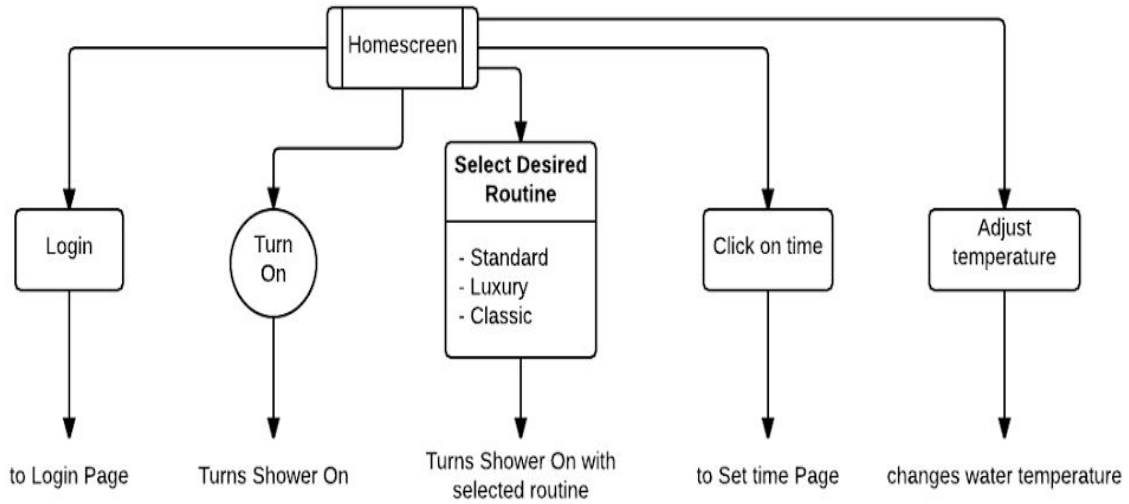

Figure 2.1.1 Homescreen
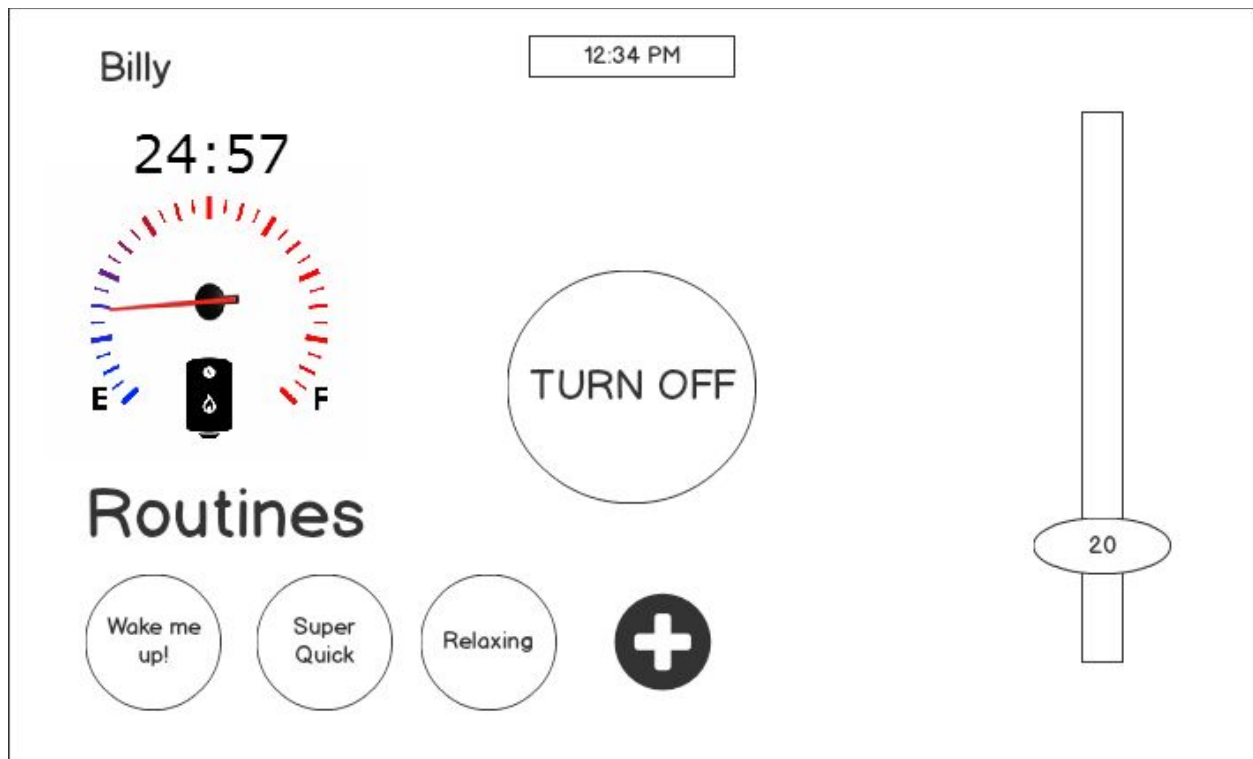
Figure 2.1.2 Homescreen Workflow

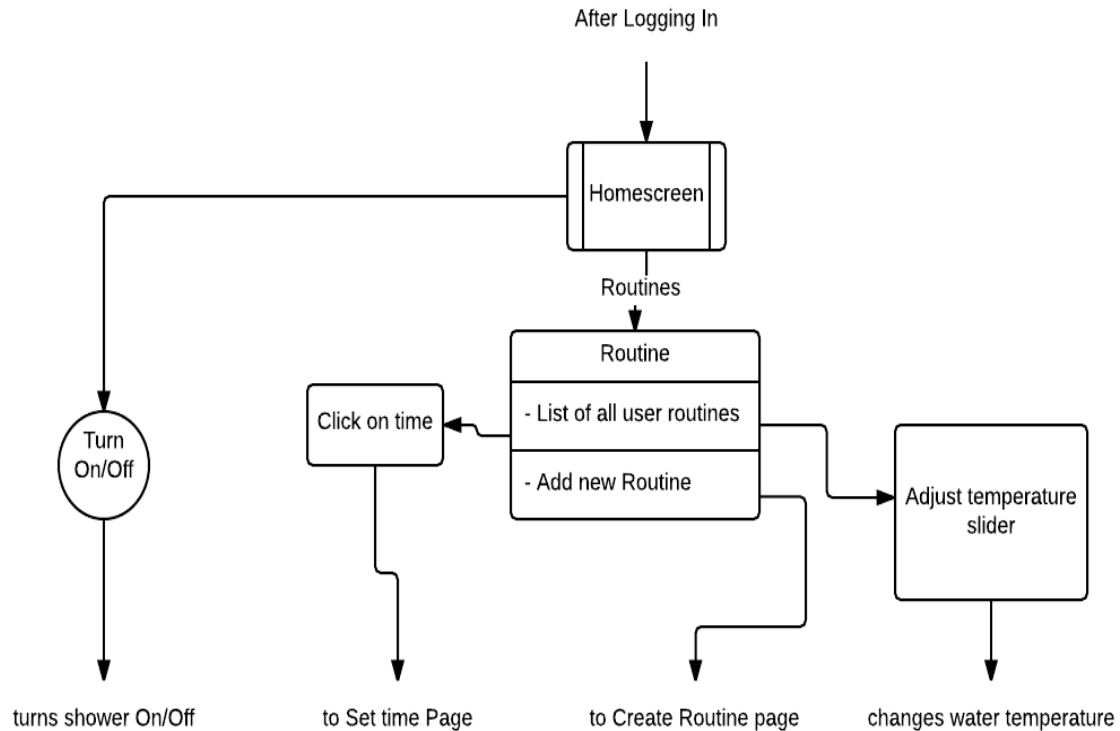**Figure 2.1.3 Homescreen after user login**

Figure 2.1.4 Homescreen after user login workflow

The user will be able to monitor the temperature, hot water level and the timing. Clicking on the User profiles button takes the user to profile screen for adding new user or selecting an existing user. The routines button will navigate the user to pre-programmed routines screen and the settings button is used to change settings of the system. The system will automatically log the user out after it has been turned off for at least twenty seconds.

Expected output:
1. If the user on the system, the system by default works with a pre-configured standard routine. Based on that routine, the hot water level, timing and the water temperature might change.
2. The user needs to turn off the water in order to choose any option because the system locks the user from selecting any other buttons when the water is on.
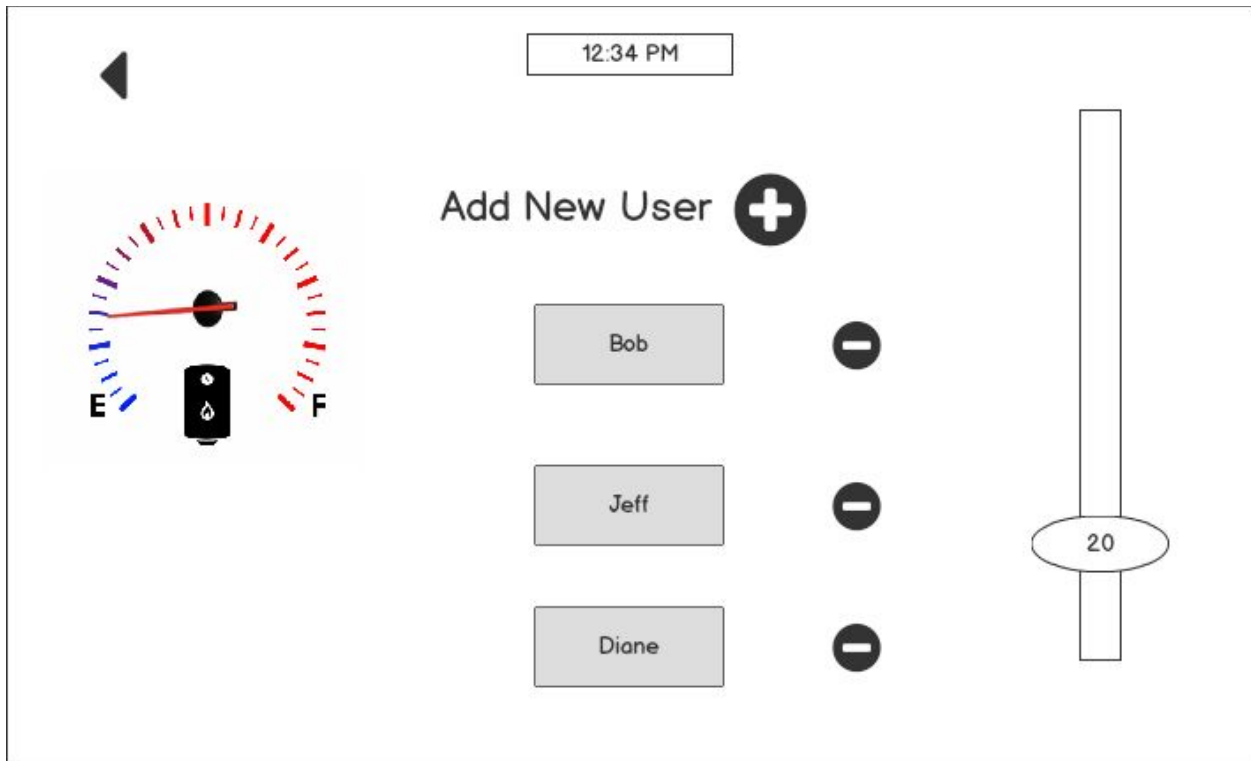
2.2 User profiles screen

Figure 2.2.1 User Profiles

The user can tap the different user profiles available in this screen. If the user wants to create a new user, he can click on the "Add New User" button.
Expected output:
1. Clicking the preferred user profile will prompt the user with a new screen. This screen shows the summary of the user profile which was selected.
2. If the user taps the "Add New User" button, the system navigates to the new user profile screen.
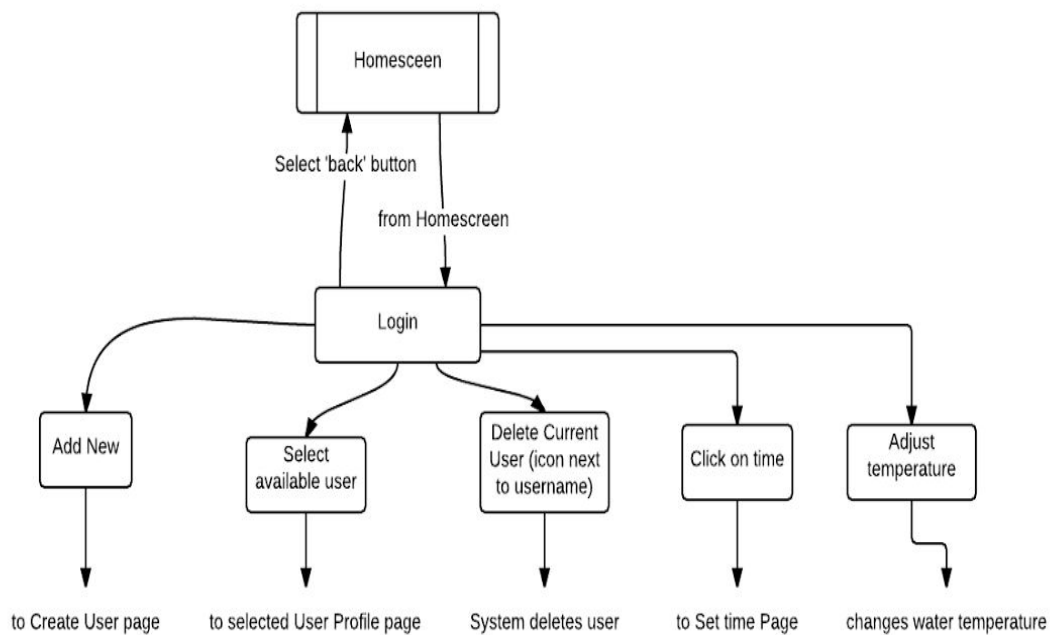3. Clicking the back button would take the user back to the home screen.

Figure 2.2.2 User Profile workflow

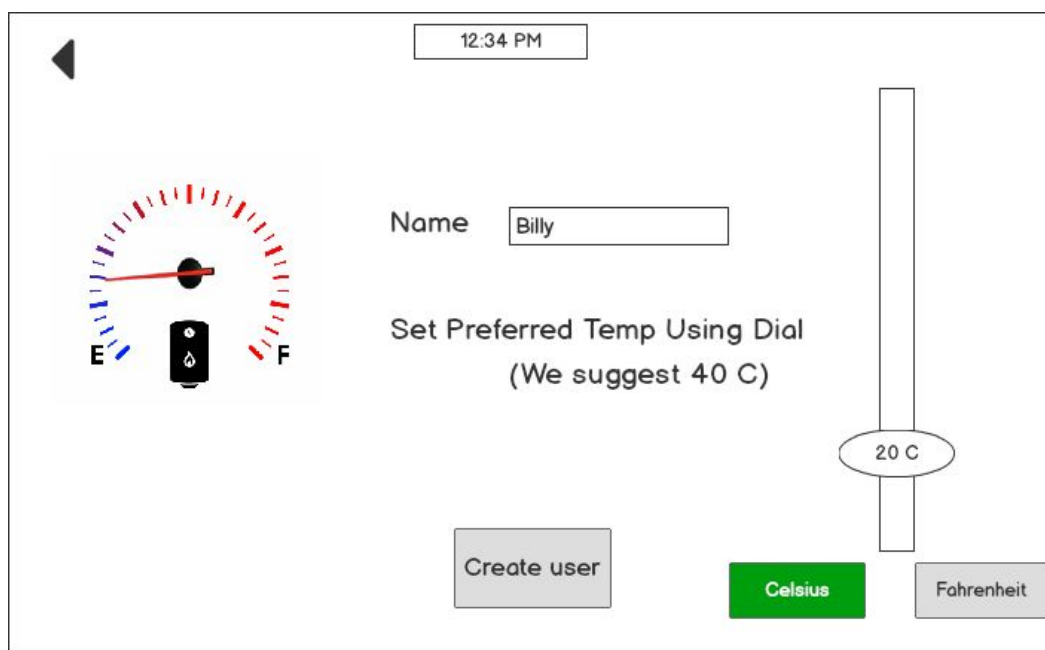## 2.3 New user profile screen

Figure 2.3.1 Create User Profile

Figure 2.3.2 Prompt to create personal routine

Users will be able to create a profile and set their own routines. Creating a profile includes the following steps:

1. The user is required to provide a username that contains only alphanumerical characters. A touch-based keyboard will appear on the screen for this purpose. Input will be limited to 25 characters.
2. The slider lets the user select their preferred temperature. The lower bound on temperature will be set according to the system's sensors, based on the temperature of the cold water pipe. The upper bound will be set to 43 degrees Celsius for safety reasons.
3. There will be a button at the bottom of the form labeled "Create User" and an arrow in the top left corner to cancel the operation, and go to the previous screen.
4. In order to successfully create the user profile, the user needs to tap on "Create User" button. When creating a new user profile, the system the prompts the user to create a new routine. If they press yes, they will be directed to the "Create Routine" screen, and if they click "Skip" they will be directed to the "Home" Screen.
5. There will be two buttons below the slider labeled "Celsius" and "Fahrenheit". It will allow the user to pick between the system displaying the temperature in Celsius or Fahrenheit.

Expected output:

1. If the user taps on "Create User" button, the system checks whether inputs for the username is correct. The system will not allow the user to input more than 25 characters, and will not proceed if the input is empty.

2. When the correct inputs are present in the form, the system prompts the user to create a routine. A dialog box will be shown to request the user for creating the routine. There will be two buttons available to tap. The "skip" button can be tapped to skip the process and the "Yes" button to create a routine.
3. Clicking on the "Yes" button takes the user to the Create Routine page.
4. Clicking the "Skip" button alerts the user that the user profile was created successfully.
5. If there was no input for the temperature, the temperature defaults to 40 degrees Celsius.
6. If the user wishes to cancel the process, tapping the back arrow will return the user to the home screen.
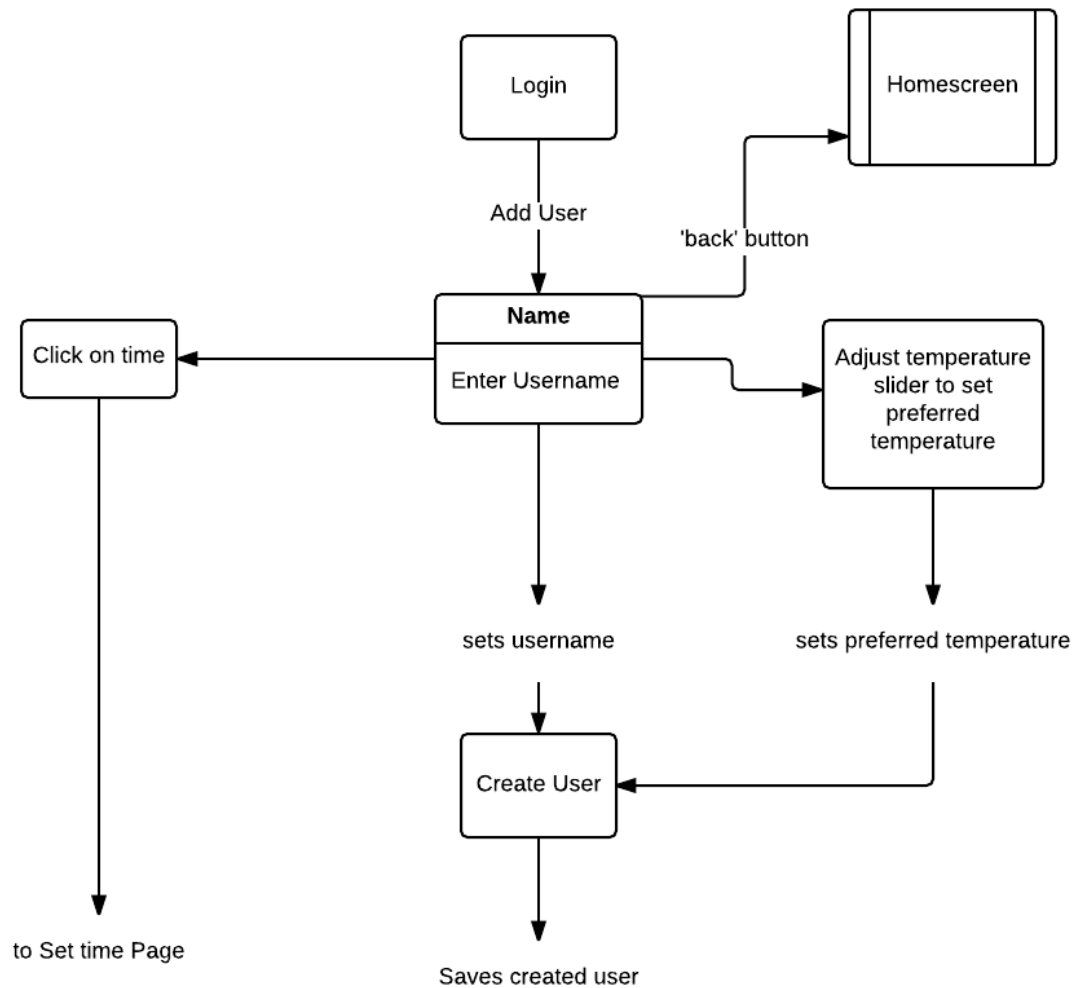
Figure 2.3.3 Create New User workflow

2.4 User profile summary screen
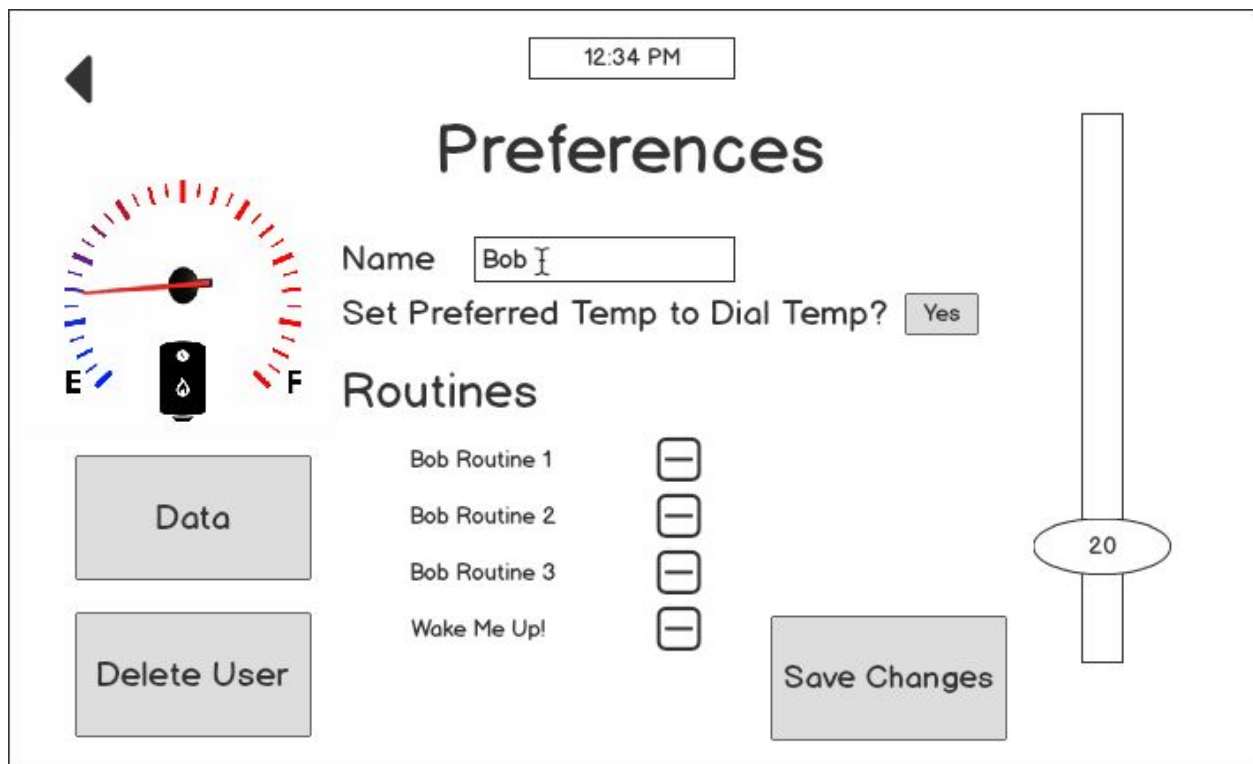

Figure 2.4.1 User Profile

A summary page will be displayed when the user selects a particular user profile. The user is able to get to this screen by clicking on their username in the top left corner if they are logged in. This page contains the following information:

1. The username
2. Temperature that was already set
3. Routines
4. Shower data
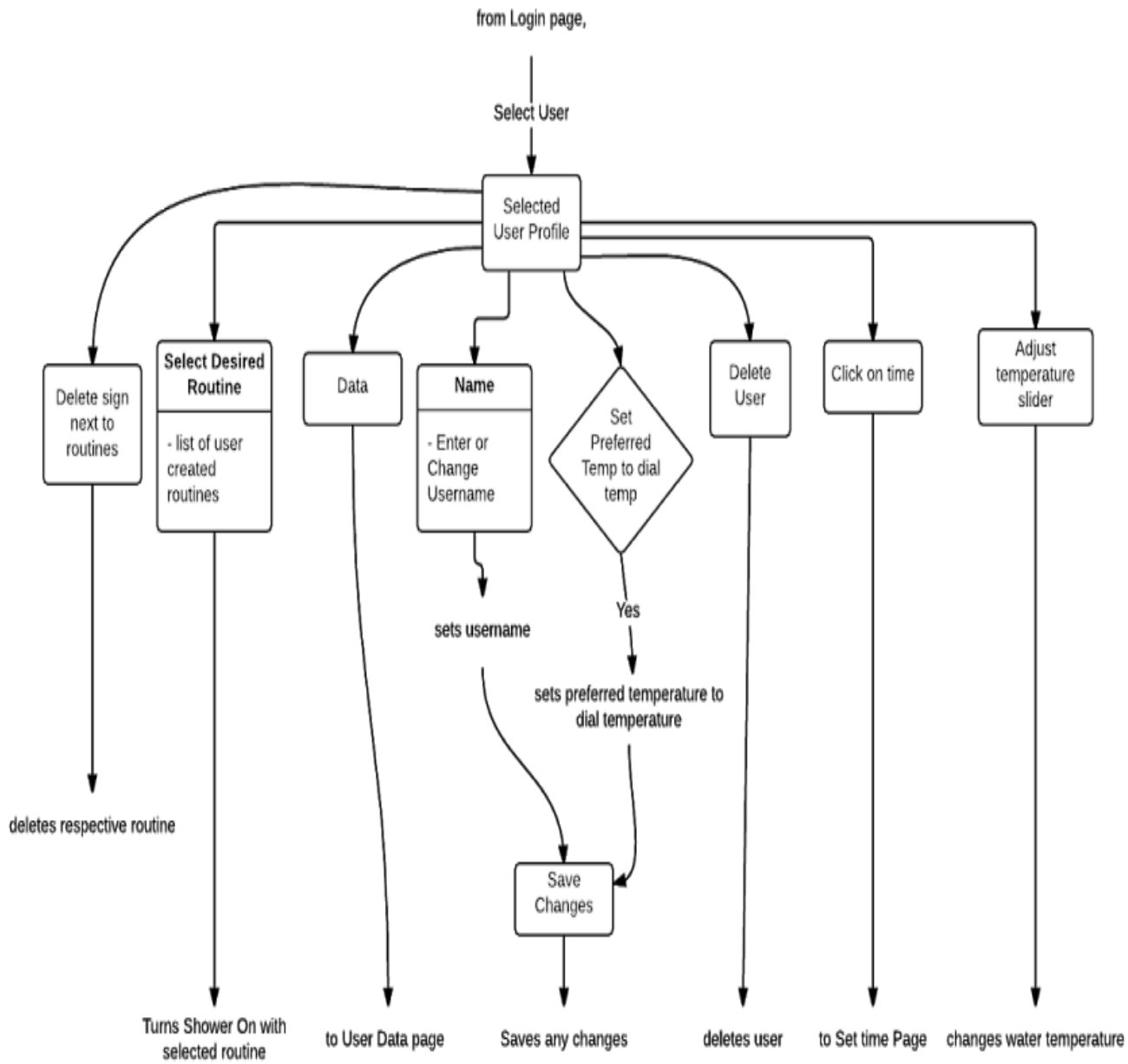
Figure 2.4.2 User Profile workflow
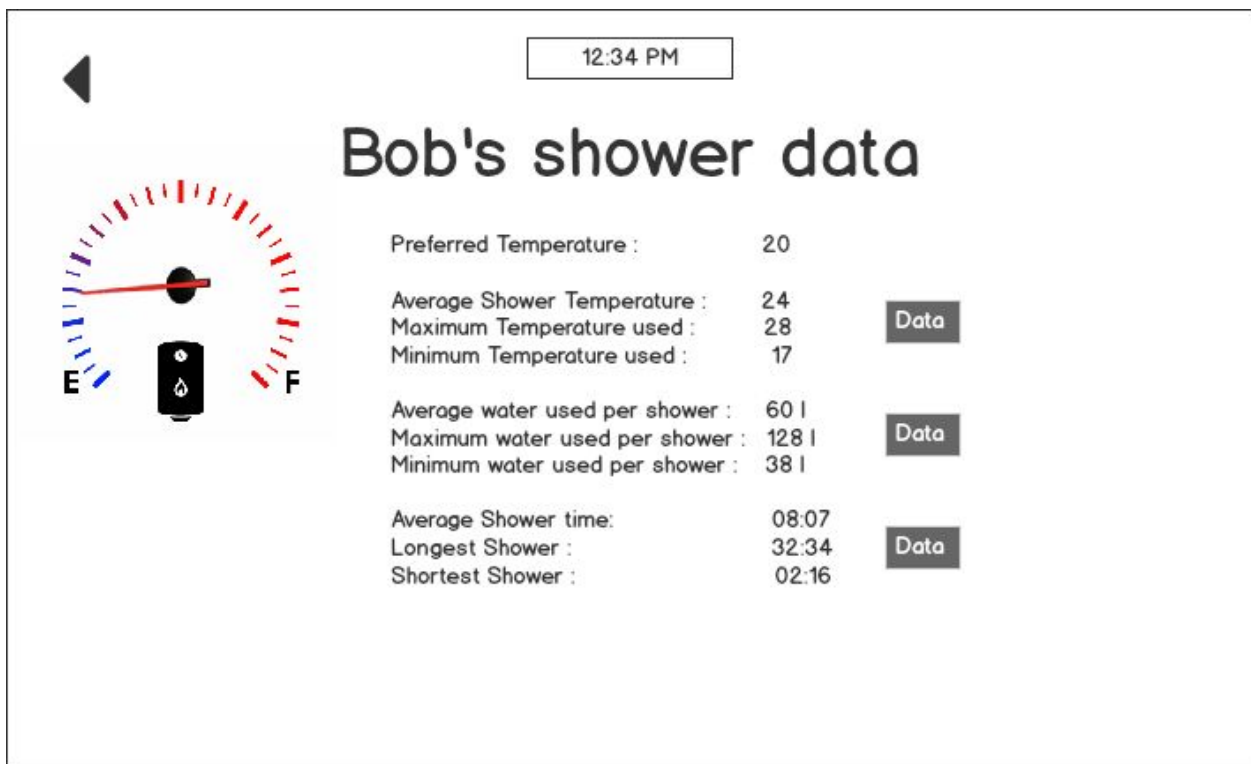
Figure 2.4.1.1 User Data

1. The user can click on the "Data" button in the "User profile summary " page which leads to the above shown page.This page contains the following shower data information:
   a. Temperature Analytics
   b. Water Usage Analytics
   c. Shower Usage Analytics
2. Clicking on the respective "Data" button will show a pop-up window showing the respective analytics. The user needs to click on the Exit button to hide the pop-up window. This window is show below.
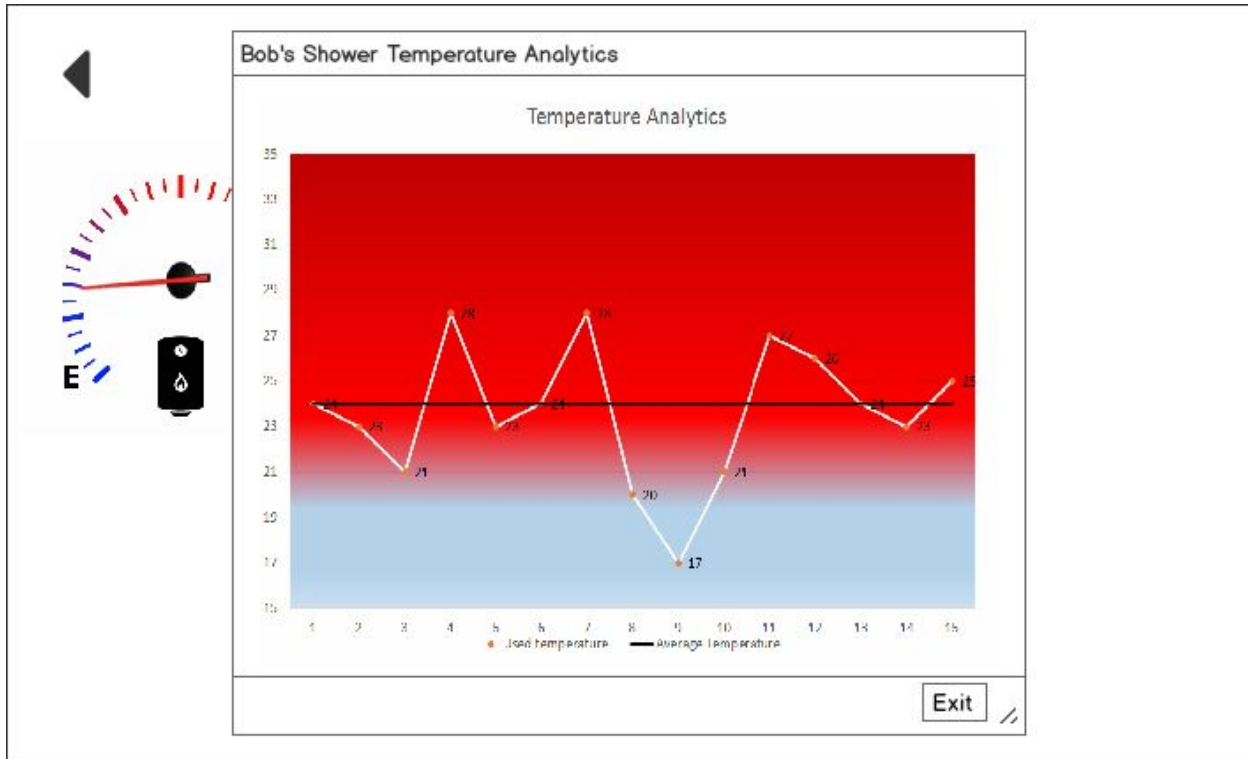
Figure 2.4.1.2 User Data Analytics
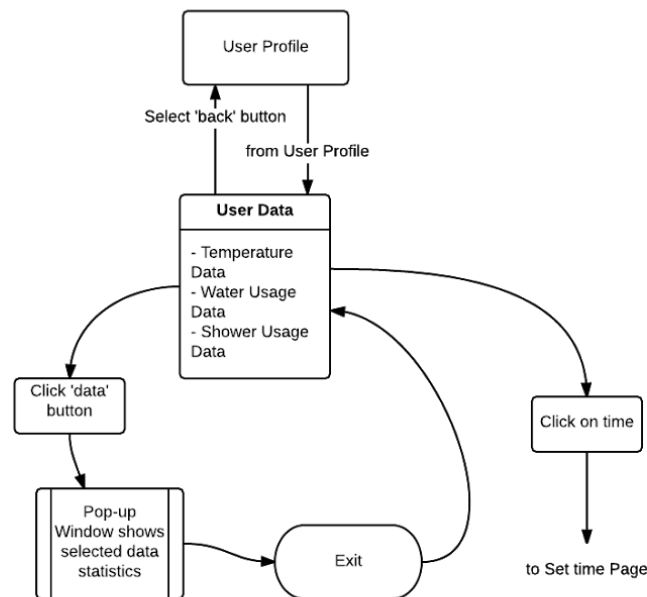
Figure 2.4.1.3 User Data workflow

2.4.2 Preferences

The user can tap on the name if he or she wishes to modify it. The temperature can also be changed at this point. The user has to click on the "Yes " button for the message prompt in order to confirm the temperature change.

When logging in, each user name will have a "-" sign beside them to allow the user to be deleted. The user can also be deleted from his or her "User profile summary" page.

Moreover, there will be a back button to navigate to the "User profile summary screen".

Expected output:

1. If the user taps on the username, the field becomes active and the user can change the username.
2. If the user need to delete one of the routines, the system will prompt a message to confirm the deletion of the routine.
3. If the user is clicks on "Delete" button in the "User profile summary" page, the system prompts a message to confirm the deletion. Once the user confirms the deletion, the user will be deleted and the system will navigate to the home screen.
4. Clicking the back button will take the user back to the user profile summary page.
5. Clicking the start shower button would turn on the water and user can shower.

2.5 Create routine

Figure 2.5.1 Create New Routine

Figure 2.5.2 Routine modes description

The user will be able to create a new routine from the home screen. This routine will be associated with their user account, as th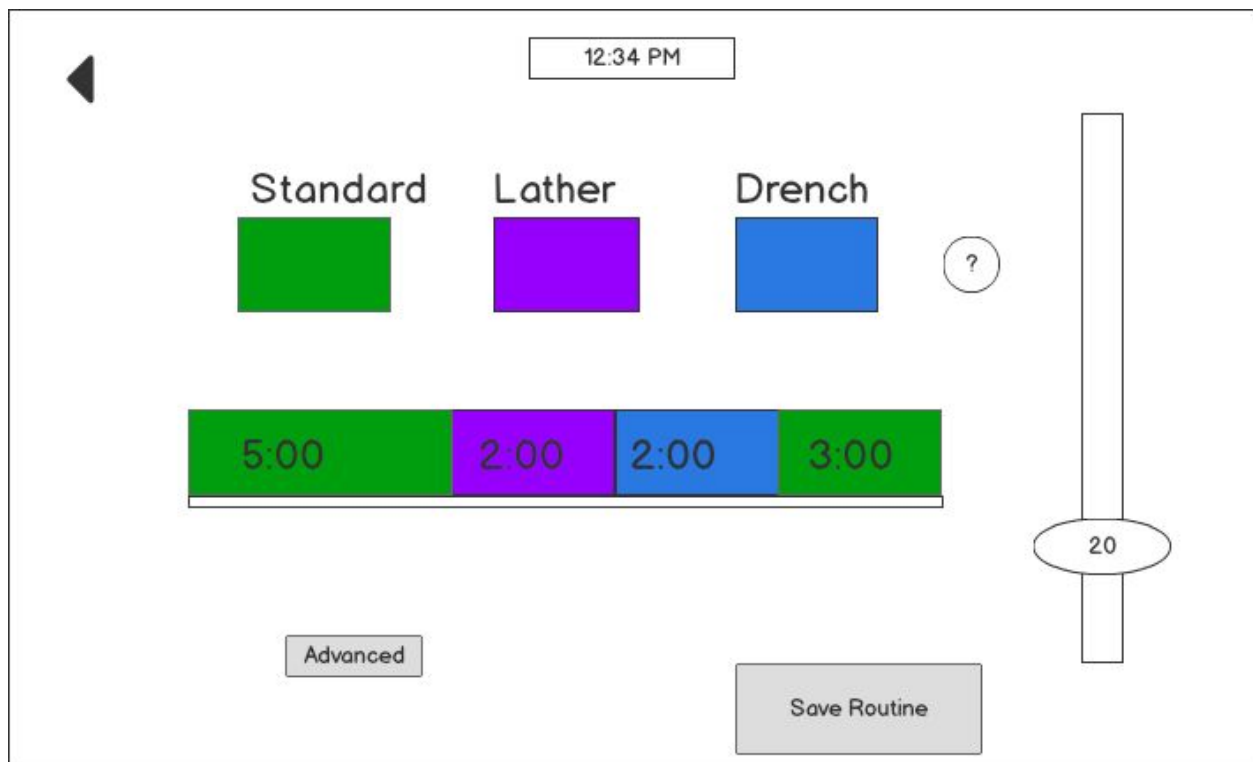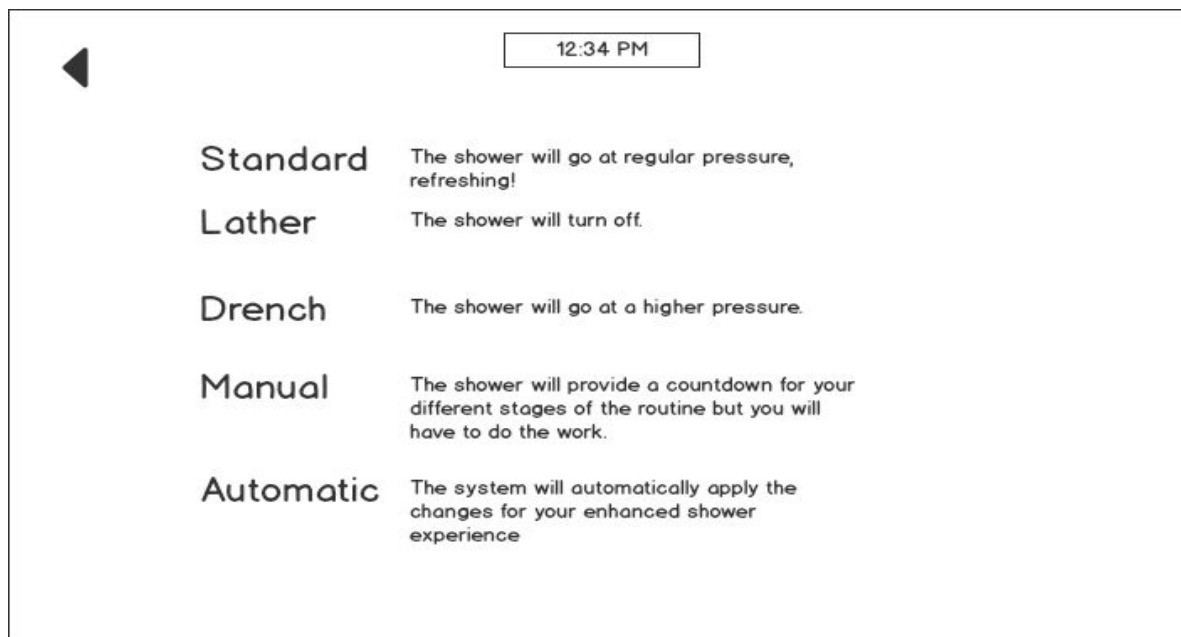ey will need to be logged into a user to be able to create a routine. It will then only be visible when the user that created it is logged in. The user will be able to create a number of stages for the routine to follow.

The number will be capped at a finite value of twenty-five. We chose this number as we don't think most users would use more than this, as well as making sure each stage is visible to the user. Stages will appear as rectangular objects in a sequence and will be executed in order from left to right. They will be differentiated by colour.

For each stage, the state of the shower can be set by the user: the state of the shower, the temperature, and the duration of this stage.

By state of the shower, we mean on/off and the pressure. This is defined by three states: lather (the shower is off), normal (lower pressure option) and drench (higher pressure option). In future implementations we would like to add a slider for pressure, but currently there are only these three options.

The default temperature is 40 degrees Celsius, since this is the average shower temperature. If a user has signed in before creating the routine, the default temperature will be the user's default temperature. The default duration of a stage will be one minute but can be adjusted by choosing between the values: 30 seconds, 1 minute, 2 minutes, 3 minutes 5 minutes, and 10 minutes.

The routine can be automatic or notify the user when to manually change the shower state. The routine can be run as automatic or manual.

When an automatic routine is running, the button to turn off the shower will be part of the view. The routine can be interrupted in this way at any time.

Beside the three stages, there is a button with a question mark; this button can be tapped to see descriptions of each shower state and definitions of "manual" vs "automatic".

The user can click the "Save Routine" button to save the routine and complete the process. If the user wishes to make advance changes, he can select the "Advanced" button which takes him to "Advanced options" screen. The advanced options page will allow user to name the routine, and each stage of the routine.

Tapping on "save routine"(in Figure 2.5.1) returns the user to the main screen. The new routine is now available along the bottom of the screen.

Figure 2.5.3 Create Routine Advanced Options

Advanced options allow the user to name different sections of their routine. Again, tapping on "save routine" returns the user to the main screen. The new routine is now available along the bottom of the screen.

Figure 2.5.4 User Profile with available routines

Expected Output:
1. Clicking on the "Save Routine" button will successfully create the routine. If there are wrong inputs provided by the user, an error message will be displayed to correct the error. An error message can occur due to the following reasons:
    1. The total length of the routine exceeds two hours.
2. Additionally, a warning message will be displayed if the routine would require more hot water than is actually available in the tank.
3. The "back" arrow will take the user back to their previous page. If they started creating a routine during the new user creation, they will be returned to the new user page with all of their previous user details intact. If the user started creating this routine from the home screen, they will be taken back to the home screen.
4. When the user taps the "back" arrow, if they have entered information on this screen, a dialog box will appear warning the user that their routine information will be discarded if they leave this page. The user can tap "OK" to proceed, or "Cancel" to return to the routine creation.
5. When the user saves the routine, a new circular button will appear on their home screen with the title of their new created routine. If no title is specified the title will default to the number of the routine. The maximum number of routines the user can create is five.

User Profile with available routines workflow representation of this screen is shown in Figure 2.1.4 in Section 2.1 of the report.
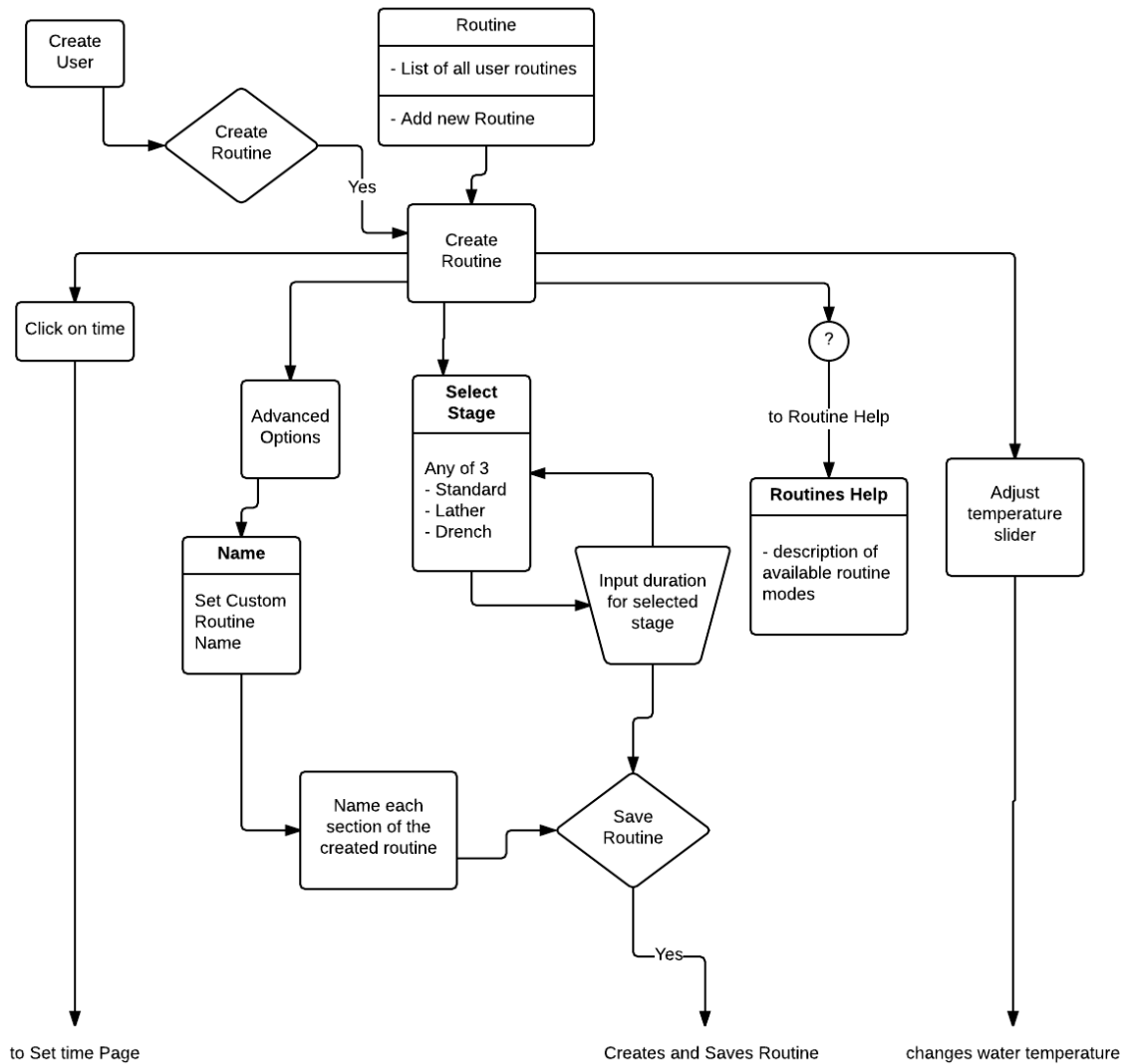
Figure 2.5.5 Create Routine workflow

2.6 Shower screen

When the user starts showering, the shower page is shown by the system. The user will be able to monitor the following information during shower:
1. The username
2. The hot water level that is available in the tank(percentage).
3. Time left until the hot water runs out
4. If a routine is in progress, it is shown as a progress bar.
5. The current temperature of the water dispensed from the outlet.
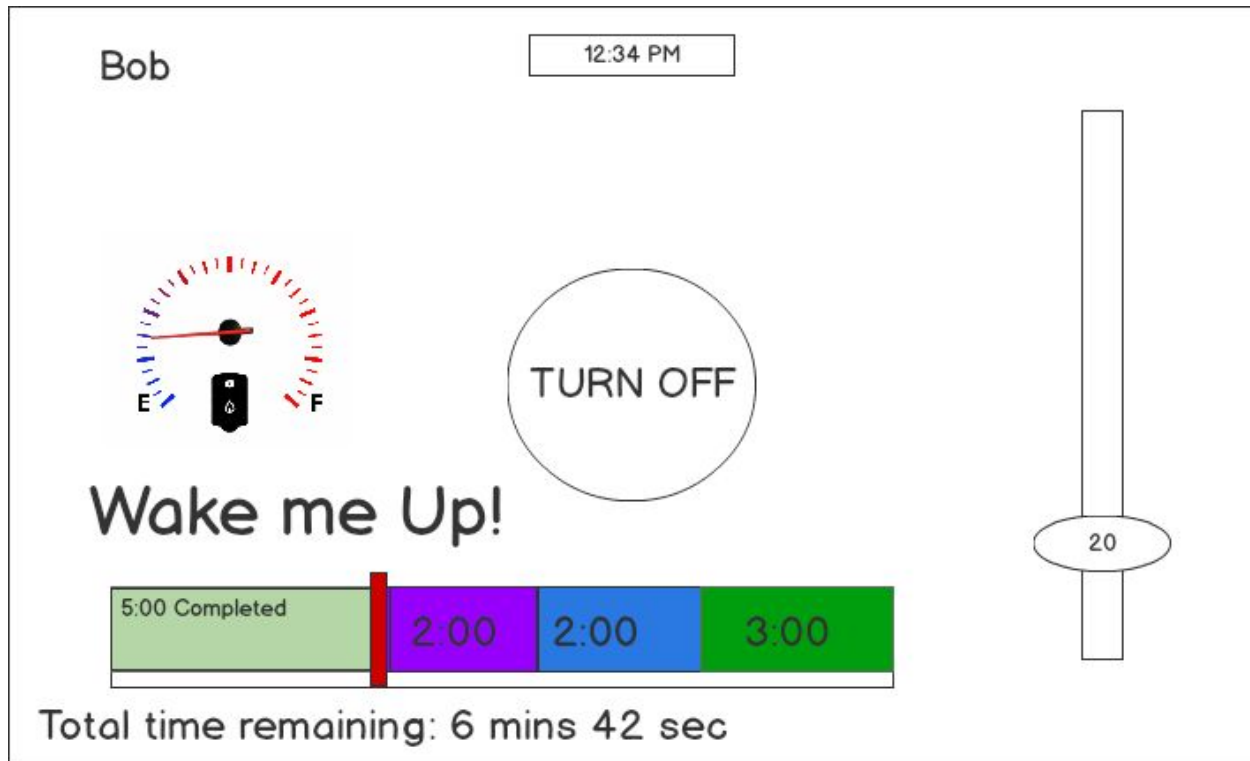
Figure 2.6.1 Shower On screen

Additionally, the user will be able to control the water by turning on/off during shower. This can be done by switching the on/off button available in this screen.

A button is available to exit the user from the system. The user will be able to tap on this button when the shower is completely done or in the middle of the shower.

Expected output:
1. If the user has selected the manual shower mode, the system will notify the user to proceed to the different shower steps sequentially. A pop-up message appears and the user needs to press the "Yes" button to proceed to the next step.
2. Automatic shower progress is fully controlled by the system. Therefore, the user does not need to control the water.
3. Clicking the exit button will make the user the exit the profile and go the home screen. The statistics will be saved accordingly.
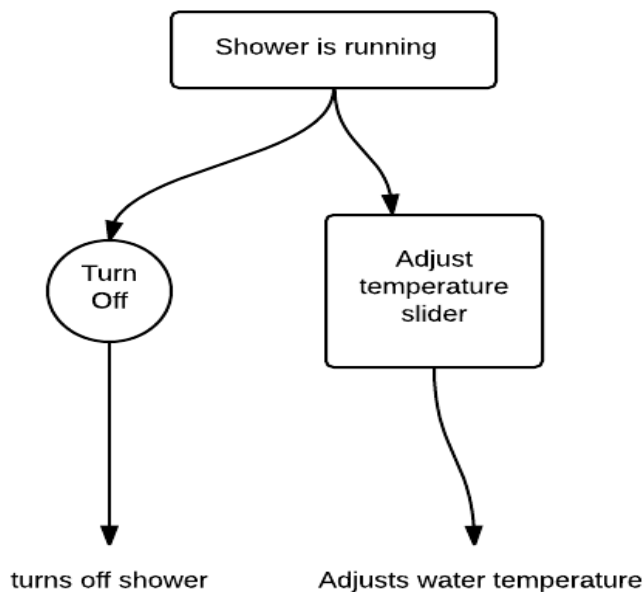
Figure 2.6.2 Shower On Workflow

2.7 Pre-programmed routines

The pre-programmed routines will be available in the bottom right corner of the home screen, before the user logs in. The intended use of the pre-programmed routines are for guest use (users who do not have an account) and to let new users try out the functionality of an automatic shower routine without having to create one.

The pre-programmed shower routines will be named:
- Environment-friendly (Enviro) - minimal water use option, aims to conserve water
- Classic - in between the enviro and luxury options
- Luxury - extended shower option

Each of the pre-programmed routines are shown below, as they will appear when running in the shower interface.

Expected output:
1. Once the user selects one of these buttons, he is taken back to the Home screen with the pre-set option that he selected.
2. Once he is in the home screen, he can turn on the water for shower.
3. The user can only select one button

2.8 Set Time
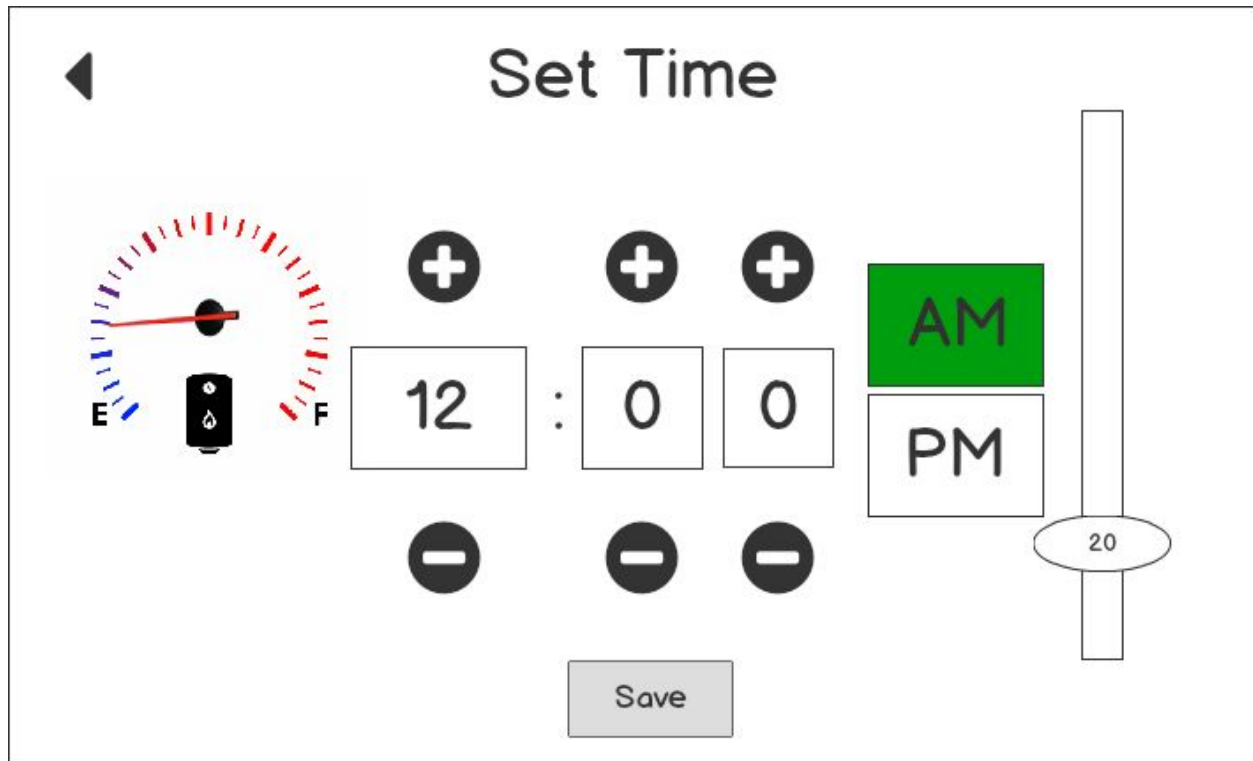
Figure 2.8.1 Adjust Time

The user will have the option to manually change the time at any time by clicking on the current time. The user will change the time by clicking on either a plus or minus button to increase or decrease the number respectively.

- The first box will allow the user to choose between the numbers 0 - 12
- The second box will allow the user to choose between 0-5
- The third box will allow the user to choose between 0-9

The user will also have the option to choose between AM and PM. Once the user presses one, the background of the box will change to the color green - indicating which one is in use.

The user will save the time by pressing on the "Save" button, which is located at the bottom middle of the screen.

When the time is changed, it will be changed for the system, not for a specific user profile. The user will have to update the system for events like time-zone change, or daylight savings time, as the system will not do this automatically.

Expected Output:

1. The user selects the number in each box, corresponding to the current time.
2. The user selects between AM or PM
3. The system's time has been changed to the time set by the user
4. The user presses the "Save" button
5. The user is sent back to the home screen.
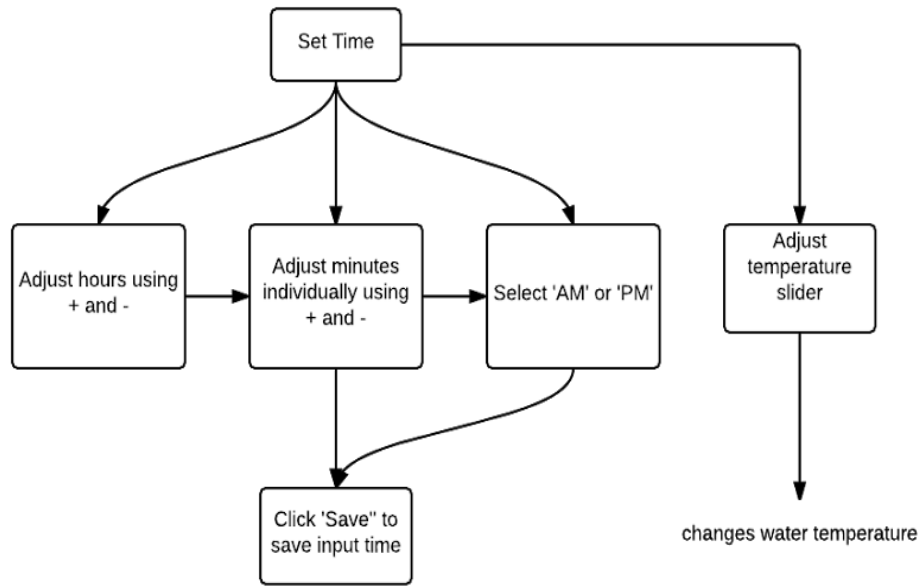
Figure 2.8.2 Adjust Time workflow

3 Pseudocode

The following section provides a description of each object in the system by using pseudo java code to describe the objects, their data and methods. In addition, some example code snippets are provided to demonstrate how the system will handle certain situations.
A state machine diagram describing the system's responses to input will also be included.

3.1 Object Classes

```
User    {
        Data:
        Username
        Default_temperature
        Routines
        Past shower duration data

        Methods:
        getName()
        setName(name)
        getTemp()
        setTemp(temperature)
        getRoutine(routine id) - returns the specified shower routine
        showRoutines() - displays each of this user's routines on the screen
        displayData() - displays this user's shower analytics data
        delete()

        Display(touch_screen) - depending on the current screen, displays some information.
        Example: on the login page, will modify the touch_screen object to
                a) display the user name
                b) make the user name interactive (login if it is tapped)

        Constructor:
        User(name, temp){
                Username = name;
                Default_temperature = temp;
        }

}

Default_user {
        Data:
        Username: none (static)
```

Default_temperature = 40 degrees C (static)
Default routines: environmental, classic, luxury (static)

Methods:
getRoutine(routine id) - returns the specified routine
showRoutines() - displays each of this user's routines on the screen
display(touch_screen)
}

showerState {
Data:
Temperature
Pressure

Methods:
getTemp()
setTemp(temperature)
getPressure()
setPressure(pressure)
sendState() - transmits the shower state information to the shower control system

Constructor:
showerState(temperature, pressure){
this.temperature = temperature;
this.pressure = pressure;
}
}

Routine {
Data:
routine_name
Shower_state[] shower_state_array;
Double[] duration_array;

Methods:
display() - displays this routine on the screen (called by user.showRoutines())
getNextState() - returns the next state in this routine.
add(showerState) - adds a new shower state to the shower_state_array
setTime(showerState, time) - finds the showerState in the shower_state_array,
then updates the corresponding time in duration_array
Time is in seconds.
}

```
Shower {
        Data:
        Current_showerState
        Current_user
        Drench_pressure = 75.0; // percentage of maximum pressure, allowing room for
                                            temperature control
        Standard_pressure = 50.0; // percentage of maximum pressure
        The values given for drench_pressure and standard_pressure are suggestions.
        These values can be tweaked by a technician at the time of installation for customer
        satisfaction. In the minimum viable product, these values cannot be modified by the user;
        however, in future implementations pressure will be user-selected with a slider (similar to the
        temperature slider).

        Static Off_pressure = 0.0;

        Methods:
        login(user){
                current_user= user;
                current_showerState.setTemp(user.getTemp());
        }

        update(){
                current_showerState.sendstate();
        } This method is called periodically to update the shower control system.

        changeState(temperature, pressure){
                current_showerState.setTemp(temperature);
                current_showerState.setPressure(pressure);
        } Pressure = 0 turns the shower off, so this is used for the on/off functionality

        on(){
                changeState(current_user.getTemp(), standard_pressure);
        }

        off(){
                changeState(current_showerState.getTemp(), off_pressure);
        }

        getRealTemperature() - reads the shower head sensor
```

Determines the actual temperature of the shower to display

display(touch_screen)
What the shower object displays:
The temperature slider position and value - value is from current showerState.getTemp()
The shower on/off button
}

Water_tank {
    Data:
    water_level
    time_remaining
    Static final Tank_heating_rate - established
    Static final Tank_size

    Methods:
    Update_level(tank sensor input) - called every second, it calculates the rate of hot water leaving the tank based on the hot water tank sensor input and updates the value
    Update_time(tank sensor input)

    Display_level(touch_screen)
    Displa_time(touch_screen)
}

touch_screen {
    Data:
    Interactivity matrix - contains the touch screen interactivity information.
    Each location lists if it is interactive, and points to the action to take if it is touched.
    Pixel state matrix - contains the visual information for the display
    These data structures are modified by the other objects in the system.

    Screen ID - this identifies which screen is being displayed right now.
    Example: login, main screen, user preferences etc.
    Based on the screen ID, objects know whether to write their locations to the screen or not.

    Methods:
    getInput() - gets user input to the screen
    This method is called whenever the screen is touched.
    It compares the touch location to its internal interactivity matrix.
    Based on the result, the system takes the appropriate action.

    Constructor:
    Touch Screen(ID){

```
            New Interactivity matrix();
            New Pixel state matrix();
            Screen ID = ID;

            switch(ID):
            // take some actions depending on the screen ID
            // this handles cases where interactive elements don't belong to an object
            // for example: login button
        }
}
```

3.2 Example code snippets

Actions taken by the user that result in input to the system are described here in black text, and they are numbered. The behaviour of the system in response to the input is described in blue.

Action: Logging in

1. User touches the login button
touch_screen.getInput();
Result: the coordinates touched match the touch_screen object's interactivity matrix; the associated action at this point is "change screens - display users"
Touch_screen = new touch_screen(ID = "login_page");
touch_screen.screenUpdate();
When screenUpdate() is called on this touch screen object, these display functions are called:
- For each user in the system, user.display()

2. A given username is pressed
touch_screen.getInput();
Result: the coordinates touched match the touch_screen object's interactivity matrix.
The action at this point is to call the method:
shower.login(user);
Touch_screen = new touch_screen(ID = "main_page_user_<username>");
touchs_screen.screenUpdate();

Action: changing the shower temperature

1. Temperature slider is moved by the user
touch_screen.getInput();
Resulting method call: shower.changeState(new_temperature, unchanged_pressure)
shower.Display() - shows the new value and position of the temperature
The new temperature is now being sent periodically to the shower control system.
The actual temperature will adjust to match the chosen temperature within 3 seconds.

Action: turning on the shower

1. User taps the On button
touch_screen.getInput();
Resulting method call: shower.on();

Action: creating a shower routine

1. User taps the plus button next to the list of routines
touch_screen.getInput();
Resul: touch_screen = new touch_screen(ID = "routine creation");
        touch_screen.screenUpdate();

2. User taps the square labeled "Standard" to add a stage to the routine
touch_screen.getInput();
Result: new_routine = new Routine();
        new_state = new showerState(default_temperature, standard_pressure)
        new_routine.add(new_state);
        new_routine.setTime(new_state, 60);

3. User changes the duration of the state
touch_screen.getInput();
Result: new_routine.setTime(new_state, user_selected_time);

4. User saves the shower routine
touch_screen.getInput();
Result: Shower.current_user.routine_list.add(new_routine);

3.3 State machine

The state machine diagram below describes the SAM 5000 smart shower system. It shows how the system responds to user input by moving between states, and defines which actions are possible in which states of the smart shower system.

SAM 5000 state machine
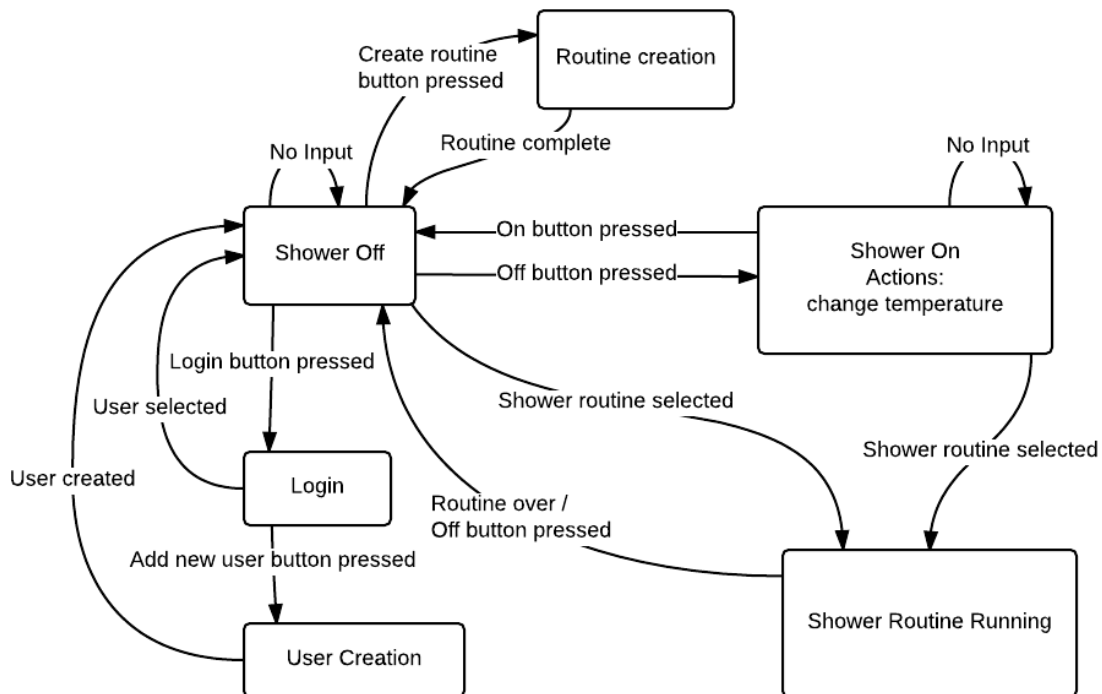
This is a simplified state diagram describing the operation of the SAM 5000 smart shower system. Note that individual stages (e.g. User Creation) can have multiple sub-stages.

4 Data flow

4.1 Data Sources

Temperature sensors
- Hot water pipe (near shower): associated with pipe valve actuator
- Cold water pipe (near shower): associated with pipe valve actuator
- Shower head: measures exit temperature of shower water
- Hot water tank temperature sensor: measures the temperature of the water as it exits the hot water tank

Positional sensors: one in each actuator, records the position of the valve. It gives a value between fully shut and fully open.

Other
- Hot water tank flow sensor: measures the rate of flow of water out of the hot water tank

Touch screen
- User input

4.2 Definitions and Relationships

The system will have to maintain the following data to function correctly. The source of the data is given, along with how it is derived (if applicable). The relationship between data sources and the system's outputs is described in Figure 1-1.

- Amount of hot water remaining in the hot water tank
  This value is maintained as a percentage. When the system is first installed, it is calibrated by the installation technician. The system is given the volume of the hot water tank and the rate at which the water can be heated. This is a function based on the current level of hot water vs. cold water, time, and the power output of the boiler.
  When the system is operating, the rate at which the water is leaving the hot water tank is measured. This data is combined with the rate at which the water is heated and the cold-water temperature of the house (based on the cold water pipe sensor). The result is a running total of the remaining hot water in the tank maintained by the system. The total is dynamically adjusted according to the heating rate and the exit rate of the water.

- Amount of hot water water remaining (time)
  This value is calculated based on the current hot water heater level (see above) and the

current rate of water exiting the heater.

● Current water temperature
This is reported by the sensor in the shower head and displayed to the user.

● Target water temperature
This value is set by the user with the on-screen slider, or by the system itself when a shower routine is running. Most of the time, the current water temperature and the target water temperature will be equal. However, because of the nature of the shower control system, a few seconds of lag time while the shower adjusts to the new temperature should be expected.

● Current user
This value is input by the user when they log in to the system, and cleared when they log out. The current user affects what is displayed on the home screen, including which routines are visible. It also affects other aspects of system state, such as the current temperature.

● Preferred temperature
This value is tied to a specific user and it can vary between users. This value is empty when no user is logged in.

● Default temperature
The default temperature is 40 degrees celsius. This is a system value common across all users, and it fulfils the role of "preferred temperature" whenever that value is empty (for example, when no user is logged in).

● Current routine and current stage
These values are only relevant when a shower routine is running. They are maintained to keep track of the state the shower is supposed to be in at a given point in time. Each stage has an associated duration, shower state (on/off, pressure level) and temperature. The system will keep track of how long each stage has been running for in order to switch to the next stage at the right time. The system will display this information to the user.

● Time of day
This value is set by the user, and maintained by the internal system clock of the MCU.

The following diagram illustrates the relationship between these data sources in the system:
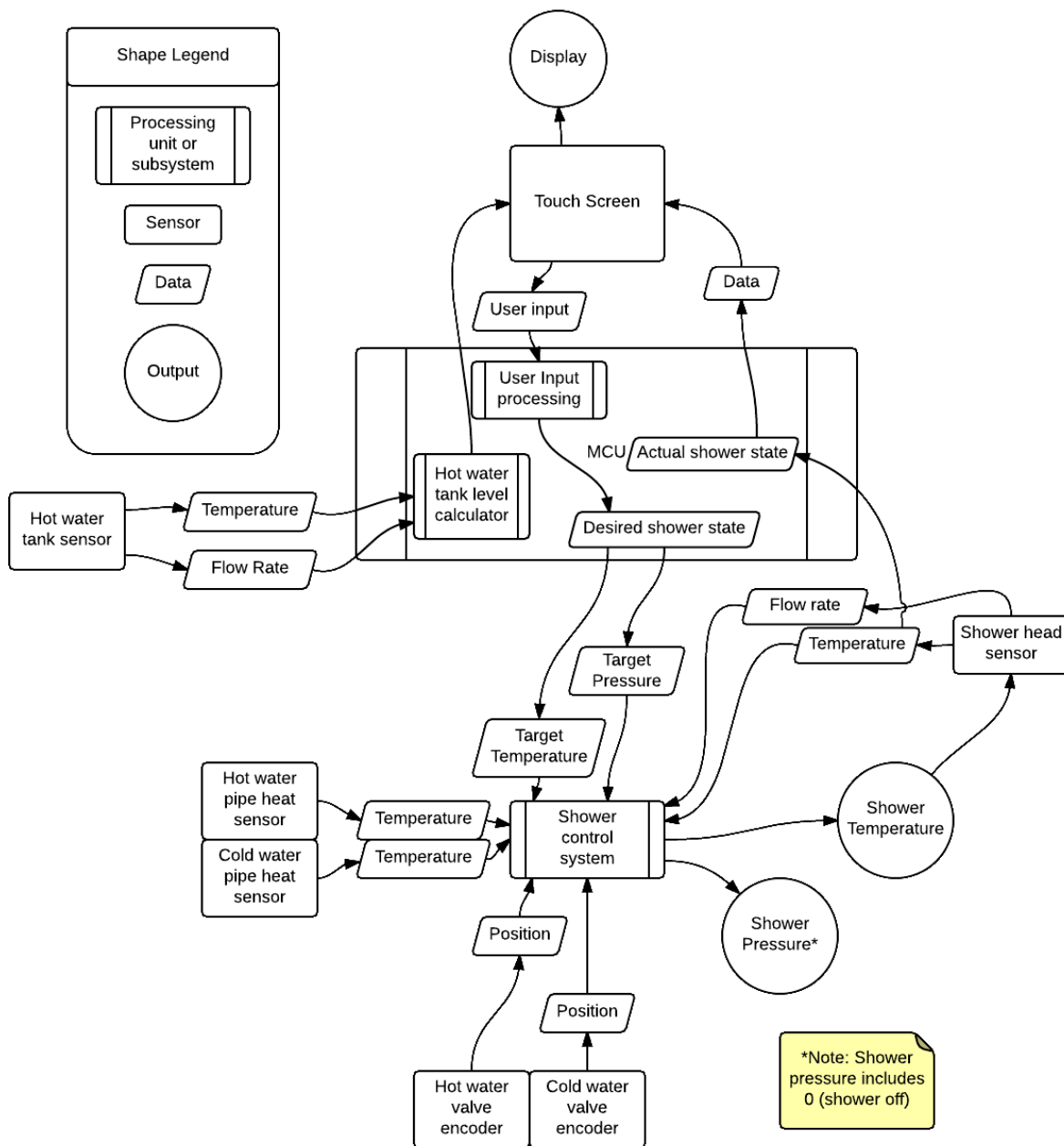
Figure 4.1 Data Flow of SAM 5000

4.3 CRUD table

This table provides an overview of which object classes can be created, read, updated or deleted in the course of which tasks.

	User	**Guest**	**Shower**	**Shower State**	**Routine**	**Water Tank**	**Touch Screen**
Create User	C	-	-	-	-	-	RU
Delete User	D	-	-	-	-	-	RU
Log Into User	U	-	RU	RU	RU	-	RU
Log Out of User	U	-	RU	RU	RU	-	RU
Change Temp	-	-	-	RU	-	RU	RU
Set temp	U	-	RU	RU	-	RU	RU
Create Routine	U	-	-	-	CRU	RU	RU
Delete Routine	U	-	-	-	DU	-	RU
Start Routine	-	-	-	RU	R	R	RU
Change Phase in Routine	-	-	-	RU	R	R	RU
End Routine	-	-	-	RU	-	R	RU
Check Analytics	R	-	-	-	-	R	RU
Set/Change Time	-	-	-	-	-	-	RU
Hot Water Remaining Display	-	-	-	-	-	R	RU

Table 4.2 CRUD Table

5 Management Plan

5.1 Features

- Touch Screen Interface
- Temperature Sensing,Changing
- Pre-programmable shower options
- Amount of Available Hot Water Sensing
- Routine Creator
- Timer
- Shower Data, Analytics

Touch Screen Interface

- Will display User Name of screen if user is logged in or display a "login" button if not
- Will allow client to switch User Profile using touch pad by logging in with username
- Will display temperature of water on screen
- Will allow client to change water temperature using slider
- Will display different pre-programmable shower routines on screen if user not logged in
- Will display user-created routines if user is logged in
- Will allow user to choose a pre-programmable/ user created routine using touch pad
- Will display amount of available hot water on screen; with a scale that slides from red to blue (red indicating lots of available hot water left, blue indicating little)
- Will display amount of time left remaining on shower using a countdown timer

Temperature Sensing and Modifying

- System will be able to sense what current temperature of water is within +/- 1 degree
- System will be able to change temperature

Pre-Set Shower Routines

- System will have three pre-set shower options for users not logged into a user: Enviro, Classic, and Luxury
- Environmental Option will be 5 minutes long at a default temperature of 40 degrees Celsius
- Classic Option will be 8 minutes at set preferred temp at a default temperature of 40 degrees Celsius
- Luxury Option with be 15 minutes at set preferred temp at a default temperature of 40 degrees Celsius

User - Created Shower Routines

- System will allow users to create a showering program by altering preferred temperature and duration of three different showering modes: Standard, Lather and Drench
    - Standard mode: water pressure of 55 psi
    - Drench Mode: water pressure of 65 psi
    - Later Mode: water turned off

Amount of Available Hot Water Sensing

- System will keep track of how much water is available in the hot water tank
- System will use the amount of hot water remaining and the current rate of hot water use to calculate how much time is left before the hot water runs out

Shower Data, Analytics

- System will calculate time of duration for a particular user, while user is logged on, system will keep this data permanently
- System will calculate average temperature for a particular user, while user is logged on, system will keep this data permanently
- System will use duration and temperature of shower to calculate energy used during shower
- System will purge all data and analytics if user profile is deleted

Future Implementations

If all goes well, we would like to implement a separate mobile/desktop application where clients can set up a specific user profile and have access to shower data, and be able to create different shower routines. Also, we would like to implement a pressure slider that would allow the user to directly manipulate the pressure of the water. Currently, pressure only has three set values: off, standard and drench. The slider would allow for a more tailored shower experience, allowing for direct control as well as specific pressure choices while creating routines. Also, in future implementations of the SAM 5000, which creating stages in a routine, we wish to implement a multi-touch dragging interface, which would allow users to create stages with more specific times instead of a time selector.

5.2 Team Structure

Rhiannon - System Integration Expert

Rhiannon is In charge of the physical usability, software integration with mechanical components and sensors of the SAM5000. This includes:
- Placement of TouchPad Interface in shower
- Temperature Sensor and Hot Water Heater Sensor
- Wired communication between sensors, shower actuators and touch screen
- Processing of Sensor data into display values for touch screen
- Processing of user input into instructions for the shower actuators

Kathleen - Client Account Manager

Kathleen is the client - supplier relationship expert, and is in charge of making sure clients are happy with the design and progress made during the project. Her main duties include:
- Scheduling regular client/supplier meetings
- Answering client questions
- Addressing client concerns in all stages of development
- Creating client/supplier links

Kushal - Front End Developer

Kushal will be In charge of creating the Graphic User Interface for the Touch Screen Interface. This will include:
- Creating icons
- Placement of icons on screen
- Transition to different screen

Ushanth - Back End Developer

Ushanth will be In charge of back-end design of Touch Screen Interface and Interface usability documentation.This will include:
- Displaying the rest of time left in the timer
- Displaying the water temperature
- Displaying the amount of hot water available
- Displaying the shower options
- Saving client-made shower routines

6 Test Plan

There are 8 major test cases to test the SAM 5000. Each of these test cases has user input, input from the water sources, walkthrough for each steps, exceptions and expected output from the system. Each of the test cases evaluate a combination of several modules or units of the system.

Test Case 1-Temperature Control

Inputs	-User interaction(touching the touch screen interface) - Hot water from hot water pipe -Cold water from cold water pipe
Steps for testing	1. Before turning on the shower, set the temperature on the display to the lowest setting allowed. 2. Turn the shower on, let the water run for a short period of time. 3. Measure the temperature, the temperature should be that of what is displayed and set on the touchscreen interface. 4. Rerun the test case by incrementing the temperature by 2 degrees celsius. This iteration should be done till the max temperature allowed in the system
Alternate Steps	After Step 1, instead of turning the water off before incrementing temperature, leave the water running. Continue test case.
Exceptions	Hot water tank is out of hot water prior to beginning the test, interface should notify user of this.
Outputs	Water of the desired and displayed

	temperature (+/- 1 degrees Celsius) with an acceptable flow.
Non-functional requirement to consider	At any point during the test, user instrumented temperature adjustments should occur as fast or faster than a regular manual shower.

This test is performed to to check whether the right temperature is displayed in the interface and also check if the correct temperature of water is coming out from the hot water system. We increment the temperature by 2 degrees each time and rerun the test to check if the temperature is changed.

Test Case 2 - Time taken for the temperature to change

Inputs	-User interaction(touching the touch screen interface) - Hot water from hot water pipe -Cold water from cold water pipe
Steps for testing	1. Turn on the shower with the default temperature and let the water run. 3. Measure the temperature, the temperature should be that of what is displayed and set on the touchscreen interface. 4. Change the temperature by 3 degrees in the interface and measure the time taken for the temperature to change in the water 5. Repeat the above steps by incrementing the temperature until the maximum temperature is reached.
Exceptions	Hot water tank is out of hot water prior to beginning the test, interface should notify user of this.

Outputs	Water of the desired and displayed temperature (+/ 1 degrees Celsius) with an acceptable flow and the time time taken for the temperature change should be less than 30 seconds.

We will be testing the time taken for the system to change the temperature. This test is done to observe the performance of the system for the user input.

Test Case 3-Preset and User Defined Routines

Inputs	-User interaction(touching the touch screen interface) -Hot water from hot water tank - Cold water from other source
Steps for testing	1. Start the routine. 2. Ensure examined output temperature at each stage matches that specified of the routine (+/ 1 degree Celsius). 3. Ensure that the time spent on each stage is accurate(+/ 200 ms). 4. Iterate for each of the routines.
Exceptions	Hot water tank is out of hot water prior to beginning the test, interface should notify user of this.
Outputs	Water is temperature controlled and turned on/off as specified in the routine.
Non-functional requirement to consider	At any point during the test, user instrumented temperature adjustments should occur as fast or faster than a regular manual shower.

This test is conducted to examine the temperature control of the routine and the time spent on

each stage of the routine. Moreover, we will be testing if the water can be turned on/off at each stage in the routine.

Test Case 4- User Defined Routine Creation

Inputs	-User interaction(touching the touch screen interface)
Steps for testing	1. Log into the system with a user profile. 2. Press the "Create new Routine" button. 3. Create a routine with one stage. 4. Iterate, creating routines with more stages each time until a routine is created with the maximum number of stages.
Exceptions	-If the number of stages created as reached the maximum, an error message should be displayed. - Attempting to create a routine that has the same name as a routine that exists within the scope of that user should be disallowed; the routine name must be changed before moving forward.
Outputs	A routine containing the desired shower stages.

We perform this test to check if the system disallow user from creating additional stages when the number of stages created is reached the maximum. Furthermore, this test should be repeated for several newly created routines in order to observe the behavior of the system.

Test Case 5 - Profile creation

Inputs	-User interaction(touching the touch screen interface)
Steps for testing	1. Start the shower management system.

	2. Navigate to the user creation screen. 3. Enter a username less than or equal to 25 characters. 4. Create the profile. 5. Logout, then re-login as the newly created user to confirm that the user was created successfully.
Exceptions	- Attempting to create a user profile that has the same name as another user profile should be disallowed, the name must be changed before moving forward. -User tries to create a user profile using a name which already exists. -Attempting to create a profile with a username longer than 25 characters should result in an error.
Outputs	User profile is created
Non-functional requirement to consider	The system should be able to create the user profile both accurately and promptly.

This test is performed to check if the user profile is successfully created by the system. We will be also evaluating if the system prompts an error when the user tries to create a profile with a name that has been already assigned to a different profile in the system.

Test Case 6- Displaying remaining hot water level

Inputs	-User interaction(touching the touch screen interface) -Hot water from hot water pipe -Cold water from cold water pipe
Steps for testing	1. Run shower at a desired temperature. 2. Compare times of which the water

	reduced in temperature to that which displays on the system. 3. Wait for hot water tank to reheat, iterate at different temperatures.
Exceptions	-Hot water tank is out of hot water prior to beginning the test, interface should notify user of this.
Outputs	-Time and gauge of the currently available hot water is displayed. Time should countdown at an accurate rate, it shouldn't jump around or be inconsistent.
Non-functional requirement to consider	-The time and gauge should be a fair representation of the remaining hot water available.

Test Case 7- Analytics

Inputs	-User interaction(touching the touch screen interface) -Hot water from hot water pipe -Cold water from cold water pipe
Steps for testing	1. On user profile 1, run the shower at the minimum allowed temperature for 5 minutes. 2. On the same user profile, run the shower at the maximum allowed temperature for 5 minutes. 3. Follow the same process on a different profile but for 10 minutes rather than 5. 4. Calculate the temperature and time averages.

	5. Compare the temperature and time analytics between profiles, ensure they are the same relative to the run time. 6. Graph the water used, the graph should be fairly linear as the time is the only variable between the user profiles.
Exceptions	Hot water tank is out of hot water prior to beginning the test, interface should notify user of this.
Outputs	An analytical view for a particular user.
Non-functional requirement to consider	- The system should be able to present the analytics both accurately and promptly.

This test is performed to check if the analytics of the user recorded by the system are accurate when compared with the test results.

Test Case 8- User Water Override

Inputs	-User interaction(touching the touch screen interface) -Hot water from hot water pipe -Cold water from cold water pipe
Steps for testing	1. Begin a preset or user defined routine. 2. During a stage of the routine, turn on/off the water as a user override. The system should allow this. 3. Re-run the routine, but this time adjust the temperature as a user override. The system should allow this. 4. Iterate over different routines, overriding at different stages in different ways (on/off, different temperatures.
Exceptions	Hot water tank is out of hot water prior to

	beginning the test, interface should notify user of this.
Outputs	Water should shut off or change temperature based upon the user input
Non-functional requirement to consider	At any point during the test, user instrumented temperature adjustments should occur as fast or faster than a regular manual shower.

We perform this test to check if the system allows the user to change the temperature, turn on/off the water when the user uses a routine.

Test Case 9- Time check during different stages of a routine

Inputs	-User interaction(touching the touch screen interface) -Hot water from hot water pipe -Cold water from cold water pipe

Steps for testing	1.Create a new user profile.
	
	2. Set 3 minutes for standard stage, 2 minutes for lather stage and 4 minutes for drench stage.
	
	3. While the water is running during a routine the following should be checked.
	    1. Count the time taken during each stage manually and check if that time matches with the time elapsed from the system.
	    2. Count the time taken for the system to change to a different stage.
	
	4. Iterate over different timings and check if the system manages the timings accurately.

	Hot water tank is out of hot water prior to beginning the test, interface should notify

	user of this.
Outputs	System should switch to a different stage when the time is elapsed.

This test is used to check if the system manages the timings accurately when a user is using a routine. We will be measuring the time taken for a stage to complete and check if that time duration is same as the time that we initially set. Moreover, we will be checking the amount of time taken for the system to change from one stage to another another.

Acceptance testing

As a final stage during testing we will be checking if the system has passed all the above mentioned test cases. If there are any errors encountered during any phase of the testing, it will be reported in the acceptance testing report. Following is the format of the acceptance testing report.

Test cases	Results	Errors
Test Case 1-Temperature Control	▢Passed ▢Failed	
Test Case 2-Preset and User Defined Routines	▢Passed ▢Failed	
Test Case 3-Preset and User Defined Routines	▢Passed ▢Failed	
Test Case 4- User Defined Routine Creation	▢Passed ▢Failed	
Test Case 5 - Profile creation	▢Passed ▢Failed	
Test Case 6- Displaying remaining hot water level	▢Passed ▢Failed	
Test Case 7- Analytics	▢Passed ▢Failed	
Test Case 8- User Water Override	▢Passed ▢Failed	
Test Case 9- Time check during different stages of a routine	▢Passed ▢Failed	