# User Manual

Version 2.8.x

The objective of the project described in following manual is the mashing workflow and process automation in "all grain" beer production with a single vessel (BIAB/RIMS) system.

Open Ardbir is largely inspired by the original project formerly Braudino from Stphen Mathiso and then upgraded and modified by Mike Wilson under the Mike's Brewery appellation.

The micro controller Arduino Uno is, like in the original project, the core for the process automation and can be used in both fully automated mode and manual mode. The controller automates all the phases: from mashing to boiling and hops addition providing all the capability to both beginners and advanced homebrewers. The system is intereractive and programmable and can be configured via 4 push buttons and LCD display provides all relevant information in all phases. A specific shield has been developed in order to connect temperature probe, SSR relay for heating element, Pump relay, buzzer as well as LCD display (16x2 and 20x3) and 4 push buttons.

For all HW details and schematic please refer to following link

http://goo.gl/qMhPgu
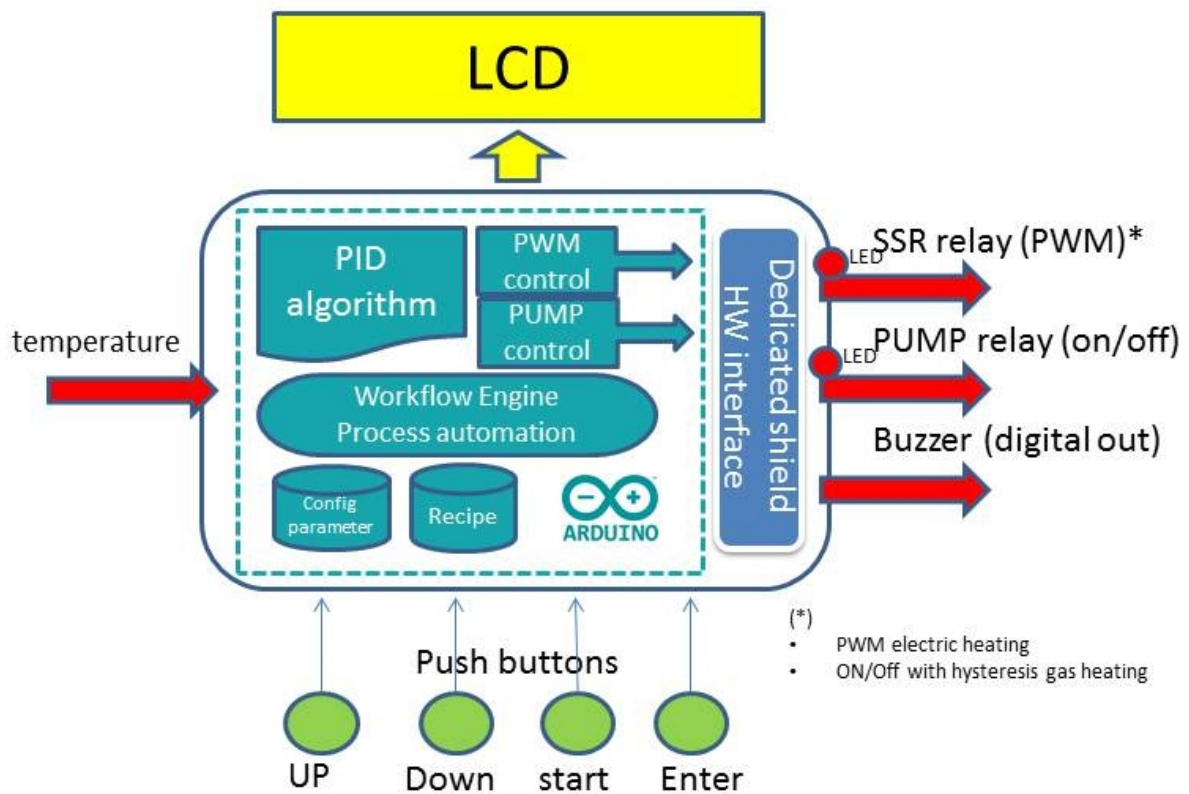
In the initial part of the source code a simple way to adapt the configuration to the different environment based on PCB HW type, LCD type (16x2 or 20x4) and language has been inserted. Once the code has been adapted inserting the proper reference (see below) the compilation can be performed and binary uploaded on the board

```
// ================================================
// ATTENTION!!!!!
// YOU MUST SET ONLY THIS SECTION
// ================================================
//SET PCB
// 1 Brauduino Original (Matho's PCB)
// 2 Brauduino by DanielXan
// 3 ArdBir by DanielXan
#define PCBType x
// SET LCD and Language
// LCD 16 or 20
#define LCDType x
// LANGUAGE
// 1 English
// 2 Italian
// 3 Spanish
// 4 Portuguese
// 5 Russian (only 20 x 4)
// 6 Norwegian (only 20 x 4)
#define LCDLanguage x
// ================================================
// END OF SETTING SECTION
// ================================================/
```

Finally some mandatory additional libraries are need in order to compile properly the sketch
*These libraries can be easily downloaded from the Arduino official site* http://arduino.cc

Onewire: http://playground.arduino.cc/Learning/OneWire
PID_v1: http://playground.arduino.cc/Code/PIDLibrary

WARNING:

First step to be performed in order to guarantee the right system operation is the system configuration and reset of EEPROM in order to manage correctly recipe storing. Please read the proper section for the right parameter configuration

Let's see the step by step configuration trough the push button and display menu

0.0 – Startup Display
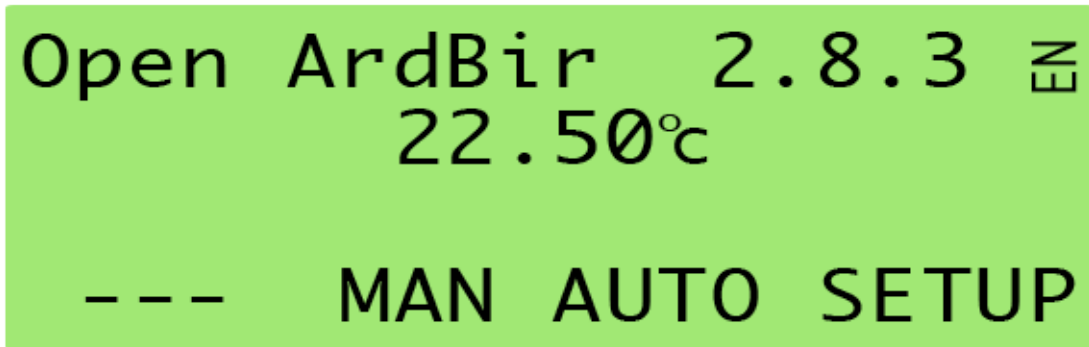
This is the boot screen of ArdBir. In order to enter the proper menu user should push the proper button for a couple of second.

At the end of both manual and/or automatic process user get back always to this initial menu as well as when the user exit from the CONFIGURATION menu

UP   **----**
DOWN   **MANUAL program**
START   **AUTOMATIC program**
ENTER   **SYSTEM CONFIGURATION**

1.0 – System Configuration

User can access set up menu pressing for 2 seconds the ENTER push button

This menu allow the user to set up all the basic parameters and configurations and so the final behavior of the brewing system.
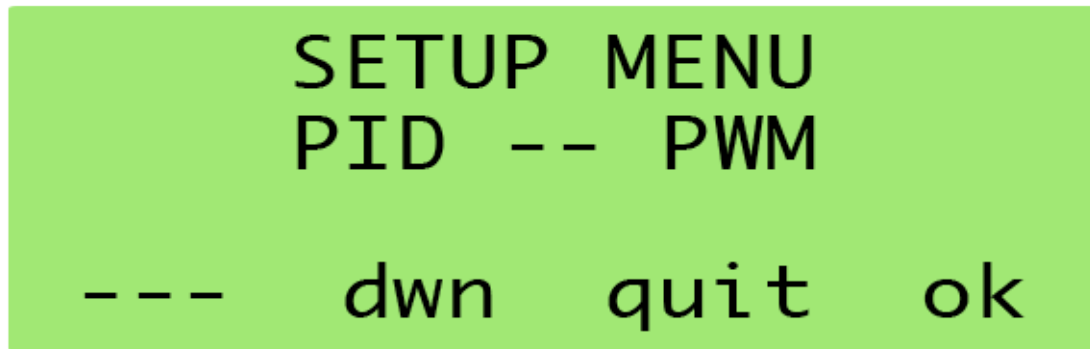
The set up menu allow the user to access

- PID parameters
- Unit parameters
- Process Automation Set Up
- Recipe Management
- Credits

Via UP and DOWN push buttons user can scroll through menus, selection can be confirmed by pressing ENTER.

UP	**Sub-menu scrolling**
DOWN	**Sub-menu scrolling**
START	**Exist form CONFIGURATION menu**
ENTER	**Confirm Selection**

1.1 - P.I.D. - PWM parameters

First section is related to PID parameter tuning according to the heating mode selected (electric or gas). Through this menu the relevant constants that influence the PID controlling algorithm and so the heating element control. It is also possible to configure output power of the heating element during boil phase and temperature probe calibration. In details

Heating Mode	Electric/Gas	This configuration is fundamental since it affects the entire algorithm to control temperature and secondary parameters configuration

Electric Heating parameters configuration

Constant P	-100 100	Proportional part of the PID control algorithm.
Constant I	-100 155	Integral part of the PID control algorithm.
Constant D	-100 100	Derivative part of the PID control algorithm..
Window ms(*)	500 7500	PID control time window in millisecond
Sample Time(*)	1500 3500	PID sample time

(*) In Gas configuration parameters are fixed

Common Parameter configuration

PWM	0-100	Heating power percentage applied to heating element during boil.
Calibration	-5,00° 5,00°	Temperature probe offset calibration (0,10° step)

Gas Parameter configuration

Hysteresis	0,0 10,0	It is used to manage the on/off control algorithm inserting a no action zone in order to preserve the solenoid gas valve.

UP	**parameter increase**
DOWN	**parameter decrease**
START	**-----**
ENTER	**Confirm selection**
UP+DOWN	**Exist from PID -PWM menu**

Notice that fine tuning of the PID parameter is out of scope of this user manual and may factor related to the brewing system can influence the optimal setting

For a more detailed explanation of PID control algorithm please refer to Wikipedia
http://en.wikipedia.org/wiki/PID_controller

A simple method the get an easy calibration of PID algorithm suggests to set to 0 the value Ki and Kd and try to fine tune anly the Kp that allow the PID to get as closer as possible to set point trying to minimize the difference between actual temperature and set point
Subsequently it is possible to tune the Ki and Kd considering that
- *In case the measured temperature overshot the set point reduce Kp and Increase Kd*
- *In case to much time is need to get the control to the set point increase Ki*
- *In case of a permanent error below the set point increase ki*

1.2 – Unit Parameters

SETUP MENU
Unit Parameters

up   dwn   quit   ok
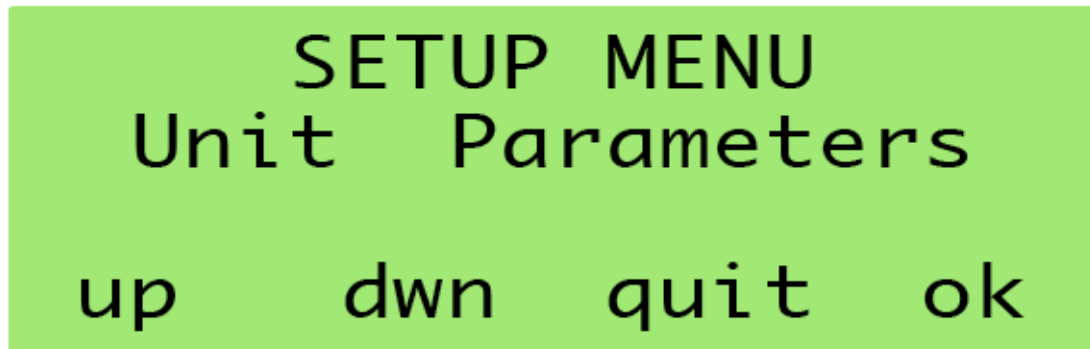
Through this section the user can configure the overall system parameter and global variable that will affect the end to end system behavior. Typically this set up is specific for the brewery and should be performed once.

There is a dependencies in some of the choice and so not all reported values are allowed, some consistency and validation rule are applied automatically

Temperature Unit	°C/°F	It's possible to select either Celsius of Fahrenheit.
Sensor	Internal External	this parameter should be set according to sensor physical placement Internal means that the temperature probe is inside the Vessel while External means that the sensor is external in the recirculation circuit (near the pump). This choice will influence pump behavior
Boiling	90°-105°C 194°210°F	this parameter sets the boiling point. Is automatically set in both measurement units
Pump Cycle	5 15 minutes	this parameter set the pump cycle duration once the temperature has been reached during automatic mashing cycle
Pump Rest	1 5 minutes	This parameter set the rest pump time between one cycle and another. This rest period is also influenced by temperature so in case there is a drop of temperature in order to preserve enzyme integrity the pump will start again for a new cycle
Pump PreMash **Pump on Mash** **Pump MashOut**	ON/OFF	These On/Off flags control the pump behaviour during the relevant phases
During Boil	ON/OFF	The parameter indicates whether the pump is ON or OFF during boil. In case of external sensor the choice is always disabled
Pump Stop	80°-(105)°C 176°-(194)°F	The parameter controls the maximum working pump temperature In the selectable range it is equivalent to boiling temperature parameter set In case of external sensor the choice is always disabled
PID Pipe	Active-Passive	This parameter regulate the PID behaviour during malt pipe management
Skip Add **Skip Remove** **Skip Iodine**	Yes/No	These parameters allows to skip the notification provided by the controller in relevant phases. The workflow proceeds to next step automatically Without interruptions
Iodine Time	OFF-1:30:00	This parameter regulates the maximum time used by controller to keep Alpha amylase 2 before moving automatically to Mash Out step. In OFF case it's

mandatory manual confirmation to proceed. I automatic mode the manual action override the control

Whirlpool OFF/Cold/Hot This parameter enables to manage at the end of the boil phase the whirlpool process either in hot or cold mode. OFF skip the whirlpool step

UP	**parameter increase**
DOWN	**parameter decrease**
START	**-----**
ENTER	**Confirm selection**
UP+DOWN	**Exist from System Parameter menu**

1.3 - Automation Process Setting

Through this menu it's possible to configure all the relevant parameter for the automatic mashing process.
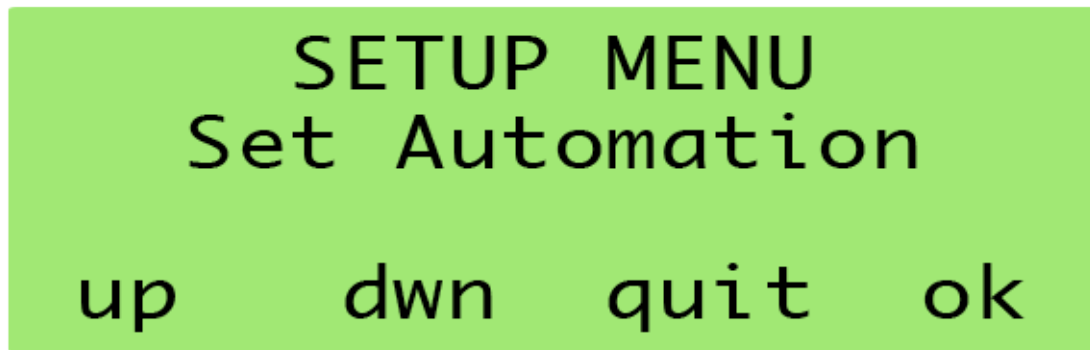
The basic principle of this configuration menu is the "step mashing" process. For each step user can configure target temperature (SetPoint) as well step duration. Moreover it's always possible to skip some of the steps according to the recipe schedule trough the START button.

Some steps are mandatory (Mash In – A-Amilasi2 e Mash Out) in order to guarantee the correct mashing workflow.

The system performs some integrity check and tries to avoid user mistakes in configuration: if some input value are not coherent (ie a step with lower SetPoint than the previous one) the step is automatically skipped.

The only exception is the first step after Mash In where the temperature can be set lower up to 3.5°C

Here the full steps list

Phase	Temperature	Duration	Description
Mash-In	20°-80°C 68°-167°F	-----	The strike temperature for mash in start phase should be entered No duration is foreseen since unless the grain are added (and confirmed) the temperature is maintained constant This step can't be skipped
Fitasi	25°-55°C 77-131°F	1-140min	Fisrt step, both temperature and duration should be entered It's possible to skip the step pressing the ENTER button during the temperature or duration setting
Glucanasi	35°-50°C 95-122°F	1-140min	Second step configurable as above. It's possible to skip pressing ENTER
Proteasi	45°-60°C 113°-140°F	1-140min	Third step configurable as above. It's possible to skip pressing ENTER
B-Amilasi	50°-70°C 122°-158°F	1-140min	Fourth step configurable as above. It's possible to skip pressing ENTER
A-Amilasi 1	60°-76°C 140°-168°F	1-140min	Fifth step configurable as above. It's possible to skip pressing ENTER
A-Amilasi 2	60°-76°C 140°-168°F	1-140min	Fifth step configurable as above. This step is mandatory
Mash-Out	75°-80°C 167°-176°F	1-140min	Sixth step completely configurable. Mash out is mandatory step.

| Phase	TEMPERATURE	Duration	Description
N° Hop additions	0-10	-----	This parameter indicates how many hop additions are foreseen during the boil phase
Boil Duration	-----	1-180min	this parameter reports the total boiling time from the boiling temperature achievement.
Hop(x)	-----	0-180min	This parameter set the boiling time of each hop and should be repeated for the whole hop additions configured above

Example for Hop Additions time distribution

Let's suppose 60min boiling time with 4 hops additions in 4 steps 5,10,15,50 minutes the hop section should be configure like this

N Hop Additions	4
Boil Duration	60
Hop 1	50
Hop 2	15
Hop 3	10
Hop 4	5

The time parameter is used as a countdown and the value provide exactly reaming boiling time

UP	**parameter increase**
DOWN	**parameter decrease**
START	**-----**
ENTER	**Confirm selection**
UP+DOWN	**Exit from Automatic Process Setting Menu**

1.4 – Recipe Management and Saving

```
SETUP MENU
Manage Recipes


up    dwn   quit    ok
```
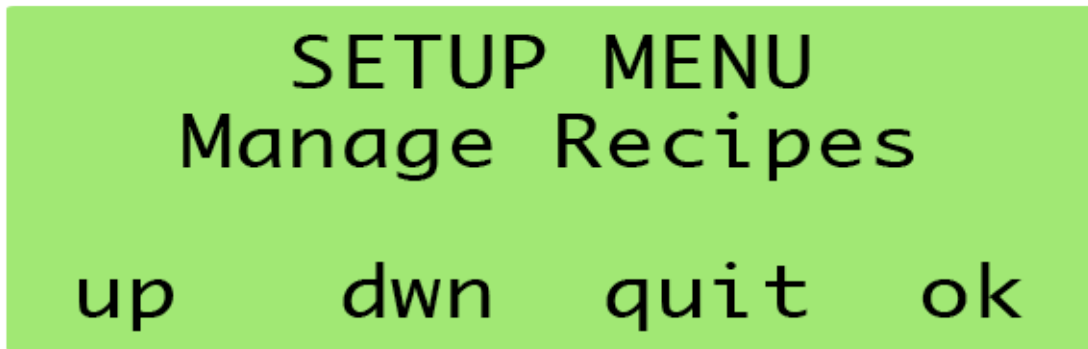
In this section is possible to save inside the controller memory up to 10 different settings for future use.

The stored info are related to mashing steps, hop additions, a progressive number is assigned to the parameters sets according to first free memory position

It's possible to load the settings, store and delete

Notice that first time it's needed a EEPROM initialization process through the dedicated menu

```
SETUP MENU
Manage Recipes
Initialization
up    ---   quit   ok
```
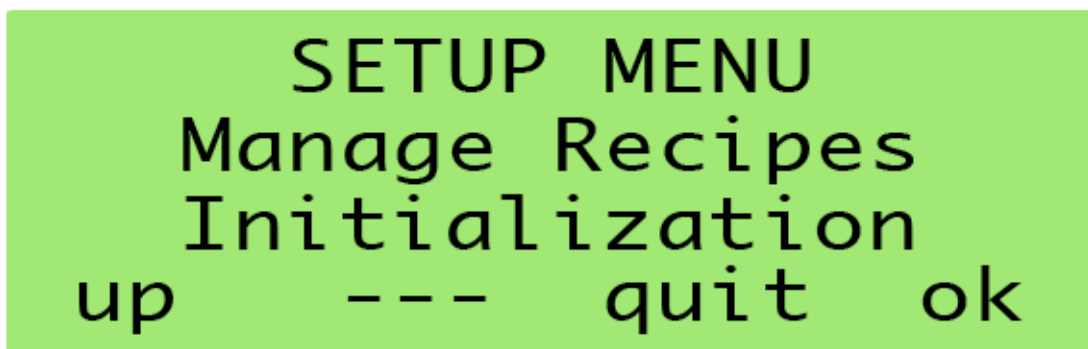
Once the EPPROM initialization has been performed it's possible to start settings saving operations

```
SETUP MENU
Manage Recipes
Save Setting
up    dwn   quit    ok
```
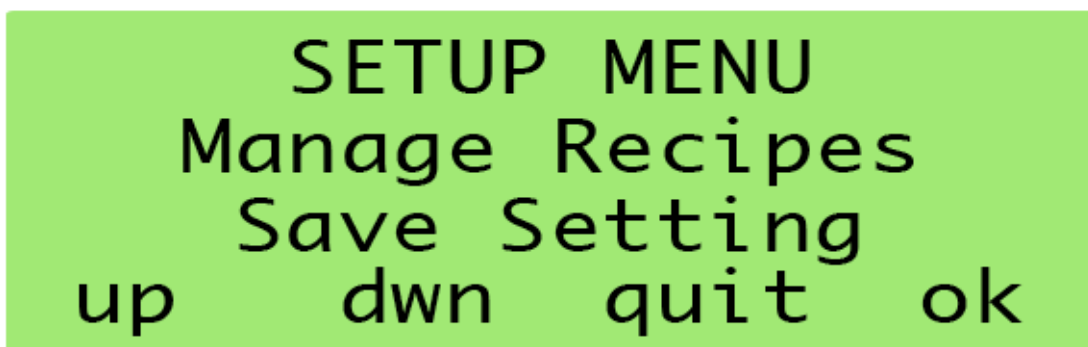
The user can enter a name in order to identify the specific recipe using alphanumeric string with max 10 chars (a-z ,0-9, space)

```
      SETUP  MENU
   Manage  Recipes
   xx  >  abcde  0123
  UP*  *DWN   back   ok
```

With UP/DOWN push button is possible to scroll through the char list and ENTER is used for selection

At the end the full name composed must be confirmed trough START button

The user can modify the recipe name during editing by pressing the START push button. This option allow to go back one char and modify. Multiple pressing of ENTER allow to scroll back to up to first char.

A shortcut in order to insert missing space char to name completion can be done pressing together UP+DOWN push button

```
      SETUP  MENU
   Manage  Recipes
   Save  Setting  xx?
 Sure?->    Yes    No
```

In order to load or delete a specific recipe the ENTER push button is used for selection while the confirmation is done through the START push button.

Below the details of a recipe loading screenshot

```
      SETUP  MENU
   Manage  Recipes
    Load  Setting
  ---   dwn   quit   ok
```

And recipe deletion screenshot

```
        SETUP MENU
     Manage Recipes
     Delete Setting
 up    dwn   quit   ok
```

UP   **Parameter Increase**
DOWN   **Parameter decrease**
START   **Loading /Saving/ Deleting /Recipe Name**
ENTER   **Selection Confirmation**
UP+DOWN   **Exit form recipe automation menu**

2.0 – Manual Process

Manual process allow the user the full control of the entire mashing process by temperature settings and switch ON/OFF of both pump and heating element.

Temperature control will be performed automatically trough the PID-PWM control that will try to reach the manual set point and LCD display will report the manual SetPoint temperature and current temperature. An automatic timer is started when the measured temperature will reach the set point . Sound notification is provided reaching the set point.

Pressing together ENTER and START push button the controller enter in countdown mode. The user can set a count down instead an increasing timer for the running step. Basically there are 3 actions

- Enter countdown mode pressing together START+ENTER push buttons
- Setting the countdown duration by UP+DOWN push button
- Count down confirmation pressing together START+ENTER push buttons

5s before ending of the countdown the user is notified via alarm. When the countdown is completed the normal timer is started. It's possible to enter count down mode anytime

Any set point change will reset the timer if the set point temperature 2°C will be greater than measured temperature. The 2°C hysteresis has been added in order to avoid the timer reset due to small temperature changes.

During the boil phase, that start when temperature reach the proper values configured in the system settings menu, only current temperature is reported on LCD and it's possible to regulate the heating element power with UP/DOWN button, The % of power used is reported on the LCD
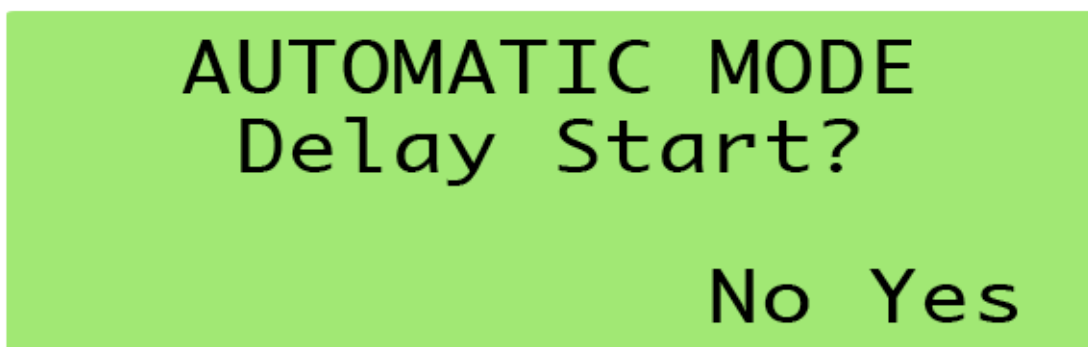
UP	**Temperature/Power Increase**
DOWN	**Temperature/Power Decrease**
START	**Heating Element ON/OFF**
ENTER	**Pump ON/OFF**
UP+DOWN	**Exit form Manual Process**

3.0 – Automatic Process

The automatic process automation is the real "core" of the systems and the controller execute in sequence all the steps previously configured in the Automatic Process Settings menu.

The wide parameter setting allow a very flexible usage of the controller for different mashing systems. Trough a proper parameter configuration just adding grains and hops it's possible to execute a complete automatic process

3.1 – Delayed Start

It's possible to program the brew day through a delayed start so the user can fill the vessel with water and decide to postpone the initial heating phase

The controller ask if the user want to postpone the start and in positive case the amount of delay in minute should be entered. In case of immediate start the ordinary sequence will be started.

3.2 – Recovery of previous brew session

If a previous run has been for some reason aborted the system will asks the user if he wants to recover the previous process. In affirmative case the system will restart exactly form the step where the process has been aborted, otherwise the system stat from the first mashing step.

```
AUTOMATIC MODE
Resume Process


Continue:   Yes   No
```
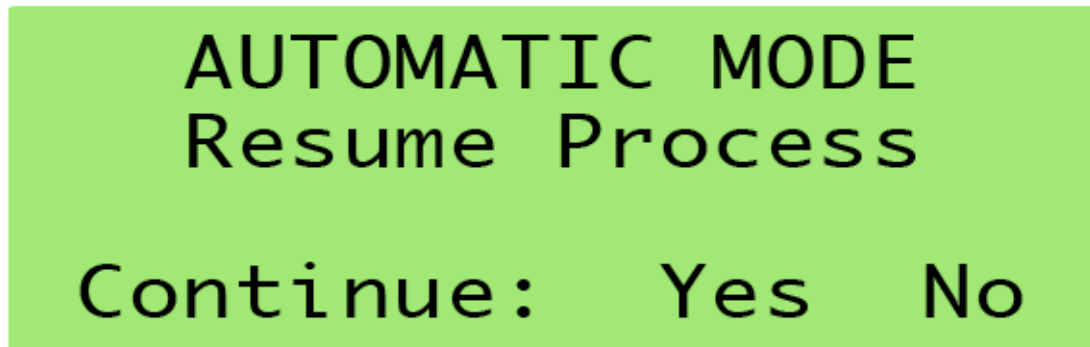
3.3 – Water addition

First step is Mash In and the systems ask explicitly if the proper amount of water has been added into the vessel

```
AUTOMATIC MODE
Water Added?


Continue:   Yes   No
```
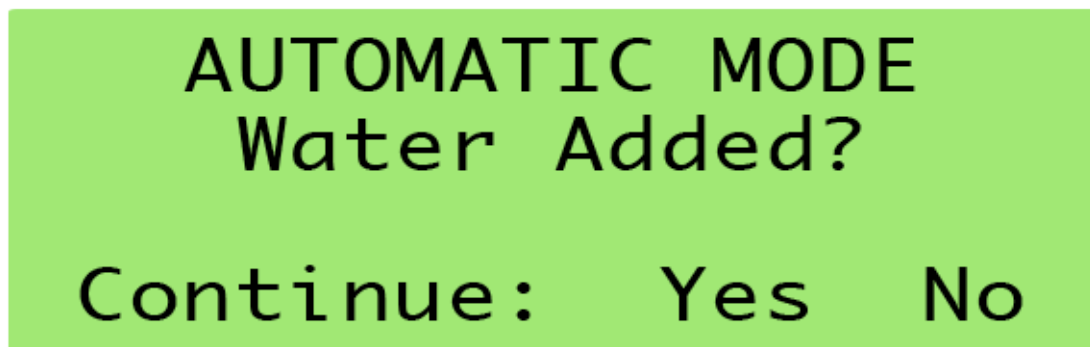
Positive answer to this question allows the process to continue otherwise the user is reported to initial menu.
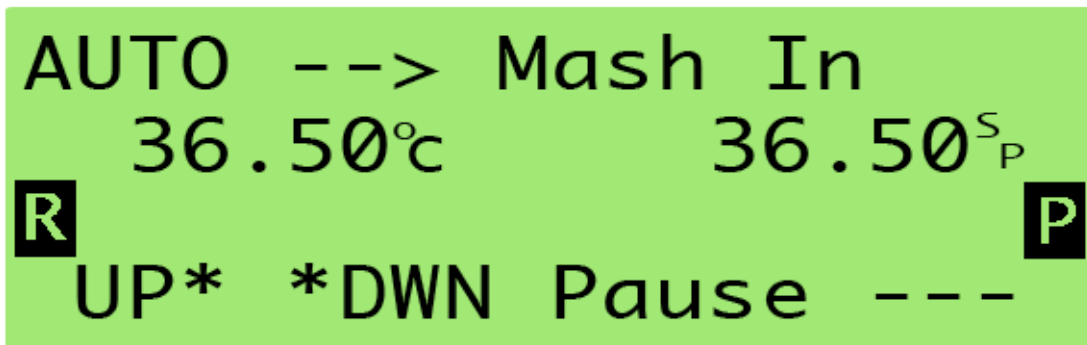In order to allow regular worth recirculation the pump is initialized with short ON – OFF cycle. At the end of this phase the pump is started and the water re-circulated. This operation is useful to expel form the circuit air bubble and fill the pump impeller.
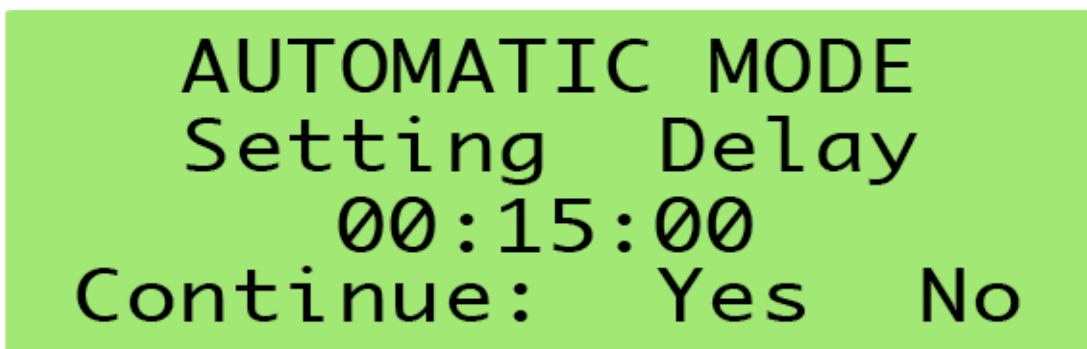
```
AUTOMATIC MODE
Pump Prime


                    P
```
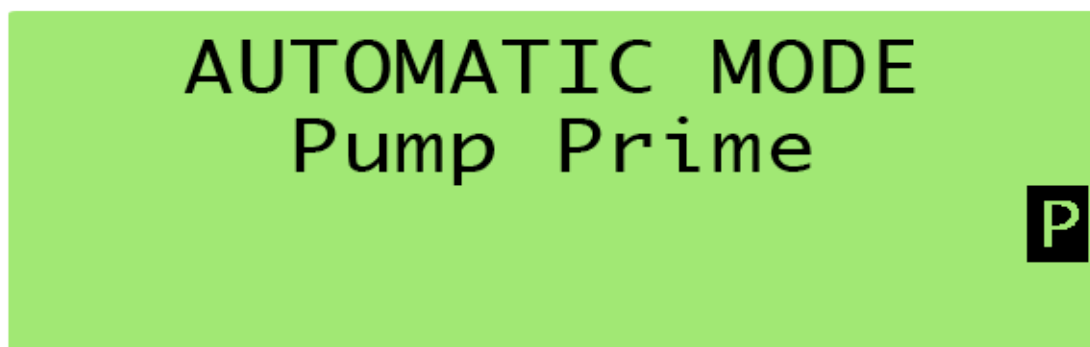
3.4 - Mash IN

After this operation the automatic process starts effectively and the heating element i switched on in order to heat the water up to the strike temperature.

In case of a delayed start have been programmed the user is requested to enter the delay value in minute
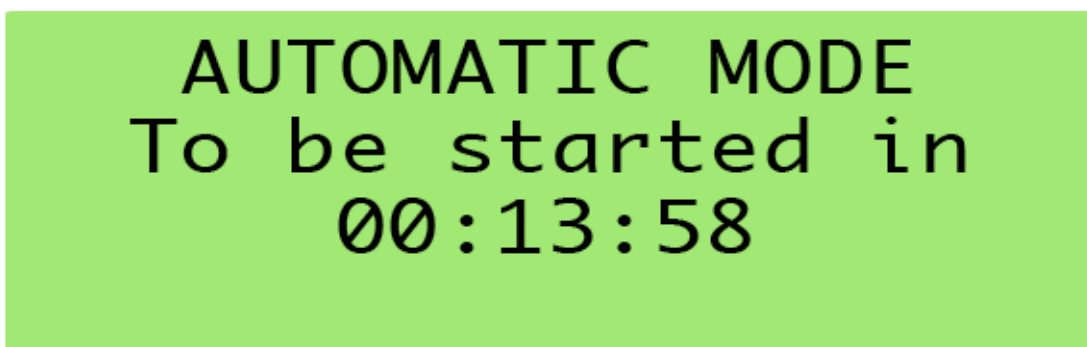
```
AUTO --> Mash In
   36.50℃      36.50ˢP
R                        P
 UP* *DWN Pause ---
```

```
   AUTOMATIC MODE
 Setting  Delay
     00:15:00
Continue:   Yes   No
```

Once the delay has been programmed and confirmed the system enter in a stand by mode

A count down will be displayed on the LCD

```
   AUTOMATIC MODE
 To be started in
     00:13:58
```

At the end of the standby period sound notification alerts the users that the process effectively starts and the heating element is switched ON.

From that point on and all the operation are common regardless the initial choice

```
AUTO  --> Mash In
   36.50℃        36.50ˢᴘ
R                          P
   UP*  *DWN Pause  ---
```

The system start heating and recirculating the water and reached the strike temperature the systems enter in a pause/loop status.

Waiting for the confirmation the heating element is continuously controlled by the PID algorithm so the temperature stays stable.

```
AUTO  --> Mash In
   36.50℃        36.50ˢᴘ
   Temp.  Reached  P
Continue:   Yes  ---
```

Once the user confirms the system enter another loop phase in order to allow the grain load in the malt pipe.
The pump is stopped while the temperature is maintained constant. An explicit question if the grain has been loaded in the malt pipe is proposed by the system.

```
AUTO  --> Mash In
   36.50℃        36.50ˢᴘ
R         Add Malt        P
Continue:   Yes   No
```

After confirming the malt loading the system goes to the next step

3 .5 – Step Mash

From this point on no manual intervention is needed and the controller will execute the complete workflow step by step adjusting the mashing temperature for the configured time duration. The pump cycle will be controlled accordingly.

One notice related to the pump rest: in some cases the foreseen rest will be skipped or last more than the configured value. This is due to the programming logic where the pump start working at set point for the specific step and enter is rest time accordingly to the value set in the proper menu but this rest time is also linked to heating processes.

If the temperature will decrease below a configurable threshold the heating element and the pump will be started again. A sound trough the buzzer and a specific indication of the pump status is reported on LCD display when the rest period start.

```
AUTO  -->  xxxxxxxxx
     xx.xx°c       xx.xxˢP
R                  00:22:55 P
    --   Pump  Rest    --
```

For each step a countdown timer is started when temperature reach the set point. A beep sound will advise the user 5 seconds before the step ends.

3.6 – Iodine Test / Mash out

Before the Mash Out step the process will stop with a new advice prompt in order to check the full starch conversion

```
-----    72.00°c   -----
      Iodine  Test
      00:01:34
    ---   ---    Ok   ---
```

This step is called "iodine test" and **the temperature settings are the same of previous step**. The phase will be completed pressing ENTER

Once the mash out has been completed the pump is stopped and the system wait until the user confirms the malt pipe removal operation completion.

Once confirmed to continue the process the system notify the user to remove the malt pipe

If the user confirms the system enter the boiling phase.

```
AUTO --> Mash Out
  78.00°c       78.00ˢₚ
R  Remove  Malt      P
Continue:   Yes   No
```

3.7 – Boling / Hop additions

In this final phase the system will provide sound and visual (LCD) indication of hops addition request. No explicit confirmation in this case is needed

```
AUTO --> Hop      XX
  98.00°c       98.00ˢₚ
RPWM= 85%  01:00:00 P
 UP*  *DWN Pause  ---
```

3.8 – Step Skip / Pause Mode

During all steps after Mash IN it's possible to skip one step and force the system to go to the next one
This can be done by long pressing ENTER button. A confirmation is always requested in order to avoid mistakes.

```
AUTO --> xxxxxxxxx
  xx.xx°c       xx.xxˢₚ
R Go to next step? P
Continue:   Yes   No
```

It's always possible to PAUSE the process during automatic mode pressing the START push button for few seconds

```
-----   52.50℃   -----
        In Pause
        00:02:40
   ---     ---    Esci  ---
```

To go back to automatic process the user can simply press the STRAT push button again

At the end of step mashing the controller enter the cooling process

3.9 – Cooling / Whirlpool

The whirlpool step in order to clarify the worth is optional depending of the capability of the vessel (it is supposed to perform the whirlpool via recirculating pump).

Depending on the parameter set up the sequence will be the following

- Hot Whirlpool → whirpool and cooling
- Cold Whirlpool → cooling and whirlpool

In case whirlpool parameter is OFF the controller proceed to cooling step directly

```
START   COOLING


Continue:   Yes   No
```

It's always possible to skip this step by pressing ENTER push button

```
AUTO  --> Cooling
  93.00°C        30.00 Sp
                          P
  UP*  *DWN    ---   pmp
```

During cooling phase user can set the desired temperature set point for cooling (max 30°C) and pump behaviour
It's possible to exit the step by pressing UP-DOWN push button together

```
       WHIRLPOOL


Continue:   Yes   No
```

If whirlpool has been selected in one of the two options a notification to proceed is provided by the controller. Like in the cooling phase it's always possible to skip this procedure

```
Timing Whirlpool
     00:03:00
Up   Dwn   Exit   Ok
```

In the whirlpool step user is requested to set the process duration time

```
AUTO  --> Whirlpool
   28.00°c      30.00$^S_P$
            00:02:55[P]
__*  *__       ---   Pmp
```

If Hot Whirlpool has been selected the process will start reaching 85°C, in case of cold whirlpool the process will start at 30°C.

During whirlpool phase user can control the pump activation/deactivation. In case pump is stopped the countdown timer will be reset
The operations can be performed by
  • stop pump pressing ENTER push button
  • press START push button to go back to setting procedure
  •
It's possible to exit the step by pressing UP-DOWN push button together

At the end of the entire process the system go back to initial settings

```
Brewing  Process
    Finished
```

During the process the push buttons will be used for below operations

UP	**Parameter Increase**
DOWN	**Parameter decrease**
START	**Step confirmation**
START	**PAUSE/START (long press)**
ENTER	**Selection confirmation/Step Skip (long press)**
UP+DOWN	**Exit Automatic Menu**