IJARIIT
INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact factor: 4.295
(Volume3, Issue2)
Available online at www.ijariit.com

Automation of Multiproduct Herbal Juice Manufacturing Plant

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Abstract: In the market, there are more types of herbal products are available which are used as medicine. There is a Neem is one of the most useful medicinal plants. There are many other plants also use as medicine like Aloe Vera. Neem plant is a most eco-friendly plant for a human being from medical or/and hygienic point of view, And also for agro point of view. Each part of Neem tree has medicinal property. Juice of Neem leaves free from chemicals useful for exporting the products to countries that are very cautious about residual pesticides. Also, the extracted residue can be used as organic fertilizer, thus increasing agro output. Automation is useful for reducing human effort in industrial working. This gives more accurate results with high quality. With help of automation, the only single worker can handle the manufacturing plant. We used ARM microcontroller based automation system for multiproduct herbal manufacturing plant system is basically embedded system. The main objective of this system is to automate the process for the efficient functioning of the plant. In this automation project, we control solenoid valves and relays means motor, pump with the help of ARM7.

Keywords: Herbal Juice Plant, Automation in Juice Plant, Juice Plant, Modification in Juice Plant, ARM7, Microcontroller.

INTRODUCTION

Society in its daily endeavors has become so dependent on automation that it is difficult to imagine life without automation engineering. In addition to the industrial production with which it is popularly associated, it now covers a number of unexpected areas. Trade, environmental protection engineering, traffic engineering, agriculture, building engineering, and medical engineering are but some of the areas where automation is playing a prominent role. Automation engineering is a cross-sectional discipline that requires proportional knowledge in hardware and software development and their applications. In the past, automation engineering was mainly understood as control engineering dealing with a number of electrical and electronic components. This picture has changed since computers and software have made their way into every component and element of communications and automation.

Industrial automation engineers carry a lot of responsibility in their profession. No other domain demands so much quality from so many perspectives of the function, yet with significant restrictions on the budget. The project managers of industrial automation projects have significant resource constraint, considering the ever-changing demands of its management, trying to adopt the rapid acceleration of the technological changes and simultaneously trying to maintain the reliability and unbreakable security of the plant and its instruments.

Overview

Automation or automatic control is the use of various control systems for operating equipment such as machinery, processes in factories, boilers, and heat treating ovens, switching in telephone networks, steering and stabilization of ships, aircraft and other applications with minimal or reduced human intervention. The major benefit of automation is that it saves labor; however, it is also used to save energy, materials and to improve quality, accuracy, and precision.

Objectives

There is three main objectives of determining an industrial process material, energy, and information. The basic objective of plant automation is to identify the information and to manipulate the material and energy needed for the given process in desired, optimal way.

The most common benefits of automation are:

- Productivity increase
- Production cost reduction
- Control plant safety
- Optimal production scheduling
- Product quality improvement

Nowadays, a combination of conventional and modern automation means i.e., of process instrumentation and process control computers, as well as methods of systems engineering, are used for the optimal solution of complex automation problems in the industry.

Problem Statement

For Final year project work, we have decided to design, install and develop an automation system for Herbal Juice Manufacturing Plant using Microcontroller System. The objectives of this project work are:

1. To establish a Neem herbal juice manufacturing process.
2. To procure and fabricate the essential elements and instruments for the process.
3. To build the Hardware setup and installing process equipment.
4. To control the efficient working of the process.

METHODOLOGY

There are several herbal juices which are required by a human being for health purpose and are to be manufactured. However, in order to demonstrate a juice manufacturing process, our project team opted for Neem Herbal Juice processing plant. The Neem is readily available in plenty and is most important human blood purifier. It also can be used as a most eco-friendly pesticide for crops. There are four major processes to be carried out in manufacturing Neem Herbal Juice.

Process 1: To churn Neem leaves to make a paste. Add demineralized water to dilute a paste so that it will not block the flow of water and Neem paste mixture is controlled by solenoid valve through the pipe.

Process 2: The second main process is to make the herbal juice. The diluted Neem liquid paste from Churning Tank(tank 1) is taken in the process vessel and further shredder tank (2). The Neem paste liquid mixture is boiled at 70^0 C to extract the Neem ingredients from Neem liquid paste. During this step, the entire liquid mixture is stirred for thorough extraction of Neem ingredients. Once the above process is completed, it is filtered out and then cooled down to atmospheric temperature by heat exchanger so that the juice is readily bottled for consumption.

Process 3: The thoroughly extracted juice with slurry is drained out and filtered to separate the slurry in the tank and can be used as a pesticide. In filtering, we have to clean the filters at regular intervals.

Process 4: The final process is to take out the liquid juice from the process vessel and to fill the desired quantum in the bottles automatically.

Constructional Details

Herbal juice manufacturing system consists of Mixing and Boiling Tank, Storage Tanks, Heat exchanger and Bottle Filling System to carry out the process. Water Supply tank and Drain Tank for supplying water and collecting the waste from the process comprise an essential part of the system. Electrical equipment like Pump, Stirrer and Churner Motor and Heater along with Process Instruments Solenoid Valves, Relays, and IC form an integral part of the system. In the section below details of hardware components are mentioned.

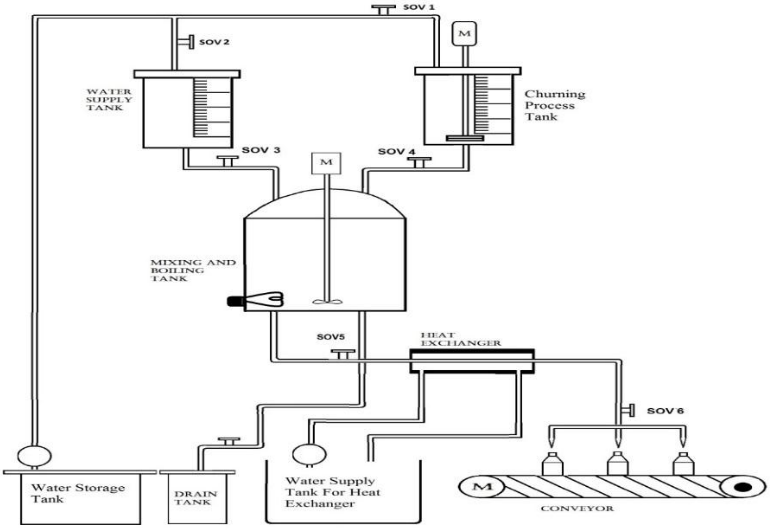


Fig. 1 Block Diagram of Manufacturing Plant

Project Components

Mixing and Boiling Tank

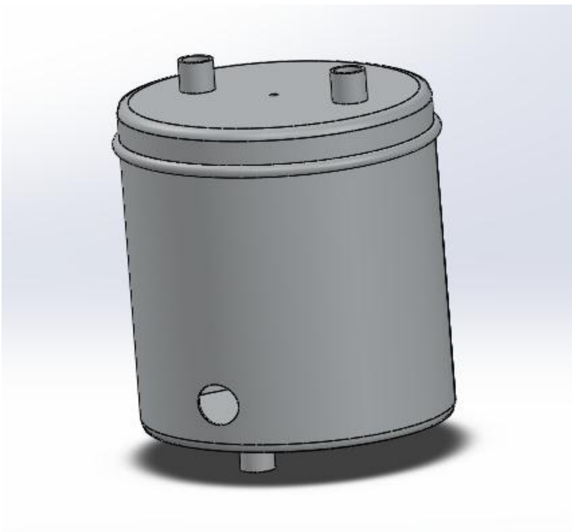


Fig. 2 Mixing and Boiling Tank

Specification

- Material: Stainless Steel
- Dimensions:
  - Dia.:270 mm
  - Height: 320 mm
- Capacity: 16 liters

Function application: Mixing And Boiling Tank plays a key role in the herbal juice manufacturing process. Water and Neem Paste from the two storage tanks enter the tank from the top. The process is heated here to extract the Neem paste essentials. The heated fluid is stirring and taken as an outlet. Process tank level fills up is done with the time in terms of delay.

Churning Tank

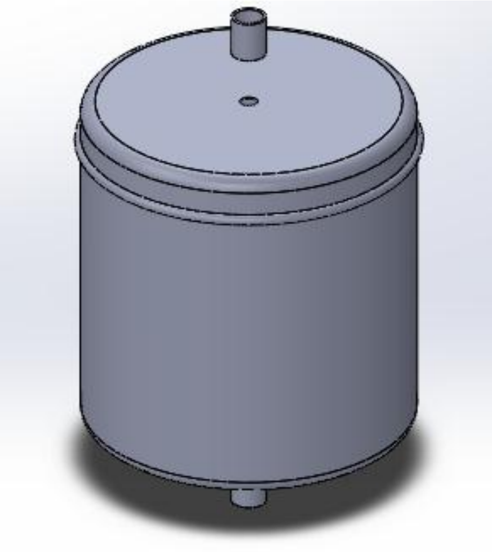


Fig. 3 Churning Tank

Specification

- Material: Stainless Steel
- Dimensions :
    - Dia.: 230 mm
    - Height: 260 mm
- Capacity: 10 Liters

Function application: Storage tank 2 is used to shred the Neem leaves with the help of blades connected to the motor. The Neem paste is diluted with the help of water and passed to the storage tank.

Water Supply Tank

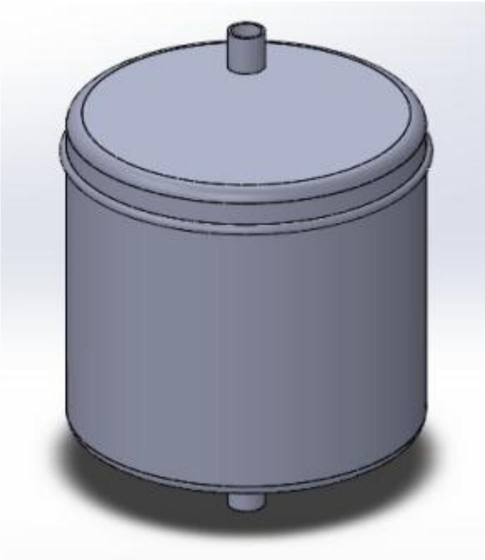


Fig. 5 Water Supply Tank

Specification:

- Material: Stainless Steel
- Dimensions :
    - Dia. : 230 mm
    - Height: 260 mm
- Capacity: 10 Liters

Function application: Water supply tank supplies water to the Mixing and Boiling Tank for dilution of concentrated juice of Neem leaves.

Heat Exchanger

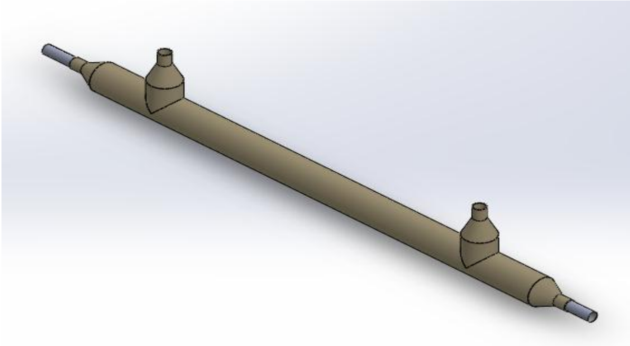


Fig. 6 Heat Exchanger

Function application: Heat exchanger is used for cooling the juice which coming from Mixing & Boiling Tank. Neem juice having temp 55^0C & Heat exchanger cool that temperature from 55^0C to normal atmosphere temperature.

Design Calculations for Heat Exchanger:

By Using LMTD (Log Mean Temperature Difference) Method:

With the Following Data,

T_{hi} = Hot Fluid Inlet Temperature (°C) = 55 °C

T_{he} = Hot Fluid Exit Temperature (°C) = 35 °C

T_{ci} =Cold Fluid Inlet Temperature (°C) = 30 °C

T_{ce} =Cold Fluid Exit Temperature (°C)

K_C = Conductivity of Copper (W/mK) = 386 W/mK

K_w = Conductivity of Water (W/mK) = 0.615 W/mK

m_h = Mass Flow Rate of Hot Fluid (Kg/sec) = 0.01818 Kg/sec

m_c = Mass Flow Rate of Cold Fluid (Kg/sec) = 0.25 Kg/sec

C_{pc} = Specific Heat of Cold Fluid (J/Kg K) = 4178 J/Kg K

C_{ph} = Specific Heat of Hot Fluid (J/Kg K) = 4000 J/Kg K

d_i = Internal Diameter of Inner pipe =17.8 mm

d_o = Outer Diameter of Inner pipe =18.8 mm

D_i = Internal Diameter of Outer pipe = 38 mm

D_o = Outer Diameter of Outer pipe = 48 mm

- Heat Transfer Rate,

$$q = (mC_p)_h (T_{hi}-T_{he})$$
$$= 72.72\ (55-35)$$
$$= 1454.4\ \text{W}$$

$$q = (mC_p)_c (T_{ce}-T_{ci})$$

$$T_{ce} = \frac{q}{(mCp)_c} + T_{ci}$$
$$= \frac{1454.4}{1044.5} + 30$$
$$T_{ce} = 31.39^0\text{C}$$

- Log Mean Temp. Difference,

$$\boldsymbol{\theta}_m = \frac{\theta1 - \theta2}{\ln(\theta1/\theta2)}$$

$$\boldsymbol{\theta}_1 = T_{hi} - T_{ce}$$
$$= 55 - 31.39$$
$$= 23.61\ ^o\text{C}$$

$$\boldsymbol{\theta}_2 = T_{he} - T_{ci}$$
$$= 35 - 30$$
$$= 5\ ^o\text{C}$$

$$\boldsymbol{\theta}_m = \frac{\theta1 - \theta2}{\ln(\theta1/\theta2)}$$
$$\boldsymbol{\theta}_m = \frac{23.61 - 5}{\ln(23.61/5)}$$
$$= 11.9876$$

- Overall Heat Transfer Coefficient,

$$UA = \frac{1}{\frac{1}{hiAi}+\frac{1}{hoAo}+\frac{\ln(\frac{r2}{r1})}{2\pi KL}}$$

Where,

h_i = Heat Transfer Coefficient of Inner Surface of pipe of internal pipe (W/m^2 K)
h_o = Heat Transfer Coefficient of Outer Surface of pipe of internal pipe (W/m^2 K)
A_o = Area of Outer Pipe
A_i = Area of Inner Pipe

Heat Transfer Coefficient,

$$h = 0.023\ (K/d)\ (Re)^{0.8}\ (Pr)^{(1/3)}$$

Re = Reynold's Number
Pr = Prandtle Number

$$Re = \boldsymbol{\rho}Vd/\boldsymbol{\mu}$$

Where, $\boldsymbol{\rho}$ = Density of Fluid (Kg/m^3)
V= Velocity of Fluid (m/s)
$\boldsymbol{\mu}$ = Dynamic Viscosity (N sec / m^2)

$$Pr = \boldsymbol{\mu}\ C_p / K$$
$$m_h = \boldsymbol{\rho}VA$$
$$m_h = \boldsymbol{\rho}V(\boldsymbol{\pi}/4) \times (d)^2$$
$$0.01818 = 1000 \times V \times (\boldsymbol{\pi}/4) \times (17.80 \times 10^{-3})^2$$
$$\therefore V = 0.0730\ m/s$$

$$Re = \boldsymbol{\rho}Vd/\boldsymbol{\mu}$$
$$= \frac{1000\times0.0730\times17.80\times10^{-3}}{0.001}$$
$$Re = 1299.4$$

$$Pr = \boldsymbol{\mu}\ (Cp)_h / K$$
$$= \frac{0.001\ \times 4000}{0.615}$$
$$Pr = 6.5040$$

- Heat Transfer Coefficient

$$h_i = 0.023\ (K/d)\ (Re)^{0.8}\ (Pr)^{(1/3)}$$
$$= 0.023\ (0.615/17.80\times10^{-3})\ (1299.4)^{0.8}\ (6.5040)^{(1/3)}$$
$$h_i = 459.4491\ W/m^2\ K$$

$$m_c = \boldsymbol{\rho}VA$$
$$m_h = \boldsymbol{\rho}V(\boldsymbol{\pi}/4) \times (d)^2$$
$$0.25 = 1000 \times V \times (\boldsymbol{\pi}/4) \times (38 \times 10^{-3})^2$$
$$\therefore V = 0.2918\ m/s$$

$$Re = \boldsymbol{\rho}Vd/\boldsymbol{\mu}$$
$$= \frac{1000\times0.2918\times18.80\times10^{-3}}{0.001}$$
$$Re = 5485.84$$

$$Pr = \boldsymbol{\mu}\ (Cp)_h / K$$
$$= \frac{0.001\ \times 4178}{0.615}$$
$$Pr = 6.7934$$

Heat Transfer Coefficient

$$h_o = 0.023\ (K/d)\ (Re)^{0.8}\ (Pr)^{(1/3)}$$
$$^{=}0.023\ (0.615/18.80\times10^{-3})\ (5485.84)^{0.8}\ (6.7934)^{(1/3)}$$
$$h_o = 1397.018\ W/m^2\ K$$

Area of Pipe,

$$A_i = \boldsymbol{\pi}\ d_i\ L$$

Where, L = Length of Pipe (m)

$$= \boldsymbol{\pi}\ (17.80 \times 10^{-3})\ L$$
$$A_i = 0.0559\ L\ m^2$$

$$A_o = \boldsymbol{\pi}\ d_o\ L$$

$$= \pi\ (38 \times 10^{-3})\ L$$
$$A_o = 0.1194\ L\ m^2$$

- Overall heat Transfer Coefficient,

$$UA = \frac{1}{\frac{1}{hiAi} + \frac{1}{hoAo} + \frac{\ln(\frac{r2}{r1})}{2\pi KL}}$$

$$UA = \frac{1}{\frac{1}{459.4491 \times 0.0559L} + \frac{1}{1397.018 \times 0.1194L} + \frac{\ln(\frac{9.4}{8.9})}{2\pi \times 386 \times L}}$$

$$UA = \frac{1}{\frac{0.0389}{L} + \frac{0.00599}{L} + \frac{2.2536 \times 10^{-5}}{L}}$$

$$\mathbf{UA = 22.2655\ L}$$

$$UA\ \theta_m = (mC_p)\ (T_{hi} - T_{he})$$
$$22.2655\ L \times 1.9884 = 72.72(55 - 35)$$
$$\mathbf{L = 5.4486\ m}$$

Result:

Length of Pipe (L) = 5.4486 m

Pump

- Specification :
  - Make: Real Cool
  - Volt: 240 V
  - Power: 36 Watt
  - Flow: 2800 LPH

Function application:

Pump 1 supply the water from Water Supply Tank to the two storage tanks placed at a higher level in the rack. The water is also supplied to the Heat Exchanger from pump 2 for the cooling purpose. Pump plays a key role in the process.

Heater

- Specification:
  - Make: Bajaj Electricals
  - Watt: 2 KW
  - Volt: 230 V

Function application

The heater is mounted at the base of the Mixing & Boiling tank. As per the recipe to make the Neem juice the valuables of the Neem extract can be obtained when it is heated at 55^0 C. This is where the heater heats the water in Mixing & Boiling tank containing Neem extract to make a proper Neem juice.

Churner Motor

- **Specification:**
  - Make: Black and Deceker
  - Speed: 2600 RPM
  - Power: 300 Watt
  - Volt: 230 V
  - Frequency: 50 Hz

Function application: Churner motor is mounted on Storage Tank 1 to cut the Neem leaves and from the Neem paste which is diluted in water and taken in the process vessel.

Stirring Motor

- **Specification**
  - **Make: Roxy**
  - Speed: 550 RPM
  - Power: 90 Watt
  - Volt: 230 V
  - Single Phase AC

Function application:

Stirrer motor is used in the application to properly stir & mix the Neem extract in water. It also plays an important role in equivalently distributing the heat in the liquid mixture as well as cooling the mixture in the Mixing & Boiling tank faster.

Conveyor Motor

- Specifications
    - Make: Black and Deceker
    - Speed:6 0 rpm
    - Voltage: 12 V
    - Current: 2 A

Function application:
Conveyer motor drives the conveyer belt for bottle filling mechanism.

Process Control Instruments
Solenoid Valve

- **Specifications:**
    - Volt: 24 V
    - Current : 1.6 A
    - Operating Pressure : 0 to 10 Kg/cm^2
    - Pipe Size: 6 mm

Function application: The on – off solenoid valves are used to automate the process by turning on and off the valve when required in the process in order to efficiently control the flow of the liquid in and out of the tank in the process

Relays

- **Specifications :**
    - Voltage: 12 V DC

Function application: We use this relay circuit for the motor, pump, Stirrer motor, churner motor for the ON-OFF purpose.

Integrated Circuit

- **Specifications**
    - Voltage: 5V DC

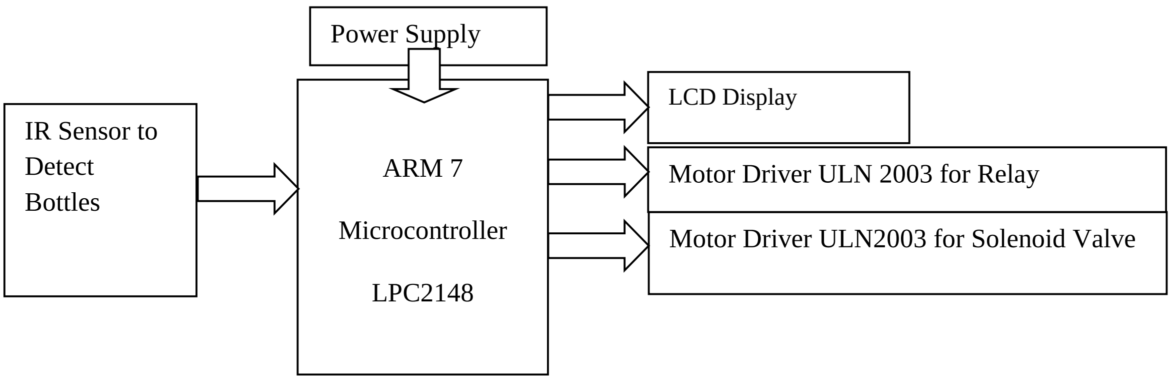
Function application: This Versatile device is useful for driving a wide range of loads including solenoid valves, relays DC motors, LED displays etc.

IR sensor
Function application: The motor of the conveyor is controlled by the IR module to detect the bottles.

Power Supply

- The power supply section consists of a step-down transformer.
- It transform of 230 v primary to 9v & 12v secondary voltages of the +5& +12v power supplies respectively.
- Most of the electronic system based on the dc power supply.The range is from 0 to 30v.The ARM 7 microcontroller is operating on +3.3v DC and other hardware has required +5v dc supplies.
- The solenoid valves operate on +13.1 V DC.

ARM 7 Microcontroller (LPC 2148)
LPC 2148 microcontroller is based on 16 or 32-bit ARM7 TDMI-S-CPU architecture with real-time emulation. Due to the small size and low power consumption, it is ideal for all applications. It also supports serial communications such as multiple UART'S. It has single or dual bit ADC(S) and 45 fast GPIO lines. These features make LPC2148 as a powerful microcontroller for medical and industrial applications. Microcontroller with embedded high-speed flash memory ranging from 32Kb to 512Kb.It is suitable for the constant power sensitive application.

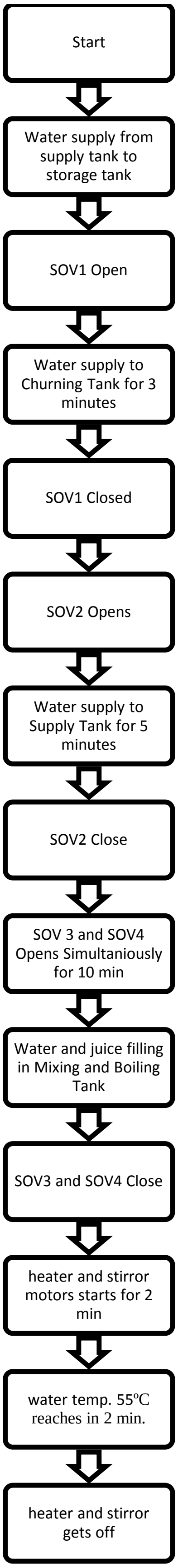


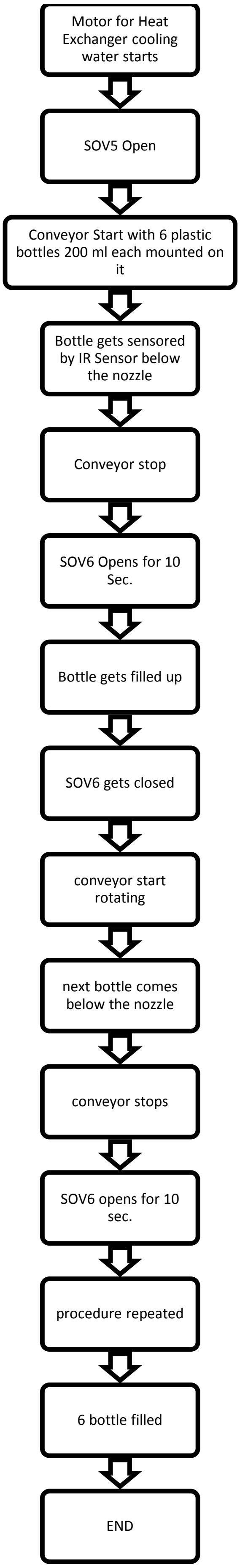
Features

1. 32 bit RISC processor**.**
2. Low power consumption 0.6mA /MHz

3. Fast interrupt response.
4. Simple but powerful instructions.

Flowchart




Motor for Heat Exchanger cooling water starts
SOV5 Open
Conveyor Start with 6 plastic bottles 200 ml each mounted on it
Bottle gets sensored by IR Sensor below the nozzle
Conveyor stop
SOV6 Opens for 10 Sec.
Bottle gets filled up
SOV6 gets closed
conveyor start rotating
next bottle comes below the nozzle
conveyor stops
SOV6 opens for 10 sec.
procedure repeated
6 bottle filled
END

CONCLUSION

This is most eco-friendly both for a human being from the medical/hygienic point of view. For the agro point of view, this is free from chemicals and useful for exporting the products to countries that are very cautious about residual pesticides. Also, the extracted residue can be used as organic fertilizer, thus increasing agro output.

We designed a proper process, studied each and cleared every loopholes in the process. Modified the design of the process and finally designed a proper process for herbal juice manufacturing plant. Later on- Procurement of the instruments required for the process, fabrication of tanks was done with minimum necessary finance. A proper piping work was carried out in due time. Interfacing of the input and output devices are done as explained earlier. Finally, testing of the process is done and the Herbal juice is ready at the outlet.

Application

1. Juice of several other herbal products can be made. –Like: Aloe Vera, Amla, Bitter gourd etc.
2. Mixing or chemical reaction for other processes can also be done by suitable modifications in this setup.

Advantages

1. The process will make the juice making process precise.
2. Human Intervention in making the juice is eliminated.
3. Juice obtained at the outlet is more hygienic.

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