Chapter 1: Introduction to automation

Introduction

Nowadays society is on a constant relationship with autonomous systems, which were which were developed to ease the tasks in the industrial sector as well as in our homes. The Coexistence with automation is a priority and we hardly notice it:

- At the work site, for example the machinery in the production and assembly lines of any factory being it a robot that does heavy work or receives raw material for further processing or even a system in charge of quality control, control of any variable either for its drive or adjustment within any unit operation.

What is a unit operation?

A unit operation is a total and harmonic set of an industrial transformation process where physical energy of a component is exchanged or a raw material in another different product than initially processed.

Redo and Reset!

- In a home, several tasks can be done using a remote control several such as a garage door opening or closing, burglar alarms, and so on.

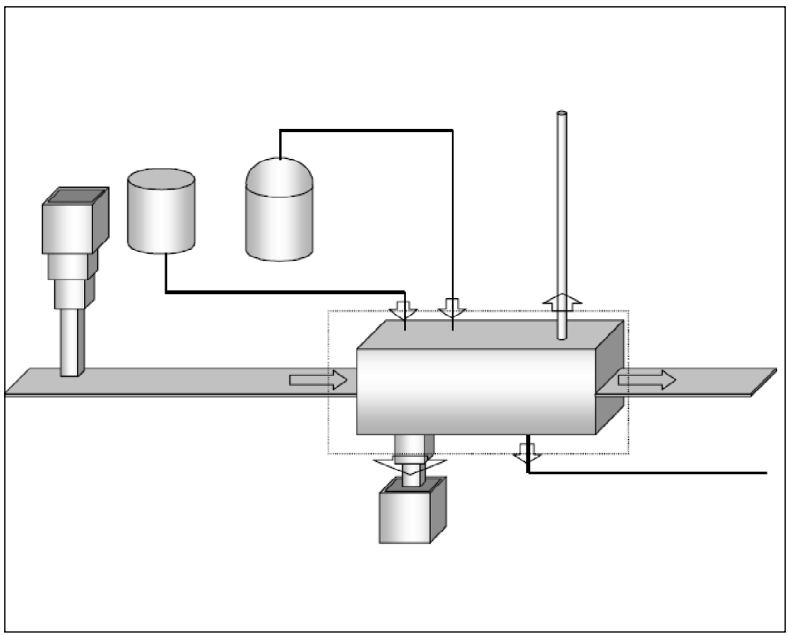
One can say that our lives are surrounded by automation. Our body is a complex machine composed of self-controlled subsystems: vision, digestion, breathing, movement, etc. Which, in comparison, our body has a very close resemblance to an automatic system in general: sensors, comparison and control. Even in the basic example of taking an object with a hand, we use vision (sensors) to locate the object, the information is processed by our brain (controller), which then gives an order to execute some action through our hands (actuators). There are other subsystems that are interacting with

each other with additional information to the controller, for example weight, shape, among others. In any event, they will support the most accurate and faster-controlled actions.

The analysis of unit operations in order to automate

Consider any system, such as the one in the following figure:

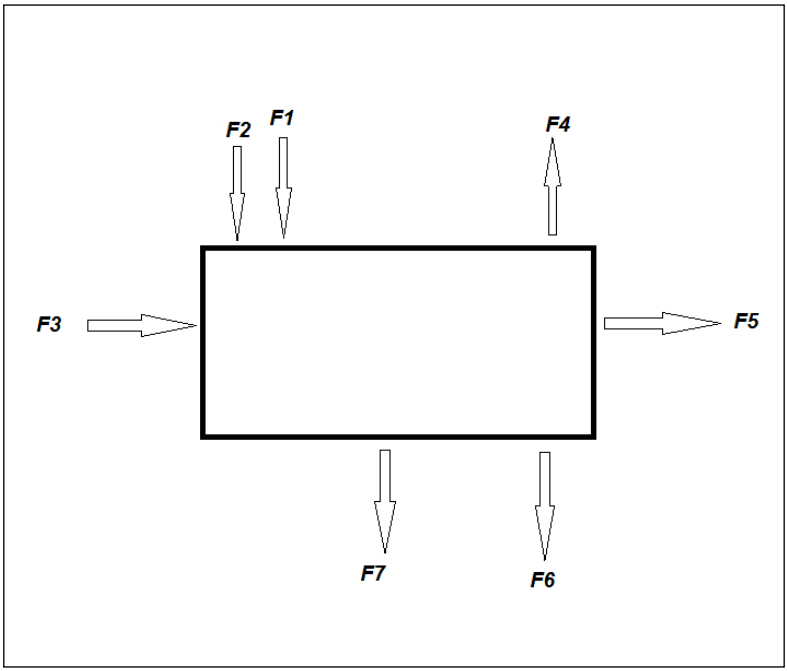
Figure 1. Identification of a unit operation to automate



It is a system whose inputs are solid, liquid and gaseous substances and whose outputs are presented in the same states. This information is important in order to quantify the streams that flow in the system. By creating a simplified system diagram, it helps for a better understanding of the task at

hand, enabling a faster more viable solution. Figure 2 represents this task, executed on the previous system.

Figure 2. Matter flows entering and leaving the system to automate



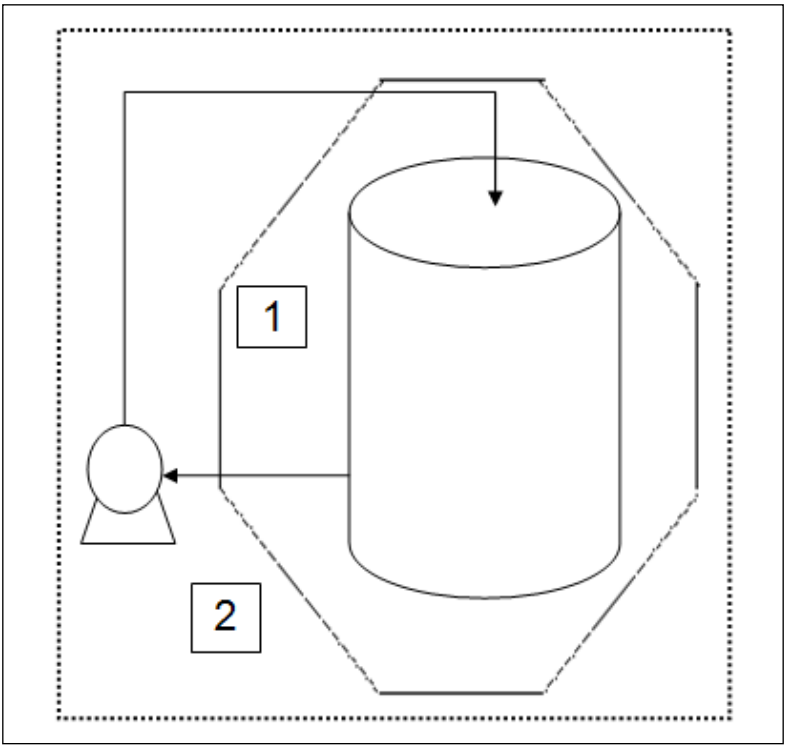
Where,

Fi = flows of processed raw and secondary material

Information that is not important as forms of transport, for example must be omitted from the diagram so that it maintains simplicity and functionality for further analysis and study.

A system is closed when there is no mass flow through the limits and is open when the mass flows through its own limits. See figure 3.

Figure 3. Types of systems formed by unit operations



Where
1= Open system
2= Close system

In each system the unit operations that interact with each other are defined by the condition changes of a determinate amount of raw material in any of the following ways:

- Modifying its mass or composition.
- Modifying the quantity or quality of energy.
- Modifying its displacement

Every unit operation needs a driving force or a gradient in its differential properties that characterize the main transfer mechanism. The following tables present a great diversity of unit operations under the different mechanisms for its operation.

Table 1. The different mechanisms present in unit operations

Case	Mechanism	Gradiente
Mass transfer	Diffusion	Concentration
Heat transfer	Conduction, convection, radiation	Temperature
Momentum Transfer	Friction	Velocity

Table 2. Unit operations whose study objective is the amount of mass present

	Definition	Operation	Equipment	Examples
Distillation	Separate or mix liquid by volatility	Simple, sudden, rectification, extractive	Packing	Petroleum, solvents, liquors
Absorption	Purify gas from a composition by contact with liquid		-Similar to distillation -Towers -Centrifugal Pumps	Removal of acid gases from streams
Extraction (leaching or washing)	Mix (liquid - liquid or solid - liquid) in a selective solvent	-Contact by phases -Continuous contact	-Columns -Soxhlet	Petroleum, oil extraction, mineral leaching
Adsorption	Elimination of fluid phase by solid that retains it	-Fixed bed, Alumina, gel, carbon	-Fixed-bed parallel flow column	Gas drying, odor, solvents
Ion exchange	Replacement of dissolution ions with solid ones.	-Cationic Resin - Anionic resin	-Two columns for operation and regeneration	Soften water, demineralization

For example, the distillation unit operation in figure 4, It is based on the separation of components of a liquid mixture based on its different volatility (vapor pressures).

Figure 4. Unit distillation operation

Source: Zhengjiu Machinery (2018).

Table 3. Unit operations whose objective is the amount of heat present in its operation

	Definition	Operation	Example
Heat exchange	Exchange between fluids	concentric tubes housings and tube plates	Extended use in the industry
Ovens	Solid or fluid	Radiation: carbon, fuel, gas	Gasoline, Naphtha cracking
Air coolers	Ambient air fluid	Fans, forced induced draft	With corrosion
Evaporators	Concentrate a solution	Single and multiple effect	Desalinated water
Condensers	Condensation of vapor by **a** cold liquid	Single and multiple effect	Extended use in the industry
Heat accumulators	Recover heat from FAS currents	Stacking materials such as bricks, stones	Glass manufacturing furnaces
Solar panels	Water heated by the sun	Radiation goes through glass that affects the coil	Photovoltaic energy supply

Among the examples for this type of unit operation are the heat exchangers and furnaces, as can be seen in figure 5 and figure 6.

Figure 5. Serpentine heat exchanger

Figure 6. Industrial type oven

Among the advantages of unit operations are:

- Suppression of loading and unloading times.
- Easy recovery of heat and cold.
- Reduction of manual labor caused by automation use.
- More hygienic working conditions and end-product uniformity.

Table 4. Unit operations by the amount of mass and heat present

	Definition	Operation	Equipment	Example
Gas conditioning or liquid cooling	Modify wet / air or water temperature		cooling towers	Thermal power plant
Crystallization	Solid to liquid crystal transformation	High temperature heating **process**	Crystallizers: -tank -evaporators -vacuum pump	Crystal production
Drying	Reduction of liquid content in solid	Contact: -direct -continuous	-tray equipment -Rotary - Sudden evaporation	Extended industrial use
Cryo dehydration lyophilization	Water removal from a solid, sublimation	High vacuum. Less than the water PF	-Hot flat plates, trays	Soluble Coffee Drugs

Table 5. Unit operations whose objective is the circulation of fluids

	Definition	Equipment
Conductions	Transportation from and to process operations	-Open channels -Circular section: pipes -Square section
Compressors	Increase pressure by supplying mechanical energy	-Alternatives -Rotatives -Axials
Pumps	Boost liquids by supplying mechanical energy	-Centrifuges -Positive displacement: * Alternatives or piston * Rotary (gears, fins, eccentric) * Peristaltic
Valves	Regulate the fluid flow through a conduit	Parcial o Total closure

The most common unit operation is, for example, hydraulic pumps, as can be seen in figure 7, that drive liquids by supplying mechanical energy.

Figure 7. Hydraulic centrifugal pumps

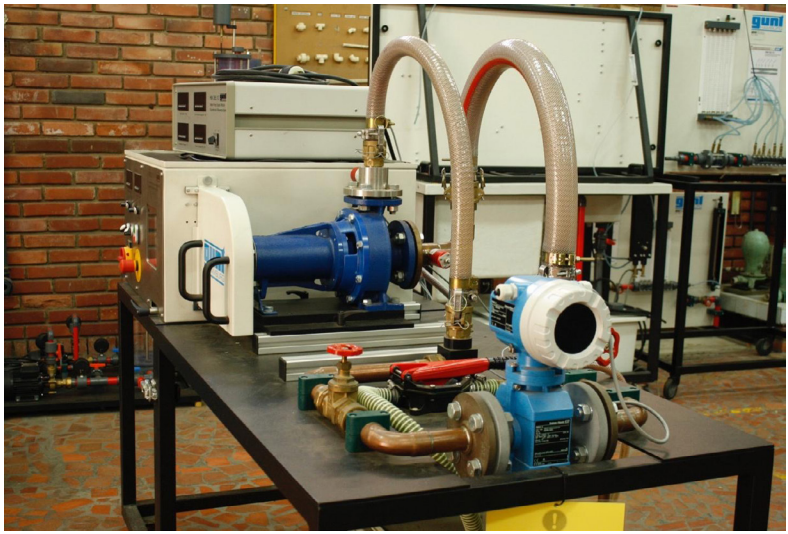


Table 6. Complementary unit operations

	Definition	**Operation**	**Equipment**	**Example**
Trituration	Particle size reduction	Large pieces are broken by compression	Jaws, rotary, roller	Extended industrial use
Grinding	Particle size reduction	Friction and impact by using wheels or pistons	Ball, hammer, bar and jet mills	Extended industrial use
Material storage	For raw materials, intermediate or final	Cost of container, material, volatility	-Bulk, silos, hoppers -Gasometers, liquefied	Extended industrial use

Within this complementary family of operations, there are the *Batch* type mixers, as can be seen in figure 8. Its purpose is to allow the reaction in a homogeneous and continuous way of the different raw materials interacting with each other.

Figure 8. Batch type reactor mixer

Source: EKATO (2018).

Some disadvantages of unit operations usually require the maximum optimization of resources, among these disadvantages are:

- Need for uniformity in the composition of raw materials.
- Start-up is sometimes very complicated (avoid stops).
- The equipment is more delicate and expensive (greater investment).
- Difficult adaptation from production to consumption (storage).

In real life, process development is born from basic ideas and small-scale tests up to the consolidation of the respective processes on an industrial scale. The results are the efforts in which they combine the use of knowledge with intelligence, imagination, trial and error and dedication.

Basic principles of industrial automation

Automation is focused on any automatic system in which the mechanisms control their functioning without human interaction. In automation, machines can control their unit operations.

Another important aspect is that with automation we see the improvement in process' quality, and it is the execution and maintenance guarantor of production with the highest standards of productivity and competitiveness. Additionally, when thinking about the environment, automation can guarantee the fulfillment of new norms.

What do we look for in automation?

- *The automatic control of processes and tasks, especially heavy, repetitive and dangerous ones*
- *Reducing financial expenditure, implement cost-saving production, assembly, and manufacturing processes with a higher rate of control*
- *Higher level of safety and security processes and procedures*
- *Operation of most processes at constant loads*
- *The interaction amongst the large number of variables present in a process with a higher degree of control and supervision*

Some considerations that must be made in process automation:

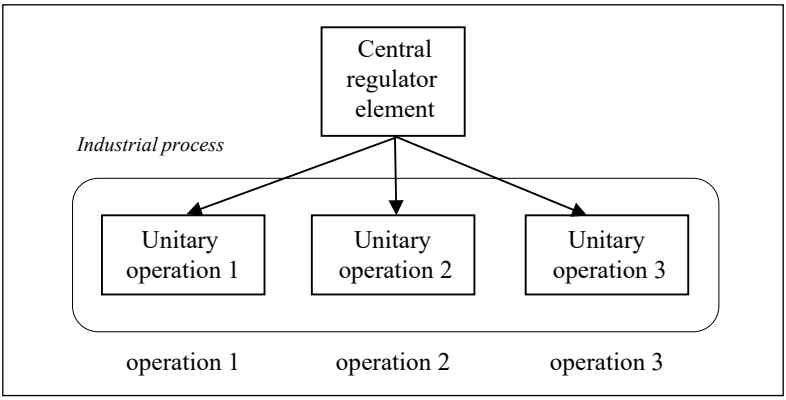
Individual automation

It is applied in a single machine (system). This type of automation does not require communication with other regulatory elements.

Centralized automation

It is used when various machines or systems are regulated by just one central regulator element, for example, a PC.

Figure 9. Example of centralized automation



Distributed automation

For this type of automation there is a regulator element dedicated to each system. This structure typically involves communication networks (LAN, modbus, etc). Its communication is carried out through protocols transmitted by physical (cable) or wireless (radiofrequency) mediums.

A Process is a set of unit operations or transformations performed on one or more materials in order to vary their properties

The types of processes where automation is present are grouped into three areas: