AUTOMATION IN COOKED MEAT PRODUCTS

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ABSTRACT

The individual operations involved in the process of manufacturing whole muscle cooked meat products are analyzed regarding today's state of the art in automation possibilities, together with possible applications of new technologies in the near future. Regarding the interfaces among the individual process steps, two industrial models are analyzed (Large batch sizes, few products - Medium sized batches, many different products) providing examples of advanced automation projects for both models.

Although the title of this talk is "Automation in cooked meat products", we will analyze only cooked whole muscle products, leaving aside the manufacture of emulsified products. The reason for that is that the automation problem is simpler in this case, as emulsified products are essentially homogeneous and they can be produced in a continuous way. The degree of automation achieved today with this kind of products is well known for everybody, so I think it is more interesting to analyze the future possibilities existing in the whole muscle products.

In this type of products there is a time variable that, till today, we cannot forget. It is what we know as maturation time. Once the brine is integrated in the muscle, a certain time is required in order to hold the water added and to develop and homogenize the characteristic pink color of nitrified cooked products. In the actual state of technology, we can achieve very good water holding results in very short times between injection and cooking (Usually 3 hours are enough) but, in order to achieve a good degree of stability and uniformity in the color of the end product, in most cases, minimum times of 18 hours are required. It is true that in some particular cases acceptable products can be manufactured in much shorter times, but this is not the general rule. In most cases, the time of the mechanical treatment will be much shorter then the total maturation time required.

Recently we have seen the outcome of technologies which are not really new (Our company developed similar processes some 20 years ago) tending to improve this situation (Use of gasses and pulmonary massages -alternating of vacuum and overpressure-), but the truth is that the economic costs of these techniques are extremely high compared to the poor benefits they give.

I have to say that I can't see a short term alternative leading to a true continuous process for that kind of products, so any automation project will need to take into account this intermediate meat stock during the maturation process.

While analyzing the production of whole muscle cooked meat products we find two different industrial models, both with success stories all over the world:

- **Big plants with very few product references.** The production lines are of large size and fairly optimized for the manufacturing of just four or five different products. Their key competitive point is the reduced production cost.
- **Medium sized plants with multiple product references.** The production lines are extremely flexible in order to produce what the customer requires at every moment, mainly value added products. This flexibility is their key competitive point.

The automation of the first model is conceptually simpler and can be carried out at a much lower economic cost. The automation efforts will have to be centered mainly in the interfaces between the different basic operations of the process, being easy to control automatically a few variables in these individual operations.

The second model requires monitoring a multiplicity of small size batches of different characteristics. In order to do this, the batches will have to be correctly identified and automatic control mechanisms installed in all the individual equipment used. These controls will need to be more sophisticated than in the prior model because of the flexibility of the equipment.

The automation of the interfaces will be in this case very complicated as in most cases the transport between the different steps of the process will be carried out using tanks, due to the small size of the batches.

Both industrial models have in common a series of basic operations which we will analyze individually before moving on to a description of the automation possibilities of the two models specified.

Raw meat selection:

Very few cooked products can afford the cost of a raw meat selection process, but a statistic quality control of the meat is always interesting in order to adjust the prices paid for the individual batches. Weight, fat level, haemathoms, and pH, conductivity or pY (Measure of multifreqüence impedance) are parameters which can be statistically controlled and/or used as selection criteria in a more or less automatic way.

In recent years we have seen a multitude of partial or total automation projects on this step of the process, in many cases tailor-made solutions to particular manufacturer needs. Probably in the next 10 years we will witness important developments in this field brought about by the advances and price reductions in artificial vision and robotics technology, with the creation of integrated systems which will supply complete statistics of the batches at a very high speed to the production control systems.

Deboning and trimming:

These two steps of the process are today the ones where more manpower is required. The mechanical deboning systems developed so far are of no use in the case of ham, or they seriously damage the meat quality in the case of shoulders.

The diversity in meat size and characteristics makes the mechanization of this step very difficult. Solving this problem is, without any doubt one of the biggest challenges in the near future of the industry.

Even more complicated is the automation of the trimming operations (cleaning the meat muscle from fat and tendons), in such a way that I cannot see any possibility for this in the near future. Anyway, developments can be made in the sense of automated quality control of the trimming operations, using similar solutions to the ones developed for the raw meat control.

Brine preparation:

The brine preparation operation includes the dosing of the water and ingredients used as well as the mixing operation. Nowadays only very few factories have introduced a certain type of automation in this sector. Water, salt and some other major ingredients can be automatically dosed up from stock tanks. Even though technically there are no problems involved, the cost of dosing in a computer-controlled way the multitude of minor ingredients composing the brine is still too high to be afforded by most of the plants.

In the case of lines producing big quantities of very similar products (specially without added polyphosphates), a mother brine containing just water and salt can be prepared in a fully automatic way at a low cost. This brine can then be, in a more manual way, diluted adding water and the rest of the minor additives required for the individual batches. This procedure certainly accelerates the preparation of these individual brine batches but doesn't guarantee at all the absence of errors.

The preparation of brines using formulated solid or liquid pre-mixes reduces the number of elements to incorporate into the water, making more feasible from an economic point of view the computer-controlled preparation of the brine. The problem is that while using pre-mixes instead of pure ingredients, the final cost of the brine is increased, and the possibility to eventually adjust the formulation is restricted.

For the next years, I cannot foresee any important change in today's situation regarding this concept, so the brine preparation will continue to be one of the critical points of the process, where there are more error possibilities, so I will continue recommending the use of analytical quality controls for the prepared brines.

Injection and tenderizing:

In recent years we have seen the appearance of optional PLC systems for injection control, with attempts at on-line control of the injection percentage by adjusting on-line the regulations used. Although the practicality of this on-line control can be discussed, the use of PLC offers the possibility of remote control in integrated fully automated lines.

Regarding the tenderizing operation, performed in an individual machine or in the same injector, this is a pass-through step, without on-line regulations required, so the only thing that can evolve in the future is the use of motorized regulation of roller separation in roller tenderizers for remote control in fully automated lines.

In this part of the process we find an important point for data caption, especially regarding weights.

Batch identification, raw meat weight, injected meat weight, calculation of the injected percentage, adjustment of the amount of brine incorporated in order to meet the target weight, setting alarms for misfunctioning. All these are points to be taken into account in any automation project regarding this area.

Massaging.

The automation of the massaging operation is easy when we talk about big tumblers for large batches of a reduced number of products. The loading operation can be automated totally or partially by using vacuum techniques, lifts, or conveyor belts directly coupled to the injection system. The automatic closing and opening of the tumbler door can also be performed at a reasonable cost.

Most of these products in large size batches will be massaged using a long single continuous or discontinuous step, but without unloading the tumbler, so the maturation time will be completed outside the maturation area.

As technical parameters, the rotation speed, rotation direction in some cases, massaging and resting times, and temperature will need to be controlled on-line by means of a PLC. It is very important for the massaging system to be equipped with means to lower the meat temperature rapidly after the injection step, if needed, in order to avoid microbial growth in the meat.

In the case of medium sized tumblers operating with many different products, the automation of the process is more expensive. As we have seen before, in most cases the injected meat will arrive at the massaging area in individual tanks, that will need to be properly identified in order to perform the massaging operation in a fully automatic way.

In order to improve the efficiency of the massaging installation the massage will usually be performed in several steps through the whole maturation time, requiring combined maturation-massaging facilities.

In addition to the control parameters set for the first type of installation we mentioned, in that case we will need tank identification, and also automatic cleaning-in-place facilities, as many different products can be processed, and some of them will be incompatible without a more or less thorough cleaning of the drum. Also, programming facilities will be needed in order to use multiple massaging formulae probably controlling more parameters than in the first type of installation.

Maturation.

In the case of large batch sizes the preferred stock system will be the use of large containers holding meat quantities of the same size as the massaging batch. These containers will have to be placed in temperature-controlled rooms at the desired maturation temperature and, for some products, the meat will need to be mixed from time to time in order to avoid excess of rigidity of the muscles.

For multiple product installations, the preferred stock system will be the use of tanks of not more than 1,000 kg in order to facilitate transportation. The storage can be done in the same machine or in some sort of dynamic computer-controlled storehouse.

Pre-cooking packaging.

In these cases we will have again two different kind of products: the ones needing to be reconstructed preserving the natural ham shape and the ones only restructured without preserving this shape.

In the first case the molding or packaging operation will need to be performed manually, into bags or thermoformer alveoli, and vacuum clipped or sealed.

In the second case, the use of automatic stuffers with a large diameter outlet for big muscles, coupled to thermoformers or double clipping machines, is the solution usually adopted. These stuffers are normally vacuum loaded in a fully automatic way.

For molding, the type of molds used will change depending on the industrial model. The large installations with very few products will use mainly multimold press towers, and the installations with multiple references will probably combine the multimold press towers with individual stainless steel molds.

Cooking.

Due to the long duration of the traditional cooking systems for ham products (In many cases 6-7 hours), the continuous cooking systems often used in sausage processing are rarely used because of the size and cost of the installations required. The traditional steam or hot water cooking systems show today a high degree of automation and control of the cooking process, but the loading and unloading operations are often done manually.

An interesting further step in this field has been made with the use of microwave, high frequency or ohmic continuous systems, connected to an automatic stuffer without using molds, and flow-packaging the product after cooking. Unfortunately, in today's state of the art, only very few products can be processed in such a way, but anyway it is something to take into account in the near future.

Chilling.

Chilling presents a problem very similar to the cooking process. The duration of this step makes it impossible to perform in a continuous way at a reasonable cost, so I believe that for many years chilling will be done in batch installations.

Final packaging.

For those products not cooked in the bag, the re-packaging operation represents a very important step of the process, critical to the final shelf life of the product. In this case, automation also means less human contact and, in the end, longer shelf lives. Together with hygienic improvement of packaging room conditions, automation and development of post-pasteurization techniques will be important fields of research in the following years, specially regarding sliced products, whose shelf life is today still too short.

The technologies developed during recent years are not yet effective enough, or their cost is extremely high, to be a massive alternative in the market.

After this analysis of the individual steps involved in the manufacture of whole muscle cooked meat products, I would like to show you a couple of examples of automation projects for the two industrial models we described before.

MODEL A: LARGE SIZE BATCHES, LOW FLEXIBILITY

In this project, we can see a semi-continuous and automatic production line, without using tanks or any kind of on-wheel transport inside the plant. The maturation or resting period is performed in 5.000 Kg Meat buffers, where the meat rests waiting for the stuffing step.

This project includes the equipment required for the production of 100 Tm of cooked ham in a 3-shift working day. The production will be carried out in an automatic and continuous line, computer-controlled in the key points, with information on the individual operations sent to a central production control computer. The main characteristic of this plant is the automation of the process, requiring minimum man power.

The production unit is a 5.000 Kg of injected meat batch, and all the equipment is adapted to this batch size.

The part of the process I will describe comprises the following technological steps:

- Brine preparation
- Meat Injection
- Massaging and Maturation System

Brine preparation area.

Here the brine is prepared in 2,000 kg batches. In this example the brine is manually prepared, with batch preparation times of 15-20 minutes.

The ingredients and additives are weighed in this area, with 5 Kg and 300 Kg scales. In this project, the dosage and preparation of the brine was not automated, but the transport of the brine to the injectors was.

Brine is prepared with two crushing mills assembled on 2.000 liters tanks equipped with water dosing devices. There are two buffer tanks, with small propeller mixers (5) to storehouse the finished brine, in order to leave the crushing mill free to prepare other batches.

The brine is transferred from the crushing mill to the buffer tanks by means of a pump and stored in one or the other, according to the brine level in each one. All of these operations are manually controlled from an electrical panel.

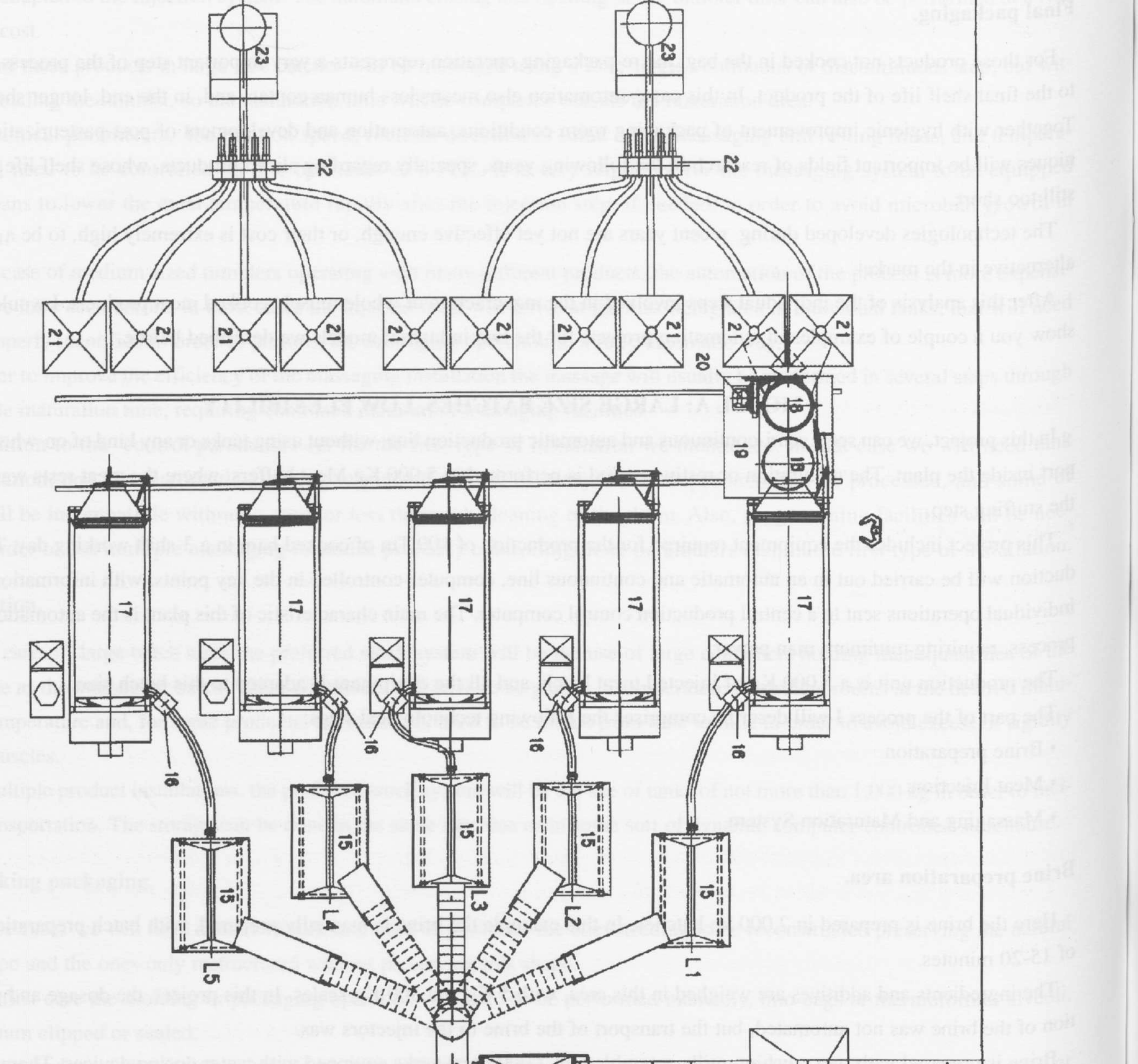
Another pump automatically transfers the brine to the injector, controlled by means of a level sensor in the injector brine tank.

There is a third circuit, providing a conduit to the different Hopper-Scales (15) in order to add brine if necessary. The injector operator controls this operation from the injector control panel.

Injection and tenderization area.

This step is performed with only one injector line with a production capacity of 100 Tm per day. This area receives the meat from the deboning lines by means of a conveyor belt. Then it is automatically weighed in batches and transferred to the injector. The injection level is computer controlled by weighing at the end of the injection process, the meat being stored in the Hopper-Scale waiting to be massaged. As this area is made up of different zones, each one will be described separately:

Figure 1. Model A: Large size batches, low flexibility



Green weight control and automatic feeding - Injection Control System.

The meat transported from the deboning line by means of a conveyor (7) is stored in a buffering-hopper (8) with a capacity of 2.000 Kg (half batch of green meat). After achieving this desired weight, an electrical signal stops the conveyor. The buffer will feed the injection line.

When the operator starts a new batch, the meat is transferred by means of conveyor nº 2 (9) to the Continuous Scale (10) with an electronic system for direct weight read-on. This scale is tared to the standard green weight batch in order to stop the conveyor nº 2 (9) after reaching this weight. All data are registered by the computer of the injection control system.

The meat is injected through the injector (12) equipped with an automatic filtering system (13) and a blade tenderizing head. To inject a 5.000 Kg/batch will take in this machine about 30-35 minutes, and this means 10-12 hours to cover all the production capacity of the line. Having in mind the elapsed time and transport of the exit conveyor, the injector will be used for 14-16 hours/day.

The automatic self-cleaning filter has autonomy enough to work a full day without requiring any kind of manual cleaning.

As I told you previously, the meat and brine arrive automatically to the injector, once the operator has activated a new batch. After injection, the meat is transferred by means of a conveyor belt (14) to the Hopper-Scale (15). A single conveyor is automatically directed to the corresponding hopper, in order to fill the different hoppers following a programmed sequence. The hopper-scale registers the final batch weight, sending the information to the injection control system PLC where the injection % will be calculated and corrected automatically if permitted by adding brine to the buffer hopper. During the injection process, the operator can see displayed on-line information on the injection level at all times.

Massaging and Resting Area.

Once the batch is injected the meat stays on the hopper-scale (15), waiting for the reactor to be free. The massaging line comprises 5 automatic reactors (17). These unit are fully automatic computer controlled machines working without labor assistance. Each machine has a batch capacity of 5.000 Kg and it can produce up to 4 batches per day. The total capacity of each line is 20 Tm/day. The time for a complete massaging cycle (loading + massaging + unloading) is in this project from 4 _ - 5 hours, depending on the meat characteristics, so the massaging line is working more or less 20 hours/day. The remaining hours are required for cleaning cycles.

Loading Operation.

As soon as the reactor finishes a batch, if there is a new batch programmed in the system and this is ready in the hopper-scale (15), the loading step starts placing automatically VACUUM LOADING ADAPTER (16) in the correct position by means of a hydraulic system. At this moment, vacuum is produced inside the reactor and the meat is vacuum loaded.

Massaging Cycle.

The required massaging step takes place during 4 -5 hours with control of the meat temperature during the process. The reactor is equipped with a chilling jacket with propylene glycol circulation when required. Any incidence produced during the massaging cycle, the starting and finishing times and the temperature evolution are registered by the system control computer.

Unloading Operation.

An Automatic Unloading System is designed to transfer the meat into a 5.000 Kg Meat Buffer (21) where the maturation process will take place. The reactor unloads the meat into an intermediate Unloading-Tank (18) controlled by a scale. An electronic signal emitted by the PLC interrupts the unloading process when the tank is full.

The unloading-tank (18) rotates on a platform (19) and an elevator (20) raises it up in order to unload it into one of the 5.000 Kg meat buffer (21). The selection to which one of the 5.000 Kg meat buffer should be unloaded is done by means of a mobile chute.

The total assembly of unloading-tanks and hoists is attached to a platform (19) traveling along in front of the 5 reactors.

Resting Hoppers

The meat maturation takes place in the 5.000 Kg meat buffers (21), where the meat stays for a period of time of 8-10 hours. After this holding time has elapsed, the meat is transferred directly to the stuffer machine by vacuum suction.

MODEL B: SMALLER SIZE BATCHES, HIGHER FLEXIBILITY

In the example we will see now, about 70 different products can be processed per day in batches of up to 3,000 kg. The total production capacity of the lines described is 220,000 kg/day.

As the solutions adopted for brine preparation and injection are similar to the first example, I will only explain the peculiarities of the massaging area.

The massaging line comprises 12 reactors (1) with a maximum batch size of 3,000 kg, a dynamic storehouse in 3 floors for the storage of the tanks used, and the robotic elements to manipulate the 1,000 kg tanks (2) used for the transport of the meat.

In this case the tank is identified by means of an electronic disk attached to the tank side. The batch is identified during the injection process, and once the injection has been performed and corrected, the full motion in the area is computer controlled and performed by robots.

Due to the multiple products to be processed, the reactors will need a much higher flexibility in this case than in the prior example.

The main characteristic of these reactors has to be the VERSATILITY, with the following characteristics required:

Diversity of mechanical action. Tumbling and Massaging: The machine needs to have the capacity to perform on the product Tumbling or Massaging actions. Usually, tumbling means an aggressive action and massage a soft and gentle action. We will keep this terminology, even if sometimes both words are used as a general name for both actions.

TUMBLING means that turning the Reactor in one direction, internal baffles lift meat up to the upper part of the Reactor and allow it to fall freely on top of the meat that is in the lower part of the Reactor, producing impacts of falling meat against the meat on the bottom. The impacts meat against meat, produce an effect that is transmitted to the whole internal volume of the meat pieces.

MASSAGE means that turning the machine in the reverse direction, the meat is moved and massaged, with a friction effect between the different muscles and without impact, producing a much gentler massage than the tumbling system. This type of massage is very suitable for products in which the pieces and the fibrilar structure must be kept intact, but with the feature of achieving sufficient solubilization of proteins for muscular binding.

These two models of massaging correspond to very different types of products and there are many others to which an intermediate process, or a combination of the two, must be applied.

Diversity of turning speeds: The Reactor must have the possibility of varying the turning speed, in both turning directions (clockwise and anticlockwise). Usually, the mechanical action is increased while increasing the turning speed, up to the moment when the centrifugal effect holds the meat against the reactor wall, reducing the mechanical action.

Internal atmosphere: In some cases, these reactors must have four possible internal atmospheres: High Quality Vacuum, Atmosphere Pressure, Pulmonary Action (alternating high vacuum and overpressure) and the possibility of using different gasses at different pressures. A combination of the four settings may be required during the mechanical action process.

Temperature control: The reactors have to be equipped with a cooling system using a refrigerant fluid, in order to cool and maintain the desired meat temperature (6-8°C, depending on the product and process) during the entire maturation process.

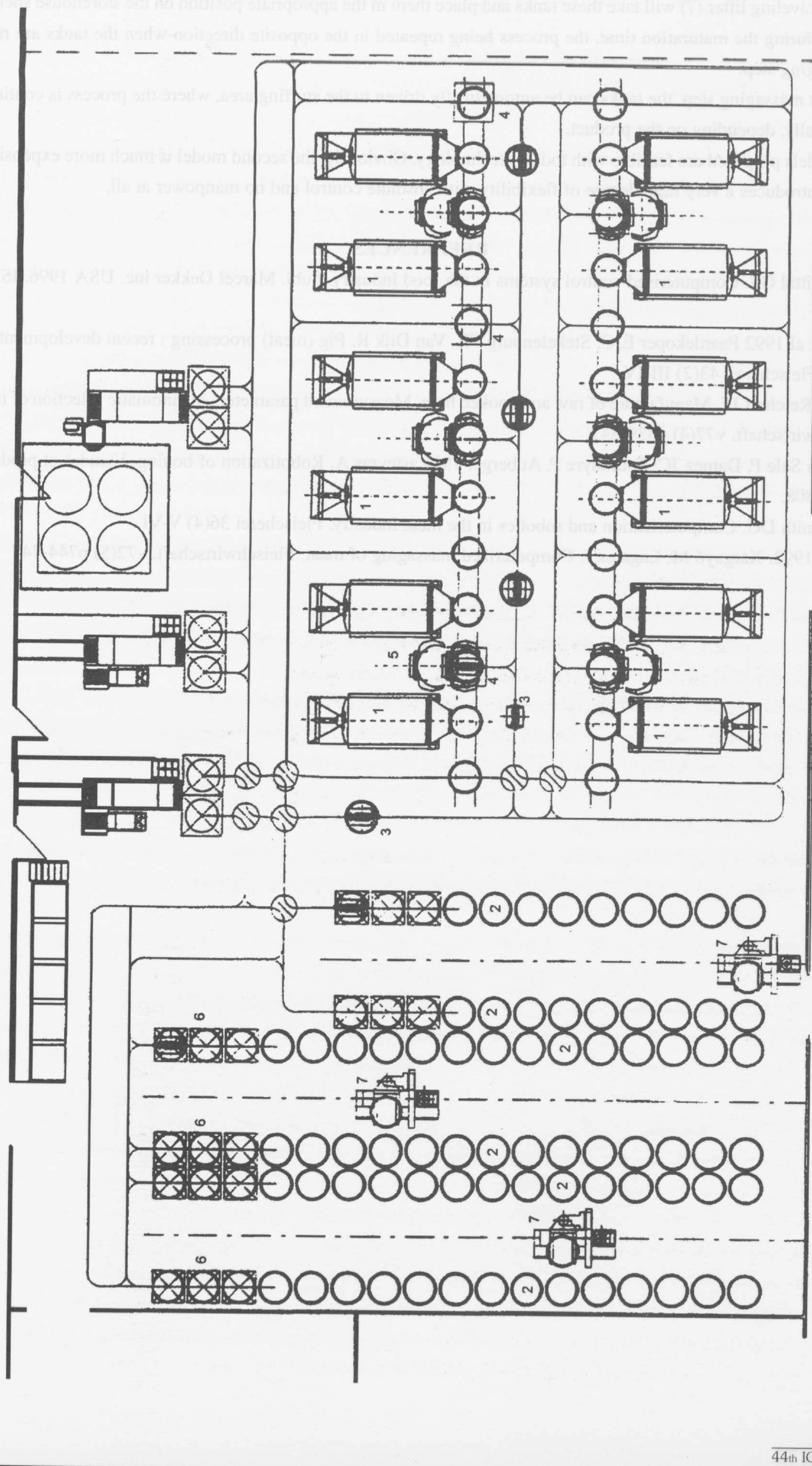
The process starts once the injection batch is finished. The injected meat tanks are lifted by one of the twelve robotic moving lifting units (3) for aerial transport to the required reactor. These units are battery operated and, when required, they go automatically to a battery charging station.

In front of each reactor there is a mobile platform (4) mounted on load cells in order to control the unloading of the reactor.

The aerial transports leave the tank on the platform (4) in front of a robotic lifter (5). The robotic lifter (5) advances, reads the tank identification and loads the tumbler (1) activating one of the massaging programs stored in the reactor's PLC. After emptying the tank, the lifter frees it on the platform which is displaced to the opposite side of the tumbler, where an aerial transport (3) picks up the empty tank and drives it to the storehouse. The same operation is repeated for 3 tanks (Or less if it is not a full batch). After the last one has been loaded in the drum, the door is automatically closed and the massaging step performed according to the type of process introduced. In order to improve the efficiency of the process, in most cases 3 massaging steps will be performed, one immediately after injection, another in the middle of the maturation cycle and another one immediately before stuffing.

Once the massaging step is finished the empty tanks are placed on the platform which displaces to the unloading position, the drum door is automatically opened and the meat emptied until a certain weight is reached, distributing the meat among the three tanks.

Figure 2. Model B: Smaller size batches, higher flexibility



After the first and the second massaging steps, the tanks are driven to the maturation storehouse, where they are left on platforms (6). A traveling lifter (7) will take these tanks and place them in the appropriate position on the storehouse shelves, where they will stay during the maturation time, the process being repeated in the opposite direction when the tanks are required for another massaging step.

After the last massaging step, the tanks can be automatically driven to the stuffing area, where the process is continued, automatic or manually, depending on the product.

The two models proposed are feasible with today's technology. Obviously, the second model is much more expensive than the first one, but introduces a very high degree of flexibility with absolute control and no manpower at all.

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