PRODUCT ENGINEERING OF A LABORATORY ELECTRONIC EQUIPMENT

G. Calva O., J.L. Pérez S., J.L. Juárez A. S. Pérez L

Center of applied Sciences and Technological Development
Circuito Exterior C.U. Apdo Post. 70-186 México D.F.
Tel. (01)56228608. Fax (01)56228617
Email. pepito@alep.cinstrum.unam.mx

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ABSTRACT

This work is the result of a group effort that follows the idea that we can build some of the laboratory equipment that is commonly found in our country labs. Here we mention the need of integration of many workgroups from many areas of expertise. This is a special work because here we are presenting some of the steps needed to build a laboratory electronic equipment from the product engineering perspective, the problems that we have found and how we dealt with them.

KEYWORDS: Electronic product design, Product engineering, Laboratory equipment

1. INTRODUCTION

For the development of a piece of equipment or a whole instrument, it is necessary to determine whether the product will have the appropriate characteristics in order to satisfy the users' requirements. Therefore it is necessary that the initial prototype, generated in the engineers' workbench, goes through a series of steps or stages in which the design is tuned or improved.

One of the main aspects to be taken into account when designing an electronic equipment is the way in which the user interacts with the instrument. An appropriate set of controls, with a proper placing and a proper labeling will allow the user to get the maximum functionality of the instrument. Equally important is to elaborate a users' operation manual and a service manual with detailed safety instructions in order to reduce any risk either for the user or the equipment.

In order to get a prototype that is suitable for mass production, it is required to follow a sequence of steps in which the first prototype is generated and then refined. This is accomplished by applying a set of tests to the prototype. As the prototype passes the tests it becomes the final prototype. At each stage of this process it is possible to go back some steps until it passes a test or it is improved.

This process is defined for equipment with electric, electronic or mechanic components or a mix of them, which is the most common case nowadays. Also the appearance of the equipment has also to be taken into account. From this, it is clear that we need to precise some definitions that help us to understand each step of the product design.

2. DEVELOPMENT LEVEL OF A PROTOTYPE

We now present some definitions that can help us to set the development level of an equipment.

Prototype: Version of the product generated from a central idea that complies with its original objective. It is generally presented in a protoboard and may be connected to other electronic devices in order to operate. This means that, at this stage, the prototype may be not capable of standalone operation.

Laboratory prototype: Version of the product generated after testing different topologies or alternatives that comply with the original objective. This kind of prototype is suitable for test by the final user, since it already has a proper case, it is capable of standalone operation and presents an advanced level of optimization regarding its component number.

Production prototype: Version of the product generated after defining electrical and mechanical fabrication tolerances, a proper set of materials and components and a method for assembling suitable for serial production. This version should also comply with any applicable quality or safety standards.

From the above definitions, it is possible to find out which stage of development corresponds to one particular design. As we can see, developing a prototype suitable for operation by a final user does not actually mean that the process is finished, though most designs in our country end at the laboratory prototype stage or even just at the prototype level.

3. ORGANIZATION

At this point, we have presented a general view of what an equipment should or should not comply, in order to be used. However, it is necessary to analyze which path should be followed and which stages comprise any available alternative.

We should start by analyzing the motive that originates the construction of the equipment. There are two cases: first, there is already in the market an equipment which solves the particular problem, but it is of interest to compete with it; second, there is no antecedent of the problem being solved and the development of a new equipment is feasible. In both cases, there should be an agent that will analyze the availability of financial sources and will manage the budget during the project. In figure 1, a block diagram presents the relationship between the administrative part and the engineering part. In both cases, the financial sources can be just from university funds or we can have some sort of external, well defined, support.

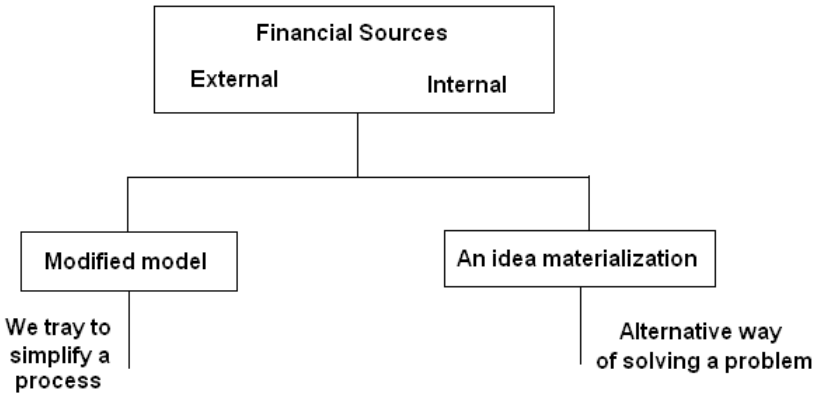

Figure 1. Block diagram of the financial sources

When an equipment is developed regarding the university founds and for solving a particular problem that only requires a laboratory prototype, it does not mean that the equipment could not have commercial repercussions, because the prototype can be worked further in order to become a production prototype.

One of the first considerations to be done during the product development is the time spent and effort done by the design team to determine the specifications of the equipment, what the instrument should do and how could do it. Once the operation principles of the equipment have been established, it is possible to develop several alternatives of the operation of the equipment. Operation ranges, type of environment and ambient ranges should be defined at this stage.

The design team should analyze several alternatives before deciding which one is the best, considering financial resources, available technology, intended use, operational environment, etc. Once the decision has been made, several electronic topologies can be tested giving as a result mesh circuits, or even a printed circuit board containing the electronic components used. It is the same for the mechanical part, it should already have a series of plans that specify all the dimensions, material and the way in which the pieces are assembled. The definition of manufacturing tolerances is one of the most important aspects to consider during product design.

The case that contains the electronic circuits can be of an easy handling and molding material for a first prototype, which allow us to visualize the final form that will be given to the equipment. By means of this first prototype, the designer can make an image development that allows him to locate each control knob, as well as to locate one display or several displays, whichever the case, in an adequate position in the frontal or rear side of the prototype according to what is needed. For cost reduction purposes, an already designed case can be used, given that it fits the requirements of the present design.

The first prototype of enclosure can have several levels of design. A first level could be just an artist conception or a sketch, in which we can think of possible forms, knob positions and gamma of colors to be used. A second level could be a physical model developed in some sort of material that allow us to visualize the artist conception. This could be done using soft materials as sponge, cardboard, or wood.

In figure 2, we propose a flow diagram as a method to develop a prototype. We basically resume the stages aforesaid and at the same level the options outlined by the designer are established. Among the several options, the one that presents the most appropriate characteristics is selected following the opinion of the designer or the designer team.

After the first prototype is built, it is evaluated. Then it is possible to return and compare the results with the other options that were considered and then to decide to change the selection or to make a mix of them. This brings a greater confidence in the fulfillment of the expected characteristics for the particular type of equipment.

In figure 2, we can see a block named Product Engineering. This block is located at the precise point where the design options are presented. At the end of the diagram, it is the Evaluation block. At this point, the staff decides if the product satisfies the requirements or the design should be redone to some extent. This does not mean that everything should be discarded, or that the return to the workbench should be considered as a failure, not, but rather that it is possible that one or several parts of the design require of a reconsideration, or some addition that could help to enhance the operation obtained until that moment.

This last evaluation involves the whole design including electrical, electronic and mechanical parts, as well as operational, aesthetical, quality and safety issues. If the evaluation is satisfactory, it will be necessary to analyze the results obtained. One possibility is to transfer the design to one who has the interest and resources in making a serial production. This implies to complete a partial or total technological transfer package with the necessary information for the satisfactory reproduction of the equipment.

4. PRODUCT ENGINEERING

As seen in figure 2, product engineering is a main block of the product design flow. Product engineering is vital in order to develop an equipment capable of continuous use. This implies that diverse considerations have been taken into account that allow the user of the equipment to trust it fully, in that the equipment will operate within the

established margins, and that the form or enclosure of the instrument will resist the environment in which it will be used.

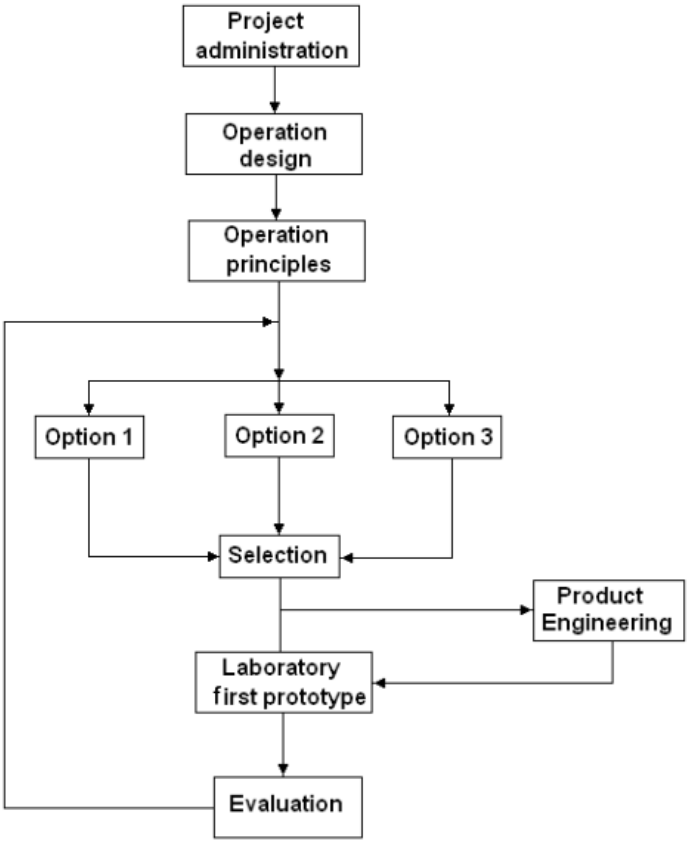

Figure 2. Block diagram of a design process

Inside the concept of Product Engineering is not only the proper design of the enclosure but the proper selection of any electromechanical components, this includes the electronic part of the equipment. It is common or even necessary to reduce the printed circuit board dimensions in order to achieve some cost reduction. This begins with some optimization of the electronic circuits for reducing the number of components. In some cases substituting an imported component may lead to further cost reductions. Another option is to try to avoid using some highly specialized components if they are expensive.

Sometimes an equipment is very expensive because it uses a couple of integrated circuits. In this case we can get the same functionality from a set of integrated circuits that despite of using a broader board area, releases the designer from depending on just one product.

Something similar may happen with the electromechanical components and with the design of the enclosure. However, the problems involved are easily overcomed when the staff works with high levels of quality and there is an adequate infrastructure. This conditions allow the development of any enclosure, from an artistic model or from a prototype model.

For the developing of a product that results attractive to the user, it is necessary to invest in the development of an attractive enclosure, which will be manufactured from a material suitable for the intended use and operation environment. During this process, it is advisable to have in mind a possible return to the design table, with the only purpose of obtaining a better model since this could be achieved after "polishing" the prototype.

In figure 3, a block diagram is presented with the different steps to follow in order to develop a prototype enclosure which will contain the equipment in functional and safety way as well as with an attractive look.

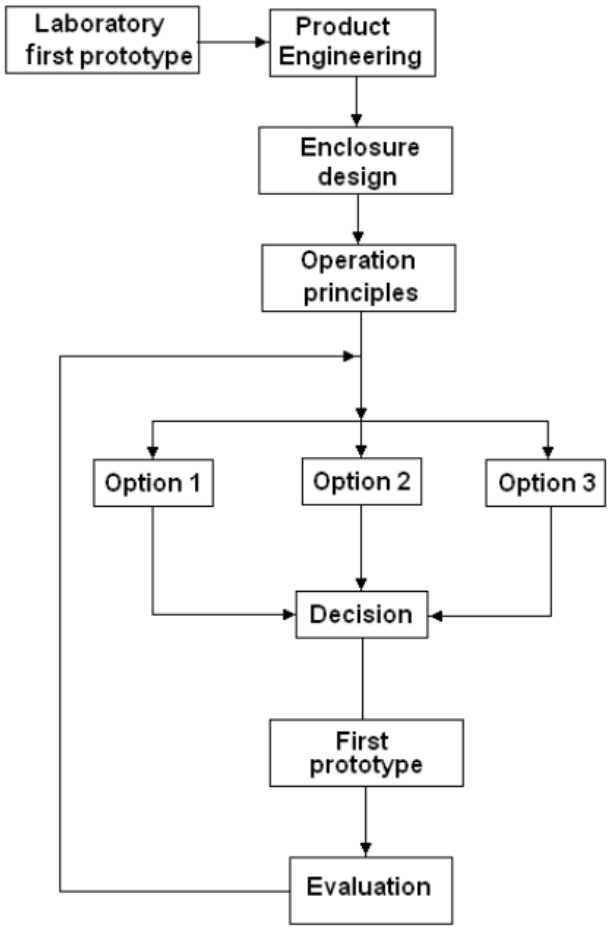

Figure 3. Block diagram for the design sequence of an enclosure

The design method proposed implies the development of an initial design from which several options are generated. From these options, the better is selected, avoiding to affect the characteristics of the equipment and having in mind the type of environment for which it is intended.

Once the best enclosure is selected, then it is manufactured. This first prototype should pass through several levels of evaluation. Operation in its intended environment, appearance to the user and even the touch texture should be evaluated and, of course, its functionality.

After these evaluations we can determine whether the choice was adequate, or we need to go back to the design table. In the last case, we can suggest any sort of changes or additions to the design, and these changes should be considered as a feedback to the original design just as it is presented in figure 3. In this figure we can see that the evaluation process can lead to a redesign of the enclosure and to the repetition of some steps. This may include the selection among a new set of options with newer or better features.

At this point, we can achieve the conjunction of the two branches in which the design of an equipment is divided: the electronic part and the enclosure. No matter how simple the design of an equipment could be considered, it requires to follow some steps or conditions to meet. Here we have presented what is involved in the design of an equipment in both its internal (electronic or mechanic) part and its external one (enclosure). We can agree that some sort of case

is needed, but its function is not limited to serve as a mechanical support. We also consider manufacturing, aesthetical and operational aspects of it.

When coupling these two parts, it is necessary that the electronic designer gets the required area for mounting the printed circuit boards and any other electronic components. In front and rear panels there should be a proper set of holes that match the requirements of control knobs, switches, power connections and displays.

We often found that the requirements of the electronic design team do not match with what was developed by the enclosure design team. This is caused by errors of measuring the physical dimensions of the components and printed circuit boards, inadequate location of control knobs, or even and improper selection of materials and structure for the enclosure which leads to inadequate support for control knobs and switches.

5. WORK STAFF

For the development of a product, many workgroups with different areas of expertise are involved. It is common to have areas such as: electronics design, electric design, mechanical design, enclosure design, and product image design. All these areas may be divided in sub-areas for management purposes. A very important point among these workgroups is the one regarding to the promotion of the developed equipment. May be the first objective is not to manufacture a small production, but given the right moment, this part of the team should support the product by generating its attractive image, emphasizing not only its technical advantages but those innovations in presentation, ease of use and availability.

The areas which can be involved in the developing of a product are listed below:

$$\text{Electronic}\begin{cases}\text{Analogic}\\ \text{Digital}\end{cases}$$

$$\text{Electric}\begin{cases}\text{Low tension}\\ \text{High tension}\end{cases}$$

$$\text{Mechanics}\begin{cases}\text{Fluids}\\ \text{Mechanisms}\end{cases}$$

$$\text{Design}\begin{cases}\text{Enclosure}\\ \text{Special accesories}\\ \text{Packing}\\ \text{Design (Internal/External)}\end{cases}$$

$$\text{Product image generation}\begin{cases}\text{External appearance}\\ \text{Nomenclature}\\ \text{Catalogs, brochures}\end{cases}$$

The participation of each group or sub-group will depend on the type of project, though most of the product designs involve the participation of various highly specialized areas.

We have presented several ideas about which areas of expertise should be part of a product design project team. This team should be capable of developing the product to a first or second prototype. In figure 4, we suggest an organization chart for conforming the workgroup.

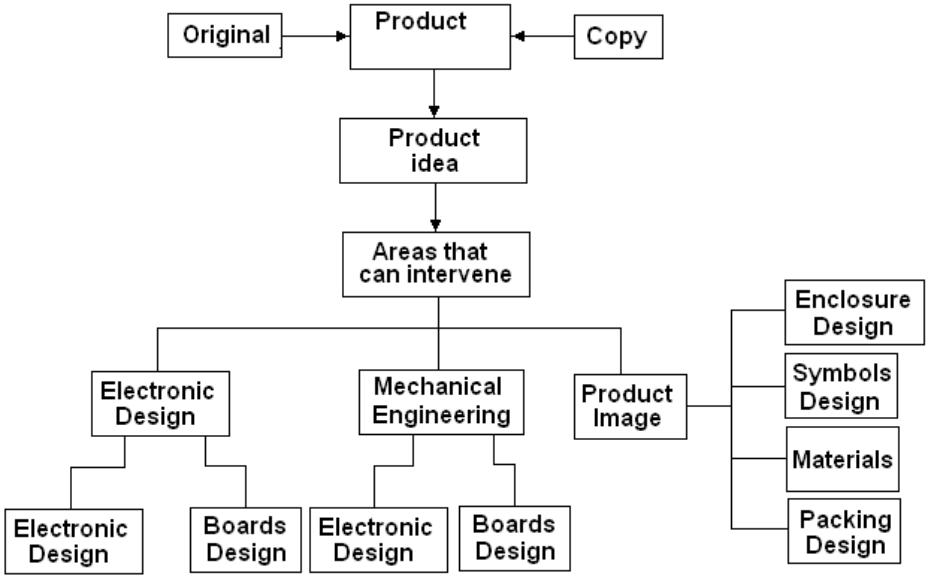

Figure 4. Block diagram of a development group

6. EXAMPLE CASE 1: PRODUCT ENGINEERING OF A MICROWAVES EQUIPMENT FOR AN ELECTROMAGNETISM LABORATORY

6.1 Electronic design

Once the project has been approved we proceed to elaborate a project plan. It comprises an research work about what is the equipment that we are trying to copy and how it works, or given the case, design it from scratch. We must consider what is the operational principle, who use the equipment and where it is used. We also have to consider what are the results expected, what are its main failures, what models are available and if there is a person who can give us support in the case of facing problems during the project. An experienced user of this kind of equipment should represent a very good source of information which will permit us to avoid some headaches.

After this research stage, we can begin to build some circuits with which the first test will be carried out. This will help us to know if we are in the right path or we will have to rectify toward a different design.

6.2 Enclosure design

From the first electronic prototype, we start designing an enclosure under some ground rules. The enclosure should have all the control knobs needed for its proper operation in the front panel, as well as the adequate set of connectors located in a easy access position. The meters have priority regarding its positioning and these should be placed first.

The first prototype of enclosure of the microwave equipment was made of aluminum sheet. This kind of material has some advantages though it is not easily worked for giving it an attractive aspect. For this equipment the modules that require a case are: the module that is coupled to the oscillator (transmitter), and the module that is coupled to the detector diode (receptor). The remaining parts are mechanical pieces that do not require an enclosure. Figure 5 shows an example.

6.3 Product image design

When the people working in the product image design does not have enough experience to obtain an image of a finished product, very little can be achieved. Hence, the person who is responsible for the product image should made the product appealing to the user by means of drawings or photographical techniques.

6.3.1 Image

Among the elements that could be considered as the product image, it should be designed the logo that identifies the equipment, and a trademark that distinguishes a series of similar equipments from others that carry out different tasks.

Figure 5. Microwaves Receiver Module

A promotional brochure could constitute a very important piece in the product image. In the brochure we summarize the main features of the equipment; it can also include the logo, and other commercial information as well as a list of uses and applications.

6.4- Packaging

Whenever we acquire an equipment for use in a laboratory, for home or for a small office, we search for the best technical characteristics, and the lowest price. We also want a properly specified warranty service.

A very similar situation occurs with the enclosure. We look for an adequate and appealing appearance for its intended use.

But, what happens with the packaging? The wrapping that kept the equipment from damage? What we usually do at first, is to open the packaging and get rid of it immediately. Who assemble the package? Why it has a particular shape? Why it is done of a particular material? Questions could go on and we will find hard to answer them. The packaging makes possible that the equipment arrives to its final user without damage, and this requires a well planned design comprising both internal and external aspects.

The packaging design for any equipment can be divided into two main parts:

- Internal design
- External design

6.4.1 Internal design

Internal design has to deal with the number of pieces that will be included, and their particular characteristics such as:

- Type of manufactured material
- Weight
- Fragility

- Sequence of use
- Especial or separate packaging, even inside the main package

The former characteristics should be considered when we are designing the internal distributions of the package contents. In some cases it is of main importance to know the weigh of each piece, in order to place the mass center near the package center. It is also convenient to spread the weight inside the package for an easier freight.

For the most fragile pieces, we need to take into account their position inside the package. We should place them in the position that would assure that in the case of excessive pressure or a hit over the package, the most of the damage can be absorbed by the package and other harder pieces. Fragile pieces often require of an additional packaging with a careful selection of protecting and shock absorbing materials.

Sometimes we should consider the sequence of use, since the user will want to take out the pieces in that order. This sequence can be determined by the weight of the pieces, by their frequency of use o simply by accessibility. Figures 6 and 7 show a package example.

Figure 6. Packaging and elements of the electromagnetism laboratory

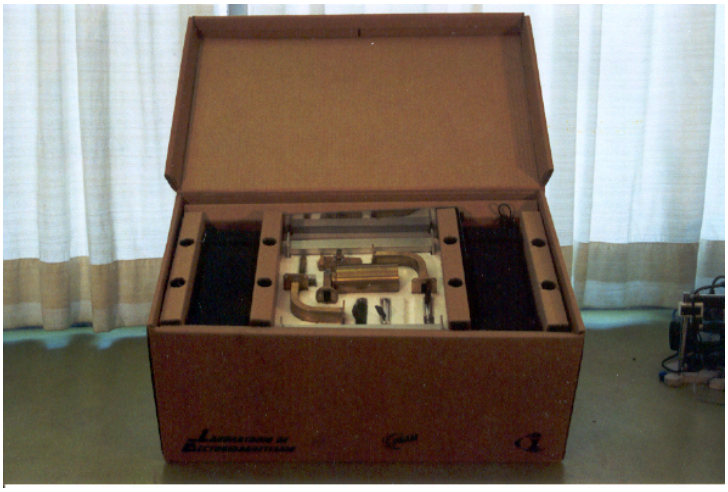

Figure 7. Elements of the electromagnetism laboratory placed inside their package

6.4.2 External design

The external design is perhaps the most recognized feature by the buyers of a product, this is because the user will have a longer contact with it. Having a proper external design can be a powerful promotion tool and not only a place for showing its main features, specifications and handling precautions. Some of the characteristics of the external design of a package are:

- Handling facilities
  -Handles
- Easy identification
  -Labeling about the product
  -Warnings
- Opening indications
  -Sequence
- Indications relative to the package
  -Recycling
  -Storage
- Flammability and other Risks

Frequently, we had to take in to consideration that the equipment will be carried on by hand, which implies that the packaging should have some sort of handles or other handling facilities. It is specially important to avoid that the corners of the package make difficult the access to handles. This can be achieved by leaving a couple of holes in the package. There is also the option of using a pair of plastic inserts which work as handles and prevent the dust from entering to the package.

The labeling that should have any package can be divided in labeling indicated by an industrial standard and labeling about the equipment.

Safety

- Do not get wet
- Do not heap more than ...
- Do not hit
- Recycling material

About the equipment

- Brand
- Name
- Model
- Number of pieces contained
- Equipment's logo
- Manufacturer's logo

When there is a defined opening sequence for the package, it is because we can expect that the equipment will be stored back in its original package. Sometimes this is possible and even advisable, however it is likely that the final user will have a better storing place. When this is the case, the equipment does not suffer any damage, but the packaging designer must have in mind all factors that may affect the equipment.

In figure 8, we can see the labeling about the equipment, the equipment's logo, and other common labeling. We also can see, at one side of the package, the handle included for carrying on the package.

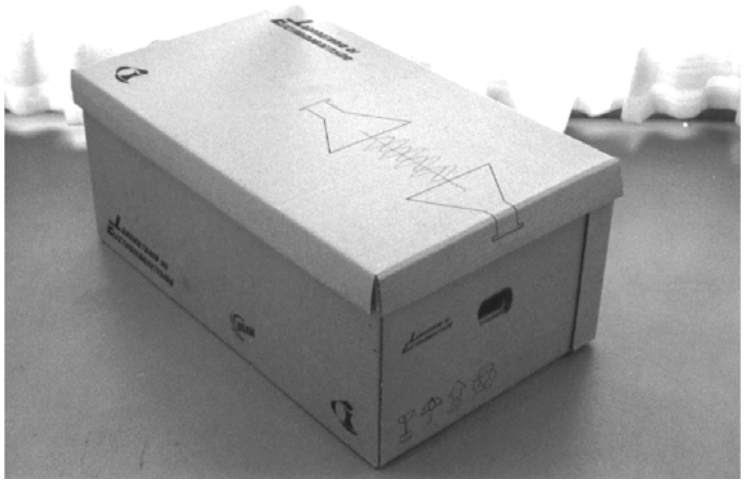

Figure 8. Final packaging of the electromagnetism laboratory

In figure 9, the dielectric antenna and its packaging is shown. With the development of the packaging for the antenna, we finish a procedure that allows to add elements to a previous design in order to complement it.

Figure 9. Dielectric antenna and its packaging

7. EXAMPLE CASE 2: PRODUCT ENGINEERING FOR A pH METER

Another example of equipment development, that illustrates the process proposed, is constituted on a pH meter. For the development of this equipment, we followed the same steps and, in order to obtain a proper enclosure, we designed the labeling for the instrument, the stand for the sensor probe, as well as its holding tweezers. An special package was design for this instrument, following the previously established steps. In the next pictures we show the instrument placed inside its package.

In figure 10, we can see the appearance of the package. Once the package has been opened, we have direct access to the instrument, and at the bottom the required accessories are perfectly placed: The probe stand with its base, and the holding tweezers for the sensor probe.

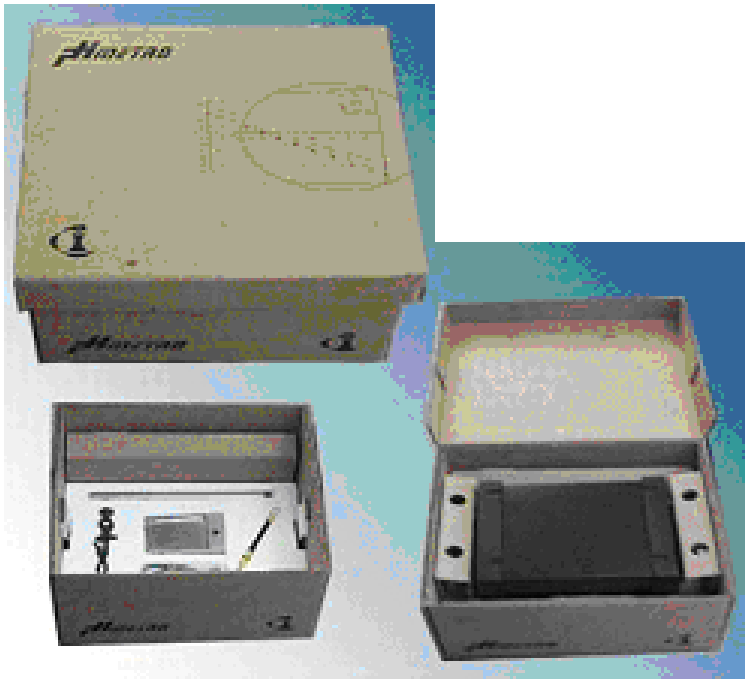

Figure 10. The pH meter and its package

In figure 11, we have another view of the placement of the instrument. The instrument is placed directly over the accessories without any direct contact which could scratch or pressure the pieces. The packaging already has all its proper labeling, which identifies the equipment and gives handling and storing precautions.

Figure 11. The pH meter and the internal placement of the instrument and its accessories

8. TECHNOLOGY TRANSFERENCE OF THE EQUIPMENT

The technology transference may be comprised of the physical presentation of the equipment, as well as a detailed technical report including operation characteristics, block diagrams of the internal functions, block diagrams of global functions, schematic diagrams, printed circuit board diagrams, components list, drawings of the mechanical parts and assembling plans. It is also important to include a user's manual and a service manual. The equipment should have perfectly specified each one of the elements in its front and rear panels. The rear panel should also have the appropriate labeling corresponding to its proper power supply voltages, serial and model numbers. In figure 12, we show a Technology transfer process.

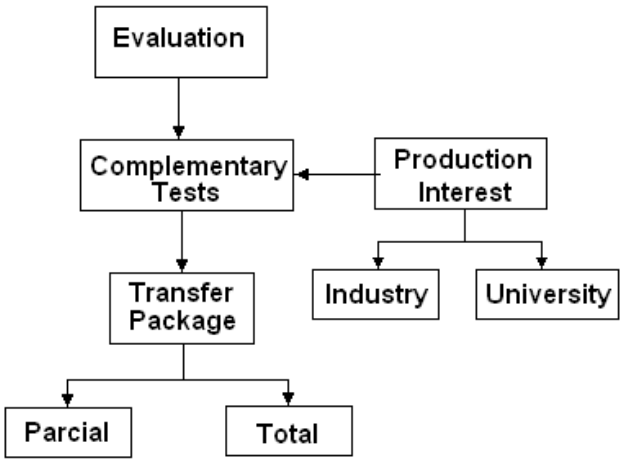

Figure 12. Block diagram of a technology transfer process

When one has the opportunity of transferring some equipment, the accompanying documentation should include the results of any tests carried out. This tests should be performed preferably in the presence of the interested in the technology transference. It is also convenient to include production diagrams, flowcharts and time charts which lead to a fast manufacturing with minimal errors. As part of this transference process, it is possible to agree in a partial transference where the designing team will continue to work through the serial production contributing with some pieces for the assembling process.