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RESEARCH-DEVELOPMENT FOR INDUSTRIAL PROCESSES

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ABSTRACT
Research-development is the work that goes from the researcher's labor to the production. It must overcome numerous obstacles whose solutions hardly deal with the Process Engineering knowledge and methods thaugt in engineering departments in universities. The present paper summarizes what is research-development which involves basic research, scaling-up, and technico-economic optimisation studies.

KEY WORDS: *Research-development, research, change of scale, feasibility, chemical industry*

I.-INTRODUCTION

Is it not surprising that only few results from the university research find their applications in the world economy ? Such a question is now a reality wordwide. Indeed, every country is now aware that innovation, research, and development, are necessary to achieve competetitiveness in different fields of the economy, and many people do not know what could be the reasons of the difficulties to transfer results to the economy.

The meaning of "research-development" is not clear at all for many people ; it needs to be clarified because it has variations such as "research and development", "research-development", "development-research", "research and local development", etc. From what development are we talking about ? Is it the development of a research process on a given topic, the development of results from an applied research, or the development of the economy ?

Among the various fields of research where transformation (mass or energy) processes can be developed, there are the chemical sciences which is generally an extended field in all countries, the environmental sciences, the agro-food industry, etc. These fields are the main elements of the **secondary sector** of the economy i.e. a sector in which are the industrial activities concerned with the transformation of materials into products useful for the humans.

Let's consider the case of a chemical compound elaborated at small-scale in the laboratory and possibly useful to humans [1] . As a large market would exist for such a compound, its production at an industrial scale can be projected. That means that results from the laboratory would have to be transfered succesfully to the design of a large-scale plant able to produce large amounts of the same product. Unfortunately, this is not so simple as one might think.

Research-development concerning a given new processing plant (or just of a deciding element of it, assuming that the rest is controlled) is the full path leading to an operating process, i.e. from the basic research work to the design of the final commercial plant. Obviously, plants very much larger than the small-scale (sometimes micro-scale) laboratory plants are often necessary for commercial productions ; not only such very large plants have to produce the amounts necessary, and with a good yield, they have to satisfy the product specificities. This means that it is necessary to perfectly managed the **increase of scale** from the small-scale laboratory equipment to the commercial plant.

II.- RESEARCH-DEVELOPMENT FOR PROCESSES

The process engineering methods originally developed in chemical engineering and now useful in various engineerings (chemical, electrochemical, biochemical, food, environmental, etc.), are essential all along the research-development path, thus allowing to solve decisive points (sometimes basic researchers do not agree with this opinion) during the progressive development of the project. The application of engineering knowledge and methodologies allows to reach finally the delicate pre-industrial stage which precedes the final plant design, the purchase of the equipment, its intallation and the plant startup in view of the expected commercial production.

In accordance with the definition given by the *National Science Foundation* regarding *R-D* (research-development) there are three types of research within a global approach of **research - development** [1] :

- First of all, there is **basic research**. It can be *pure* (without a specific purpose ; it only seeks to improve knowledge) or *fundamental* (whose purpose is to eliminate difficulties appeared during an existing application or a project) ;
- Then, there is **applied research** (also known as **industrial research**) whose main purpose is to apply the industrial results of basic research, but a very small scale i.e. at a laboratory scale ;
- Finally, there is the **research of development** during which the process is "developed" with the final technical design and construction as the objective. The **scaling-up** studies take place during this last stage.

This classification of research types for industrial purposes emphasizes that *basic research and research of development are at opposite places along the process.* It also points out that *basic research is a substantial **part** of the research-development program.*

Except if they could have some contatcs with industry, university researchers in basic sciences (chemistry, electrochemistry, etc.) do not clearly understand the scaling issues and the challenge of moving from a laboratory scale to an industrial scale. In addition, policy-makers might be surprised by the fact that basic university research, and even applied research in industrial centers, does not result in effective industrial applications. In others words many research works presented as applied cannot be applied and really are not applied.

The last phase called "**research of development**" begins **from the moment** when the decision to build a commercial-size plant has been taken by the industrial company. If the methodology used to changing progessively the scale till the final plant design is not sure or if there is a lack of representative data for the design calculations, the program may include a preliminary research or **pre-development** stage where a **pilot plant** is constructed and operated. With the pilot-plant, which is smaller than the final plant, the operation parameters can be more easily varied thus allowing to rectify the methodology for changing the plant size.

III.- PLACE AND IMPORTANCE OF SCALING-UP AND SCALING-DOWN

Let's consider the situation where the manufacturing of a given product is decided on the basis of very satisfactory results at a small scale. As a market study for the product has first to be organized, a sufficiently high amount of product is necessary. Then the **scaling-up** of the initial small scale system has to be made, thus generally leading to the construction of a pilot plant [2]. Later, the size of the pilot-plant or at least that of the production pilot-unit (for example the reactor) is increased. However a good technical scaling-up is not enough. Indeed the commercial process would be successful only if the cost of the manufactured product would be equal or smaller than the cost of a similar product having the same specifications and already present on the market. This means that even if a production on a large scale is technically possible, the final decision to conduct the commercial project can only be made after conducting a **technical and economic analysis**, the conclusions of which are the **commercial minimum cost** and the **optimum operating conditions**, as shown in [2] for the case of an electrochemical process.

If scaling-up is the most frequent case in the industry, there are situations where **scaling-down** happens. For instance, scaling-down is carried out when a technology existing for large markets has to be adapted for the supply of smaller markets.

The problem of changing the scale of processes or equipments is **one of the major obstacles in the industry** but there are scarce published informations on this topic. When detailed elements are provided, as for example in [4], no effective solutions of the difficulties are found [3-6].

Due to the difficulties and to the high cost of research-development studies, the methods used in the development of a given industrial project remain generally confidential, not only in case of success, obviously, but also in case of failure. Such a confidentiality regarding scaling-up is one of the main reasons why courses on the subject can only be academic. Very few concrete examples are commented and, as a consequence, caution is even necessary when a case is presented in details. Indeed, what industry would generously publish about its own methodology of research-development, and especially on the research and development phase, after many years of financial and human efforts to reach (or not) a commercial result ? In case of failure in the reseach-development process, after investing many money and time, what company would help competitive companies to avoid similar efforts for the same commercial objective ? There is confidentiality because the industrial studies are difficult, very expensive and related to economic intereses.

It is undeniable that, since a projected interesting industrial application is seen feasible at the laboratory scale, scaling-up studies are absolutely necessary **in almost the cases** where occur mass and energy transformations. From a technical point of vue this is a drawback, but if the studies were too easy, many companies could developed a similar project. thus removing a manufacturing interest to the project.

Basic university researchers having contacts with process sciences may be aware of existing difficulties in a research-development program and can mentionned some of these difficulties in their teachings or writings. However, many of them do not know real examples or, for confidentiality reasons, cannot speak about any example, even if they had collaboration or consulting with companies or specialized centers. As many professors do not include the subject in their teaching they idealize the future possibilities of basic laboratory results. Also such a lack of knowledge could influence decision-makers and lead to more basic research which may appear easier and less expensive than developments, in spite of the fact that, according to the above mentionned difficulties, it could be useless for the economic sector.

In fact, feasibility and scaling-up studies of industrial processes are made by professionals who, to our knowledge, do not intend to conduct basic scientific research but who are rather interested in applied research or research of development. They need to understand process engineering methods, at least in a practical way, but they do not need an extended knowledge of the discipline, in comparison with university researchers. On the other hand it has to be outlined that a scaling operation on a physical and chemical mass transformation, usually the physical and mechanical aspects are decisive rather than basic reaction aspects (chemical, electrochemical, etc.) which could have give rise to the project. In other words, many questions must be managed by engineers and not by chemists. Very often researchers do not support such an idea, thus making uneasy the necessary collaboration between them and the engineers all along the research-development study.

Only a small fraction (perhaps 10%) of laboratory results possibly interesting for a commercial application are applied up to the pilot plant scale (pre-development), and also a small part of this fraction is extended up to the commercial scale (development). Such a large skimming is mainly due to the scaling-up complexity and to its consequences (decrease in yields, inability to maintain similarity, technological limitations, too high cost, impurities, etc.).

Feasibility/scaling studies could be developed :

- within specific development or research-development departments within large industrial companies ;
- private or public specialized technical centers ;
- regional centers for research, innovation and technology transfer, on the condition that they are technically organized i.e. if there is not only transfer of documents from laboratories to companies.

Such specialized services or centers may have a suitable staff for **process** technology transfer, thus formed for scaling (up or down), and not only able to do **product** transfer. A process engineering knowledge is necessary, as complementary to a technical ***know-how*** in matter of development within the company or center.

IV.- CONCLUSIONS

As a conclusion, research-development for new industrial processes is a complex field in which scale-up is an inherent activity.

The majority of university professors are not specialized neither in scaling problems, nor in research of development. Some may have contacts with industrial companies, for example as consultants on specific basic research areas related with their own experience in laboratories.

Sometimes industrial companies have contacts with research laboratories in universities but, unfortunately, they look frequently for free consulting, especially when they are small companies, in spite of the fact that the best mean to obtain valid consultations and confidentiality is a remuneration. Good consultings may give profits in time and money to the companies and, in some countries, free consulting is seen as doubtful. Scaling-up and more generally research of development studies are **long-term**, **expensive**, **risky**, **confidential**, and with **too important consequences** to be carried out by someone who is not an expert. In other words, as the risk of free consulting could be too important in an industrial and economic context, the studies would have to be made with caution and in specialized places.

It is clear that small companies cannot conduct such studies. Regional centers could play a key role in research of development if they have sufficient technical skills and ability to carry out the studies.

([1]) F. Cœuret is a chemical engineer, Dr-Engineer, Dr in Physical Sciences, author de numerous articles, and author/co-author of books on engineering processes and more especially on electrochemical processes. He was Director of Research at the CNRS in France until his retirement in 2005. He published articles in Mexican Journals, such as : *Chemical Education* (1996, 2007), *Mexican Journal of Chemical Engineering* (2007), *Engineering, Technology, and Education* (2008). He currently works as consultant in this area of knowledge to share his experience.

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