

USEFULNESS OF PILOT STATIONS AND PLANTS (*)

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Applied Industrial Research can be, and generally is done either in the works which undertake production or in laboratories.

PRODUCTION PLANT RESEARCH:

It has the advantage of being very close to production site and, if crowned with success, its final adjustment will evidently be easy to make. This, however, has numerous disadvantages.

Production disturbances:

First of all, research causes perturbations in the normal fabricating operations of the plant, having as a result lower and less uniform production.

In point of fact, adjusting new devices sometimes causes many changes to be made. While doing so, the production units used for the trials often stand idle, thus giving a negligible yield.

The same situation arises when the trials cannot be carried out consecutively but only at rather long interruptions. This is the case, for instance, when a study of the products resulting from a test takes a long time.

Lack of precision:

Research within the works often leads to lack of precision due to unexpected variations in raw materials or in working conditions which create a dispersion masking the influence of some purposely made changes of a current industrial process, or preventing the discovery of the quantitative relationships existing between the influencing factors and their effects. This is the case, for instance, when experimenting on blast - furnaces.

Sometimes, insufficient available space or the imperative of production prevent precise measurements within the plant which would be necessary to obtain a sufficiently true picture of the results.

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For instance, it does not take long for a working platform in a steelmill to be encumbered by the necessary voluminous instruments needed for pressure, flow and temperature measurements in open-hearth furnace. The eminent research in this respect effected by Dr. Chesters, which are reported in the well-known I.S.I. Report No.38, admirably exemplify this situation.

Moreover, the dusty atmosphere and the often existing vibrations affect detrimentally measurements or put out of adjustment the sensitive devices.

Over and above all this, it often happens that materials treated in industrial units do not show enough uniformity to allow conditions of determined properly.

Expenses involved:

Research within the production plant is often very expensive, although it saves construction special machinery; trials are made with the equipment normally used in current production but, as it has been pointed out above, the time spent in tests restrains normal production time and output diminishes, which also is expensive. On the other hand, using the production equipment means making trials with a great volume of material which represents a great expenditure too. Moreover, lack of accuracy of the production plant trials leads very often to an increase in their number, which brings about another increment to the total cost figure. Finally production plant trials run the risk of disturbing the production process, which might be very costly, inasmuch as the disturbances may quite well show up only either when the product is fabricated or when it has been delivered to the customer, if defects are difficult to detect. The dissatisfaction of the customer, because of these defects, might have really inadverse consequences. On the other hand, the introduction on the market of products having undergone a modification may draw the attention of possible competitors or cause discontent among customers if the products in question have not attained the required quality.

Secrecy of research:

Finally, it should be emphasized that research made at the production plant is difficult to conceal. Too many people on the staff are aware of what is taking place, if they are not fully acquainted with all the facts. Research awakens curiosity and it often happens that strangers to the proprietary enterprise might get information about the trials, when on the premises of the production plant.

Laboratory research:

All the fore-mentioned disadvantages fully justify small scale laboratory research. As trials are made on small volumes of material, the expenses herewith are consequently small. Precision of measurement is generally better in a laboratory than in a plant, because of the more convenient environment: in addition, it is easier to work on specimens uniform in quality and temperature. Moreover, it is less difficult to keep the trials secret and these interfere in no way with current production.

Problem of extrapolating laboratory results:

However, extrapolating laboratory scale results to industrial practice is generally a difficult problem and often cannot be done.

The main reason of it is the fact that the ratio of area to volume is far greater in laboratory tests than in industrial practice. According to the case, results of extrapolation will be very different. For instance, heating of voluminous bodies creates conditions which are difficult to reproduce in a laboratory. In such a case, the surface of the body is heated at a far greater rate than the inside, slowing down heat exchange with the environment or creating internal stresses which may lead to cracking or rupture.

A small-sized specimen in a colder environment cools off very quickly, in some cases too quickly to give time to perform operations which usually may easily be done on an industrial scale. Steel, for instance, cannot practically be hot-rolled to sheets less than 0.08 in (2 mm) thick or wire less than 0.2 in (5 mm) in diameter.

Because of too high a value for the area/volume ratio, walls of laboratory containers exert a far greater influence on processes than the walls of industrial equipment. Current metallurgical refractories react too promptly with liquid metals when they are used in laboratory crucibles, giving off, therefore, impurities. When used in industrial equipment, the same refractories react relatively less. As a result, laboratory crucibles should be made of special resistant refractories which do not react as usual linings.

Another example of the importance of areas are the capillary phenomena which play a far greater part in laboratory tests than in industrial practice. Solid particles suspended in liquids set with difficulty, or not at all on a laboratory scale. Moreover, it is often difficult, if not impossible to take specimens for analysis or observations from a laboratory unit without causing great disturbances to the process. On the other hand, this can easily be done in industrial practice.

At any time when labour or maintenance expenses play an important part in the cost of a fabrication, laboratory tests will give no information of use for economy calculations.

From what has been stated above, it follows that it is very often impossible to extrapolate laboratory scale results to industrial practice. Laboratory tests must, therefore, be completed with experiments made within the plant.

However, if the industrial scale tests are made in the production plant, they present the disadvantages already enumerated - except that they will come to a successful end sooner, having been preceded by laboratory tests.

PILOT STATIONS OR PLANTS:

Taking in account what has been said before, one naturally comes to the conclusion that industrial research must incorporate an intermediate stage where the tests are made on a medium or semi-industrial scale, half way between laboratory and industrial production scale.

At this stage, it is practically necessary to have available specially installed premises which will be called pilot station or plant, according to their size. As a matter of fact, the object is to have available a plant which will enable production to be made on a reduced industrial scale. These facilities are generally devised to allow easy modification of equipment and more numerous and precise measurements as is generally the case in normal production.

Choice of the pilot plant capacity:

While planning a pilot station or plant, the most important question is to decide on the scale of production. The more the pilot plant capacity differs from planned industrial production, the lower will be the expenses involved and the results of extrapolation less accurate. Evidently, there only exist compromise solutions.

In most cases, pilot plant capacity should be chosen at no less than 1/8th the planned industrial production, which gives a ratio of 1:2 for linear dimensions in case production varies proportional to the volume, which happens rather frequently. For economy reasons, pilot plant capacity is sometimes chosen down to 1/20th of the planned production, that is to say a ratio of 1 : 3 for linear dimensions. Hereafter are some examples:

At the experimental station of IRSID, at Maizières-les-Metz, experiments are being made with a size-ton furnace whereas in France, at the present time, current production steel furnaces have capacities from 20 up to 120 tons.

The experimental furnace of the International Flame Research Committee at Ijmuiden, has linear dimensions approximately half of those of the open-hearth furnaces of the production plant.

In the same way, the low-shaft furnace at the metallurgical plant of Ougree is used as an experimental blast-furnace and, as such, runs on 50 tons of coke per day while European blast-furnaces need daily between 200 and 1000 tons.

The situation was different when choosing the size of the pilot coking plant at Marienau, which was built jointly by Charbonnages de France the Saarbergwerk and IRSID. For this plant, the coke ovens have been given the same width and height as normal production ovens, while length was reduced to half the normal size. Therefore, the production of an experimental coking cell was set at 50% of the output of a full size industrial oven. The choice of this size has been

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dictated by physical considerations. The coking process depends too much upon heat transfer inside the charge as well as upon the way coal compresses in the cell under its own weight. This last case illustrates fairly well the limits of using small production pilot stations. However, the Marienau pilot plant is only equipped with four ovens, that is ten to fifteen times less than a normal coke oven battery. When industrial production in a plant is assumed by a great number of small production units, it is easy to reach a small output, without much change in the scale of the test but this is rather seldom the case.

Passing to industrial production:

In some cases, it can be anticipated that the pilot plant will pass to current production after satisfactory tests have been completed. In this manner, it will pay off at least a part of the capital invested. If such is the case, the plant may be constructed on a less reduced scale and extrapolation will be more reliable. This implies, however, that the cost of the pilot plant production would not be too high. In this respect, the pilot plant is handicapped by its small size. Small size construction demands proportionally larger investments on the basis of annual turnover than erecting a big factory. On the other hand, pilot plant equipment generally devised for replacement and extra measuring devices increase the cost of the installation beyond the investment required to erect of production plant of the same capacity. From the foregoing it may be considered that cases in which a pilot plant having completed its tests can be used for industrial production are rather seldom. However, when the pilot plant product is a novelty and its market yet limited, there is no risk of competition by the big factories producing at low prices. The pilot plant can, therefore, produce a marketable product for a certain time.

This is not the case for an iron ore direct reduction plant using reducing gases, where the pilot installation cannot be economically sound as a production unit: if the process would produce profits on a pilot plant scale, it would give still more on a tenfold scale. As a result, big plants would be erected within a short time as the sale of the product is guaranteed on a very large scale if price is low.

Administration problems of the pilot plant:

Administrating pilot stations or plants is often very expensive. Their equipment should be, therefore, used to the utmost. However, this use cannot often be continuous because of series of tests generally demands compilation of results and their interpretation before any new research programme can be initiated. Of course, every thing should be done to reduce idle time to a maximum.

Other idle time results from repairs or modifications of equipment. Great care must be taken to maintain it to a minimum. In this respect, the pilot plant should be able to do promptly the necessary repairs or changes. To do so, the plant will have to have attached to it a maintenance shop and a small designing department if none is already available in the neighbourhood.

During periods of testing, plenty of manpower is often needed. Between these periods, employment is a difficult problem to solve. To remedy this the pilot plant can be erected in the vicinity of a large factory so that workers may be obtained on a part time loan basis. Another possibility consists of grouping several pilot stations at the same place and employing manpower in rotation. This is a solution which has been adopted by large research institutes, such as CERCHAR or IRSID. In such a case, the maintenance department is centralized with evident advantages.

Liaison between laboratory and pilot plant:

When testing on a pilot plant scale is very expensive it may be possible to reduce costs by a preliminary study in the laboratory. This does not mean that pilot plant scale testing is not necessary. We might give several examples where a pilot plant was necessary to check the trend of laboratory research. In fact, testing in the production plant is often too inaccurate to be sure that laboratory tests are made in conditions close enough to industrial practice. In this case, only pilot plant trials may be able to evaluate the laboratory tests. It happens that a rather good correlation can be set up between both. When such correlation has been ascertained, the bulk of testing may be performed on a laboratory scale with reduced control testing by the pilot plant.

The International Flame Research Committee at IJkuden is acting actually in such a way while testing liquid or gaseous fuels. Research on the subject of recirculation of combustion gases is made on reduced scale models of the oil or gas burning pilot furnace. Then, some control runs are performed with the pilot furnace to check that analogy laws have been followed.

The same practice has been adopted at Marienau Research Station where different coal blends are first tested in a 900 lb oven (400 kg) before testing the best blends in the pilot coke ovens. We would like to insist on the merits of such a procedure.

Full scale pilot Plants:

The present paper would not be complete if nothing was said on the feasibility of using a normal production factory as a pilot plant, where experimenting would be carried out on a full scale. The necessary steps should be taken, of course, to avoid the already mentioned disadvantages which generally occur when research is performed in a production plant. According to the circumstances, some or all of following steps should be taken:

- fabricate products as regularly as possible
- study the effects of systematical changes in supplies or nature of the product
- use numerous measuring devices.

Of course, the administration of such a plant might be very expensive but we feel sure that the tests would give much information and prove remunerative, at least in the long run.

It is evident that only large corporations owing a great number of plants could contemplate the expenses involved in operating a pilot plant on a industrial scale. We regret that, to our knowledge, nobody has yet ventured to do so. Theoretically, a group of companies could do it but psychological difficulties are here much greater.

Just to give one example, it might be extremely interesting to have available a pilot crushing plant able to work on an industrial scale. Nobody has been able, up to now, to check comparatively the work of big crushers used for breaking iron ores, so that any choice based on ascertained facts is nearly impossible.

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