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THE MAKING
OF THE WEALTH PLANT

BY

O. OGBOJA



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THE MAKING OF THE WEALTH PLANT

PROLOGUE

The state of a nation is a reflection of the state of its economy. The developed nations have developed economies while the under-developed nations have under-developed economies. Characteristic of under-developed economies are unstable polity, squalor, graft on the part of their leadership, illiteracy, planlessness, high unemployment, badly ordered society with badly functioning systems and so on. On the other hand, the advanced economies are characterised by efficiently functioning systems, stable polity, high literacy, low unemployment, high accountability on the part of their rulers and so on. In such economies, there is relative comfort and the citizens can plan their lives and live the way they choose.

Wealth is the difference between the situations in the developed and under-developed economies or nations. In the developed economies, the people have used their human resources to develop their natural or material resources. Material resources can be converted to wealth by transformation into more valuable products, which can be exchanged for money. The human endeavour, which creates wealth by transformation of material resources, is engineering. The highest percentage of the activities in the production sector of any economy is material transformation. This is why factories are a common sight in such economies.

The transformation of a material from one form to another may involve many stages. The stages and their interconnections are called a *process* and each stage is called a *unit operation*. The process and the ancillaries such as pumps, storage tanks, and so on, are called the *process plant*. The aspect of engineering, which produces and manages the process plant, has been known as *chemical engineering* but the more correct description, *process engineering*, is now being adopted universally. In this lecture, I shall endeavour to describe to you how the process

engineer (or the chemical engineer) creates the process plant, the wealth plant, and the environment it requires to thrive.

1. INTRODUCTION

The first step in bringing a baby into the world is a man having the courage to smile at a lady. If he is not rebuffed, many things can follow: *Your face is familiar, I met you somewhere, and you must be Bisi* and so on. The man's guesses do not have to be right; all he needs is for the lady to continue to say something. That kind of cooperation always leads somewhere. Initially the man needs it to build confidence for launching to the ultimate - *you are beautiful, I like to keep in touch, what is your telephone number?, what is your address?* If the man is lucky to get answers to these questions, everything else shall be added unto him. He can then take the bold step, which is to make the phone call or pay the first visit to the lady's house. If he is once again lucky, the lady will co-operate. A permanent relationship may develop and they may live happily together thereafter with issues as the benefit of the relationship.

In all the above, the element of luck has a tremendous role to play. The man has to be bold and lucky to penetrate the cocoon of protection of the lady. The lady too has to be lucky to meet a man who is adept and patient enough to persist even when the lady is acting solely for the purpose of showing that she is not cheap.

The realisation of the process plant can be compared to the procedure for baby making. A man, a group of men or a government, who has the financial capacity, must have the urge to own a process plant. He must approach the chemical engineer, the professional who has the capability to mother the plant. In his own case, the chemical engineer carries the baby in his brain and he can shape it the way he deems best, going by his training and experience. As long as the entrepreneur is ready to pay the prescribed fees, he is not likely to have cocoon-breaking problem with the chemical

engineer. Just as money is the catalyst for sustaining social or marital relationship between a man and a woman, it is the basis of the relationship between the entrepreneur and the chemical engineer. The man (or suitor) and the entrepreneur cannot afford to be miserly during courtship.

Ab initio, the entrepreneur sets out to make money. He wants to put his money into a system that will multiply it, if possible, exponentially. The more returns he gets, the greedier he becomes. The attitude of the businessman lends credence to the Latin saying *amor habendi habendo crescent* - the love of having increases with having. The love of the successful businessman for money is insatiable, it is maniacal. Money is therefore the motivation for the marriage between the entrepreneur and the chemical engineer.

In this introduction, it has been shown that there are parallels between the man/woman marriage and the entrepreneur/chemical engineer marriage. I shall now go on to examine how the entrepreneur/chemical engineer marriage is consummated and products derived.

The entrepreneur/chemical engineer relationship begins when the entrepreneur conceives the idea of owning a process plant and consults a chemical engineer. A serious commitment is made when the entrepreneur gives the chemical engineer a mobilisation fee. The job of the chemical engineer is to conceive the plant, carry it through gestation, bring it to life and give it a profitable life. The conception stage is the process synthesis stage where the various processing activities are selected and arranged in a desired order. The gestation stage is the design stage during which the plant components are sized and the cost of realising the plant is predicted. The birth stage is the commissioning during which the new plant is test-run to correct design and implementation defects, operators trained and operations manual formulated. The life of the process plant is the length of time it makes profit without deterioration. Once deterioration sets in, the plant is discarded as a scrap just as old people are consigned to old

people's home by their children. The various stages are described in the following section:

2. PROCESS DESIGN

The purpose of engineering is to create new material wealth and chemical engineering does this by chemical, physical or biological transformation and separation of materials. The chemical engineer creates or designs the process and the facilities (plant) for achieving the transformation. Hence, we can define *Process and Plant Design* as the creative activity whereby ideas are generated and translated into processes and equipment for producing new materials or for significantly upgrading the value of existing materials. Ideas may be generated to

1. convert raw materials to products;
2. convert waste by-product to a valuable product;
3. create a completely new material (synthetic fibres, food etc);
4. find a new and better way of producing an existing product (using a new catalyst or by a bioprocessing alternative); and
5. exploit a new technology (by genetic engineering).

The steps to follow are:

1. Define primitive problem: State what the need is that demands the engineer's attention;
2. Gather cognate facts: Review the situation with those directly concerned and obtain pertinent business, technical and scientific information;
3. Create specific problems: Devise several specific problems the solution of which could solve the primitive problem;
4. Screen specific problems: Test the proposed specific problems for obvious defects in logic, cost and safety; and
5. Engineer a solution: Perform the detailed selection of the equipment and determine the optimum

operating conditions required for the best solution of the most promising specific problems.

2.1 Problem Definition

The job of the chemical engineer is made easier if the entrepreneur can describe precisely what he wants. The best patient is one that can describe his ailment to his doctor while the worst patient is the deaf and dumb. Usually the entrepreneur comes to the engineer with a problem, a statement of need, that cannot facilitate immediate action by the engineer, for example,

I have some money, which I want to invest in the production of chemicals.

This is a very primitive problem. The chemical engineer has to refine it to a specific problem. This statement has, among other things, failed to say how much money is available, what particular chemicals are desired and from what raw materials, the product rate and the target market and consumers.

The primitive problem is therefore an expression of the gap which exists between the available raw materials, energy and know-how and the local needs of the society. The first problem faced by the engineer is how to recast the primitive problem into the best possible specific problem.

2.2 Process Synthesis

The synthesis of plausible alternative problems is the first and the most critical step the engineer must take toward the solution of a primitive problem. The alternatives are then screened carefully. *Process synthesis is the selection of equipment and the interconnections between them, which will achieve a certain goal.* It is the conception stage in building a process plant. The information needed is usually obtained from the chemist, researchers and market survey. The chemist supplies the reaction conditions and the market

1. the process units to be employed,
2. how the process units are to be interconnected; and
3. the pressure, temperature and flow rates required.

is the concept logical?, does it violate common sense or the principle of technical logic e.g. a law of thermodynamics?, can the concept be shown to require too much technical or economic extrapolation from existing technology thus involving too high a risk?, is the concept unsafe?, does the concept suggest a better alternative?, does the concept involve special technical competence which the design group is not capable of?

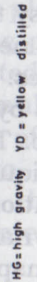


Figure 1: Example of process synthesis for the manufacture of glycerin from soap waste

2.3 Process Design

For a process plant, experience has shown that there are 10^4 to 10^9 ways of accomplishing its design objective. Obviously, selecting one out of so many is a herculean task. Consequently, design problems are said to be open-ended. It may be possible to eliminate some of the alternatives by rule of the thumb (heuristics). The others are then designed and their costs compared. Those that appear profitable are then subjected to more rigorous design calculations. The best alternative is selected by optimization and the final design prepared. The undefined and open-ended nature of design problems and the low success rates make the development of strategies for solving design problems imperative. Therefore the chemical engineer has to follow a tortuous and non-definite route.

The objective in process design is to find and select the one process route, among the many plausible alternatives, that:

1. has the lowest cost;
2. is safe;
3. satisfies environmental constraints;
4. is easy to start up and operate.

The tools needed are Engineering Science, Mathematics and Economics. Material and energy balances establish the demands by the process for raw materials, energy, cooling water etc. Thermodynamics is brought to the solution of vapour/liquid and chemical equilibrium problems and to the solution of compression, liquefaction and other thermodynamic problems. The principles of unit operations and transport phenomena are employed to firm-up segments of the processing concept. The methods of process control and dynamics are used to ensure the operability of the concept.

A design has to be implemented with money. Therefore the designer has to be cost-conscious right from the outset. Engineering cost is reduced by using order-of-magnitude

estimate to predict the cost of the plant in the early stages. This is a rapid way of eliminating the non-viable options among the possible designs. In general, the method employed must have a quick way of estimating the potential payout of new ideas. Initial studies must be on the aspects that will have the greatest economic impact on the process, rough designs should be used to identify high-cost parts of the process and the dominant design variables.

2.4 Economic Design Criteria

The screening of alternatives comes up with the process that will yield the highest financial benefit in a given time. The preliminary screening uses approximate analysis to detect and eliminate dominant weaknesses, thus reducing attention to the more plausible alternatives. In order to select the best of these, precision is required. The engineer must define the economic environment in which the process is to function and establish a criterion that will lead to an economically optimal process.

The design engineer must predict the total investment components, the manufacturing cost components and consequently the operational profit. In addition, the engineer must predict the economic life of the plant. When the plant is commissioned, it starts generating profit from which the borrowed capital is gradually liquidated. Once the loan liquidation is completed, cash is accumulated at a constant rate until towards the end of the life of the plant when the rate declines and eventually hits zero - when the plant dies. The beginning of the decline in the rate of accumulation of profit is the end of the economic life of the project. Figure 2

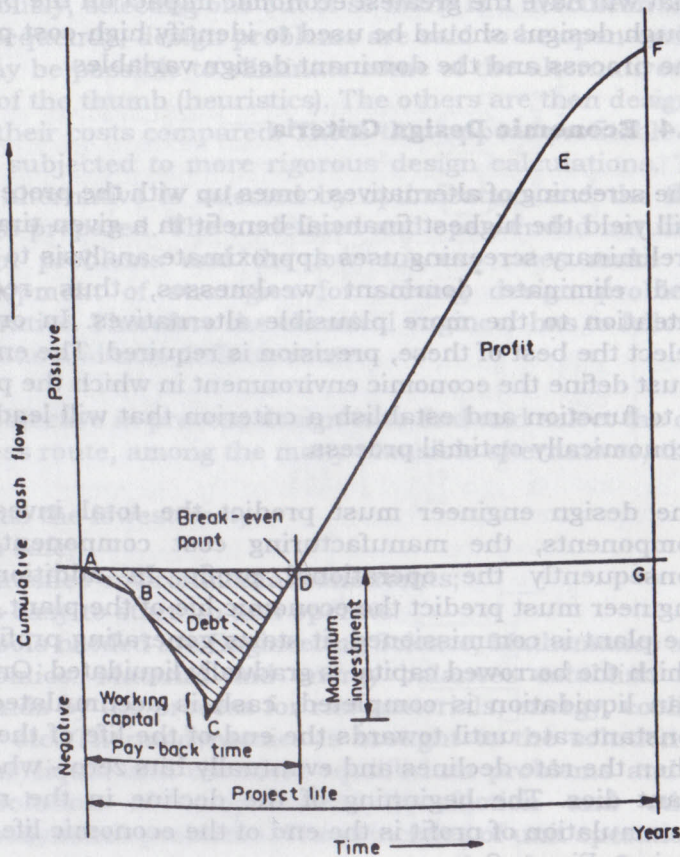


Figure 2: Cash generated during the life of a plant

is a representation of the cumulative cash generated by a plant during its life.

The economic details outlined above are applied to estimate the economic life of a process when the process is still in the planning stage. Thus process design is an exercise in predicting completely the performance and life of a process plant at the design stage. The design engineer is a seer.

2.5 Cost Estimation

In order to carry out the optimization procedure and be able to select the best process, the engineer needs information on the costs of the various items of equipment and activities. Cost equations relate design variables to the economic parameters which appear in the design criterion. They facilitate appreciation of changes to the design variables and immediate optimization. Therefore, in order to be able to manipulate the design criterion, we need reliable sources of information for the fixed capital and the auxiliary capital items. In other words, we have to know what it will cost to procure the various items of equipment that make up the plant and auxiliaries, the construction cost, the contractors' fees, the commissioning cost and the engineering fee. This is a very tedious task as there are many components involved from very big ones to small bolts and nuts. Gathering such information alone can take years depending on the size of the proposed plant. Investors can hardly afford that kind of waiting time. They become restive once they commit money into the engineering aspect.

The engineers have to devise quick means of ascertaining the capital investment with sufficient accuracy. The fastest means is to compare the proposed plant with an existing plant where that is possible. But the accuracy of the method is low - 30%. A more reliable approach is to base the estimation on the delivered cost of major items of equipment and then deduce other costs such as piping, instrumentation, land and so on by multiplying with

experience factors. The best estimate is obtained when the design is well advanced and drawings and specifications are available to give to fabricators and equipment vendors to provide quotations.

2.6 Plant Design

Once the best process has been selected, the next step is to design the various items of equipment. This exercise leads to the specifications of the sizes and dimensions of the equipment items and their operational conditions. If the equipment are available in standard forms on the market, for example, pumps, compressors and pipe fittings and joints, all one needs to do is to specify their ratings. For the non-standard equipment such as tanks, columns, heat exchangers and reactors, the engineer has to use the knowledge of material flow rate and conditions to specify the geometry and size of the equipment.

This exercise is by no means an easy task. Design data are never easy to come by and, when they are available, they are seldom in the exact specification that we desire. In the face of these uncertainties, the engineer must make intelligent decisions and approximations in order to move forward. Equipment design involves rigorous and time-consuming computations. The rigour and time taken are often reduced by reshaping the model equations to make them amenable to easier solutions. The simplification actually results in less accurate design and therefore less efficient equipment.

The rapid development of the computer and its relative cheapness have been of tremendous relief to engineers and scientists. In 1981, I was trying to solve an iterative problem using the system at the University's Computer Centre. After thirty minutes, my cards were always thrown out. When I got to the University of Wisconsin, Madison, in October of the same year, I did the same computation on their PDP 11 system. My program ran to completion in only 3 seconds. You could appreciate what I had been missing. Cards are

now rare even in this country, thanks to the microcomputer for its affordability which has made it ubiquitous. Nowadays, matrices of scary dimensions and iterative problems can be handled by desktop computers.

The computer has not and cannot eliminate all the hurdles of the design engineer. His main problem arises from the formulation of the equipment model and the integrity of the sources of its parameters. The parameters are obtained from experiments and are therefore mere approximations. The design engineer drops the transient components of most models in order to make them more amenable to solution and avoid chaos. The subject of chaos is beyond the scope of this lecture, but we should note that ultimate design cannot be achieved without considering chaos. I may be creating chaos if I consider chaos in this lecture.

In recent years, many research engineers have produced design data and procedures aimed at simplifying the work of the design engineer and producing more accurate designs. My associates and I have joined in this quest and have left indelible marks. My experience has shown that the grand design is as elusive as the *Holy Grail in King Arthur's Round Table*. However, I believe with the tenacity of Christians on the second coming of Christ that the grand design is not unattainable.

2.7 Sources of Design Data

Researchers have been generating design data over the years. Usually for reasons of space and cost limitations, simulators of industrial-size equipment or laboratory equipment are employed. In using the data from such rigs, the designer has to do some scaling up. It has not been possible to develop scale-up criteria that can predict perfectly the performance of an industrial equipment from a laboratory simulator. This is due mainly to the complex flow dynamics in the equipment which cannot be modelled with precision. Let us consider the sieve tray as an example.

The sieve tray is the simplest and the cheapest type of gas-liquid contacting device. It is a flat sheet of metal perforated with holes and installed in a rectangular or circular section column. Liquid flows across the tray and is prevented from weeping down through the holes by gas under pressure which flows up from below. Figures 3 to 6

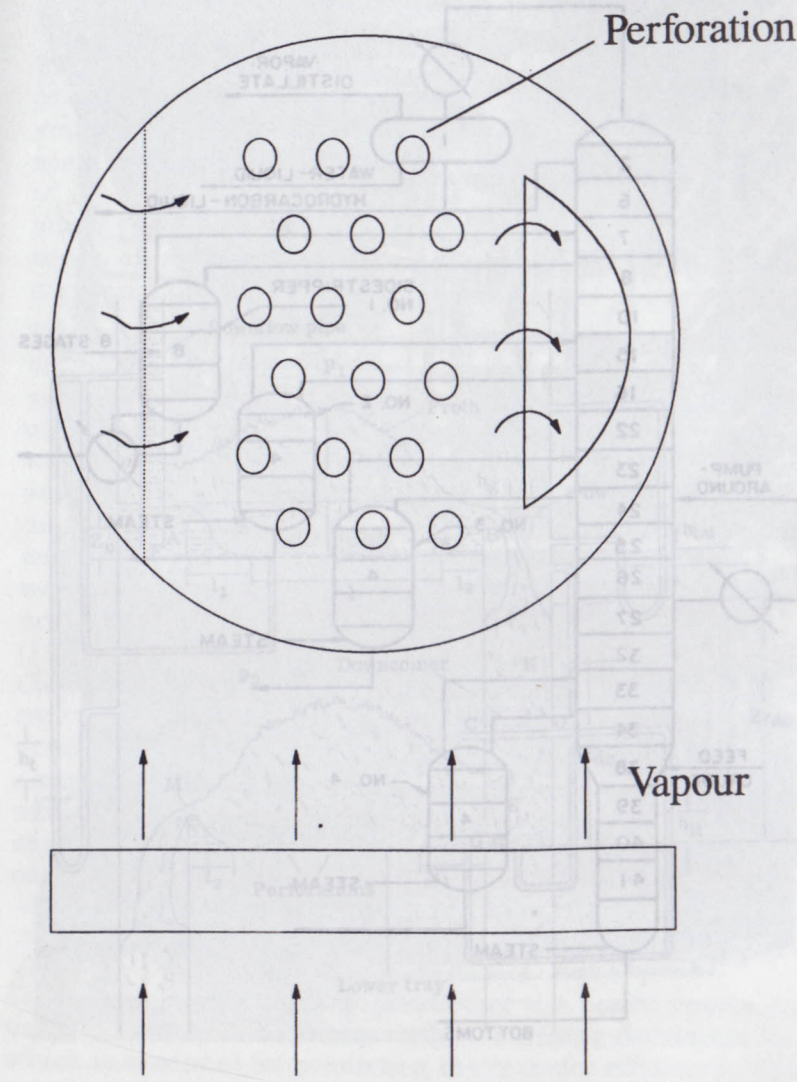


Figure 3: The sieve tray

The sieve tray is the simplest and the cheapest type of gas-liquid contacting device. It is a flat sheet of metal with a series of holes and is installed in a rectangular or circular section in a column. The flow of gas and liquid through the tray and is prevented from weeping through the holes by gas under pressure which flows from below. Figures 3 to 6

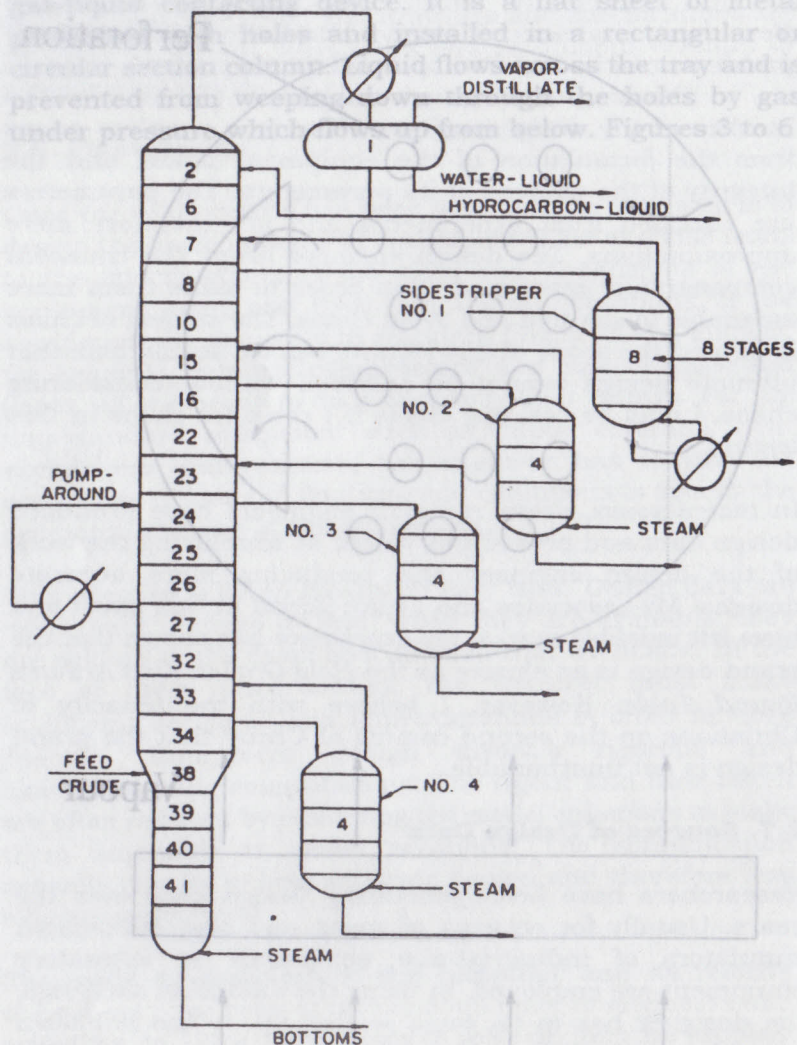


Figure 4: A system of sieve tray columns

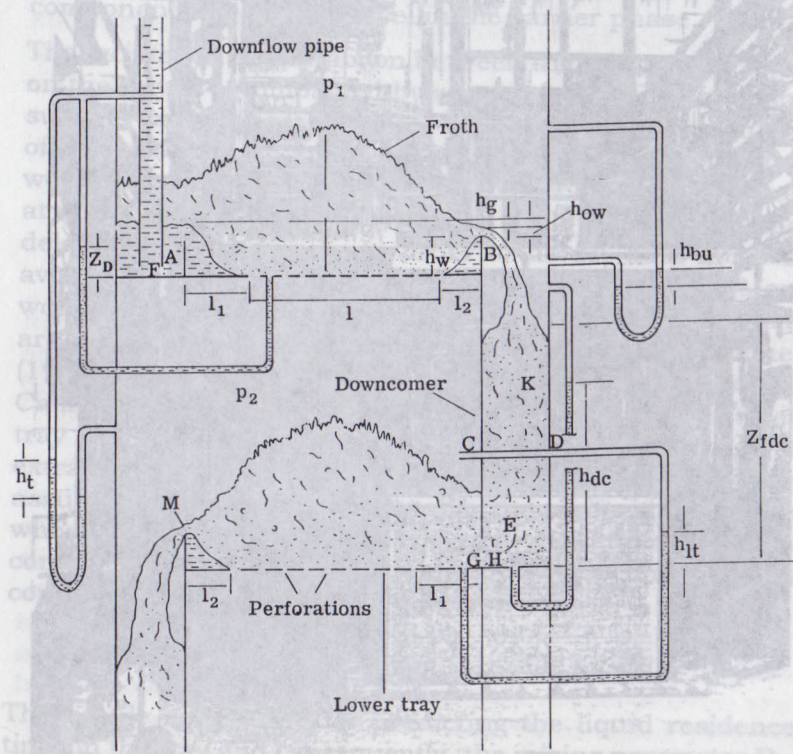


Figure 5: Sieve tray dynamics

which is essential for predicting the transfer efficiency. The solution of this equation is complicated by the nature of the boundary conditions. A pulse injection of dye is delivered at the tray inlet and it is assumed that:

1. there is no distribution at the tray inlet; and

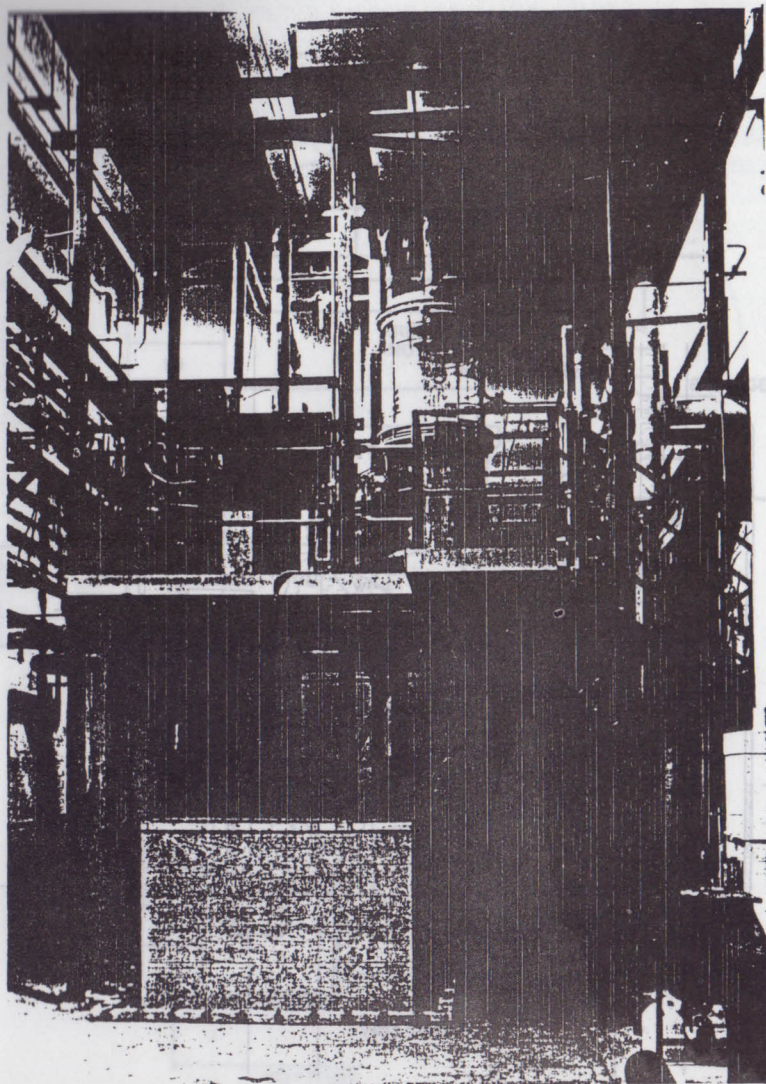


Figure 5: Sieve tray dynamics

Figure 6: A sieve tray rig

show the sieve tray geometry and its installation.

The interaction between the gas and the liquid on the tray produces a frothy mass or a mass of bubbles, akin to what you observe while washing your dress with detergent or bar soap. Mass transfer takes place in the froth. The component of interest leaves the carrier phase (the gas phase or the liquid phase) and goes into the other phase. By installing a series of plates in a column we can reduce the transferring component to a desired level in the carrier phase.

The facilitation of interaction between the gas and the liquid on the tray is accompanied by some deleterious phenomena such as weeping, liquid-to-gas entrainment, too much loss of gas pressure and flooding. The design of the tray (in other words, specifying the geometric layout of the tray), is aimed at maximizing separation efficiency while minimising these deleterious phenomena. In order to do so, data must be available on the hydraulic characteristics of the tray. Many workers have produced design data, some of such workers are Foss and Gerster (1956), Hughmark and O'Connell (1957), Bain and van Winkle (1961), and Thomas and Campbell (1967). All these workers used different hole sizes, tray and column geometries. Therefore, it is difficult to extrapolate their results to other situations. Besides, many assumptions were made to enable them obtain their data whose result is reduction in accuracy. For example, let us consider the following equation, which models the concentration profile of a tracer on the tray:

$$\frac{\partial C}{\partial t} + u_x \frac{\partial C}{\partial x} = D_E \frac{\partial^2 C}{\partial x^2}$$

The profile is required for predicting the liquid residence time on the tray and consequently, the mixing parameter D_E , which is essential for predicting the transfer efficiency. The solution of this equation is complicated by the nature of the boundary conditions. A pulse injection of dye is delivered at the tray inlet and it is assumed that:

1. there is no distribution of dye at the inlet; and

2. the dye/liquid mixture is in plug flow at the inlet. Consequently, the convective term is ignored to obtain

$$\frac{\partial C}{\partial t} = D_E \frac{\partial^2 C}{\partial x^2}$$

In reality, there is very serious distribution at the inlet and the flow very much turbulent. While the assumptions facilitate an easier solution they introduce errors right from the outset which vitiate the accuracy of the results. In my work, (Ogboja, 1984), I actually measured the distribution at the inlet and consequently produced a solution of the form

$$C = \frac{2\beta \exp[(\mu/2D) - \alpha\theta]}{\pi} \int_{\kappa\mu/2}^{\infty} f(p) dp$$

where

$$f(p) = [\theta - (\kappa\mu/2p)^2] \exp(-[p^2 + (\kappa\mu/2p)^2 (a^2 - \alpha\theta)])$$

The concentration profile calculated from this equation compared very well with what I actually measured at the tray exit. The improvement required painstaking effort and could only be achieved with modern computing facilities.

The other problem with sieve tray data is that most researchers (especially the earlier ones) restricted their studies to small hole sizes in the range of 3 mm to 10 mm for fear of weeping. Thus for a long time, design data were not available on hole sizes in the range 10 mm to 25 mm. One thing made research into this range inevitable and that is the fact that small holes were susceptible to blockage in dirty services and in situations where solid deposition could block the holes. In 1972, I took the bold step of embarking on research to produce design data on 1-inch or 25 mm diameter holes in trays installed in industrial size columns. The results of the extensive research were reported in top journals in the USA and UK (Thomas and Ogboja, 1978 and 1982; Ogboja 1984). On comparing my results with those obtained by other workers on small trays, it was obvious that no meaningful scale-up criteria could be produced without including the effect of size and geometry in their

studies as variables.

Another problem that the designer faces is the use of data from various sources which are of different descriptions and characteristics. In order to minimise the errors attendant on the inevitable use of such data, the designer must know which one to use, under what conditions and how to scale it up. Usually, many researchers do not provide enough information to permit the manipulation of their data. The best thing for the designer is a source of generalised data which will take into consideration equipment geometry, transport phenomena and similarity criteria between laboratory and industrial equipment. I have given an illustration of this in my work on the mixing on the sieve tray where I used dimensionless numbers to correlate the geometric, flow and transfer parameters. The beauty of this approach is that as many parameters as are necessary to describe the function of interest can be included in the correlation equations.

2.8 Design Packages

Many steps are involved in the design of any particular equipment. At the outset, these steps must be formulated and arranged in the correct sequence. This is always helpful as the result of one preceding step may be and is usually needed in the next step. It also facilitates rechecking of calculations and readjustment of design data. When the design procedure is very involved, especially if it is long and very iterative, it is best adapted for computer implementation. The computer facilitates speedy and accurate calculations.

Most long procedures are now available as computer packages. Ogboja and Kuye (1985) produced the first most detailed computer package on the sieve tray. Similar packages have also been produced by my associates and I on the water cooling tower, shell-and-tube heat exchanger, multiple effect evaporators and multiphase reactors (Ogboja 1987, Kuye and Ogboja 1989, Dosunmu and Ogboja 1995a, 1995b and 1995c).

Simulator packages are also available on the market for studying the performance of process plants. Such packages are generalised in that they are designed to be applicable to all manner of process plants. They sometimes fail, because no matter how bulky and detailed they are, they cannot take into consideration the peculiarities of all process plants. The Generalised Process Flow Simulator, (GPFS), one of the first packages to be available on the open market, was used by Ogboja and Daramola (1985) to simulate the topping unit of the Warri refinery. It failed because the analysis of recycle streams were not available. Consequently, Ogboja and Kuye (1985) designed another program specifically for the topping unit and it performed excellently. Specific programs are usually proprietary and their owners use them only for their process plants to monitor performance and predict the effects of changes to input rates and conditions. For a process plant, a simulator package is a must. Kuye and I have produced a package that can be of tremendous benefit to the Nigerian refineries.

2.9 Other Considerations

This discussion concludes the section on plant design. We can say that, up to this point, the best process has been selected by using technical and cost considerations. The individual plant items and ancillaries have been specified. At this point in time, the engineer can prepare his final drawings and call for bids from vendors and contractors. At this point also and with the knowledge of all the materials featuring in the process and the nature of the plant, the plant must be subjected to environmental impact assessment. This is to ensure that it is a safe process and that its products and effluent will not be harmful to the environment or that enough measures have been taken for their handling and disposal. The construction of the plant can only be embarked upon when the relevant institutions, such as FEPA, have given it a clean bill.

A site should be selected for the plant early in the planning stages. Economic considerations are usually the

main criteria for site selection. The site must be easily accessible by road, rail and air. It must be close to the markets for raw materials and products. Infrastructures such as water and power must be available in the area. The labour and expertise needed to run the plant must be available and there must be schools for children, mosques and churches for worshippers and shopping centres for housewives.

The construction of the plant can commence once all the social and legal considerations have been satisfied. Consequently, the plant will be constructed under the meticulous supervision of the engineers. The completion of construction corresponds to the end of gestation period and the baby is ready for delivery. Anxiety is mounting on the part of father and mother and prayers are being said profusely. I like to join with the appropriate prayer: *may we hear the voice of the mother and the cry of the baby.*

3. PLANT COMMISSIONING

Plant commissioning is the initial start-up of the plant after the completion of fabrication and construction. A plant manager is usually appointed during the construction of the plant to allow him familiarise himself with the plant components and its layout. He is assisted by some personnel of the plant who have been recruited and some special personnel who are brought in for just the commissioning purpose. The plant manager takes over from the project engineer and his first major job is to commission the plant. He organises for the commissioning by providing the needed personnel and materials.

The commissioning should be planned and scheduled meticulously in order to achieve success. Commissioning requires the coordination of a large number of people and activities. Planning is required for pre-start activities, initial start-up, budget, documentation, recruitment and training while in scheduling, all activities are broken down into their constituent parts and man-hours/machine-hours required

to perform each activity are determined. The operation of the plant, after the commissioning, requires the creation of a large number of systems and procedures many of which may have to be formulated prior to and during the commissioning. Examples are operating instructions and process records. Operators have to be trained during the commissioning by both the training department and the plant management. In particular, the operators have to familiarise themselves with the chemicals to be used, the nature of equipment and its location, the procedures for operating the plant and safety and loss prevention procedures. Lectures and use of plant simulators may be employed for the training. Further training may be obtained on the plant to familiarise with equipment layout and to learn how to operate equipment and instrumentation. The inadequacies revealed during the training should be documented and rectified.

The successful commissioning of the plant brings it to life. It is always an occasion for immense joy and jubilation especially on the part of the engineer, the mother, and the entrepreneur, the father. The birth is celebrated with champagne and kolanuts and those who stand to benefit from it apart from the parents - househelps - in this case, factory workers, can be seen engaging in a flurry of activities. After a few days, the doctor and his team, in this case, the commissioning engineers, hand over the baby to its parents. Thereafter, the parents continue the caring for the baby, giving it food, clothing (raw materials and maintenance) and getting in return products - physical and mental development, errands and materials.

4. PLANT MANAGEMENT

The plant attains full life after the commissioning. Thereafter, it yields products continuously which translate to financial wealth. The benefit from the plant can be made steady by creating the right infrastructural and economic atmosphere to operate in and maintaining it adequately. In order to achieve an efficient system, the plant management

should organise and be seen to be in control of the following activities:

1. raw materials supply
2. products evacuation
3. maintenance and documentation system
4. marketing and promotion
5. finance management
6. personnel management.

Particular attention should be paid to maintenance. Maintenance is the work done on a functioning equipment to keep it functioning or on a broken-down equipment to restore it to the functioning state. The types of maintenance activities carried out in plants are:

1. *Preventive maintenance* which entails regular checks at specified intervals to prevent break down.
2. *Planned maintenance* which involves a complete shut-down of the plant for maintenance activities, e.g. TAM;
3. *Break-down maintenance* which involves the repair of a broken-down equipment to restore it to the functioning state.

The need for plant maintenance is an indication of abnormality and often portends imminent hazard. Therefore, preventive maintenance should be carried out before any signals.

The benefits of preventive maintenance are:

1. prevents frequent breakdowns
2. production rate and quality can be predicted
3. financial losses can be reduced to a minimum
4. hazards are reduced to a minimum
5. benefits from the plant are maximized

5. THE CHEMICAL ENGINEERING PROFESSION

5.1 Training of Chemical Engineers

The first department of chemical engineering was started at the University of Ife (now Obafemi Awolowo University) in 1969. That of the University of Lagos followed in 1973. Many other universities have since started chemical engineering. Today, there are twelve chemical engineering departments in the country. The products of these departments have attained high positions in the process industry, academia, government service and private practice.

Tremendous training and experience are needed to acquire the required skill in plant design. That is why plant design is an art in addition to being a creative activity. It is interesting to compare plant design with other art activities such as painting, theatre design and building design. (See Tables 1 and 2)

Table 1

PAINTER	PROCESS DESIGNER
1. Starts by developing a pencil sketch to show only the most significant details	Discovers the most expensive parts of a process and the significant economic trade-offs
2. Evaluates the preliminary painting and makes modifications using only gross outlines of the subject	Generates a number of design alternatives that might lead a reasonable looking rough process before adding details
3. Adds colour, shading and the details of the various objects in the painting and re-evaluates the results	Uses more rigorous designing and costing procedures for the major items of equipment and adds more details in terms of the minor items.

Table 2.

SN		THEATRE DESIGN	BUILDING DESIGN	PLANT DESIGN
1	Team members	Scenery, lighting, costume, sound	Architect, soil Eng. engineering services (mech. & elec.) structural Eng., QS	Process, mech., elect., Civil Eng.
2	Initial Survey	Location Survey	Programming to understand family structure and interaction - reasons below present set-up ∴ formulate concept	Market and technical survey
3	Concept	Defined and agreed upon	Derives from survey. Functionality & minute cost	Derives from Survey functionality, cost.
4	Procedure	Scenery designer: makes a rep. of each setting, working drawing, execution scheme, supervisions	Architect: designs building scheme of supervision	Process Eng. designs process, unit ops. drawing, scheme of supervision

5	Co-ordination of work	Team co-ordinated by Producer/Director	Team co-ordinated by Architect	Team co-ordinated by Process engineer
6	Principles	Harmony, contrast, variation, pattern composition, gradation	Airflow, traditional and management principles	Math & Sciences, Thermo Principles
7	Materials	Best available	Dictated by environmental forces and cost	System requirements and costs
8	Clients View	Considered in design	Accommodated in concept	Accommodated in concept
9	Location plan	Depends on location	Depends on the environment	Depends on the environment
10	Communication	By drawings and models	By drawings, models promote appreciation	By drawings, models promote appreciation.

In all the activities, it can be observed that

1. The procedures go through a series of successively more detailed synthesis and evaluation stages - that is, successive refinement. While doing this, the designer must maintain focus on the overall problem;
2. They terminate when a point of diminishing return is reached, that is, when little value is achieved after additional large effort;
3. The art problem does not have a single solution, many routes can be employed to produce a given product for about the same cost; and
4. They all require judgement to decide how much detail should be added.

It is therefore apparent that all art activities are comparable no matter the field. However, each one has its own focus and peculiarities. In particular, process engineering utilises scientific principles in the development of a design. Therefore, process engineering is a combination of science and art in a creative activity. This makes process design a fascinating exercise for the chemical engineer.

For the artist to become adept in his art, he has to undergo a long period of supervised training and then acquire tremendous experience by continuous and rigorous practice and interaction with more experienced artists. We can, therefore, conclude that a chemical engineer is not an artist in the sense of the art until he has acquired sufficient experience in the practice of the art of chemical engineering.

The training of the chemical engineer, like that of any budding artist, has two parts - academic training and practical training. The academic training is being hampered by poorly remunerated lecturers and inadequate, derelict and obsolete facilities. To remedy the situation, each

department of chemical engineering in this country needs only one hundred million naira - that is just about one billion naira in total. Government should be willing to spend this sum in order to give Nigeria an industrial base. The situation in Nigerian universities now cannot be compared with those overseas or even in Ghana or South Africa. When Prof. Ogunye induced me to join this department in 1976, the situation I met on ground was better than that at the University of Surrey where I came from. We were not using chalk to write on the board - our board was formica on which we wrote with felt pens. Every room was airconditioned. There was money for teaching, research and academic travels. Salaries were adequate and we had respect in the society. That was why the Obasanjo regime could enact the Private Practice Decree. Today, such a decree would be ridiculous and a total mockery. My former student who is now at Shell takes home at least N50,000 per month while I take home N20,000.

The practical training is not the business of the universities but in order to make our graduates useful immediately after graduation, we make them undergo a total of twelve months industrial training. We have instituted a course - Entrepreneurship - in which we teach the students how to plan, fund and sustain small and medium scale businesses. The process industry is in the best position to give fresh graduates the required experience. I am not oblivious of our present plight - plants are closing down or operating at 30% design capacity. You know who to blame - government. Wealth does not reside in situations where the atmosphere is not right. How can you continue to make wealth when industries are closing down?

6. NIGERIA'S STATE OF PREPAREDNESS

So far we have examined how to bring a process plant to fruition. We now want to examine the conditions available in Nigeria for making wealth from the process plant.

6.1 Availability of Expertise

Today, there are many Nigerians that are adept in the art of design, having participated in the preliminary studies, design and construction of plants such as the Warri refinery, Port Harcourt refinery, crude oil flow stations, chemical plants and so on. Nigerians too are responsible for managing and maintaining the plants. The activities of Nigerians in the refineries and in the food, brewing, and chemical industries show that design expertise is not lacking. However, there is no policy that encourages design and manufacture of equipment in the country. Consequently, there is no coordination of the available expertise. The big and especially the foreign companies exploit this failure by patronising their home companies. The absence of a guiding engineering and construction policy encourages capital flight from the country and perpetual dependence on foreign expertise. Of course, it slows down technology transfer. The policy, when in place, should require companies to show evidence of local content in their set-up and mode of operation and readiness to develop local infrastructure and put in place a training plan for their Nigerian employees. The benefits of this would definitely include

1. boosting of national wealth and reduction in capital flight,
2. creation of quality jobs for Nigerians;
3. lowering of project execution costs; and
4. development of local expertise.

The plant design art can only be developed in this country by a concerted effort on the part of government to promulgate a policy and effect it. The only significant effort so far made is the establishment of NETCO in 1989. NETCO was established as a joint venture company between NNPC and Bechtel Incorporated of USA to provide engineering services to the Nigerian petroleum, gas and non-petroleum industries. The joint venture arrangement terminated in

December of 1996 and NETCO now operates solely as a subsidiary of NNPC. NETCO has well-trained and experienced engineers and makes use of modern tools such as computer aided design and drafting facilities.

NETCO has been providing high-quality engineering services to the oil industry and a proof is the design of the Onshore portion of the NNPC/Chevron Escravos Gas Development Project which was done in Nigeria by NETCO engineers and a total of 143,000 man-hours were expended. This is the single largest and most technologically complex engineering effort ever undertaken locally, within Nigeria, by Nigerians.

Besides NETCO, there are well-established private consultancy outfits that have proved their worth and capability in the Nigerian industries. These companies need encouragement to take Nigeria to the height of technological self-sufficiency. A policy that will guarantee their survival is required.

6.2 State of Machine Tool Industry

The machine tool industry needs materials from the steel industry. The Delta Steel Company plant has become almost morbid and the Ajaokuta Steel plant has never been realised in the way it was conceived. Of course, the makers of machines and tools get round the problems by using what they can get from scrap melters and imports. They cannot easily get specialised materials and what they get is much costlier than it should be if these two factories were active. The machine tool factory is responsible for implementing designs of tools, machines and equipment that are beyond the capability of the ordinary welder. The machine tool industry at Oshogbo in Osun State has never performed near its target design owing mainly to administrative and financial problems. The African Regional Centre for Engineering Design and Manufacture (ARCEDEM) at Ibadan, is plagued by lack of finance since most of the African countries that are supposed to finance it do not pay their contributions regularly, if they pay at all. In the face of

these failures and deprivations, it is difficult to find a place to implement serious designs in the country. What I am suggesting therefore, is that design capability must be developed *pari passu* with the development of the materials and machine tools industries.

Today, we can claim that we refine iron and platinum in the country, but there are many more essential materials that we just exploit and export. The polymer and ceramic industries are the most neglected. In the developed world, the dependence on steel is on the decrease and polymers and ceramics are replacing steel components. The so-called super materials that can withstand high temperatures and stresses are now being made from polymers and ceramics. It has now become obvious that the world will survive when the last grain of iron on earth has been consumed. To my chagrin, nobody is looking at the development of the super materials in the country today. That means we depend on the West and Asia for these too, just as we depend on them for many other things. Economic independence is a precursor to political independence, therefore, for a long time to come our independence will remain a dream.

6.3 State of Transportation Facilities

Transportation facilities are needed in the industry to move materials and personnel fast. For this reason, they are essential parameters in the consideration for siting a plant. Nigeria is contiguous to the sea and she has many rivers that can be developed for inland waterways. We do not suffer from earth tremors or earthquakes, so we could have efficient rail system ramifying the country making access to every nook and cranny a child's play. The pernicious neglect of the railway sector is the reason air fares are astronomical, that food prices are impossible, that Nguru looks to a Lagosian farther from Lagos than New York. By now it should have been possible to leave Lagos in the morning for a meeting in Sokoto in the afternoon and return in the evening. When Kaduna refinery was conceived, it should have occurred to the decision makers that being the only

inland refinery in the whole of West Africa, it should be supported with an efficient railway system to facilitate fast transportation of its materials and plant maintenance components. Fuel distribution should have been easier and the destruction of our roads by trailers would have been less.

6.4 Infrastructural Facilities

One big reason why many factories have been closed down and many are still facing the threat of closure is the fact that every factory has to provide its own water and power. These two items are so basic to the survival of a factory that they ought to be readily available. They are secondary only to capital and in most cases, they consume between 20 and 50% of the capital depending on the type of industry. Unless something is done to create a turn-around in the provision of these essential facilities, the growth of the Nigerian industries will be hampered for a long time to come and the quest for abundant wealth will remain a dream.

7. HOW TO MAKE WEALTH

Only people who invest in production can make the country wealthy. There is no alternative to it. Buying-and-selling and supplying-and-removing are primitive activities. Those who indulge in them are timid and they cannot conscientiously contribute to development. Imagine what they would do if the few factories that are still functioning should close down. Those who put their money in deposit accounts are no better. They are merely escaping the risks involved in investing. Money is the one item that God has not given rest. It hates to be in the state of stupor. This is why those who keep their money at home can hardly enjoy mental rest. Their money troubles them. When you have money in millions and billions, ensure your rest by investing it in a productive venture.

When you have the problem of what to do with your money or money that you can have the privilege of loaning, talk to

a chemical engineer. It does not matter as to whether you know what you want to do with it or you are totally bereft of ideas. It is his business to refine your ideas or give you an idea and take whatever you two agree upon from conception through to the commissioning of the plant.

Three things are important to the quest for wealth: expertise, raw materials and capital. One needs expertise to transform the raw materials to products and capital to initiate the project and take it to the commissioning stage. We shall now examine the availability of these essential components.

The nation is endowed with abundant mineral resources and agricultural products. The NARICT in Zaria, FIIRO in Oshodi, PRODA in Enugu and RMRDC have developed processes and machinery for converting many of these resources into valuable or desired products. Investment in preservation processes can make mangoes, corn, plantain and vegetables available all year round. They can be exported to earn scarce foreign exchange.

The departments of chemical engineering in the universities and the research institutes can be of tremendous assistance. Our department has developed quite a few processes and facilities. Dr. Olatunji and I have perfected the alcohol plant. Dr. Victor Adeniyi has developed and perfected the shaving cream and the toilet soap. Drs Olatunji, Bello and I are at the moment working on the production of bakers yeast. If money is available we could hit the market with our products in a matter of months. For limited capital and small and medium businesses the universities and research institutes are the best option. PRODA, FIIRO, NARICT, RMRDC will more than satisfy your quest.

Interaction with the universities can really be made symbiotic: we put our expertise at your disposal while you, the entrepreneur, use your money to dot the country with process plants or factories. Consequently, more training

facilities will become available to our students and more jobs to Nigerians. We can go further by saying that more able-bodied Nigerians will leave the streets and area-boyism will become a thing of the past. Of course, you will become richer and richer, you can then marry more wives, buy more mercedes benz cars and throw more all-night parties to celebrate your arrival.

Juicy, you will say, but you have the hurdle of finance to clear. You really should not fear. Institutions that can give the required support abound - FEAP, NBCI, NIDB, Commercial banks and Merchant banks. You can also approach cooperatives and individuals. If you do not have securities, opt for cooperatives. They are the best and the cheapest, the only problem is their predilection for quick-return investments - trading. Individuals may not be as attractive because of the prohibitive interest rate they charge and what they may do to you if you default. When you are at a fix, consult an expert. The path to wealth can be depicted as shown in Figure 7.

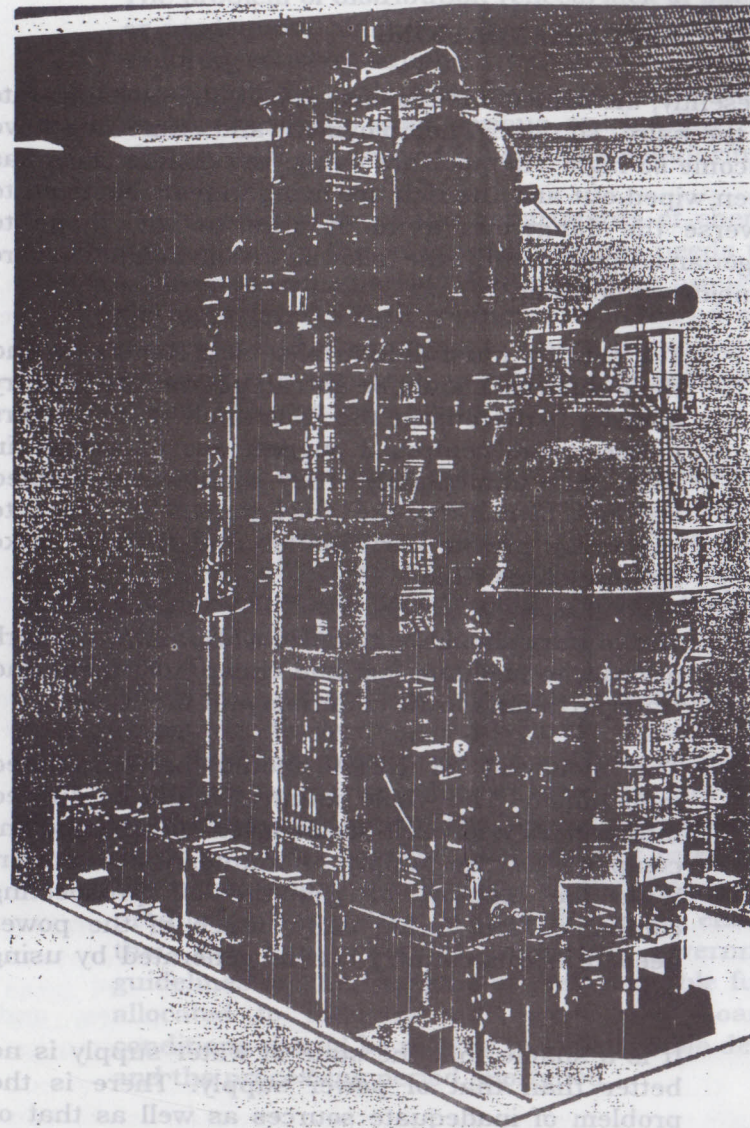


Figure 7: An example of a plant - Catalytic Cracker, Pembroke Refinery (Courtesy : Texaco Ltd)

8. RECOMMENDATIONS

Presently, the state of the economy is bad, the exchange rate of the naira, so poor. Unemployment and crime rate have become so high. The poor are dying, the middle class has been wiped out and the rich are living in fear. We need to reverse the dangerous trend in order to give hope to Nigerians. Consequently, the following recommendations are considered pertinent:

1. The country must industrialise at a rapid rate and the industries should be spread all over the country in order to discourage the gravitation of job-seekers to the urban centres. I suggest two industries in each State immediately. They should be promoted but not owned by the Government in order to encourage private participation and thereby make the industries virile;
2. The country should be ramified with railway network in order to facilitate fast and cheap movement and transportation of raw materials and products;
3. The monopoly of NEPA should be terminated immediately. The whole country should be divided into sectors and each sector given to a competent company for the supply of uninterrupted power. With the amount of gas the oil prospecting companies are flaring daily, much of the power needed in this country can be generated by using gas;
4. It is a shame that the state of water supply is no better than that of power supply. There is the problem of inadequate sources as well as that of distribution. The common sources are rivers and boreholes. The river source fluctuates with the season and the boreholes die with age. The problem of source is therefore known and can be combated.

The problem of distribution reflects lack of planning or inadequate planning. The only realistic way of ensuring constant supply is to contract the supply to companies in each state or sector. The present supply networks need serious overhauling. They should be computerised for effective monitoring;

5. The derelict state of the departments of chemical engineering in the various universities needs to be addressed immediately. They should be brought to the same level as their counterparts in the advanced countries if this country is to close the gap between her and the advanced countries and achieve the dream of becoming a world power;
6. In order to encourage Nigerian practitioners in the process industry and the development of local expertise, Government should institute a policy, which should require companies to develop local infrastructure and have training plans for their local employees; and
7. There is a need to promote investment and discourage the keeping of idle funds. If people know that they can make more money from investment than from savings and deposit accounts, they would go for the former option. The interest rates should be made as low as possible. High interest rates make the banks and the rich richer to the detriment of productive businesses. It should also be ensured that the banks comply with the government guidelines on the fractions of their loanable funds allocated to industry and agriculture. Loaning conditions should be relaxed to a reasonable degree and the processing period shortened.

If these steps are taken, tremendous achievements will surely be made.

EPILOGUE

Mr. Vice-Chancellor Sir, we have examined the developmental stages of the process plant and itemized the activities at the various stages. The roles of the process engineer and the entrepreneur have been clearly defined. It has been shown that the product of the entrepreneur/engineer relationship, the process plant, is comparable to that of the man/woman in human marriage. The family is propagated through the child while the economy is given growth by a multiplicity of process plants. I have also shed some light on the environment that this abstract child, the process plant, needs to thrive. The infrastructures must be steady and adequate, his doctor, the process engineer must be well trained and given adequate facilities to work with.

In the industrialised countries, the process plant is supported to grow and multiply. Policies are formulated to protect it and facilities are provided to make it thrive. Exactly the same thing is done for the child. The process plant is to the country as the child is to the family. The process plant is a thing of joy, the hope of the country, the fountain of its wealth.

Mr. Vice-Chancellor, Sir, when Paul presented his apologia to King Agrippa, the king understood but failed to use his powers to give Paul a positive pronouncement. It is my hope that you have understood me and that you will use your powers to ratify my chair.

Mr. Vice-Chancellor Sir, Distinguished Ladies and Gentlemen, I thank you very much for your kind attention.

ACKNOWLEDGEMENTS

To God be the glory for what He hath done.

I like to thank my brother, Chief Dayo Ogboja, who fathered me from the age of ten years. He extricated me from peasant life and today to the glory of God and to his honour and pride I stand before this gorgeous audience to present my academic apologia. With his meagre salary, he gave me all the indulgences the affluent of our time could give their children. Indeed Nigeria would be better if every brother were like him. I rejoice with you.

The principal of my beloved secondary school, Ekiti Parapo College, commented about me in my school leaving testimonial as follows: *An exceptional student with exceptional ability; highly intelligent yet sober and highly disciplined, a pride to the College.* Chief Ade Akomolafe, these words of yours motivated me all through my academic pursuits. Today, you are a proud father of a Vice-Chancellor, many professors, permanent secretaries and gurus of industry because you are a focused disciplinarian, a perspicacious leader and an adroit motivator. I thank you.

I owe the beginning of my engineering training to my teachers in the University of Lagos. I mention with immense gratitude Prof. A. O. Adekola the best teacher of engineering mathematics I ever came across, late Prof. Awojobi (dead easy), Prof. Alaba Akinsete, Prof. R. I. Salawu, Drs. Sonubi, Okurounmu, Adenubi, Olu, Ajayi, Sonuga and late Drs. Onafeko and Olubode. Dr. W. J. Thomas of the University of Surrey, Guildford, England supervised my Ph.D. He contributed immensely to what I am today. Early in life, he had seen what it meant to lack and is oppressed. That history of his evoked kindness in him towards other people. I will ever remain a grateful beneficiary.

When future was bleak and friends were few, Femi Anibaba was by my side. When University of Lagos cut off my grant during the first year of my PhD, we survived on Femi's grant. He was and he still is a friend indeed.

Prof. Ayo Ogunye was the reason I came to this University after I finished at Surrey. He was an inexorable persuader. When I got here, he provided a focused and forthright leadership in the department. He inculcated in us the spirit of togetherness, forgiveness and tolerance. Ogunye is a rare human being, a cornucopia of energy, an assiduous worker and an embodiment of successes. Ogunye, may your tribe increase.

I owe a lot to my former research students: Lekan Daramola (1979), Ayo Kuye (1981) whose appointment as a professor is being expected, Dotun Dosunmu whom I used to pioneer the implementation of orthogonal collocation in the Department. I thank all my colleagues who have provided a conducive working atmosphere and made the department the envy of all.

I must thank my in-laws for their support and understanding. My father-in-law is exceptionally tolerant and loving. I have not met another man who holds tenaciously to Paul's injunction - *it is more gracious to give than to receive*. Baba will rather give and go hungry than see a hungry man around him. I want to particularly thank my uncle-in-law, Rev. L. L. Eso for his love and the quality leadership he gives us. My brother-in-law, Kolade Olofin, has been most so supportive.

Lastly, I thank my family for their love, understanding and tolerance. My children, Yemi, Yinka, Kayode and Toyin are a source of pride to me. My wife, Ayo, is joy to me. She is the most delectable queen God ever created. She is extremely loving, accommodating and supportive. She even had to change her profession in the interest of the family. Today, the Nursing Sister is a bank manager. I cannot ask God for more by way of children and wife.

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