THE CHEMICAL ENGINEER AND THE CHANGING WORLD

BY AYODELE FRANCIS OGUNYE

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THE CHEMICAL ENGINEER AND THE CHANGING WORLD

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By

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DEDICATION

To an able Lawyer

SENATOR ABRAHAM ADE ADESANYA

For his resolute pursuit of the cause of Justice

THE CHEMICAL ENGINEER AND THE CHANGING WORLD

INTRODUCTION

Mr. Chairman, Pro-Chancellor, fellow engineers, distinguished ladies and gentlemen.

By definition, every inaugural lecture heralds the start of something new and this would apply if I were the latest in succession to the Chair of Chemical Engineering at Lagos rather than the first. As Professor Olusanya explained in his inaugural lecture, such an address may take any of three forms. It may:

1. Concentrate on the development of the Department, if the lecturer is also the occupant of the chair to which the headship is attached. This I shall do extensively during the course of this lecture.

2. Be focussed on the Professor's own work within the general framework of his discipline.

3. Be on any general topic where the Professor considers that he has something fresh and stimulating to tell his audience. The title of this lecture is related to this.

My address today will encompass all the three forms.

In some of the inaugural lectures which I have attended in this University, the speakers managed to discourse in an interesting way on their specialist fields without a great deal of introductory matter. They have an advantage over me because they assumed that their audience was at least aware of their subjects; or that their listeners were familiar with the products of their labours, be these material or abstract.

The history of engineering is in many respect the history of civilisation itself; the progress of developed and industrial countries has been due to the advances in science, engineering and technology. Engineers constantly seek to understand the laws of physical universe, they take advantage of the beneficial aspects of nature while converting or modifying the adverse factors so that man can become master of his environment. Unfortunately, the importance of the engineer is hardly appreciated in everyday life. This is partly because the work of the engineer, being an impersonal one (unlike that of the doctor, lawyer or accountant) is easily taken for granted, and partly because the engineers are content to let their achievements speak for themselves rather than impress them on a forgetful public. I am sure not up to five percent of the audience here today know much about the chemical engineer. You may be a bit aware of mechanical and electrical engineering, they are brought home to us, literally, in our cars, our washing machines and our television sets. Or the civil engineer whom we remember when we ride along well-paved highways and live in well-built structures.

Chemical engineering in the more advanced countries is the most recent of the four main branches of engineering. The British Institution of Civil Engineers (as distinct from Military Engineers) was founded in 1818, that of Mechanical Engineers in 1847, that of Electrical Engineers in 1871 and that of Chemical Engineers not until 1922 – although the American Institute of Chemical Engineers was founded in 1908. The Nigerian Society of Chemical Enginers is just about to be incorporated. Any branch of engineering can develop only in connection with some type of large-scale activity. The oldest large-scale activity of mainkind which involves engineering is building. In the early days of civilisation in Mesopotamia and the Nile Valley, large strctures were erected such as palaces, temples and fortifications. In the

same period, irrigation canals were built on a large scale. Two thousand years ago, the Romans were building their famous roads and aqueducts. Thus civil engineering, although the name was not invented until many years later, is the oldest branch of engineering and was developed as a result of large-scale activity of building. The reason for the comparatively late recognition of the chemical engineer is the relatively late development of large-scale manufacture and particularly of continuous process – not until the early part of this century. Chemical engineering, even after 60 years (the first Nigerian Chemical Engineers graduated about 23 years ago) is apparently still so unfamiliar a subject that one is called upon embarrassingly often, even by the people who should know better, for an outline of its purpose. It is therefore not uncommon for a chemical engineer to be called a 'chemist' an 'industrial chemist', an 'applied chemist', a chemist who has picked up a good deal of engineering or *vice versa*, or other titles which do not describe the profession.

The Chemist and the Chemical Engineer

The name "chemical engineering" is perhaps unfortunate. The emphasis on chemistry and/or association with the chemical industry leads to an overrestrictive description of the discipline and the misconception of the chemical engineer But as I shall show later, the chemical engineer serves a very wide range of process industries.

The chemist and the chemical engineer represent two distinct professions. Adequate training for both professions has become too great an assignment for a single course of undergraduate instruction. The distinction between the work of a chemist and of a chemical engineer is analogous to the distinction between the duties of a physicist and an electrical engineer.

The chemist is primarily a scientist. His prime activities and contributions are in the problems of organic synthesis, in the development of analytical procedures, in basic scientific research and in developing the complex molecular aspects of chemical change.

The chemical engineer is primarily an *engineer* who is engaged in the engineering problems of processing industries in process design and control, in plant operation, in the selection and design of equipment, in establishing the most economical conditions of operation with respect to the controlling variables. He is concerned with the unit operations, with heat and mass transfer, with fluid flow and with economics, all superimposed upon the chemical aspects of the industrial process. It is his duty to combine the physical, chemical and engineering problems of chemical processing into the most profitable performance. He has an indispensable and unique contribution to make, which is not embraced by any other single profession.

After the academic training, the pursuits of a chemist and a chemical engineer may merge. The chemist may subsequently develop into a good chemical engineer and vice versa. This was how the first chemical engineers were developed. In smaller companies, great versatility is required and the combined service of both professions in one individual may be required. However, industry may be demanding too much in expecting significant achievements in both fields from the same person. The chemical engineer or the chemist falls short of expectations when loaded with the responsibilities of both professions. The interrelated technical services of the chemist, chemical engineer, mechnical engineer, and electrical engineer in the chemical industries are shown in Figure 1.

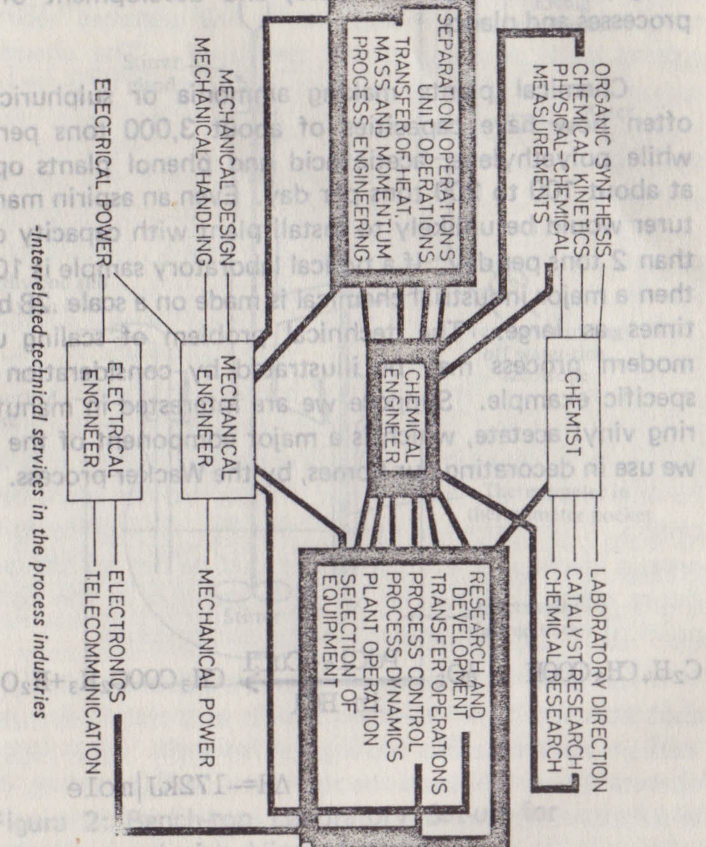

Figure 1: (From O.A. Hougen, The Chemical Engineer, 1965, CE222).

A major difference between the chemist and the chemical engineer is in the scale of operation of the modern chemical industry. Plants developed and used during the early stages of growth of the chemical industry were generally not too different from the items of equipment used in the laboratory for the concerned purposes; and the chemists with ability based on experience were primarily responsible for design, operation, maintenance, and development of such processes and plants.

Chemical plants making ammonia or sulphuric acid often now have capacities of about 3,000 tons per day, while polyethylene, acetic acid and phenol plants operate at about 100 to 200 tons per day. Even an aspirin manufacturer would be unlikely to install plant with capacity of less than 2 tons per day. If a typical laboratory sample is 10 gm., then a major industrial chemical is made on a scale .28 billion times as large. The technical problem of scaling up of modern process may be illustrated by consideration of a specific example. Suppose we are interested in manufacturing vinyl acetate, which is a major component of the paint we use in decorating our homes, by the Wacker process.

$$C_2H_4\, CH_3COOH + \tfrac{1}{2}O_2 \xrightarrow[\text{in HCl}]{PdCl_2-CuCl} CH_3COOC_2H_3 + H_2O$$

$$\Delta H = -172 kJ|mole$$

A typical bench-top laboratory set up is shown in figure 2, which consists of a 500ml 3 necked flask equipped with an inlet for reacting gases, thermometer, a stirrer and condenser.

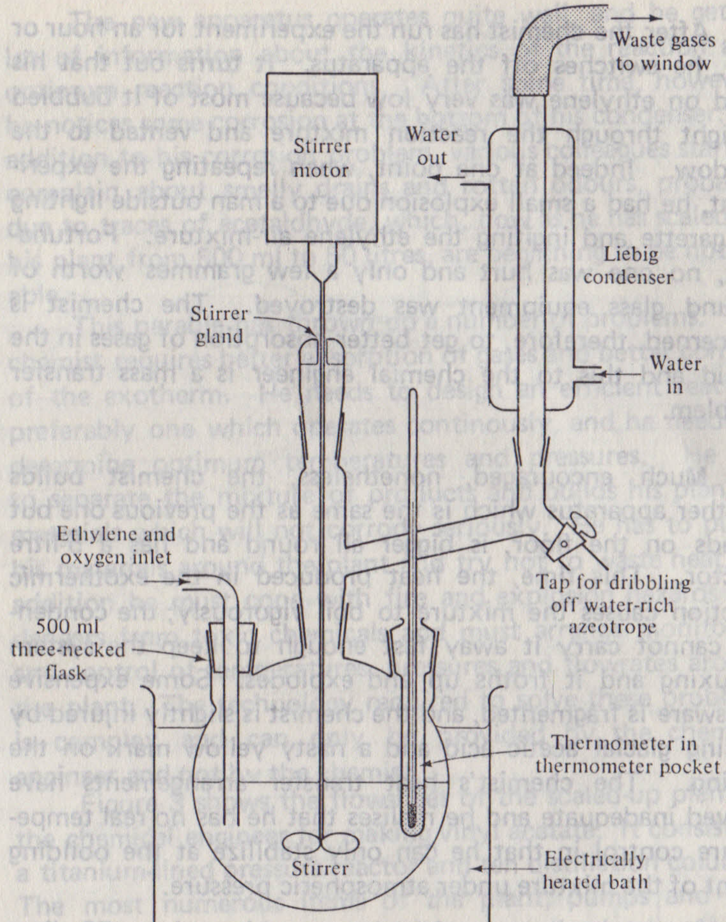

Figure 2: Bench-top Laboratory Set-up for producing Vinyl Acetate.

After the chemist has run the experiment for an hour or two, he switches off the apparatus. It turns out that his yield on ethylene was very low because most of it bubbled straight through the reaction mixture and vented to the window. Indeed at one point, when repeating the experiment, he had a small explosion due to a man outside lighting a cigarette and igniting the ethylene air-mixture. Fortunately, no one was hurt and only a few grammes' worth of ground glass equipment was destroyed. The chemist is concerned, therefore, to get better absorption of gases in the liquid and this to the chemial engineer is a mass transfer problem.

Much encouraged, nonetheless, the chemist builds another apparatus which is the same as the previous one but stands on the floor, is bigger all round and has a 5-litre reactor. This time, the heat produced in the exothermic reaction causes the mixture to boil vigorously; the condenser cannot carry it away fast enough to keep the system refluxing and it froths up and explodes. Some expensive glassware is fragmented, and the chemist is slightly injured by boiling glacial acetic acid and a nasty yellow mark on the ceiling. The chemist's heat transfer arrangements have proved inadequate and he realises that he has no real temperature control in that he can only stabilize at the boilding point of the mixture under atmospheric pressure.

He tries to cope with these problems in a 50–litre apparatus built of stainless steel, a material for which medium-scale chemists have great fondness. He arranges to operate under pressure because that will give him better absorption and also enable him to control temperature more easily because it will stabilize at whatever is the boiling point and the reaction mixture at the pressure under which he is working. He replaces the mercury-in-glass thermometer by built-in thermocouples and pressure gauges, which feed to chart recorders and he redesigns and enlarges his condenser to be sure it is of sufficient capacity.

The new apparatus operates quite well, and he gets a lot of information about the kinetics of the reaction and optimum reaction conditions. After some time, however, he notices some corrosion at the bottom of his condenser. In addition to his corrosion problem, various colleagues start to complain about smelly drains and rotten odours, probably due to traces of acetaldhyde, which, now as he has scaled up his plant from 500 ml to 50 litres, are beginning to be noticeable.

This parable has thrown up a number of problems. The chemist requires better absorption of gases and better control of the exotherm. He needs to design an efficient reactor, preferably one which operates continously, and he needs to determine optimum temperatures and pressures. He has to separate the mixture of products and builds his plant of materials which will not corrode seriously. He has to pump his materials around the plant and try not to waste heat. In addition he must cope with fire and explosion hazards and dangers from toxic chemicals and must arrange monitoring and control of temperatures, pressures and flowrates around the plant. The technology required to solve these problems is complex and can only be provided by the chemical engineer and not by the chemist.

Figure 3 shows the flowsheet of the scaled-up plant by the chemical engineer for making vinyl acetate. It consists of a titanium-lined pressure reactor and ten distillation columns. The most numerous items of the plant, pumps and heat exchangers are omitted to avoid overcomplicating it. Almost all columns come into contact with acetic acid and must be titanium lined. The overall yield of the chemical engineer plant of this type is very high – about 98% – quite unlike the chemist – 15% or so, – and the major byproducts, acetaldehyde, ethylene glycol, diacetate are saleable. Any unsaleable light or heavy ends can be burned, so the only true effluent is virtually pure water. From the flowsheet a chemical complex of a size two to three times the size of the Port Harcourt Refinery may emerge with a production capacity of up to 1000 tons per day of vinyl acetate.

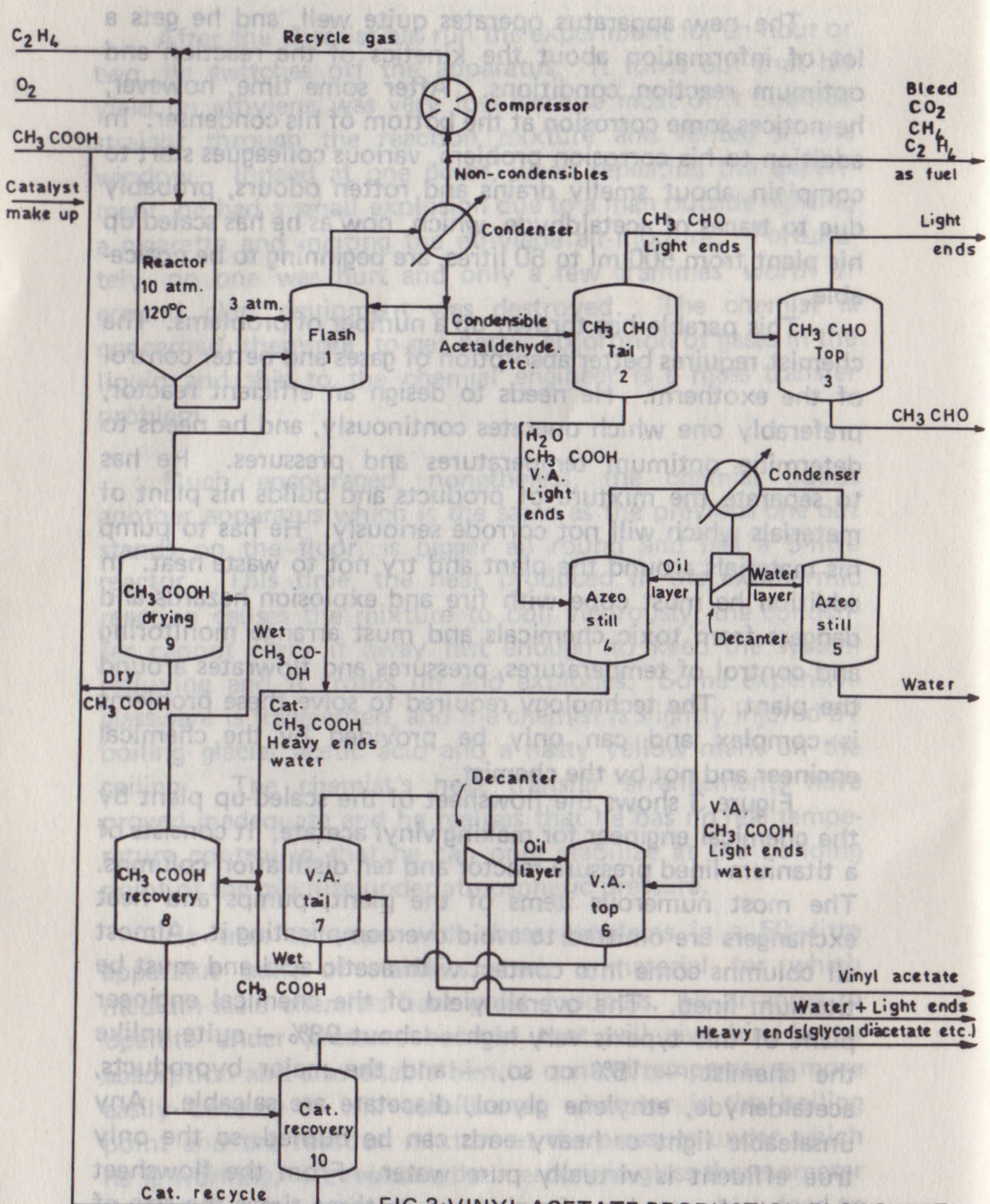

FIG 3:VINYL ACETATE PRODUCTION FLOWSHEET

Mr. Chairman, I must say with humility Sir, that without the chemical engineer, life would not be so easy for us as it is today. Products of the chemical process industries are used in all areas of our everyday life. The raising of food plants and animals requires chemical fertilizers, insecticides, food supplements and disinfectants. Many building materials have been chemically processed; for example, metals, concrete, roofing materials, paints and plastic fibres and dyes. Transportation depends upon gasoline and other fuels. Written communication uses paper and printing ink, and electronic communication requires many chemically processed insulators and conductors. The nation's health is maintained by drugs and pharmaceuticals, soaps and detergents, insecticides and disinfectants – all these are products manufactured by the chemical engineer.

I have concentrated for some time on these very elementary basic ideas of chemical engineering because of the public misunderstanding of what this subject is all about. I hope this will dispel the popular idea that a chemical engineer is some kind of mechanical engineer who has learnt applied chemistry or also a chemist who has learnt how to design ironmongery.

WHAT DOES A CHEMICAL ENGINEER DO?

The development of chemical engineering is a result of the growth of the chemical industry. During the early stages of its development, the chemical industry was mainly concerned with developing processes and providing new products that were not only new but which gave esteem and satisfaction to the chemists, who were responsible for these developments and from necessity engineered their own processes. Plants developed and used during the early stages of growth of the chemical industry were generally not too different from the items of equipment used in the laboratory for the concerned purposes; and the chemists with ability based on experience were primarily responsible for design, operation, maintenance and development of such processes and plants. During the 19th century, when the chemical industry was firmly based on the science of chemistry, the role of the chemical engineer was mainly to provide vessels, pipes, pumps, etc., to enable the reaction to be carried out under conditions specified by the chemist. The chemical engineer in that case had little influence on some early processes, such as the lead-chamber sulphuric acid process, the solvary ammonia process, and the Harber-Bosh ammonia synthesis. However, with the increasing world need for larger plants involving complex control systems, the trend had to shift to the responsibilities of design, etc., shouldered by engineers who were expected to promote "the art of directing the great sources of power in nature for the use and convenience of man". The chemical engineer of today occupies a different position. He is called upon to involve himself in one or more of the following activities: process design and evaluation, construction, process operation, maintenance, production supervision, management, process research and development, product sales and marketing and equipment selection. His education and training should thus be an inter-disciplinary one where parallel lines of various disciplines meet.

THE CHANGING ROLE OF THE CHEMICAL ENGINEER

Whilst the designation "chemical engineering" may reveal his genesis, he has indeed made a lot of progress to make it clear that he is not confined to chemical processes or to the manufacture of chemicals only. Chemical engineering science is now an established and successful discipline, which has prooved its value in relation to chemical and petroleum industries. It is becoming clear, however, that it can also make valuable contributions to other industries which have been developed without the benefit of chemical engineers. In recent years the scope of the chemical engineer

has become much broader and he now plays a major role in plastics manufacture, paint and paper production, fertilizer processing, ceramic and metallurgical industries, development of nuclear energy, food industries, powers, gas, cement, pharmaceutical, medicine and many others.

The Chemical Engineer in the Food Industry:

The occurence of famine has always been the lot of man, and has not been restricted to the distant and remote part of the world alone. Famine is everywhere. Man has proved himself to be the most successful animal to inhabit our planet; and through the application of science and technology, particularly medicine, agriculture, and an ability to exercise some control over his environment, his numbers are showing what is to a great many people an alarming rate of increase. The population of the world at the beginning of the Christian era has been estimated at about 250 million. Growth rate was slow until the mid-seventeenth century, by which time it doubled to 500 million. It doubled again to 1,000 million by 1850 – only 200 years later. Within 80 years, by 1930, the population doubled again to 2,000 million and by the mid-1970s the population has doubled once more[1]. In order to help meet the need for a vast increase in food supplies, the plant breeders introduced new high-yielding varieties of food crops, and the concequent Green Revolution enable food production to keep pace with increase in population. But the high yields from these crops are dependent on what has now become an expensive and scarce input fertilizer. The chemical engineer is accepting this challenge by introducing new technologies to increase annual tonnage of fertilizer to the world; the maximum size plant of synthetic ammonia for fertilizer industry has grown from 30,000 tons per year in 1922 to 500,000 tons per year to meet the increased world need for ammonia. This is a great engineering achievement. World annual production of ammonia is 70 million tons, and if animal protein remains the mainstay of human requirement of protein, it is estimated that by the end of the century, fertlizer ammonia requirement may double.

Pressures on protein supplies have sent world prices of protein of animal origin soaring and rising affluence has placed a major additional strain on world food resources particularly protein supplies. The *per caput* beef consumption per man has doubled between 1940 and 1975. Because large number of potential mothers will be continuing to reach reproductive age, this increase will continue for several more decades, even with today's lower fertility rates. At the same time, world fisheries are in serious trouble because of overfishing, lack of enforcement of international regulations, and increasing effects of coastal pollution. Far from providing to be an inexhaustible source of protein, absolute fish catches are now fluctuating unpredictably, and *per caput* availability of marine protein sources is falling. What all this means is that the world will need some other protein sources than animal protein. The chemical engineer in the last decade has been working hard on methods of synthesising protein in the factory. He now produces protein from natural gas, n-alkanes, gas-oil, methanol, ethanol, acetic acid, sugar-cane bagasse, citrus waste, sulphite waste liquor from the pulp and paper industry effluent, sugar-cane molasses, animal manure, sewage, carbon dioxide, starch, sugar and cellulose.

Another area of the food industry in which the chemical engineer is playing an important role is the meat industry. The chilled meat you buy at Iddo terminal has undergone many chemical engineering operations. The application of chemical engineering in the meat industry is still in its infancy and much of the work is of pioneering type, in the sense of introducing completely new processes and/or products, rather than making minor refinements to well established technological processes. The chemical engineer is applying the principles of transport phenomena to the difficult types of materials encountered in this industry.

These materials have complex, rheological and thermal properties. To the chemical engineer, meat is a deformable solid, often in the form of the highly irregular geometry of carcasses or units with their non-homogeneous structure of lean meant, fat and bone. Meat processing often involves the phase changes inherent in chemical engineering unit operations of evaporation, sublimation, freezing, melting, and thawing. Complex non-Newtonian multiphase solid/liquid/gas mixtures are often encountered in byproduct processing of meat. With the in-road of the chemical engineer into the industry, much of the meat can now be preserved for a long period and a considerable reduction of waste achieved.

Application of Chemical Engineering Science to the Human System:

Reference is frequently made to the increasing specialisation of science which, it is contended, makes it more difficult to obtain an overall view of available knowledge and to cultivate contact between the research pioneers of the various disciplines. Yet it is forgotten that with the increase of knowledge, the variegated pattern of phenomena is reduced more and more to a few basic principles, resulting in a greater measure of similarity between different branches of research, particularly in their methods. Sharing these principles, the chemial engineer and the physician have now succeeded in cooperating on a broader basis, for which the following examples may be cited[2].

The chemical engineer is now playing an increasing role in the study of the body processes of physiology, respiration, blood rheology, gastro-intestinal processes, metabolic processes, energy balances, lubrication processes, as in rheumatism and water loss and control in burns. To the chemical engineer, these are studies of systems involving the complicated movement of unusually complex chemical substances in narrow pipes or through membranes, against a complicated energy transfer background in much the same way as in larger chemical plant processes.

The indicator dilution technique of the chemical engineer is a very important diagnostic method for the calculation of cardiac output (i.e. the blood flow rate), cardiopulmonary volumes and mean transit times, as well as for the detection of circulatory diseases and abnormalities. This technique is based exclusively on the principles of chemical reactor analysis. Figure 4 is a simple representation of the heart. The chemical engineer views the right chambers as

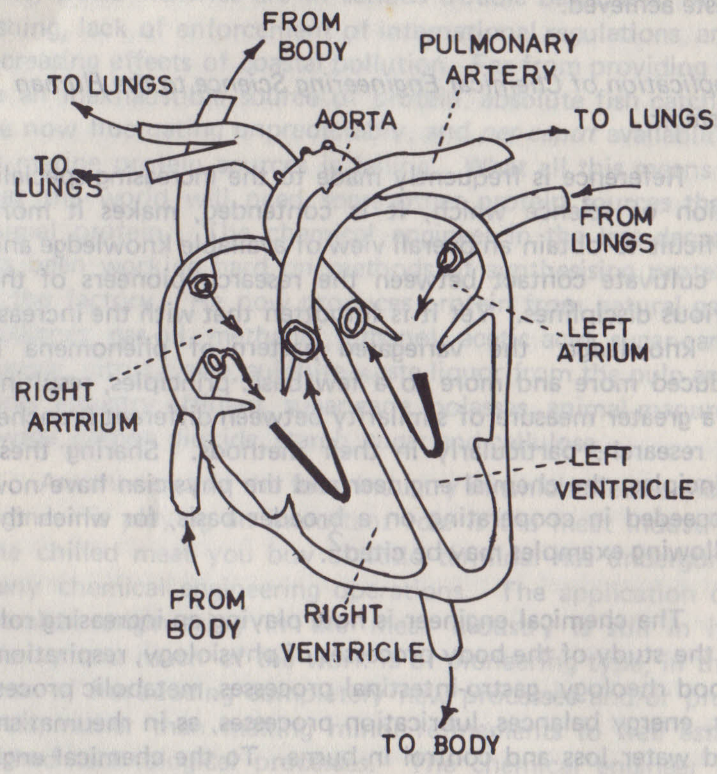

FIGURE 4A: BLOOD FLOWS PATTERNS IN THE HEART CHAMBERS

essentially a mixed flow reactor that pumps blood into the lungs. Since pulmonary circulation is an extended capillary system, flow oc̀curs with little mixing and the chemical engineer models the behaviour here to a Plug Flow reactor. The left side of the heart is analogous to the right; it, too, is a mixing chamber whose purpose is to force the flood into the body (systemic circulation).

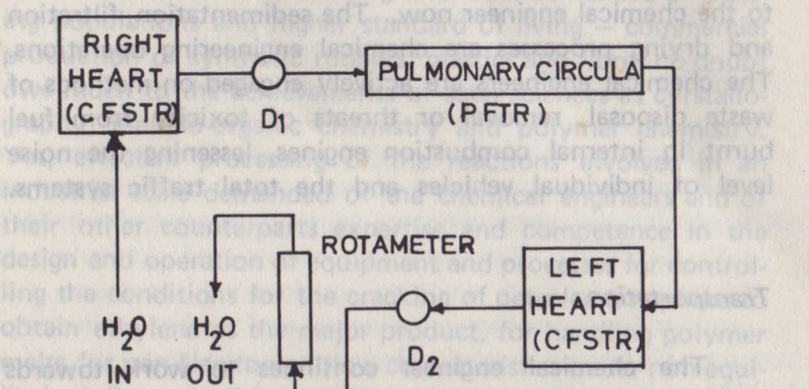

FIGURE 4B: SIMULATION OF THE CARDIOPULMONARY CICULATION

Other areas of medicine in which the chemical engineer is playing important roles are in:

(a) the substitution of diseased or defficient parts of. the body by artificial replacements, e.g. artificial hearts, kidneys, livers, bladders, pacemakers, implant materials and joints;

(b) aids to medical activities external to the body, for example, external kidney dialysis machines, such as the one applied to President Tito of

Yugoslavia to purify the 87-year-old leader's blood, heart lung machines, and other temporary by-pass arrangements.

Environmental Conservation:

Sewage-treatment, which has traditionally always been the business of the civil engineers, is an area of great interest to the chemical engineer now. The sedimentation, filtration and drying processes are chemical engineering operations. The chemical engineers are actively engaged on methods of waste disposal, removal or threats of toxicity from fuel burnt in internal combustion engines, lessening the noise level of individual vehicles and the total traffic systems.

Transportation:

The chemical engineer continues to work towards meeting the fuel needs of transport vehicles by obtaining increasing demand for fuels and upgrading their quality. The rising price of crude oil and the estimation that the proven reserves of crude oil were enough for 30 years only are forcing the chemical engineers to look for alternative sources of petrol. Victor Ogundipe, the Business Editor of *Punch* on Monday March 31, 1980 report "CARTER URGES GREATER USE OF COAL". President Carter, addressing a White House audience, said: "The accelerated national effort in reducing dependence on imported oil is essential. This year we will spend more than $95,000 million overseas in payment for our oil imports. . . . every barrel of oil we can save through the use of coal. . . . will provide American jobs, cut down on the inflation rate and enchance our nation's security". The hands of the American chemical engineers are on the desks. They have succeeded in finding alternative source of gasoline and petrochemical feedstocks through alcohols and petrols from coal-based hydrocarbons. Alcohols

are also synthesised from agricultural residues and wood — corn stover, corn cobs, wheat straw, rice straw, oat hulls, bagasse, pine and oak.

Manufacture and Amenities:

Manufacture of durable consumer goods, substituting natural products and providing amenities demanded of growing populations and higher standard of living — commercial production of synthetic rubbers, plastics and fibres no doubt owe much to the achievements of such sciences as cyrstallography, metallo-organic chemistry and polymer chemistry. Yet, effective processing of the reactions involved in an industrial scale demanded of the chemical engineers and of their other counterparts expertise and competence in the design and operation of equipment and processes for controlling the conditions for the cracking of petroleum naphtha to obtain ethylene as the major product, for handling polymer melts for non-Newtonian flow characteristics under non-equilibrium flow conditions, and for assuring the supply of the needed raw materials such as adipic acid, hexamethylene diamine, caprolactum, terephthalic acid and acrylonitrile, for the economic production of poly-amide, polyesters and acrylic fibres which we wear everyday, to replace or to blend with cellulosic fibres and wool.

Mr. Chairman, Sir, there has been a continuity of challenge to and contribution by the chemical engineer in merging the "Objective" Sciences with the "Applied" engineering practices and in harnessing both for human advantage. "This is not the end. It is not even the beginning of the end. But, it is, perhaps, the end of the beginning" — said Winston Churchill in 1942. This is certainly true of the tasks that would continually be facing the chemical engineer in future, particularly in Nigeria, eager "to enter into more industrial production, to raise her standard of living by application of science and technology, and to increase her capabilities by more education and training in science and engineering".

You will have seen, I hope, that he is in fact a very different and, altogether distinct species of scientific animal.

TRAINING OF THE CHEMICAL ENGINEER

In order to make this man a versatile man, his education and training have continued to change with time.

Curricula in chemical engineering in advanced countries have undergone progressive changes in content and area of emphasis, ever since the first curriculum appeared in MIT around 1888[3]. Early chemical engineering curriculum in America comprised electrical engineering, contracts and specifications, graphics, mechanical and descriptive drawing, hydraulics, machine design, mechanics, shopwork, steam and gas engineering, surveying, thesis, chemical engineering courses which were chemical manufacfure, fuel and gas analysis, gas manufacture and distribution and industrial chemistry.

Over the last seven decades the nature and contents have undergone complete change and replacement. None of the chemical engineering courses taught seventy years ago are taught today and the chemical engineering courses taught today were unknown seventy years ago. The curricular changes which occurred between 1906 and 1965 are summarised below (3).

	1906	1965
Chemical Engineering	4%	28%
Chemistry	17%	21%
Mathematics	13%	13%
Physics	7%	7%
Other Engineering	23%	10%
Liberal Subjects	31%	21%

The changes in chemical engineering curricula have been caused by (4):

1. *Changes in chemical engineering practice.* The early chemical processes were batch processes, with the development of continuous plants of high capacities with a completely integrated energy system, the importance of thermodynamics, mass and energy balances and automatic control came to the fore. The chemical engineer needs not be a Jack-of-all trades and master-of-them-all as well. He can leave much of the mechanical and electrical details to the mechanical and electrical engineers and concentrate on such things as reactor design, thermodynamics, energy balances, control systems and optimization.

2. *Changes in chemical engineering theory*. Much of the early chemical engineering theory was purely empirical.

3. *Developments in other fields which have affected chemical engineering:* Many developments outside

chemical engineering have had a marked effect upon chemical engineering.

The development of the computer has enabled the chemical engineer to solve complex problems that were previously too long and tedious. It has also given rise to new techniques of mathematical modelling, simulation, optimization and computer control of chemical plant.

The creation of larger chemical plants has stressed the importance of good management and management techniques such as work study, critical path analysis, and operational research have been adopted and put to good use by the chemical engineer. New accounting methods such as Discounted Cash Flow (DCF) are also of interest to the chemical engineer.

The Structure of the Undergraduate Curriculum in Lagos

The composition of an undergradute degree can be related to three separate fields of activity[5]. These are:

1. Pure Science — The study and investigation of natural phenomenon.
2. Technology — The study and investigation of industrial processes.
3. Engineering — The design, construction and management of plant and machinery.

As pointed out by Tailby[4], these three activities tend to shade into one and other in practice and the pure scientists are often concerned with technology and the engineers are always concerned with both technology and pure science.

One can have a course which is a mixture of pure science and technology with no engineering (Industrial

chemistry) or a course which is a mixture of engineering and technology with no pure science. One can also have a course which contains approximately equal parts of each component.

Degree courses in the U.S.A. and U.K. have tended in recent years to cut down on the amount of chemistry and mechanical engineering and to fill up the vacant space in the timetable with more and more chemical engineering. Most of the graduates from these courses go to Shell, ICI, Du Pont, and Chevron Companies, which employ both chemists and mechanical engineers to provide them with background services. Such graduates, with a highly specialised training in chemical engineering, would not be the best product for a developing Nigeria.

In the University of Lagos, rather than taking a short-term view and devising a degree course full of the latest technologies and techniques or taking an extremely long-term view and devising a degree course in chemical engineering science which could be so theoretical that it resembled a course in mathematical physics, we have chosen to steer between the two extremes. The disadvantage of the former course is that the products of such a course would soon find out that their knowledge would become out of date and they would be unable to adapt to change if insufficient time had been devoted to fundamentals. In the latter case, the product of such course would find great difficulty in settling down in Nigerian industry, because much of their knowledge would seem to be irrelevant.

In this country, we must concern ourselves with what we teach our students. The function of the University is not primarily to teach a man how to do a job, but to train his mind and to give him a grounding in fundamentals which will not change and which he can apply throughout his lifetime. It is pointless to give students the capability of solving

Navier-Stokes equation in idealised situations and yet to leave them without any real confidence in being able to draw a material balance on a plant. I feel that if a reasonable amount is taught thoroughly rather than trying to make students too sophisticated from the beginning, a much more meaningful result will be achieved.

We have chosen the range of subjects covered in our course selectively, using the need to inculcate the right approach as the guiding principle. The chemical engineer is involved in a lot of different disciplines and he cannot become an expert in all of them. He has to be taught enough chemistry to have the chemist's approach to chemical problems, enough physics to have the physicist's approach to physical problems and enough mathematics to have the mathematician's approach to mathematical problems; but it is not necessary to teach extensive courses to achieve this.

The aim of the course is to produce chemical engineers whose training will make them very flexible to fit into any aspect of process industries or small manufacturing firms. The course contains a fair amount of basic chemistry and basic mechanical engineering as well as chemical engineering which runs throughout the course.

The course is biased towards design because we feel that in training the students' minds in chemical engineering, there are three things one wishes the students to learn. The first is to take a complex problem of a large complex situation, break it down, and isoiate the individual problems that it contains. Secondly, the students have to be able to apply their general knowledge of physical and chemical mechanisms to analyse those problems and come up with a solution. Thirdly, they must be able to put those individual pieces of solution back together to provide a coherent solution of the whole. This is the epitome of the engineering approach and

design is the best teaching tool to put such an approach to the students.

DEVELOPMENT OF THE LAGOS DEPARTMENT OF CHEMICAL ENGINEERING

The Department was established in October 1973 and received its first intake of studnets in that month with a Senior Lecturer, Dr. Ogunye. The growth of the Department has been impressive, thanks to the succeeding Deans of Engineering, particularly Professor Oladapo, to a great friend of the Department and former Vice-Chancellor of this University, Professor J. F. Ade. Ajayi, the principled administrator and seasoned intellectual of our time, to the Planning Officer, Dr. E. O. Akinluyi, regarding our staff development programme, and to the Bursar's Department, that handled all our overseas orders with dispatch, the staff strength has improved from 1 Senior Lecturer and a Typist Grade 1 in October 1973 to 1 Professor, 1 Associate Professor, 2 Senior Lecturers, 8 Lecturers, 5 Assistant Lecturers, 1 Junior Research Fellow, 2 Lecturers who will be joining the Department from July 1, 1980, and 7 Senior Administrative and Technical Staff. I am very proud that 7 of these are my former students, 5 from Ife and 2 from Lagos.

The Department is fully developed now in terms of undergraduate training of personnel capable of handling the chemical process industrial development programmes of the country at the senior level. Since June 1976, the Department has turned out 8 First Class, 17 Second Class Upper, 22 Second Class Lower and 8 Third Class, Chemical Engineering Degree graduates. Also three graduates have received their Master of Science Degrees within this period. These graduates are employed both in the private and public sectors of the Nigerian economy. We have the testimony of our overseas and local External Examiners, the Council of Registered Engineers of Nigeria, and the reports received from graduate schools where some of these graduates are doing postgraduate studies, that these students have shown evidence of good training. I am proud of our academic programmes and the physical facilities, equipment and staff, which are comparable to those of first class department of chemical engineering overseas. These achievements are not mine alone, they are the result of the team-work of my young and dedicated lecturers, technical and administrative staff. We work, act and react like a team. To these lecturers, I say thank you, for your dedication. A great proportion of the research facilities in the Department has been provided through grants from external sources. The Department has attracted grants totalling over ₦500,000.00 within the last three years. I acknowledge with gratitude the grants from NNPC, (Petroelum Technology Development Fund), the Industrial Training Fund, the Committee of Vice-Chancellors, Mobil Oil (Nig.) Ltd. and the Ministry of Science and Technology.

We hope to develop futher the following optional courses in our final year degree programme.

1. Petroleum Production Engineering

2. Biochemical Engineering

3. Pulp and Paper Technology

4. Sugar Technology.

Three sugar estates at Sunti, Savanna and Lafiaji are being established during this plan period. In view of the attendant manpower requirements for the project, the Sugar Technology course will be developed with a grant of ₦150,000.00 from the ITF; the course will be intergrated with the present

B.Sc. course and also at graduate level. Special summer courses including shorter refresher conversion or initiation course for scientists, engineers, technicians and management personnel in the sugar factories will be started.

It is also in the planning stage that some of our graduates specialise in Biochemical Engineering. Courses in biochemistry and microbiology will be included in the present Chemical Engineering programme as alternatives to the present course in organic and inorganic chemistry.

CHEMICAL ENGINEERING RESEARCH

I would like to touch on some of the research subjects in which I have been involved over the past few years and the research activities currently going on in my Department.

Proficiency in a combination of chemistry and engineering is the chemical engineer's principal claim to uniqueness and to distinction from the professions of the chemist and other engineers. Chemical reactor design, with optimization in both design and operation, is the most distinguishing characteristics of chemical engineering. This is also the most challenging and difficult field, since it requires a comprehensive knowledge of physics, chemistry, mathematics and chemical engineering. By means of high speed computers it is now possible to undertake these problems with some degree of thoroughness and accuracy not previously attainable because of prohibitive expenditures of time and money. This is my area of specialisation — Chemical Reaction Engineering.

My early research has been concerned with the optimal control of chemical reactors experiencing catalyst decay. The phenomenon of both reversible and irreversible catalyst decay is very common in catalytic chemical reactors. About

70% of the total output of the chemical industry is obtained from solid catalytic processes. The decay may be due to poisons (when impurities are contained in the reactant feed), to sintering (when the catalyst surface area is reduced by physical deterioration due to high operating temperatures), or to fouling (when coke or high polymeric material is deposited on the catalyst). Among the numerous commercial processes in which catalyst decay is an important factor are: the cracking, reforming, and desulphurisation of petroleum to produce high octane gasoline for high compression automobiles[6]; the dehydrogenation reactors for production of styrene and butadiene for production of synthetic rubber[7]; the hydrogenation reactors for production of ethylene, ethane and cyclohexy-lamine in the production of polymeric materials like plastics used in every household[8] and the production of vinyl chloride monomer from actylene which is an intermediate step in the production of PVC which is used in the footwear, pipes and conduit industries etc. For this reason the optimal control of chemical reactors experiencing catalyst decay is of commercial importance. Take the performance of a single-bed reactor, the conversion is 100% on the first day of operation when the catalyst activity is unity. As the on stream time of the reactor increases, the catalyst activity decreases and the conversion also decreases because of the catalyst decay.

One of the most important factors in any catalytic process operation is the length of time for which it is possible to run the reactor before catalyst re-generation or replacement. This is governed by the amount of catalyst deactivation. It will be necessary to choose conditions to make the period not too long but as economically long as possible. The optimal policy on a given day may not be that one to give the maximum conversion, as, for example, higher temperatures which may give maximum conversion may lead to a more rapid catalyst deactivation. Because of this, a number of optimization problems arise from catalyst deactivation.

In fixed bed catalyst reactors all these problems can be related to two basic questions:

1. When should we regenerate or replace the catalyst (the regeneration or replacement problem) ?

2. How should we operate between regeneration (the operation problem) ?

The regeneration problem is strongly influenced by many economic factors, such as feed values, product values, heating or cooling costs, regeneration costs etc. In this case, it will be necessary to maximise the profit (or at least some profit-like function) over the lifetime of the catalyst while taking into consideration the lack of production while the reactor is shut down for regeneration or replacement.

Because of the spatial distribution of a catalyst, in order to to maintain a precise control of the distributed parameter variables, it is necessary to consider the distributed parameter models which are in form of partial differential equations.

The more general problems are described by the following partial differential equations:

$$\frac{A\partial x}{\partial t} = f(x, \frac{\partial x}{\partial z}, \frac{\partial^2 x}{\partial z^2}, u)$$

$$o < t < \theta$$

$$o \leq Z \leq L$$

where

$x(t,z)$ is an N vector of state variables

$u(t,z)$ is an M vector of control variables

A is an NxM matrix

with the appropriate boundary conditions.

The optimization problem can be stated in the most general way as to maximize the functional

$$I\{u(t,z),v(t),y(t),w(z)\}$$

$$= \int_0^L G_1(x(\theta,z),w(z))dz$$

$$+ \int_0^\theta G_2(x(t,L),x(t,o),y,v)dt$$

$$+ \int_0^L \int_0^\theta G(x,u,\frac{\partial x}{\partial z},\frac{\partial^2 x}{\partial z^2})dzdt$$

by choosing the trajectories $u(t,z)$, $v(t),y(t),w(z)$

Where G, accounts for the value of product concentrations, heat credits for exit temperatures, feed costs etc; G_2 accounts for catalyst cost, salvage value of the spent catalyst etc, and G_1 accounts for heating and cooling costs etc. Some of the problems solved with this general formulation were:

1. Isothermal Tubular Reactor[9]
2. Single Bed Non-Isothermal Reactors[10]
3. Semiregenerative Isothermal and Non-Isothermal
4. Reactors[11,12]
5. A Vinyl Chloride Monomer Reactor[13,14]

6. Recycle Non-Isothermal Reactors[15]
7. Cyclic Non-Isothermal Tubular Reactors[16]

The theorems and the computational techniques developed in solving these problems form the pioneering work in this field which is constantly quoted in the literature by the newcomers to this field of research.

Some of the other research projects in which I have been involved recently with my immediate colleague, Dr. Susu, are:

1. We were able to reduce the level of Methanol in *Ogogoro*, which causes blindness, from the present level of between 0.5 to 0.78 volume precent to below the .005% volume maximum limit stipulated by the Nigerian Standard Organisation by charcoal adsorption technique.[17]

2. Vegetable oils are hardened for margarine and shortenings through metal-catalysed hydrogenation reactions. The kinetics mechanisms, equilibrium and mass transfer constants are being studied in order to properly scale up laboratory data for improvement of industrial hydrogenation reactors.[18,19]

3. The choice of naphtha as a feedstock for Nigeria's petrochemical industry must be based on laboratory pyrolysis studies of the Olefin Product Spectra, coke and gasoline yields as function of process variables. The Nigerian naphtha is naphthenic which accounts for the reason why there is scarcity of data in this area. We have investigated the pyrolysis of a heavy Nigerian naphthenic naphtha and cyclohexane in a flow system to gather design data[20] and we have shown that ethylene yield was enhanced in the presence of hydrogen.

4. Studies have also been carried out on alcoholic fermentation of Bacita cane sugar molasses by proteolytic enzymes. In this project, alcoholic yield was found to be between 16 and 22% as against the present yield of about 10% at NIYAMCO in Bacita with engedura baker's yeast.[21,22]

Other significant research projects we are currently working on are:-

1. The accumulation of physico-chemical data on our crude oils

2. Local utilisation of the heavy fuel oil with a view to determining the yields of lubricating oil and bitumen.

3. The hydrocracking of crude residues to establish the product distribution.

4. The pyrolysis of the petroleum fractions and natural gas in order to determine the product distribution as a function of process variables.

5. Mathematical modelling of refining operations.[23]

6. We are also trying to find out the fermentation conditions for optimal protein production from cassava as a means of enriching the staple food, gari, with protein from the same source.

Other research activities in the Department include the studies of the drying characteristics of local food products by spray drying to preserve the food products, the utilization of Nigerian coal, studies on dehydration of some foodstuffs,

kinetics and optimum yeast growth on cane molasses, and experiments and theoretical study on material transport in living plants.

SCIENCE, TECHNOLOGY AND RESEARCH

There are, however, areas in which development of the national effort in technology requires far greater Government support than it has enjoyed in the past; and since expansion of technological research and development can provide a profitable field for chemical engineering, it is reasonable to discuss this in this lecture. In recent discussions on the scientific research effort of this country, it has not been sufficiently stressed that the economy of the nation can benefit by the results of scientific research only if a sufficient technological effort is available to translate these results into industrial processes. Sir Willis Jackson of Imperial College, in his Fawley lecture,[24] made the following statement about 20 years ago, and it is still true of today.

The impact of science on the life of the community and in particular on its economy, is not a direct one, but comes from the technological exploitation of its results. Unless therefore we are strong in our technology which requires that this need be recognised throughout the community, there is a danger that the economy may fail to provide for expanded scientific pursuit the increasing expensive facilities which this pursuit nowadays demands.

Throughout history, the development of engineering has been fundamentally affected by Government policy. As I said earlier, under the Roman Empire, road construction was developed to provide good communications for military and official traffic. The development of civil engineering in France in the eighteenth century was similarly stimulated by the desire of a highly centralised Government to have good communications. Chemical engineering received a strong stimulus during the last war from the U.S. Government's large programme for making synthetic rubber and aviation fuel. Today, the vast aerospace programmes in the U.S.A. and the Soviet Union and the nuclear energy programmes in these and other countries have led to far-reaching development in many branches of engineering. It is important that this problem should not only be recognised in Nigeria, but that every effort should be made by the Government, Industry and Universities to make sure that the community as a whole is aware of the need of a massive increase of the national effort in engineering and technology, aimed at improving the national economy.

There are only two Industrial Research Institutes in the country today. More Industrial Research Institutes must be established, particularly in the fields of Chemical Technology and Chemical Engineering. The total recurrent expenditure on research and development in the Government establishments and Universities between 1970/73 was ₦1,922,359.00. The recurrent allocation for industrial research by the Government during 1975/80 plan period was ₦12,634,900. This is a meagre fraction of our estimated GNP of ₦92,358, million during the plan period i.e. .0136% of GNP. Expenditure on research and development in the USA, of which about 75% is financed by the Government, is at present about $40,000 million per year. Such a figure is staggering and it is difficult to appreciate its implications. Our Government has to invest on research and development. It is easy to blame the Universities for not inventing this or that, but we fail to realise that we are working under extreme conditions. What levels of productivity do you expect from a Department that has no grant to maintain its costly scientific equipment, a Department that has to wait for nearly 2 years to get ₦1,500.00 approved for the repair of an air compressor which is essential to nearly 90% of the

experiments performed in that Department, because the University has not got the funds. One hopes that with the establishment of the Ministry of Science and Technology, the Government will invest adequately in research and development. The Government must provide adequate funds for training engineers in the Universities, technicians in our Polytechnics, and for research and development, if our level of industrialisation is to be improved.

THE NIGERIAN CHEMICAL ENGINEERS

There are about 300 Chemical Engineers in the country. They are mainly involved in: Construction — sewage, waterworks; production — soap and detergents, breweries, cement, rubber, foam and tyre, vegetable oil extration, paint, crude oil production, petroleum refining, education, fertilizer, iron and steel industries. Some are also scattered in various firms, ministries and factories engaged in operation and maintenance, sales of various detergents, hydrocarbon and chemical solvents, management in various private firms, ministries of trade and industries, and research — FIRRO, PRODI.

It is regrettable that hardly is any chemical engineer in the country today engaged in what we can call original process design. This is because most industries in Nigeria have their plants, machinery, and equipment designed in EEC countries, Britain, U.S.A. and/or Japan. Indeed the major industries that started in the country in 1960—62 like NIPOL Plastics, Berger Paints, Ewekoro Cement made use of foreign capital, foreign machinery, foreign personnel and in some cases foreign raw materials. Even up till today, all the paint companies still import their resins, pigments, and solvents from abroad, while practically all the raw materials that go into foam making i.e. Toluene Di—Isocyanate, Polyol, and Dimethly Ethyl Acetate and the manufacture of soap and detergents i.e. Sodium Hydroxide, Alkylbenzenes, are imported. Most of these raw materials could be produced by the petrochemical complex which the Government was already contemplating to establish when I obtained my B.Sc. and about which no firm decision has been taken today. Millions of naira are spent every year in importing these materials into the country.

Naturally, as long as all the plants, machinery flow sheets, actual process design etc., for a typical process are imported from abroad, there will be little left for the local chemical engineers other than to supervise or 'sell' or 'maintain' what has already been designed abroad.

The industrial development of any nation is tied down to the level of chemical engineering activities in that nation. The chemical, petrochemical, agro-chemical as well as other process industries are really pulling behind other sectors of our economy today. The chemical engineers in this country should be given the opportunity to design and construct mini-refineries, to produce gasoline, petrochemicals, tranformer oils, lubricants etc. Because the administrators and policy makers in the Government ministries have not totally accepted the Nigerian chemical engineering consultants, their roles in the development of this nation have been limited. Their complete exclusion from certain projects and reliance on foreign consultants for reasons best known to them have definitely caused this country unnecessary siphoning of much needed money away into foreign treasuries. After all, many valuable projects have been poorly handled by these foreign consultants and have failed partly because of ignorance of local conditions, and absence of cooperation with local engineers by these foreign consultants.

We still import today all the bitumen for our roads; but since early 1960 (20 years ago), Coursey Hubbard and Hitch[25] and more recently Adegoke[26] have shown that bituminous sands outcrop occurs along the E-W belt over

120km. long and about 6km. wide between Ijebu-Ode in Ogun State and Okitipupa in Ondo State. Results of shallow drilling by Adegoke indicated a reserve of about 31 billion tonnes of hydrocarbon recoverable by open cast mining. Preliminary analysis by Adegoke indicated average hydrocarbon saturation well in excess of 15-20%, compared with an average of 5-7% for Athabasca sand in Canada which is being mined profitably. Adegoke's results indicate that the yield of liquid hydrocarbons from the tar sand has a composition:

Heavy Oils	76%
Middle Oils	19.4%
Naphtha	4.6%

The heavy oil is unsaturated and is very suitable for petrochemicals and with further processing good quality bitumen can be obtained. The sulphur content is about 1.1% by weight, the middle oil is unsaturated and has olefinic character and can be processed into motor fuel or used directly for firing power plants. The Naphtha also has olefinic characters and appears suitable for the manufacture of petrochemicals.

It is obvious from the results of Adegoke and his colleagues that we have adequate resources in the country to attain self sufficiency in road construction materials, sulphur, bitumen, lube oil and petrochemicals. There is need, then, for the Government to review its decision to import heavy crudes to enable it produce bitumen and lube-oil at the Kaduna refinery. The chemical engineers should be mobilised to develop the tar sand deposits in Ogun and Ondo States into petrochemicals, etc.

Mr. Chairman, Sir, in order that the Nigerian chemical engineer may play the role expected of him in a rapid industrial development of this nation, I would like to make the following suggestions:

1. *The ministries of industries throughout the Federation should be reorganised.* Policy and decision makers on industrialisation should be technical people. The costs charged by foreign consultants and plant contractors and facilities provided them are usually very high because the decision makers do not have the technical competence of knowing what is fair and moderate in terms of cost. Such decisions in some cases are arbitrary. The result is that the projects become uneconomical and the purpose of the industrialisation is defeated. Secondly, time is immaterial to these administrators. To the technical man, time is very costly. A plant costing ₦200 million today may cost ₦250.00 million next year, because of inflation. We all know that the petrochemical complex is a key project that is much needed for our industrialisation, yet this project hás remainded under consideration by the Ministry of Industry since 1968 when Arthur D. Little Company wrote its first report on the project.

   In the 1975/80 plan a period the project was supposed to go into production in 1978, yet it is still not in the design stage in 1980. I am sure that if Lever Brothers had its supply of Sodium Hydroxide and Alkylbenzenes at cheaper rates locally, we would be paying less for our soaps and detergents today.

2. *Government should not engage in building all the major industries as is the case at present.* It is the Government that wants to set up the Iron and Steel Complex, the cement factories, commercial vehicle assembly/manufacturing projects, salt, pulp and paper projects, fish and shrimp industry, petrochemical complex, nitrogenous fertilizer, oil refineries for the home market and export refinery, LNG plants and large scale carbonisation of coal. Many of these projects will not take off for 20 years. Ideally, Government should set up guildlines for implementing these projects. They should set the priorities and incentives to be attached to implementation of these projects by private investors with adequate consideration for the foward and backward linkages inherent in these projects. Government should provide the institutional framework under which the private sector and those who will implement projects can function properly and efficiently.

3. *The Federal Government should as a matter of urgency establish chemical engineering contracting firms and encourage the establishment of an efficient equipment manufacturing industry.* One hopes that the recent announcement of the Federal Ministry of Industries of its intention to establish an Industrial Data Bank will be brought to fruition as early as possible. An Industrial Data Bank would remove the prevailing difficult condition of the availability of local data which has handicapped the engineer in evolving the most appropriate engineering proposals for the problem he has to face at a particular time. The contracting firms will carry out the detailed engineering, and project management, procurement i.e. purchasing, of items of equipment, expediting (progress chasing), inspection, shipping and/or transport to site, construction and commissioning.

Half of the total professional technological strength of such contracting firms would be mechanical engineers, a quarter would probably be chemical engineers, while the balance would comprise all other branches including civil, electrical and instrument engineers as well as certain other technologists. Until we are able to carry out our chemical engineering contracting functions locally, costs of projects will never come down. One reads with dismay that 100,000 barrels/day refinery is costing ₦500 million, while similar projects are completed in other countries with about ₦150 million.

CONCLUDING TRIBUTE

Mr. Acting Vice-Chancellor, Sir, this is an opportunity for me to pay tributes to all who have contributed tremendously to my rapid achievement in life.

I have in the audience today, three friends of mine with whom I have been together from childhood, to secondary school and lived in the same building in London during my University days. They know that I have had only one ambition in life, to be a University Professor.

I am of the third present generation of my family and the first to receive formal education. My father did not receive a formal education but he was determined to spend all his cocoa money on me to receive a formal education. He sent me to school when I was 5½ years old. He died about 22 years ago while I was in Form III and my poor mother took over. My father was a hard worker and my mother is still a hard worker. I learnt from them that one should work hard to succeed. I pay my tribute to them.

The next person, is Mr. Segun Sosanya, now Principal, Community Grammar School, Ijebu-Ife. He taught me Latin before I entered secondary school, so that I nearly finished the translation of *Latin for Today Book 1* before I entered Molusi College. He put me onto the path of academic achievement. At the Secondary School, I met a fine gentleman. He was my Biology teacher. Today eveyone knows

him to be my Daddy, Mr. Ojedokun of Roseta Chemist. He has stood in as my Dad in the real sense since my father died 22 years ago.

Next is Mr. J. A. Rowaiye, now Director of Personnel, NEPA. When many of my classmates, including myself were sent out of the Additional Mathematics class in February 1959 in Form IV, he brought us back to the class in November 1959 when he took over the teaching of the subject and he had to start afresh from the point we had reached when we were sent out in February of the year. Without my studying Additional Mathematics I would not be able to give the lecture I am delivering today as a Professor of Chemical Engineering.

Two gentlemen have always motivated me. The first is Dr. A. B. Babajide, now a Director of Odu'a Investment Company. My Ph.D. thesis was dedicated to him. I followed his educational footsteps, from the subjects he offered for WAEC, to GCE A-Level, to undergraduate and postgraduate studies. He invited me to the University of Waterloo in Canada from Imperial College and stood firmly by me during a time of financial crisis. I am glad I went to Waterloo to meet my Victoria!. Secondly, Mr. O. A. Durojaiye, the Director of Administration, Central Bank. He gave me the inspiration that one can become whatever one chooses to become. I would also like to mention four teachers who were my great teachers. The are Mr. J. A. Banjoko, retired Assistant Director of Education, Federal Ministry of Education (my chemistry teacher at HSC); Dr. Abel Guobadia (one of the best teachers who taught me physics at the HSC); Mr. Ayo Alabi (my physics teacher at the secondary school who taught me the shortcut of obtaining distinction in that subject without much effort); and Mr. M. O. Eperokun, the Registrar of the University (my English and History master at Molusi College).

The greatest homage goes to Professor Willis Harmon Ray, a Professor in Madison, University of Wisconsin, my professor, supervisor and a great friend. He made me what I am today. Finally, I thank my Wife 'Sola, for her understanding and help since the start of my journey in September 1966 to achieving my ambition of becoming a Professor.

Mr. Chairman, Ladies and Gentlemen, I have wandered a great deal from the next of my lecture. The Chemical Engineer and the Changing World. This is deliberate. I have used the lecture to advertise my profession because our functions are not known. I hope you will all leave here today well informed about this special species of scientific animal, the Chemical Engineer.

Chemical engineering has served the process industries well for many years and has shown to be applicable to many other industries. These principles of chemical engineering will continue to be applied to basic problems facing civilisation in the future, notably, raw material supplies, energy supplies, food supplies, to name a few, and to their impact on the community.

Mr. Chairman, this is my inaugural lecture. I would like to seize the opportunity to thank the University for the great opportunity given me within the last six and a half years to lead a team of young and dedicated men and women. I am glad that this occasion should be graced by the presence of Prof. G. N. Bhat, my head of Department for 3 years at Ife; I brought to Lagos the administrative experience I acquired under his leadership to build a dynamic Department of Chemical Engineering, second to none in this country. I think I have completed my mission and I shall take my exit as Head of Chemical Engineering from October 1, 1980, 18 months before my present term expires. I believe that I should leave the stage when the ovation is loudest.

Thank You.

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