THE ROLE OF ENERGY IN THE MANUFACTURE OF FERTILIZER

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The major role of energy in the manufacture of fertilizer is in the formation of compounds suitable for application as fertilizer material from the compounds or forms in which plant food elements occur naturally or the forms in which they are available to the fertilizer manufacturer.

Whereas some chemical reactions to produce fertilizer materials actually release energy in the process, an aspect which is very important and to which we shall pay attention later, other reactions require energy addition to proceed. Chemical reactions may require high pressure, high temperature, or conversely low pressure or cooling or even refrigeration to proceed at satisfactory rates or for optimum yields.

A further aspect in which energy plays an important role is the handling of materials, into the factory from sources, during processing, and as final products. Energy is also utilized in the preparation of materials to render them physically suitable for reaction or processing, and rendering the final products physically suitable for use and application.

We have all be rendered extremely energy-conscious through the media and our own personal experiences, the latter mainly in the field of motor vehicle transportation, since the advent of Opec which precipitated the world oil crisis late in 1973. Symposia and speeches on the topic and research on the subject has become the order of the day and the media have avidly featured it as they did with pollution and the care of the environment. If the result would be a cool and balanced appraisal of the sources of energy available, and the optimum selection and efficient application or utilization of these, well and good, but we detect some note of hysteria and spirit of crusading which can only distort perspective and lead to irrational action as we have experienced for instance with pollution.

The manipulation, or if that is too strong a word, the rationalization, of particularly the economics but also the supply of petroleum energy for strategic or political reasons by the main suppliers is at the root of the present energy flurry and consciousness. By this statement I do not wish to denigrate the importance of the subject, and in the long run it may prove that they did the world a great service by throwing this subject into such strong focus. I do believe however that technology will again come to our rescue, and that the world will adapt itself to the new situation, surviving quite comfortably under a new set of conditions, with posterity considering the old, cheap petroleum-based energy era as one of the quaint phases of history.

At present the bulk of the world's energy requirements are met by fossil fuels, to wit coal and petroleum. Coal was the first world energy source on which industrial empires were founded until it was ousted by the more convenient petroleum, but latterday developments have reinstated coal in its importance, particularly in our country which is reasonably endowed with such resources. The direct use of coal has been superseded to a great extent by its efficient conversion into and utilization as electricity, with particularly beneficial effects in terms of pollution. The last great stronghold of petroleum is in the road vehicle section, which it has held because of technology's inability so far to develop an efficient portable storage or accumulator pack for electric energy. Petroleum also spawned a big petrochemical industry, of which the nitrogen fixation or ammonia production sector is part of and very important to the fertilizer industry, as well as the polythene-based packaging industry.

The Republic of South Africa is however in the van of world progress in switching road transport liquid fuel, as well as the ammonia and plastics industry, to a coal base. We can well remember the sharp criticism levelled at and even opprobrium cast on those who pioneered these industries on indigenous fossil fuel, coal, but today we can only thank the foresight and instinct of those pioneers.

Although South Africa has thus escaped, or rather will be in a better position to bear, the brunt of the petroleum energy crises, we should not bluff ourselves into complacency. Coal has previously been cheap in South Africa, even artificially so under Price Control, and this mining sector has suffered severely from the same effects as our own industry, namely inadequate return on investment, inefficiencies created by operating on a shoestring, and inadequately remunerated capital to ensure investment in replacement and expansion. The inescapable result of the petroleum crises will be more expensive energy, whether coal, solar, hydro or nuclear sourced, and those people who are changing from oil to coal merely and solely because it may be cheaper in South Africa today, are in for severe disillusionment.

In my opening sentence I assigned a major role in the fertilizer industry to the energy of chemical reaction, and we are really very fortunate that, in varying degree from process to process and product to product, this energy balance is positive for the processor, ie the reaction in which he is interested is positive with regard to the liberation of energy in a useful and usuable form.

The stagewise and overall chemical energy balance in the manufacture of fertilizer materials is fascinating by complex, could fill a massive text book, and is fitting for the Society of Chemical Engineers.

For our purpose at this meeting I propose to look at the overall energy balance of the fertilizer industry, ie the nett energy, consumption by product, the cost of this proportional to the user cost of the fertilizer, and the source of the energy.

However, I cannot resist a small incursion into the field of chemistry and chemical energy to illustrate that the overall energy consumption of a factory is sometimes nearly negligible in comparison with the energies of reaction taking place. Let us look briefly at two major processes, phosphoric acid manufacture and ammonia synthesis. To the conservationists' chagrin possibly, primary raw materials for these processes never appear in the final product.

The first instance I would like to mention in the use of roughly one ton of sulphur for every ton of P_2O_5 produced, via sulphuric acid, to remove lime, or calcium, from the raw rock phosphate mineral, ending up with all the sulphur as gypsum in the well-known large dumps outside phosphoric acid plants.

In round figures the ton of sulphur, in being transformed to gypsum in phosphoric acid manufacture, yields 12 gigajoules of energy. If this unit is unfamiliar, it is equivalent to 3 300 kilowatt hours. At the rate of 1 000 tons of sulphur, as consumed daily at Richards Bay, the energy released is sufficient to sustain a small town.

As a second case we can consider ammonia synthesis, where about three tons of coal is used for each ton of product produced. At the risk of horrifying the ammonia pundits, I would reduce this very elegantly engineered and sophisticated process to the bare reaction where steam is reduced by the coal to hydrogen which is then combined with atmospheric nitrogen to form ammonia, the coal or carbon ending up as carbon dioxide.

If we look at the theoretical energies of the simplified reactions involved we find that the energy required to split a ton of steam into hydrogen and oxygen is 13,5 gigajoules (3 750 kWh). However, if carbon is combining with and withdrawing the oxygen from steam this reaction will yield 11 gigajoules leaving us less than 20 per cent of the necessary energy for the hydrogen-forming reaction to be added from external sources.

The above two examples are grossly over-simplified, and in practice much of the chemical energy is lost in low-grade unusable forms, but the examples illustrate the important principle.

With the kind co-operation of the fertilizer firms we may look at the actual consumption and cost for various products. We have split this into petroleum energy, and coal-based energy, with a further subdivision of the latter into direct heat from coal, steam raised from coal, and electrical energy also basically derived from coal.

Rock phosphate concentrate

This is a mined mineral, subsequently processed for upgrading and hence lacking the energy contribution of a chemical reaction.

It is of interest to note that the energy utilized in mining the ore is approximately 20 per cent of the total energy used Explosives provide a tenth of the energy for mining. The remaining 80 per cent of energy used is utilized in concentration of the ore. Overall, size reduction of the ore body, which starts with drilling and blasting and finishes with fine grinding, accounts for 25 per cent of the phosphate rock concentrate industry's energy requirements.

The total energy utilized by Foskor is supplied as to 15 per cent by petroleum, 40 per cent as electric power, and 45 per cent by direct coal combustion. The latter is used mainly in drying the product, and shows how expensive this operation is in energy consumption although the monetary cost only amounts to seven per cent of the total.

Per ton of rock phosphate produced utilities consumption are:

Coal	0,0164 ton	cost 24 cents
Explosives	0,0036 ton	cost R1,13
Electric power	106,42 kWh	cost R1,66
Petroleum	3,83 litres	cost 33 cents

giving a total cost of R3,69 per ton of product, or 18 per cent of the free on rail price of the product in 1978.

Phosphoric acid

As indicated earlier, large quantities of chemical energy are set free when sulphur is used to produce sulphuric acid, further heat is generated when sulphuric acid reacts with rock phosphate, and thus a large proportion of energy needed to run a phosphoric acid plant, including heating, pumping, compression, concentration, etc is self-generated in the plant. Thus for every ton of P produced as phosphoric acid, for which 2,1 tons of sulphur is burnt, 7,9 tons of steam is generated virtually for free.

The ancillary energy consumption, supplied to such a plant, per ton of P produced is:

Electric power	670 kWh	cost R12,52
Steam from coal	0,6 tons	cost R 3,85
Petroleum cost	2,0 litres	cost 28 cents

or a total cost of R16,65.

If we add the rolled up energy cost in the rock used at 6,6 tons per ton P, the energy cost per ton of P in phosphoric acid becomes R41 or approximately eight per cent of the cost of a ton of P valued at R510 under price control. Here we should perhaps refer again to the fact that the value of steam raised and used is of the order of R55 per ton of P produced so that nearly 60 per cent of the energy content is "free".

Double superphosphate

The manufacture of double superphosphate consists of grinding of secondary rock, mixing of rock and acid in a den, handling to and from maturing and into and from storage. Utility consumption is mainly electric power, amounting to R2,50 per ton of P produced. If we roll up energy costs from rock, we now arrive at an energy cost of R43,50 per ton of P in the product powdered double super, representing still nearly eight per cent of the controlled selling price.

Ammonia synthesis

As stated before, and to the delight of the chemical engineer, this process generates a very useful amount of chemical energy, albeit that this is largely derived from carbon either as coal or petroleum used as a reactant, and the purist may quickly point out that these are fossil fuels. However, the process is reknown for its high pressures and temperatures required, as well as low pressures and requirements for refrigeration of air and ammonia into liquid forms at very much sub-zero temperatures, so that the overall energy consumption for the physical conditions required could have been appreciably higher were it not for the conservation and utilization of chemical energy released.

In the case of a typical petroleum-based ammonia process, energy of about 50 gigajoules is used per ton of ammonia, half of this as a chemical feedstock and half directly as fuel for supplying heat and power. Further energy requirements are relatively negligible, and electric power etc account for less than 0,5 gigajoules per ton of product.

The cost of the energy directly generated for the process is approximately R51 per ton of ammonia, or 27 per cent of the controlled price of R185,50 per ton of ammonia.

In the coal-based process, about one-third of the coal input is utilized for burning directly, and at an average coal use of three tons per ton of ammonia the total energy input is 70 gigajoules, 23 as direct coal energy and 47 as chemical feedstock. Again, the amount of utilities energy such as electric power, steam etc to be supplied from outside is small by comparison, and the energy cost in a ton of coal-based ammonia is seven per cent of the final controlled price of the product, R185,50 per ton.

Nitric acid and limestone ammonium nitrate

Both reactions, that of the oxidation of ammonia to nitrous oxides, which after absorption in water forms nitric acid, and the neutralization of nitric acid with ammonia are strongly exothermic, yielding to the delight of our chemical engineer, some useful energy for free. He needs to supply externally only of the order of 0,5 gigajoules per ton of LAN produced.

Energy costs per ton of N in LAN, rolling up from ammonia through nitric acid and ammonium nitrate, amount to R21, or four per cent of the controlled selling price of the product, using coal-based ammonia.

Urea

This time round in the nitrogen industry, the reaction of ammonia with CO_2, a waste product from the synthesis reaction, is strongly exothermic yielding theoretically 2,5 gigajoules per ton of urea, and additional energy as electric power and coal of only 2,8 gigajoules per ton is required. Rolling up N energy costs from ammonia, the proportion of energy cost in the controlled price of urea is eight per cent.

Granular fertilizers

For convenience of handling and end use, without adding to its fertilizer value, we granulate our NPK-containing materials by mixing them, wetting them, rolling them into granules, heating them to dry them out, and cooling them down. The energy consumption of a typical granulation plant is in the form of electric power for materials handling, steam for wetting and granulation and direct coal firing for drying. The use of these utilities are, per ton of product

Electricity	cost	41 cents
Steam	cost	14 cents
Coal	cost	81 cents
Petroleum	cost	7 cents

which gives an energy cost content of one per cent of the average controlled selling price of fertilizer for the granulation process.

The fertilizer industry and its customers are therefore fortunate that large amounts of chemical energy are set free in the main manufacturing processes employed. The efficient use of this energy has been improved over the years, but we must realise that most processes in use today were designed and engineered before "the energy crisis" and consequent escalation of energy costs over the last few years. In South Africa, including the effects of inflation, economic policies, taxation, transport etc this has been as follows for a typical point of manufacture:

Electricity	2,9	(for maximum demand charge) 1973/1978
	2,5	(for consumption) 1973/1978
Coal	2,85	1973/1978
Petroleum (Diesel)	6,2	1973/1978

Of further interest is the present relative cost of energy in its various forms. Again at a typical point of manufacture the relation, on a unit energy basis is:

Coal	1
Electricity	8
Petroleum (Diesel)	8

There is no doubt that our chemical engineers will still have to apply their skills to the more efficient use of energy in our field, as in other fields. Although we may not see radically new processes introduced quickly, some favour will have to be given to products and processes with the lowest energy requirements. At a rough estimate, our present procedures and process could be tightened up to save 10 per cent energy.

Apart from high-lighting the contribution of the chemical energy of reaction in fertilizer manufacture, which is of tremendous importance in keeping the energy requirements down, this paper has tended to indicate the cost proportion of energy in fertilizer prices to the consumer.

At the risk of overstepping my remit I would like to quote you a few facts from a paper on Food–Fertilizer–Energy–Efficiency by Von Monsjou delivered to the Fertilizer Society of London in 1975. According to his data the fossil fuel consumption in the American food chain from field crop production to the consumer's table is about the same in energy value as that represented by the field crop standing ready for harvest. In this chain of production 24 per cent of the energy is consumed at or on the farm, 39 per cent applied to processing in the food industry including containers and transport, and 37 per cent in the distributive trade and household preparation including cooking. Of the 24 per cent used on the farm, the energy used in the manufacture of fertilizer accounts for four per cent; or about one-sixth.

The paper following will probably deal more fully with these fascinating energy balances in the food production system, and I believe we will be surprised at the energy loss between the grown crop in the field and the food reaching the consumer's table.

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