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GENERAL ASPECTS OF SAFETY IN AMMONIA AND UREA PLANTS AND UNIDO'S TECHNICAL ASSISTANCE TO THE FERTILIZER INDUSTRY OF DEVELOPING COUNTRIES[1/]

by

UNIDO Secretariat

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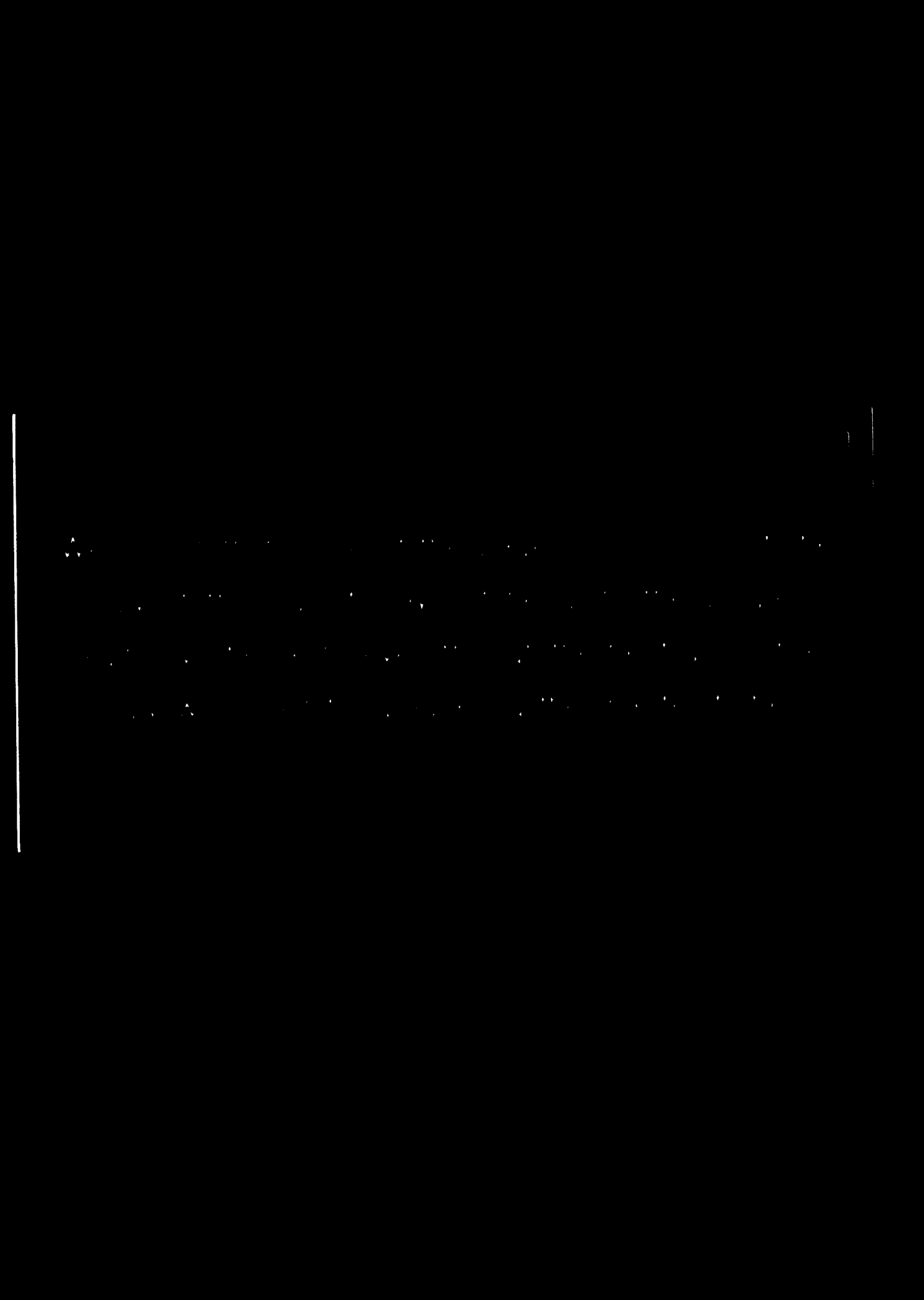


C O N T E N T S

INTRODUCTION

Safety in design and operation of ammonia plants is not an isolated issue as far as safe operation of the chemical industry is concerned in general. Safety problems which arise in modern large scale ammonia plants are common with those in urea and petrochemical plants and in many other industrial chemical processing units, where:

- fuel oil, naphtha or natural and similar industrial gases are processed;
- hydrogen is produced and processed;
- high pressure equipment is used;
- various types of corrosion occur;
- single train units of large capacity in terms of output are operated;
- large machinery and equipment of large volume is maintained.

The impact, however, of accidents in large ammonia plants on the national economy, particularly in developing countries is significantly different from difficulties caused by failures of other chemical plants.

As ammonia is the crucial basic raw material for subsequent processing to produce nitrogen fertilizers any interruption in ammonia supplies make a disturbance in the steady flow of fertilizers so urgently needed in agriculture in most developing countries. Thus ammonia has become a product of much greater importance than any other chemical product. The necessity of making up the shortage in local supplies of fertilizers would cause severe imbalances of payments in some of the countries, where there are only limited financial reserves available to fill the gap in market supplies by imports in case of an unexpected shut down of a large ammonia production unit and its downstream fertilizer plants. No further comment will be needed here to visualize how the national economy is adversely affected in the case that fertilisers cannot be made available to farmers at low prices and at the right time. To what extent the market supply is disturbed by outage of an ammonia/urea complex of approx. 500,000 MTPY of

urea (230,000 MTPY in terms of N, comparing with the output of an 1000 MTPD single train ammonia unit) is easily understood if this figure is being compared with present consumption figures of nitrogen fertilizers in developing countries. There are only few of these countries in the world where the consumption has already exceeded this figure. But even in large consumer countries where the demand is presently twice or, like in India, ten times as much, the problems incurred will be of the same nature and have a similar impact on their economies.

By and large, recent instances show that even under the best possible circumstances accidents in the chemical industry do occur and will continue to occur. This statement, however, should not discourage anybody concerned. It is intended to make all who are dealing with the fertilizer industry more vigilant and conscious of the increasing responsibilities involved.

SAFETY PROBLEMS OF THE FERTILIZER INDUSTRY

The transfer of know-how

Industrial development is indivisibly linked with mutual transfer of experience gained by scientists, engineers, technicians and workers in the industrialised world during their life-long practice which has lead to the present status of modern technology and of experience gained by developing countries during their own industrial development. The chemical industry is a sector where technology is closely connected with safety aspects and any "know how" on techniques being applied is inconceivable without simultaneous consideration of how to assure safe operations and to protect people against hazards involved. It is quite obvious that a certain kind of hazards are inherent and distinct features of applied chemical technology. The larger the scale of chemical plants the larger the danger, and, in result of this fact - there is a growing responsibility to cope with.

Transfer of technology from developed to developing countries is expanding rapidly. New light has been thrown on the moral and physical aspects and engineers are facing these obligations during implementation of projects in developing countries. Both, the engineers from a developed country and his colleague in a country where, may be, the factory is the first large scale industrial unit that has ever been constructed there, are well aware of their responsibility and of the gap to be bridged in order to ensure safe operation of the chemical plant. This gap is sometimes due to lack of technical background, sometimes it may be a problem of mentality of newcomers to work for the first time in industry. All the problems encountered, however, have to be solved, otherwise the expected success of the project would cost too much in terms of financial and material losses. While modern technology is readily available to developing countries, its application implies new liabilities, which are to some extent different from those encountered in developed countries. A wide scope of technical issues, which sometimes seem not to be fully recognized as a matter of prime importance will have to be covered by a revised approach to safety in design and operation of fertilizer plants in developing countries. It is hoped that the Symposium will develop new ideas on some of the crucial issues how to design, construct and equip fertilizer plants for safe operations, how to instruct and supervise operators and how to organise maintenance in order to avoid failures during re-start of plants.

[illegible] transfer of technology and [illegible] safety aspects of the chemical industry have [illegible] of its consequences of [illegible].

Entrepreneurs, industrialists and government officials, as well as the technical staff dealing with chemical production in developing countries are well aware of hazards and the magnitude of financial losses resulting from design deficiencies, maloperation or other avoidable matters. Their knowledge, however, how to avoid failures needs to be strengthened. Therefore, UNIDO is undertaking the task to assist countries through transfer of experience in safe plant operations. The fertilizer industry has been chosen as an example. Ammonia and urea plants provide a long list of case histories which can be taken as a basis for discussions, conclusions and recommendations. Although it seems to be difficult to find a distinct answer to the question: what has to be done to bridge the gap between the availability of highly developed technology and the lack of experience to make full advantage of its utilization in developing countries, any recommendations being made in the course of the Meeting may be regarded as a step towards the proper solution of safety problems in the fertilizer industry world-wide.

Technical and scientific aspects

As regards safety in the chemical industry no distinct difference between developed and developing countries is being made in the design. There is however, a need for applying differentiated methods to safeguard proper execution of projects, training programmes, etc. in developing countries. Owing to the single train concept in design of modern ammonia and urea plants the equipment employed is of large volume and any failure, even if a small element of the plant is responsible for, say, a leakage, huge quantities of toxic substances will escape and endanger personnel in its vicinity. An explosion may be caused by non-flameproof equipment of adjacent plant sections. This may happen anywhere, in a developed country as well, if safe operating conditions are not being followed or immediate action is being neglected.

Safety measures to be incorporated for plants in developing countries will necessarily be based on the latest achievements of scientists in the developed and developing world, specifically what concerns selection of construction materials, anti-corrosion protection, welding techniques,

instrumentation, safety devices, and safety design codes. Therefore, appropriate and timely transfer of knowledge during implementation of projects have to be secured by contractors. In cases where already some local experience exists full advantage has to be taken of information given by the future plant management and operators who have to be consulted at a very early stage of design and construction of the plants.

Although, it may sound unlikely that modern large scale plants can be designed in a way resulting in lower safety standards than would be applied in the supplier's industrialized country, it seems to be frequent contractor's practice to make savings in equipment costs at the wrong place. The lack of local standards and regulations might be responsible for such approach in some cases while in others the lack of experience of the investor's staff, whose knowledge is inadequate to comment on how the plant has to be designed to warrant long life and safety after its commissioning, could be thought of as a reason for low safety standards and poor quality of the new equipment. Aspects of moral and physical responsibility should, therefore, be regarded as a factor that needs to be discussed and evaluated along with technical issues before decisions are being made on selection of engineering firms, contractors and equipment suppliers.

Development of design for safe plant operations in countries lacking industrial experience cannot be deemed to be the sole responsibility of licensors and contractors in developed countries. Rapid industrial development of the developing countries calls for establishment of its own institutions to look after improving safety standards and techniques. There is a distinct need for having a knowledgeable staff within the countries or at least in the region assigned to function like well known institutions in the developed world which are involved in safety aspects in supervisory, advisory and legislative capacity since almost a century.

In some cases, where countries have already reached a certain level of experience scientific institutions would have to undertake the task of co-operation with corresponding institutions in other countries in order to ensure development of local standards, adaptation of external standards to local conditions and to provide advice to industries and official bodies on effective and economic safety measures to be observed.

The same applies to testing facilities which are not available in most developing countries and in some of them, it is unlikely that purchase of a complete set as required for testing of equipment, corrosion, welding

quality, etc. will ever become satisfactory. Here again, a rational approach has to be applied. It should be kept in mind that modern high pressure ammonia and urea units cannot be operated and maintained properly for a long time without safety instrumentation. Organization of services pursuant to safety issues in the fertilizer industry will have to be tackled without delay, if necessary by UNIDO's assistance especially in cases where regional or bilateral arrangement might become necessary.

The human aspect of plant safety

UNIDO's consistent fertilizer programme is aimed at continuous and unhampered growth of the fertilizer production in the developing world. Safe operation of fertilizer plants is being considered an important factor having impact on reaching the ambitious targets set by national development plans.

With respect to safety, the situation in developing countries appears to be much more difficult as compared with the highly industrialised countries. Lack of skilled labour and deficiencies in the countries' industrial infrastructure is frequently thought to be the main reason for plant failure despite the long series and wide variety of other factors which can be made responsible for the lower efficiency of plant operations in developing countries where industrial development has just made its first paces in a rural economy. No rapid progress can be expected to be made in the fertiliser industry of these countries while trying to employ modern, sophisticated technology. It is a well known fact that human mentality takes a long time to get adjusted to modern techniques, therefore, human problems have to be studied first to draw conclusions how to influence the attitude of workers in order to make them conscious of their responsibilities relating to safety aspects of their duties. Great reliance is placed on plant operators. Any start-up of plants, both initial and after shut down for repair, requires well trained alert plant personnel who thoroughly understand the plant operation and the characteristics of the equipment. There is no substitute for qualified operators if the plant is to operate safely and to have a good "on-stream" record. The same applies to maintenance staff.

It has been documented by plant experience, that more equipment problems occur during shut down and start-up phases than during normal operation. Maloperation during start-up, inadequate supervision during repair and on the linkage between the end of maintenance work and process operations are human factors which cannot be eliminated by technical means as automatic control devices and interlock systems.

Plant safety instrumentation is a fairly new field in the design of and in equipping chemical fertilizer plants to make those "fool proof" to a degree justifiable by the compromise between reliability of operators and labour costs on the one hand and the cost and reliability of safety instrumentation on the other. It is evident, however, that no ideal solution will be found even in future because the human factor cannot be eliminated from these considerations.

It becomes, therefore, crucial to recognize and study the factors in general. While developing countries are considered, it seems to be beyond any doubt that another dimension has to be added to all the well known human safety aspects and approaches encountered in the industrial practice of the developed countries.

Adopting the latest achievements of the industrialized countries for utilization in a developing country is a venture entailing as much success as can be embodied by those who undertake the task. Their willingness to understand specific situations encountered in developing countries only, and their consciousness of technical and social conditions prevailing in each particular country is of prime importance for a successful start-up and operation of plants. In many cases there is almost no reliable technical background and the experience of the technical staff is based on international short term fellowships and suppliers' training courses which are by and large felt to be inadequate in terms of duration and scope. A large number of operators will have the only social and educational background as defined by the term "first generation from peasant". Different, more detailed and through training methods have to be applied in order to achieve results approaching standard levels as being attained in developed countries. The above observations are, of course, not applicable to countries who have long experience even in the developing world.

These significant conditions have to be kept in mind by participants of the development process taking place during the establishment of new plants or operation of up-to-date large scale units, particularly in countries where the new factory being built is the first one and the operated plant is the only existing larger industrial unit. There are only few examples known where in a developing country full success has been reached i.e. fulfillment of three basic elements pertinent to expected techno-economic effects of newly constructed plants:

- construction of the plant in accordance with the time schedule;
- start-up in less than one month as per contractual obligations;
- failure free initial operations at 80-90 percent of the rated capacity during the first year.

The development process taking place during construction of a plant may be regarded, as well as a technical training programme for up-grading of skills at all levels of the local personnel. Therefore, careful attention has to be paid to co-operation among expatriate and local staff in order to take full advantage of the possibility to transfer the full scope of "know how" needed for the success of the whole venture. The willingness of the expatriate staff to do so is part of specific importance. The local counterparts, however, have to make endeavours, as well as to learn, as much as possible during the period when external specialists are at their disposal and the experience of these can easily be consulted in day-by-day practice.

True as it is, it has repeatedly to be stressed, that in many cases simple aspects of human relations are being neglected for various reasons. The results of this negligence is what has been said at the beginning of the paper: Inadequate skills of operators who are expected to safely run a huge plant for the first time taking for granted that the plant in all its parts is safely designed.

Exchange of experience is urgently needed on how to organize co-operation among expatriate and local staff both during design and operations to make the best use of the possibility of transfer of practical knowledge and how to arrange training on safety issues throughout plant operations and maintenance.

It is greatly encouraging to know of examples that plants have been constructed and are operated troublefree in developing countries by local staff from the initial start-up until now, thus providing a positive outlook for the assumption that it is worthwhile and realistic to set such targets for all subsequent plants to come on stream in the future.

FINANCIAL LOSSES

Even a brief shut down of a large scale single train ammonia/urea complex can be serious in terms of lost production, lost profits and expenditures pertaining to the fixed cost component in the production cost calculations.

The following example clearly indicates the magnitude of losses which will occur if a plant is not operative owing to a major equipment failure.

The calculations have been based on assumptions as follows:

- Financial and material losses are referred to the final marketable product of the complex i.e. urea because an accident in either the ammonia or urea plant will cause breakdown of the urea production. It is obvious that no provisions are being made in ammonia/urea complexes to store large quantities of ammonia in case of outage of the urea plant. The subsequent lack of carbon dioxide which cannot be stored in an economic way in equivalent quantities, would not permit processing of previously stored anhydrous ammonia.
- Capital costs are based on appraisals of investment being presently undertaken for setting up plants of a daily capacity between 925 and 1000 MTPD of ammonia and the equivalent urea production of 1600 to 1725 MTPD.
- The plants are operated at an average rate of 90 percent of their design capacities.
- As a comparable basis for assessment of losses the year 1980 is taken into consideration on when these plants will be in operation for one or two years. The rate of depreciation has been estimated. Costs involved are comparable with relevant cost components of new plants during the first five years of operation.
- The shut-down period is 30 days.
- Capital investment costs are between 190 and 250 million dollars. The forecasted urea market price will not be lower than 137-155 dollars per ton by 1980.
- The ammonia production is based on low cost local resources of natural gas.

The results of the approach are:

Unavoidable [illegible] costs amount to: [illegible],000 US dollars per month.
(evident losses + fixed cost component)
Associated losses are:
loss of profit including loss
of taxes of the government, repayment
of financial charges or loans etc. equal: 2,825,000 US dollars per month

total 5,150,000 US dollars per month

The largest component of the fixed cost allocation is depreciation (average: 40 per cent of the total production cost), the lowest refers to labour (5 per cent only).

Therefore, it can be concluded that long term shut-down of plants will affect mainly the manufacturers financial situation and obligations.

It should be kept in mind, however, that repair costs involved can be much higher depending on what was the prime cause of the plant failure. If a lengthy shut down is considered, in most cases it would be due to breakdown of the high capacity equipment which is expensive to replace and may require several months to be manufactured shipped and reinstalled. Costs of several hundred thousands dollars for replacement of small machines and pipe work might be encountered, as well as costs of several million dollars for replacement of waste heat boilers, damaged centrifugal compressors or structures after explosions or fire.

Another economic factor involved by shut down of large fertilizer production capacities is the necessity to import fertilizers to make up for shortage of ample market supplies. Additional government expenditures such as subsidies are sometimes involved if procurement prices in the world market are higher than the local average market price which is possibly based on the low ex-factory price. The need for foreign currency to effect purchases in emergency situations may be another source of losses and financial difficulties.

Whatever the reason for plant shut-down might be, the wide variety of financial consequences entailed is surely a sufficient argument to make all efforts in order to avoid hazardous situations in ammonia/urea plants. As appears from the above considerations expenditures of a remarkable amount of money will be fully justified for implementing safety measures as supplementary safeguards for equipment, safety instrumentation, and, of course, for continuous training of staff at all levels.

UNIDO'S ACTIVITIES IN THE FERTILIZER SECTOR

General

The development of the fertilizer industry has engaged the serious attention of UNIDO since its establishment. The supporting activities of UNIDO consist in backstopping operational projects and in carrying out certain important studies and projections of supply and demand of particular value to developing countries.

The following list of topics provides examples of UNIDO's operations, the ultimate objectives of which are the improvement of the utilization of the existing fertilizer production capacities, and assistance in creating new ones.

- Provision of experts to assist in solving any technical problems encountered in plant operations and maintenance;
- National and regional fertilizer market surveys;
- Feasibility studies;
- Preparation of tender documents;
- Analysis of tenders;
- Establishment of pilot demonstration plants;
- Assistance in the selection of the most appropriate feedstock and raw materials for fertilizer production;
- Assistance in the selection and development of processes for the use of indigenous natural resources e.g. beneficiation of low grade rock-phosphates, potash, etc.;
- Proposals on diversification of products;
- Training of personnel;
- Publications covering topics of common interest to all developing countries;

and, last but not least:

- Convening symposia and expert group meetings on technical, environmental and economic issues.

UNIDO Programme on Technical Co-operation among Developing Countries (TCDC)

UNIDO's work creates a broad basis for organizing co-operation among the developing countries themselves. This new activity follows recommendations made by the Second General Conference of UNIDO convened in Lima (Peru) in March 1975, encouraging developing countries to provide mutual assistance

and transfer of experience on a bilateral basis. Countries which are interested in the evolution of their relations among each other on mutual technical assistance can thus be able to start this fruitful co-operation through UNIDO's official channels functioning as a vehicle and an catalyst.

UNIDO's technical assistance in practice: Assistance to India

To visualize UNIDO's work several examples may be quoted concerning technical assistance to India, the host country of this Meeting.

India has just commenced to use UNIDO's assistance. It should be mentioned here, of course, that India has already a well established fertilizer industry being managed by highly qualified staff and capable operators. India's involvement in the largest investment programme that has ever been initiated in the world - constructing at the same time 18 large nitrogen and phosphate fertilizer plants - is not the initial stage of industrialization which is in most countries synonymous to industrial development operations. India is the only developing country in the world having the courage to set-up the large coal based ammonia plants of about 1000 MTPD capacity each. These plants give clear evidence of India's ambition to reach a leading position in the world fertilizer industry despite lack of feedstock and dependance on imports for essential elements.

Therefore, technical assistance has to be provided wherever requested to eliminate any bottle-necks on slowing down the growth rate of fertilizer production and hampering efforts to achieve high plant output.

At present, a team of 2 maintenance specialists is providing assistance to 6 fertilizer plants. These UNIDO experts are making recommendations on how to organize maintenance management in the most efficient way and how to improve workshop operations and in-plant repair and preventive maintenance in accordance with practices employed in developed countries.

Another expert has been fielded to assist Engineers India Ltd. on design and construction of high pressure piping in the fertilizer industry and experts will soon be fielded in the area of rotary and reciprocating compressors, and partial oxidation processes and plants operation.

India has participated very effectively in the UNIDO/ESCAP Priority Project on Regional Co-operation among ESCAP countries in Fertilizer Production and Distribution.

India's well formed position in the development of catalyst production will be strengthened by UNIDO's assistance through establishing a Regional Catalyst Development Centre of the [illegible] and FAI to agree.

Needless to say that co-operation between UNIDO and the Indian Fertilizer Industry, represented by FAI and FAI has taken a good start thus ensuring and encouraging further development of good co-operation.

Background experience and philosophy of UNIDO operations in the fertilizer programme.

The current philosophy of UNIDO's world-wide operations in the field of fertilizers is based on experience already gained by field operations and the following considerations:

- The development of the fertilizer industry has to be based on indigenous raw materials wherever available thus ensuring fertilizer supplies.
- Nitrogen fertilizer production should be established wherever natural gas is being flared and wasted. The non-renewable natural resources have to be utilized for providing the most critical of the three agricultural inputs which are: seed, water and fertilizers.
- A fertilizer industry has to be created wherever a market exists taking advantage of low transportation cost. Millions of tons of this bulky commodity are being moved all around the world before they reach their final destination: The soil through the farmers.
- All existing production capacities have to be fully utilized. High capital investment costs captive in underutilized plants on the one hand and world-wide fertilizer shortage on the other, reveal a contradictory situation which calls for action. Bottle-necks need to be identified, finance and technical assistance have to be made available to all those plants where better utilization can be attained in a short time by relatively small expenditures.
- Establishment of bulk blending units has to be encouraged wherever there is a captive market for relatively small quantities of specific types of fertilizer mixtures, following recommendations made by Soil Research Institutes on nutrient requirements, N-P-K ratios and recommended doses.
- Fertilizers should reach the farmers at the lowest price. The long chain of economic factors involving government pricing policies, subsidies and credit facilities has to be co-ordinated in order to create adequate

incentives for all those to be involved, namely, importers and producers of raw materials and fertilizer intermediates, fertilizer manufacturers and traders, and the farmers who are expected to make efficient use of fertilizers.

- Assuring optimum value-to-cost ratio in agricultural production is one of the most important problems which need to be solved in many countries in order to eliminate any factors that are likely to decrease the farmers interest in application of consistently growing quantities of fertilizers.

- The ultimate success of the "Green Revolution" should not be deemed to owe solely as the result of adequate fertilizer supplies. Improvement of agricultural yields is dependant, as well, on the efficient use of fertilizers which is in turn the result of application on scientific principles and new agricultural technique. In this field close co-operation with FAO is being maintained by UNIDO.

- Supply and demand forecasts are a tool for effective planning of future development of the fertilizer industry in the national, regional and global scale. Statistics on plant capacities and production, as well as on consumption, exports, imports and stocks of fertilizers are being evaluated by UNIDO in collaboration with other organizations e.g. FAO, World Bank, in order to provide developing countries with essential data on general trends in the fertilizer industry and on the regional and world market.

- Regional reviews of the present situation and future outlook of the fertilizer industry and trade are one of the means and ways to initiate co-operation among the countries concerned.

The UNIDO/ESCAP Priority Project on Regional co-operation among ESCAP countries in Fertilizer Production and Trade should be mentioned here as an example of fruitful investigation of the fertilizer supply/demand balance of 14 Asian countries, thus providing a clear picture of national tendencies and delineating the future outlook on the development of the fertilizer sector of the region as a whole.

The Expert Group Meeting which has been convened in connexion with this project in order to co-ordinate the results of the country review and to formulate conclusions for continued co-operation has proven to be a valuable

tool to initiate regional thinking on future development plans. During implementation of the project, new ideas on possible ways of future co-operation have evolved.

UNIDO Regional Fertilizer Programmes

The objectives of the UNIDO/ESCAP Priority Project on Regional Co-operation among ESCAP countries in Fertilizer Production and Distribution can be described briefly as follows:

- Review the present situation and future outlook of the fertilizer industry and market for at least 10 years in advance.
- Draw conclusions and make recommendations on technical assistance to be provided by UN Agencies.
- Delineate possible ways of technical and economic co-operation among the countries.
- Reveal the needs for finance, its magnitude and timing, define present and likely future bottle-necks on ways leading to ample supplies of fertilizers at the lowest price, and
- Create a basis for "regional thinking and understanding" among the countries concerned which are by and large preoccupied with implementation of national plans aiming at self-sufficiency in fertilizer production, regardless costs and efforts involved.

A similar programme is being implemented for the Arab countries in co-operation with the Industrial Development Centre of Arab States (IDCAS). African countries will be covered by a subsequent project, while the fertiliser industry of Latin America has been reviewed recently by a team of ECLA, UNDP-UNIDO and FAO experts.

PROGRAMMES

The wide scope of [illegible] to assistance to developing countries in the field of fertilizer [illegible] being covered by UNIDO's work programmes, global, regional and [illegible] are being implemented, some of which deserve to be mentioned here because of their importance for future fertiliser policies of member countries concerned.

- The Third International Fertilizer Symposium to be held in The Hague (Netherlands) [illegible]. The Symposium is of global nature following the excellent results of the former Second Symposium held in Kiev and New Delhi [illegible].

- Development of [illegible] of indigenous rock-phosphates. This programme includes:

  - exploratory missions to countries where phosphate deposits have recently been found;
  - assistance to several countries on identification of possibilities how to use local phosphates as raw materials for the existing fertilizer industry;
  - selection of appropriate methods for beneficiation of indigenous phosphate rock or its processing for direct application to the soil.

- Development of new fertilizer distribution techniques. Elements of the programme are:

  - direct application of anhydrous ammonia;
  - production and use of liquid fertilizers;
  - setting up pilot demonstration centres for the distribution of liquid fertilizers.

- Development of small scale bulk blending and bagging facilities in countries where local production of fertilizers cannot be recommended under prevailing economic conditions because of lack of raw materials, small markets or lack of agricultural infra-structure.

- Development of production and application of slow release nitrogen fertilizers on specific crops.

- Assistance in improving utilization of plant capacities, modernisation and modification of plants for change of feedstock and environmental considerations, wherever requested on an ad hoc basis.

- Promotion of the new programme on technical co-operation among Developing Countries as described at the introduction of this paper.

SUGGESTIONS FOR FUTURE ACTION

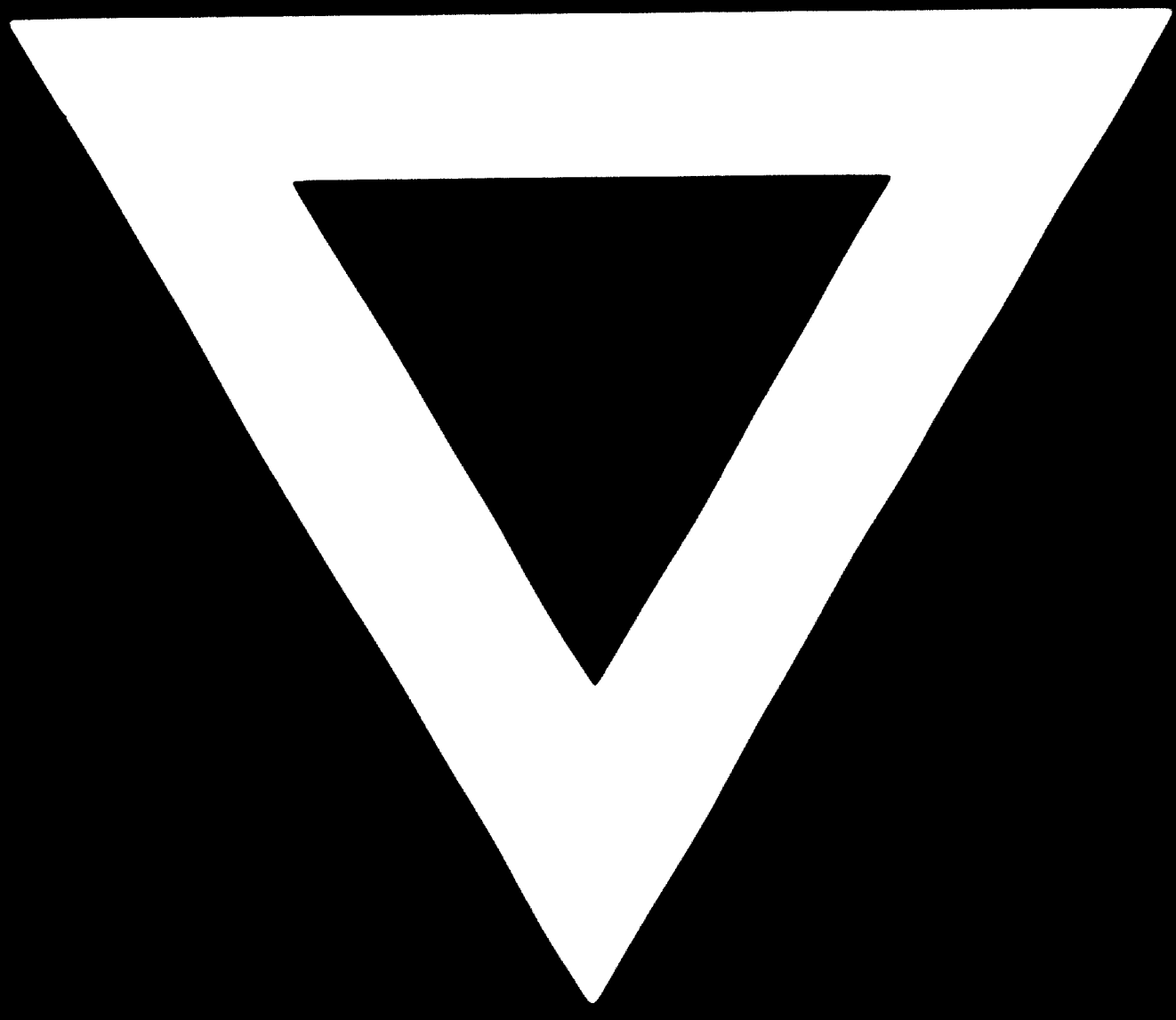
1. UNIDO programmes on technical assistance to the fertilizer industry will have to continue making efforts to stress on safety aspects in the design and operation of ammonia plants. Other processes employed in this large industrial sector should be covered by similar meetings or included in UNIDO's world-wide development activities. Technical assistance on prevention of plant failures and accidents in urea, nitric acid and ammonium nitrate plants, as well as in sulphuric and phosphoric acid plants deserves due attention in order to improve the ability of developing countries to attain high on-stream factors while operating their plants.

2. Developing countries should be encouraged to establish national or regional centres for standardization of regulations and rules on safety in the chemical industry. The centres should assume the role of information centres on standards being adopted in developed countries.

3. There is a need for establishing national or regional institutions (services) which would provide specialized testing facilities on request. Highly qualified staff will have to be employed to function as service-technicians who will be expected to carry out in plant test by non-destructive methods. These institutions should be equipped with modern instruments and should render services to neighbouring countries where the chemical industry is too small to set-up their own well equipped service units.

4. While contracting purchase of plants and equipment provisions should be made to include detailed information on testing procedures and supplies of the relevant instruments in the contracts and of course standards.

5. Human factors which might be made responsible for failures occurring more frequently in the chemical industry of certain countries need to be studied. These studies should reveal what organisational measures have to be undertaken to improve technical accident prevention.



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